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ATTACHMENTS

INTERROGATORY R313-24-1(3)-02/03: SUMMARY OF REGULATORY REQUIREMENTS

INTERROGATORY STATEMENT:

1. *Please provide a revised Tailings Management Plan that includes revisions as presented on Uranium One's response to Round 2 of this Interrogatory.*

Response 1

Uranium One has included the revisions presented in the response to Round 2 of this Interrogatory in the attached design report.

A revised Tailings Management Plan will be submitted in three parts that include the revisions as presented in Round 1 Interrogatory responses. These parts include a Tailings Design Report, included with this submittal, as well as an Operations Plan with SOPs and a Compliance Monitoring Plan, which will be submitted in the near future.

BASIS FOR INTERROGATORY:

Section 2 of the Tailings Management Plan appears to be a summary of the regulatory requirements and how the proposed tailings management will meet these regulations. This is a useful summary. Uranium One provided clarifications requested for this section in their response to Round 1 Interrogatory, as well as proposed text in response to Round 2 Interrogatory. The proposed revisions to section 2.1.1 appear to address the concerns expressed in this Interrogatory; however, the proposed revisions have some editorial inconsistencies with other portions of Section 2.1. It is assumed that once the revised TMP is prepared that these inconsistencies will be resolved and appropriate references will be included.

REFERENCES:

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-05/03: DAILY INSPECTIONS OF WASTE TAILINGS

INTERROGATORY STATEMENT:

Please provide a revised draft tailings inspection procedure that outlines what inspections, evaluations, and documentation will to be performed, and includes a commitment to finalize and provide to the DRC for review the respective detailed procedure prior to commencement of operations.

Ensure that the inspections address inspections to be performed to include, but not be limited to the integrity and proper function of:

- *Leak detection system*
- *Upper tailings (slime) drain system*
- *Cell solution elevation*
- *Tailings elevation*
- *Slurry transport system inspection*
- *Retention dam inspection*
- *Diversion and storm water channel inspection*
- *Embankment Settlement*
- *Embankment Slope Conditions*
- *Seepage*
- *Slope Protection*
- *Emergency Discharge Facility*
- *Safety and Performance Instrumentation*
- *Operation and Maintenance Features*
- *Postconstruction Changes*
- *Inspections following significant earthquakes, tornadoes, floods, intense rainfalls, or other unusual events.*
- *Groundwater Monitoring systems*
- *Tailings piles*

The procedure needs to also address:

- *Procedure revisions*
- *Conditions under which the Executive Secretary will be notified and if corrective measures are needed, how they will be identified, implemented, and documented*
- *That the inspections and evaluations will be performed by a qualified professional such as a qualified engineer or geologist familiar with the construction, operation and inspection of tailings impoundments*

Response 1

A revised SOP AP-3, incorporating the Interrogatory comments, has been developed and is submitted with these responses as Attachment A. SOP AP-3 has been revised to draft format as recommended by the DRC. The final procedure will be submitted to the DRC after tailings disposal design is finalized and prior to the start of operations.

BASIS FOR INTERROGATORY:

The revised SOP AP-3 (version 2.3) as submitted in the 11/28/07 response to Round 2 of this Interrogatory provides an initial basis for the tailings impoundment inspection procedures. However, lacks specific details on the implementation of the inspections and any follow up corrective measures that may be required. For example, the procedure calls for examination of the decant systems, effluent from underdrain pipes, and sumps for proper function. However, what the examination includes and how the results of the examination are evaluated is not specified. The proper function of these components is critical to the integrity of the cell. The specific cell component to be inspected, how it is to be implemented, and how it is evaluated for proper performance needs to be defined. This will include the evaluation of visual observations as well as data generated by the respective system component (ie, flow rates, solution and tailings characteristics and levels, etc.).

The inspections as well as the evaluations need to be performed by a qualified professional such as an engineer or geologist familiar with the construction, operation and inspection of tailings impoundments.

NRC Regulatory Guides 3.11 and 3.11.1(complete references provided below) provide guidance on the inspection of tailings (embankment) systems and can be provided, upon request, to facilitate resolution of this interrogatory.

Based on recent discussions with Uranium One, it is the DRC's understanding that the tailing cell design has been revised from what has been submitted to date, and the inspection procedure will need to be revised to address the items included in this interrogatory as reflected in the final design. It is also recognized that the development of these procedures is most effective after the design and operation of the tailings cell has been developed and finalized. In addition, the procedures will need to be updated during operations to ensure optimal efficiency and effectiveness. Therefore, to complete the license application a draft procedure needs to be included that outlines what will be done and includes a commitment to finalize the respective procedure and provide the final procedure to the DRC for review prior to commencing operations.

REFERENCES:

NRC. Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills." Washington DC. NRC December 1977.

NRC. Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mills." Washington DC. NRC October 1980.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended April 2007.

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December, 2005.

Plateau Resources, Ltd., "Shootaring Canyon Uranium Processing Facility Environmental Report, Source Material License No. UT0900480", Dated January 2006.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-06/03: MAINTAINING RECORDS

INTERROGATORY STATEMENT:

Standard Operating Procedure HP-25 (Revision 0.4) identifies a means for recording the amount of by product material generated. However, lacks details on the actual implementation of the procedure and evaluation of the data. As with the inspection procedure discussed in Interrogatory R313-24-4-05/03, a draft of this procedure can be submitted as part of the application with the final being developed and provided to the DRC prior to the start of operations.

Be sure the final procedure developed addresses the following questions identified during the review of HP-25:

1. *Please clarify the sample collection procedure for each process, or reference the applicable procedure. Please clarify how and when composite sampling will be used and performed. Please define the term, "composted," as used in Section 7.4.*

   Response 1

   The requested clarifications have been included in the revised SOP HP-25 provided as Attachment B. SOP HP-25 has been revised to draft format as recommended by the DRC. The final procedure will be submitted to the DRC after tailings disposal design is finalized and prior to the start of operations.

2. *Section 7.2, "Document and Verify the Amount of Yellowcake Produced and Transferred Offsite." Ensure the process for determining yellowcake amount does not include the weight of the container. Ensure the field inventory verification is performed by qualified personnel and documented. Ensure the applicable form reflects changes to the text.*

   Response 2

   The requested modifications have been included in the revised SOP HP-25 provided as Attachment B.

3. *Section 7.3, "Document and Verify the Amount of Tailings Placed in Tailings Facility." Ensure that the tasks identified in this section describe how a technician will determine the quantity of tailings that any sample represents and the quantity of tailings actually added to the Tailings Facility. Per form U1 25-4, the determination of the flow rate is "From Mill Operator". How is the mill operator going to determine this? This is a critical component in calculating the quantity of tailings the sample represents.*

   Response 3

   The requested modifications and information have been included in the revised SOP HP-25 provided as Attachment B.

4. *Please clarify what is done with the forms generated by the procedure following entry into the MBTD, or reference the applicable procedure.*

Response 4
The requested clarification has been included in the revised SOP HP-25 provided as Attachment B.

5. *Please clarify what is entailed in review, modification, and validation of MBTD data entry, report generation, and programming, or reference the applicable procedure.*

Response 5
The requested clarification has been included in the revised SOP HP-25 provided as Attachment B.

BASIS FOR INTERROGATORY:

The regulations require the licensee/registrant to maintain records of all sources of radiation. This implies accuracy and precision of the inventory. The questions identified above reflect the need for accuracy and precision within the inventory system. If applicable, provide additional text in the respective reference document and forms to provide additional explanation of this system. A draft procedure can be submitted with the license application that includes a commitment to develop and provide to the DRC for review, a final procedure prior to the start of operations.

REFERENCES:

Plateau Resources, Ltd., "Shootaring Canyon Uranium Processing Facility Environmental Report, Source Material License No. UT0900480", Dated January 2006.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December 2005.

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December 2005.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-12/03: SOIL FINAL STATUS SURVEY FOR SITE DECOMMISSIONING

INTERROGATORY STATEMENT:

Please provide a revised Figure 8-1 that includes the MARSSIM classification of the entire site and reflects the most current proposed design.

Response 1

Figure 8-1 has been revised to include the entire site and to reflect the most current proposed design.

Uranium One will include the text revisions presented in the response to Round 2 of this Interrogatory and the attached revised Figure 8-1 in the revised Reclamation Plan

BASIS FOR INTERROGATORY:

The Round 2 Interrogatory response from Uranium One provides clarification on the MARSSIM classification of the different areas of the site. Figure 8-1 that was included shows these different areas. However, the figure does not show the entire cell area and needs to reflect any impacts from the revised design.

The TRDP will need to be revised to include the revised text (clarifications) as well as Figure 8-1.

REFERENCES:

Abelquist, E. W. 2002. "Decommissioning Health Physics: A Handbook for MARSSIM Users," ISBN 0750307617.

Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, Rev. 1, Appendix D.

Pacific Northwest National Laboratory 2006b. Visual Sample Plan Version 4.4. Available at http://dqo.pnl.gov/

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December, 2005.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

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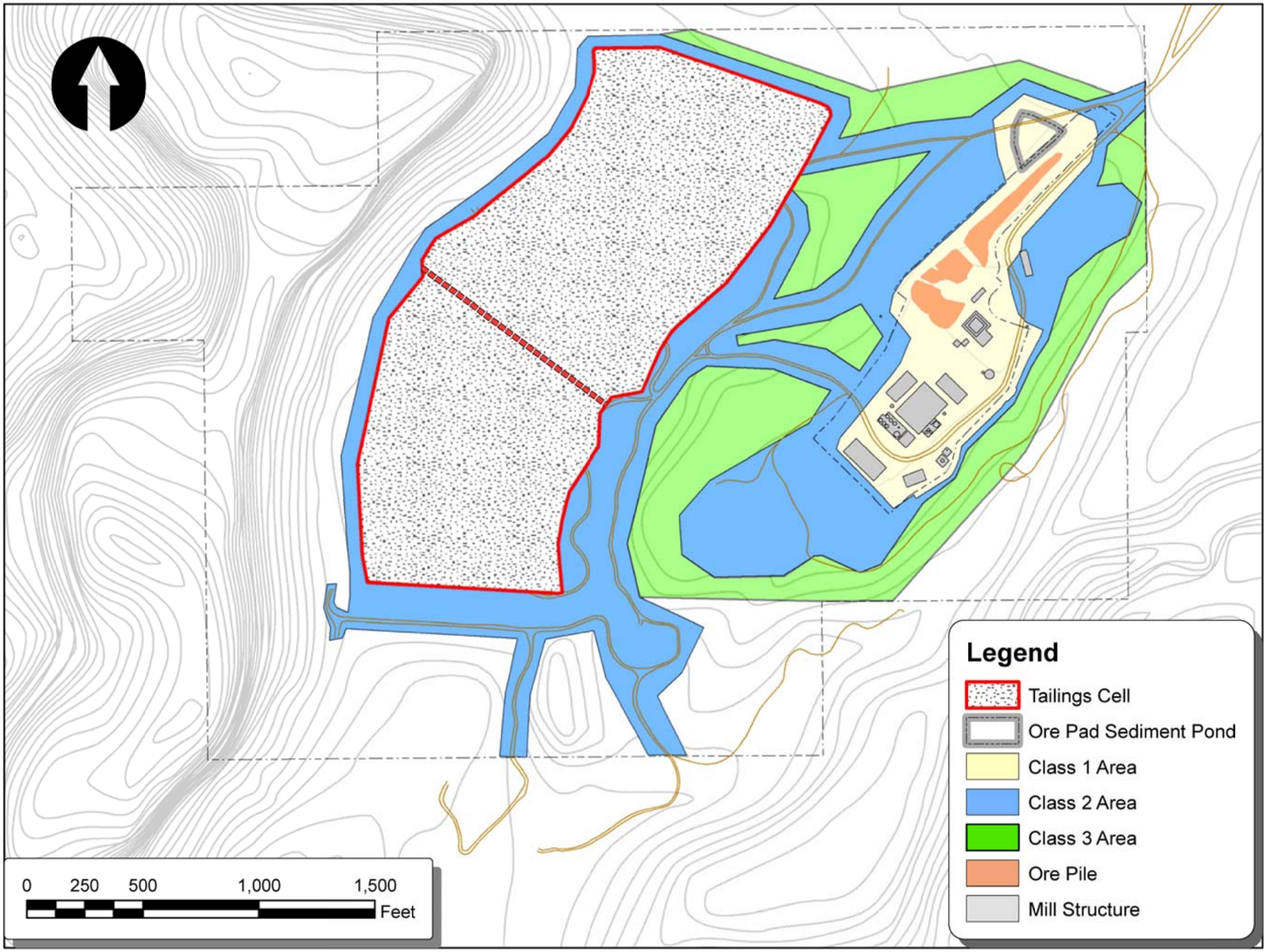

Project No. 181692

April 2008

uraniumone

Figure 8-1
Post-Operations MARSSIM Class Areas

INTERROGATORY R313-24-1-14/03: MILLING OPERATIONS

INTERROGATORY STATEMENT:

In order to understand the handling and processing of the waste tailings and slurry, please provide the following information:

1. *A complete material/production flow diagram that including estimated production and material feed rates and the properties of the solids and liquids generated, starting at the ore pile and ending up in the tailings pile, and evaporation pond. The diagram should include the proposed locations and layout of the liquid extraction equipment, tailing placement equipment, secondary containment components, and transfer piping. Include descriptions of the equipment and process.*

   Response 1

   This information is provided in Section 2 of Lyntek's 2008 Feasibility Study (Lyntek, 2008). This section is attached as Attachment C.

   Lyntek, Inc., 2008. Definitive Cost Estimate for the Restart of the Shootaring Canyon Mill, Ticaboo, Utah. March 28.

2. *Procedures covering the placement of the tailings into the cell so as to minimize the impact on the drainage and liner system and not exceed the maximum head on the upper liner as defined by the respective groundwater permit.*

   Response 2

   A preliminary discussion of the need for special procedures that will be required for placement of the initial tailings is provided in Section 6.1 of the Design Report. Full details and plans for tailings deposition are presently being developed, and will be presented in the Operations Plan to be provided in a separate submittal.

3. *A demonstration that the head on the upper liner will not exceed the maximum allowable head on this liner as defined by the respective groundwater permit.*

   Response 3

   A discussion of the maximum head on the primary liner is provided in Section 7.6.4 of the Design Report.

BASIS FOR INTERROGATORY:

A material flow diagram should be provided that includes the production rates and the properties of the product generated, liquids generated, tailings generated, reagents used, losses, etc., starting at the ore pile and ending up in the tailings pile, and evaporation pond. This information is required to demonstrate that the objectives set forth in 10 CFR 40.31(h), Appendix A, have been addressed.

Uranium One's response to Round 2 of this Interrogatory states that the tailings will be placed into the cell as slurry and that dewatering of the tailings will be done through the use of a conventional underdrain system. Also, as a result, there will be free liquid ponded in the cell during operations. Therefore, procedures for alternate tailings solution extraction will not be employed. However, the means by which the tailings will be placed so as to minimize the impact on the underlying drain and liner *system and not exceed the maximum head on the upper liner, as defined by the respective groundwater permit, needs to be provided and demonstrated.*

REFERENCES:

Plateau Resources, Ltd., "Shootaring Canyon Uranium Processing Facility Environmental Report, Source Material License No. UT0900480", Dated January 2006.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended April 2007.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-16/03: SEISMIC HAZARD CHARACTERIZATION

INTERROGATORY STATEMENT:

Please address the following comments on the seismic hazard analysis that was included with Uranium One's response to Round 2 of this Interrogatory:

General Response

The comments listed below have been addressed in the attached Seismic Hazard Analysis for Shootaring Canyon Uranium Processing Facility, revised April 8, 2008, which is attached to these responses as Attachment D. Where necessary, additional response information has been provided below.

Significant Comments:

1. *Section 1.2: Which "USGS Peak Acceleration Map?" Please provide a reference. Is it a deterministic or probabilistic map?*

   Response 1

   The reference for the map, provided by others, was not given. It can be reasonably inferred that the map corresponds to peak accelerations associated with a 1 percent probability of exceedance in 50 years. The last sentence in Section 1.2 has been revised to incorporate this information.

2. *Section 1.2.1: Provide a reference for the LLNL report.*

   Response 2

   The first sentence in Section 1.2.1 has been revised to include the reference for the LLNL report.

3. *Section 1.2.1, third paragraph: What "fault splays?"*

   Response 3

   The sentence was in reference to the three faults of the Bright Angel fault system. The faults were included in the deterministic analysis by Bernreuter et al. (1995), but were not included in their probabilistic analysis. The last sentence in Section 1.2.1 has been revised to incorporate this information.

4. *Section 1.2.2: If the PGA map is not well documented, an attempt needs to be made to determine its origin and documentation?*

   Response 4

   The assumed origin of the map is discussed in Response 1. Section 1.2.2 has been revised to provide more information regarding the map.

5. *Section 1.2.2: The hazard is not due to "random seismicity of the central and eastern U.S. (CEUS)." The hazard is due to background seismicity within the Colorado Plateau around the site. Please clarify.*

   Response 5
   The last paragraph in Section 1.2.2 reflects this clarification.

6. *Section 1.2.2: The site is not located within the CEUS. The USGS has assigned the Colorado Plateau to the CEUS for the purposes of assigning attenuation models. Please clarify.*

   Response 6
   The last paragraph is Section 1.2.2 reflects this clarification.

7. *Section 2.0: This section either needs to refer to other documents or needs to be expanded. As it stands, it is an inadequate discussion of the topic. For example, there is no discussion of the tectonic stress field, which is mentioned later when selecting ground motion attenuation relationships to be used in the seismic hazard analysis. References need to be cited.*

   Response 7
   Section 2.0 has been revised as requested.

8. *Section 3.1: Replace "repeat occurrences from different reporting stations" which is incorrect, with "duplicate events."*

   Response 8
   The text is Section 3.1 has been revised as requested.

9. *Section 3.2: No need for this subsection here since it is under the heading of "Seismicity." Move the discussion to Section 4.1.*

   Response 9
   The Section 3.2 header has been removed, and text from Section 3.2 has been included in Section 4.1.

10. *Section 4.0, first paragraph: Faults are "not attenuated to the site." Ground motions are attenuated. Same with the MCE. It is not "attenuated to the site." Please clarify.*

    Response 10
    The first paragraph in section 4.0 has been revised to provide additional clarification as requested above.

11. *Section 4.0, first paragraph: Median plus one sigma ground motions are used in deterministic analysis. The log mean of medians from several attenuation relationships is also used and preferred. Please clarify.*

Response 11

The first paragraph is Section 4.0 has been revised to clarify that the median plus one sigma ground motions are reported. Section 4.2 has been revised to clarify the method of averaging results from several relationships.

12. *Section 4.0, second paragraph: The random earthquake is not placed underneath the site in traditional deterministic hazard analysis. The earthquake is generally placed at a horizontal distance of 15 km from the site. Please clarify.*

Response 12

Section 4.0 has been revised to provide additional clarification as requested.

13. *Section 4.0, third paragraph: "Building codes typically utilize 10% chance of exceedance." This is no longer the case. The International Building Code, which is the prevalent code in the U.S., uses a 2% probability of exceedance in 50 years. Please clarify.*

Response 13

Section 4.0 has been revised as requested.

14. *Section 4.0, third paragraph: Starting with "For the purpose of the seismic hazard evaluation…" Please clarify; are the authors suggesting a 10% exceedance in 1,000 years results in a return period of 10,000 years?*

Response 14

Section 4.0, third paragraph has been revised in order to clarify that a 10 percent probability of exceedance in 1,000 years results in a return period of approximately 10,000 years.

15. *Section 4.1.1: Expanded justification of why these 7 faults were selected is needed. Just because it may be "conservative" is not an acceptable criterion. For example, it is well known that the Needles fault zone is due to shallow salt tectonics and is not seismogenic. Numerous studies have been done on this fault zone. Similarly, the Shay Graben faults are due to salt tectonics. I refer the authors to the PSHA that was performed for the Atlas Uranium Mill tailings site in Moab by Woodward-Clyde Consultants (1996) (also Wong et al., 1996). Work by Brumbaugh (2005) evaluating the Bright Angel fault system suggesting they are not seismogenic should be cited.*

Response 15

As stated in Section 4.1.1, faults that are included in the USGS Quaternary fault and fold database and have the potential to produce peak ground accelerations of 0.05 g or greater based on a deterministic evaluation were selected for further evaluation in the probabilistic model. The Needles fault zone has been removed from the probabilistic analysis because it is a structure resulting from salt movement that does not extend deeper than the evaporites of the Paradox Formation and is not considered seismogenic (Wong et al. 1996, Huntoon, 1982). The Shay Graben faults have been assigned a lower probability of seismogenic activity (0.10) due to evidence for late-Quaternary deformation being associated with salt-dissolution collapse (Wong et al. 1996, Oviatt, 1988). The work by Brumbaugh (2005) references the Bright Angel fault zone in eastern Grand Canyon in Arizona. His study area is approximately 70 miles southwest from the Bright Angel fault system in

Utah. Although both fault zones/systems are within the Colorado Plateau, they are mapped separately by USGS and don't appear to be structurally related. Therefore, it appears that the work by Brumbaugh (2005) is not specific to the Bright Angel fault system. However, focal mechanism studies by both Brumbaugh (2005) and Wong and Humphrey (1989) indicate that within the Colorado Plateau, northwest striking normal faults are compatible with the modern state of stress of northeast-trending extension of the plateau, and northeast trending faults tend to not be active. Based on this data, the northeast trending faults of the Bright Angel fault system (labeled Fault 1 and 3 on Figure 2) have been assigned a low probability of seismogenic activity (0.10). Although Quaternary deformation has not been proven (Black and Hecker, 1999) and USGS did not consider this fault system to be active in the NSHMP, the northwest-trending Fault 2 has been assigned a higher probability of seismogenic activity of 0.50 because it is oriented favorably to the stress field. Section 4.1.1 has been revised to incorporate this information.

16. *Section 4.1.1: There needs to be expanded discussion on the selection of seismic source parameters and the associated weights.*

Response 16
This expanded discussion has been added to Section 4.1.1. Table C.2 has also been revised.

17. *Section 4.1.2: Explain why Gaussian smoothing (Frankel, 1995) was not considered in the PSHA? Background seismicity does not need to be treated as "random."*

Response 17
The evaluation of background seismicity has been modified to include two models: 1) areal source zone assuming uniformly distributed seismicity and 2) gridded seismicity which retains a degree of stationarity using 0.1 degree latitude and longitude grid spacing. The text in Section 4.1.2 has been revised to incorporate this information.

18. *Section 4.1.2: How was the recurrence calculated as shown on Figure 4? It appears to be a simple least-squares fit. The maximum likelihood technique using the truncated exponential model is generally used in hazard analysis. A truncated exponential model should have been used since there is a maximum magnitude of* ***M*** *6.3 for the random earthquake. Note the recurrence curve goes out to* ***M*** *6.5.*

Response 18
The recurrence shown on Figure 4 of report dated November 12, 2007 was calculated using a least-squares fit. Although Figure 4 did show the least-squares fit line extending out to 6.5, the probabilistic model did incorporate a maximum magnitude of 6.3. The recurrence has been reevaluated using the maximum likelihood technique by Weichert (1980). Revised text in Section 4.1.2 and a revised Figure 4 reflects these changes.

19. *The inclusion of the Intermountain Seismic Belt (ISB) events may not lead to more conservative (shorter) recurrence. This needs to be demonstrated.*

Response 19

Both the recurrence developed for this study which incorporates some events from the ISB, and the recurrence developed by Wong et al. (1996) for the Colorado Plateau interior have been used in the analysis. Source contributions to total hazard indicate that the calculated hazard is higher for the area source zone using the 200-mile radius about the site as compared to the Colorado Plateau interior. The text in Section 4.1.2 has been modified to incorporate this information.

20. *Section 4.2: There is no mention of the Pacific Earthquake Engineering Research (PEER) Center Next Generation Attenuation (NGA) relationships, which have been released in 2007. For example, the Campbell and Bozorgnia (2003) model used in the study has been replaced by Campbell and Bozorgnia (2007), which was released in May 2007. The latter explicitly includes normal faulting. Abrahamson and Silva (1997) has been replaced by Abrahamson and Silva (2007), but this model was probably not available to the authors at the time they performed the seismic hazard analyses.*

Response 20

The Campbell and Bozorgnia (2003) relationship has been revised to incorporate Campbell and Bozorgnia (2007). The 2003 relationship is still retained in the deterministic analysis shown in Appendix C.1 for faults with an associated PGA of less than 0.05 g. However, the 2007 relationship has been incorporated into the probabilistic analysis and the deterministic analysis of the more critical faults. The Abrahamson and Silva relationship was still in draft form at the time of this study, so it was not incorporated into the analysis.

21. *Section 4.2: How many ground motion sigmas (aleatory) was the hazard truncated in the PSHA?*

Response 21

The hazard was truncated at three ground motion sigmas for all three relationships. Section 4.2 has been revised to incorporate this information.

22. *Section 4.3, first paragraph: State the PGA of 0.25 g is an 84th percentile value. Are the PGA values shown in Table 2 lognormal means from the three attenuation relationships?*

Response 22

The PGA values shown in Table 2 have been revised to be the lognormal mean of the three attenuation relationships. The text for Section 4.2, 4.3, and Table 2 have been revised to incorporate this information.

23. *Section 4.3, Table 2: It is meaningless to cite MCE magnitudes to a hundredth of a unit. The epistemic uncertainties in rupture length and magnitude and the aleatory uncertainty in the Wells and Coppersmith (1994) relationship results in an uncertainty on the order of 0.3 unit. Please clarify.*

Response 23

The MCE values in Table 2 have been revised to report to a tenth of a magnitude.

24. *Section 4.3, Table 3: Explain this table as being the hazard contribution to the total mean hazard at a return period of 10,000 years. The table is being portrayed in a deterministic manner as in Table 2, which it is not. Please clarify.*

Response 24
Table 3 and the third paragraph of Section 4.3 have been revised to provide clarification as requested.

25. *Section 4.4: It would be useful to see the magnitude and distance deaggregation plots for a 10,000-year return period. What are the modal magnitude and distance value for a return period of 10,000 years?*

Response 25
Pseudostatic slope stability analyses have been performed to evaluate stability of the tailings impoundment. Such analyses use only the PGA coefficient as the seismic input. Therefore deaggregation, response spectra, and vertical ground motions are not required.

26. *Section 5.0: Are vertical ground motions required?*

Response 26
No. See Response 25.

27. *Figure 1: Showing all the known seismicity in the site region particularly near the site would have been valuable. These data are available from the University of Utah and other organizations. This leads to the question of whether the historical seismicity (**M** < 4) was adequately evaluated in this study.*

Response 27
All seismicity available on the USGS NEIC website (Mw>2.4) is shown on Figure 2.

28. *Appendix C.1: Calculating the ground motions for faults beyond 100 km is really of no value because they have no engineering relevance. See Comment 23 on magnitudes. The "average" PGA values appear to be an arithmetic average. Ground motions are lognormally distributed so the lognormal mean should be calculated.*

Response 28
Appendix C.1 has been modified to show magnitude values to the nearest tenth. Lognormal mean values of PGA have been calculated, replacing the arithmetic average column.

NRC documentation (10 CFR Appendix A to Part 40 and 10 CFR Appendix A to part 100) gives specific criteria for faults that should be considered as follows:

Distance from site (miles)	Minimum length of fault to be considered (miles)
0 to 20	1
20 to 50	5
50 to 100	10
100 to 150	20
150 to 200	40

Therefore, faults meeting these criteria have been preserved in Appendix C.1 to demonstrate that they have been considered, even though most are insignificant.

29. *Appendix C.2: See Comment 15. What are the bases of the weights? Why were these weights chosen? MCE magnitudes needed to be rounded (Comment 23).*

Response 29
Bases of weights have been addressed in revised Appendix C.1. Appendix C.2 has been modified to reflect additional weight factors, and to show magnitude values to the nearest tenth.

Minor Comments:

1. *Section 1: Interestingly only PGA is required for the seismic stability analysis rather than a spectrum. What type of analysis was performed?*

Response 1
See Response 25.

2. *Section 1.1: No figure cited. A small-scale location map with the towns mentioned would be useful.*

Response 2
The towns of Hanksville and Ticaboo have been added to Figure 1. Section 1.1 has been revised to include additional information.

3. *Section 1.2.1, first paragraph: "1-sigma" should be replaced with "median plus one sigma."*

Response 3
"1-sigma" has been replaced with "median plus one sigma" in Section 1.2.1.

4. *Section 3.1: "Aftershocks and foreshocks" are removed to obtain a catalog of independent events since a Poissonian assumption is used in the PSHA.*

Response 4
We are in agreement with this statement. Section 3.1 has been modified to clarify that the catalog is of independent events.

5. *Section 3.1: Replace "low intensity" with "small magnitudes." Very few of the events in the catalog were felt and so intensities were not reported.*

Response 5
This replacement has been made in Section 3.1.

6. *Section 3.1: Expand the discussion on the largest event in the site region, a* ***M*** *6.5 near Richfield, and the 1986 earthquake near the site, which is discussed in Wong and Humphrey (1989).*

Response 6
This discussion has been expanded in Section 3.1.

7. *Section 4.0, third paragraph, first line: What is meant by "characteristic ground motions" in this context?*

Response 7
The word "characteristic" has been removed from Section 4.0.

8. *Section 4.1.1, fourth paragraph, 14th line: What is this sentence meant to say with the "± 0.3" at the end? Sentence needs to be rewritten.*

Response 8
Section 4.1.1 has been rewritten as requested.

9. *Section 4.1.2: The Woodward-Clyde Consultants (1996) study used a maximum magnitude of* ***M*** *6.0 ± 0.5 for the background seismicity not* ***M*** *6.3.*

Response 9
Section 4.1.2 has been rewritten to remove reference to Woodward-Clyde Consultants (1996) in the last sentence of the first paragraph.

10. *Section 4.2: Please cite justification for the use of extensional ground motion attenuation models.*

Response 10
Between revised text in Sections 2.0 and 4.2, adequate justification has been provided.

11. *Figure 3: It would be helpful to label the linear fits(?) by the magnitude bins.*

Response 11
Best-fit linear parameters have been labeled on Figure 3.

BASIS FOR INTERROGATORY:

As stated in the June 2006 interrogatory R313-24-4-16/02 request:

> *"Please provide additional information to support the determination of an appropriate and consistent maximum predicted horizontal ground acceleration (MHGA) for the site. Please include sufficient information regarding historical seismicity and deterministic or probabilistic methodologies used to derive the estimated MHGA value, and to demonstrate that the proposed*

> *MHGA value reflects the most current information available regarding predicted seismic hazard levels in eastern/southeastern Utah and the area including the site. Seismic stability analyses should be based on this MHGA value."*

The updated deterministic and probabilistic seismic hazard analyses described in Attachment D represents a state-of-the-practice approach to assessing ground shaking hazard at a site. However, the approach taken to the analyses is simplistic and mechanical. Overall the documentation of the analyses is lacking with very little discussion on the justification of the input parameters. The analysts have relied upon the readily available USGS Quaternary fault and fold database and have not attempted to update these data with more current information. Important references have not been evaluated and/or they are not cited. In particular, a study of the seismicity and active faulting in the site area by Wong and Humphrey (1989) and studies across the border into Arizona by Brumbaugh (2005) have not been cited. The analysis by Woodward-Clyde Consultants (1996) for a site near Moab in the same tectonic setting as the Shootaring Canyon site should have been discussed since the inputs and results are quite relevant.

Probabilistic seismic hazard analyses (PSHA) are performed to estimate the mean hazard at a site. If properly done, the mean hazard should not be conservative or unconservative. Conservatism is addressed by selecting a higher hazard fractile or a longer return period. In several instances, the choice of input parameters has been justified because the authors thought it was conservative (higher hazard). This is not a proper use of PSHA. The SSHAC (1997) guidelines should have been referenced and followed in the performance of this PSHA.

REFERENCES:

Abrahamson, N.A. and Silva, W.J., 1997, Empirical response spectral attenuation relations for shallow crustal earthquakes: Seismological Research Letters, v. 68, p. 94-127.

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Brumbaugh, D.S., 2005, Active faulting and seismicity in a prefractured terrane: Grand Canyon, Arizona: Bulletin of the Seismological Society of America, v. 95, p. 1561-1566.

Campbell, K.W. and Bozorgnia, Y., 2003, Updated near-source ground motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra: Bulletin of Seismological Society of America, v. 93, p. 314-331.

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Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

Wells, D.L. and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, p. 974-1002.

Wong, I.G. and Humphrey, J.R., 1989, Contemporary seismicity, faulting, and the state of stress in the Colorado Plateau: Geological Society of America Bulletin, v. 101, p. 1127-1146.

Wong, I.G., Olig, S.S., and Bott, J.D.J., 1996, Earthquake potential and seismic hazards in the Paradox Basin, southeastern Utah, in Geology and Resources of the Paradox Basin, 1996 Special Symposium, A.C. Huffman, W.R. Lund, and L.H. Godwin (eds.), Utah Geological Association and Four Corners Geological Society Guidebook 25, p. 241-250.

Woodward-Clyde Federal Services, 1996, Evaluation of potential seismic and salt dissolution hazards at the Atlas Uranium Mill Tailings site, Moab, Utah: unpublished report prepared for Smith Environmental Technologies and Atlas Corporation.

INTERROGATORY R313-24-4-19/03: DOUBLE LINER SYSTEM CQAP PLAN AND SPECIFICATIONS

INTERROGATORY STATEMENT:

Please revise the CQAP:

- *To include testing to demonstrate that the clay used for the bottom liner meets the 1x10^{-7} cm/s* ***field*** *hydraulic conductivity requirement. This can be done by using the following test method (or an approved variation):*
    - *ASTM D5093-02 Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring*

  If a variation of this method or an alternate method is proposed (such as a single-ring infiltrometer), it needs to be submitted to the DRC for review and concurrence.

Response 1

This response is has been prepared to present Uranium One's proposed testing methodology for the clay layer to be constructed as part of the liner system for the proposed Shootaring Canyon Tailings Disposal Facility (TSF). Once an agreement has been reached with the Division of Radiation Control regarding the proposed methods, the CQAP will be revised to reflect the agreed upon testing methods.

General

Uranium One proposes to use clay from on-site or nearby sources to construct the clay layer forming the lowermost liner of the multi-liner system at the proposed Shootaring Canyon TSF. A laboratory program will be performed to identify the appropriate degree of compaction and moisture content range needed to achieve a maximum saturated hydraulic conductivity of 1x10^{-8} cm/s. A test pad will then be constructed at the site using the parameters derived from the laboratory testing program to verify that a maximum saturated hydraulic conductivity of 1x10^{-7} cm/s can be achieved in the field.

In the Division of Radiation Control's (DRC) interrogatory R313-24-4-19/03, DRC recommends that Uranium One use ASTM D5093-02, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring to verify the saturated hydraulic conductivity in the field. While the sealed double ring infiltrometer (SDRI) is considered a standard test for evaluating field permeabilities, recent studies as well as ASTM have acknowledged that the SDRI test method is: a) prone to operator error in measurement; and b) somewhat limited since it does not allow for consideration of the effective stress that the liner will be subjected to during operation. As stated by Daniel, (1993), "One problem with in situ tests on test pads is that the test pad is subjected to essentially zero overburden stress. Hydraulic conductivity decreases with increasing compressive stress."

Accordingly, Uranium One proposes to verify field saturated hydraulic conductivity by obtaining 5 large block samples from the test pad and testing them in large triaxial permeability cells in accordance with ASTM D5084-Method C. Laboratory testing of block samples have been performed in lieu of field testing in confirmation studies

(Benson et al., 1997, Trast and Benson, 1995, and Benson et al., 1994, provided in Attachment E for reference). Benson et al. (1997) conducted a comparison of the hydraulic conductivity of four test pads. The test pads were constructed to the same specifications with soil from the same source by four different contractors. SDRIs were installed on each pad immediately following construction to evaluate the field hydraulic conductivity. The SDRIs were left on the test pads for 8 months after construction, at which time the hydraulic conductivity was computed using data from the SDRIs. Following completion of the SDRI testing large block specimens, sampling tubes, and two-stage borehole tests were also performed at the same locations to compare against the hydraulic conductivities obtained from the SDRIs. The results of the study performed by Benson et al. (1997) showed that the block sampling method yields hydraulic conductivities approximately two times faster than the long-term hydraulic conductivity measured with the SDRIs. The paper identified two main reasons for this difference. First, the block sample was tested with a higher hydraulic head than the SDRI which allows for a higher degree of saturation and consequently a higher conductivity. Second, the block specimens typically consist of one lift of soil, whereas the SDRI permeates multiple lifts, allowing for the lower lifts to contribute to the hydraulic conductivity value. Given that large scale block tests will be on the conservative side of the field hydraulic conductivity determination, they should be considered to be an alternative method of demonstrating that the clay used for the bottom layer of the liner system meets the $1x10^{-7}$ cm/s field hydraulic conductivity requirement

The issue of effective stress as it contributes to the hydraulic conductivity of the soil should also be considered. Trast and Benson (1995) conducted a study where both SDRI and large scale block tests were conducted to determine the effect of increased effective stress on the hydraulic conductivity of soils collected from 11 compacted-clay test pads. Trast and Benson (1995) concluded that "…the 0.3-m block specimens had essentially the same hydraulic conductivity as was measured with the SDRIs". This finding suggests that the large block specimens were of sufficient size to capture pore networks similar to those controlling flow in the field. Increasing the effective stress applied to a sample resulted in a decrease in the hydraulic conductivity of that sample by, on average, a factor of 4. As the liner system will be buried under tens of feet of tailings, testing the large scale block specimens at a higher effective stress will be more representative of field conditions, and should be considered when evaluating the field hydraulic conductivity of the clay materials.

Recently, Clean Harbors Environmental Services has successfully used block samples for confirmation at some of their hazardous waste landfills. "For example, blocks were used in lieu of an SDRI on a test pad at the Highway 36 Landfill near Denver" (Geo-Smith, 2008 and Golder, 2006). Block samples were also used to verify hydraulic conductivity for the Hazardous Waste Landfill and the Enhanced Hazardous Waste Landfill at the U.S. Army's Rocky Mountain superfund site (HLA, 1997 and Foster Wheeler 2002). Copies of the referenced reports have been included in electronic format as attachments to this response.

Uranium One proposes to use large block samples to verify the hydraulic conductivity of the clay layer. Uranium One proposes to report the arithmetic mean of the tests rounded to one significant digit to verify the value of the field saturated hydraulic conductivity.

Laboratory Testing for Test Pad Construction

Laboratory testing will be performed on the proposed clay materials. Clay will be obtained from the borrow areas and delivered to the laboratory for testing. The soil will be classified in accordance with ASTM D2487 [Standard Classification of Soils for Engineering Purposes (Unified Soil Classified System)] for QA/QC requirements. Particle-size distribution and Atterberg limits testing will be performed as part of the classification process. The maximum dry density (MDD) and optimum moisture content (OMC) for each sample will be calculated in accordance with ASTM D 698 [Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort].

Laboratory testing to calculate the saturated hydraulic conductivity of the soil will be performed in a flex-wall permeameter triaxial cell following ASTM D5084 [Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter] procedures. Remolded samples of each mixture will be prepared at 95 and 100 percent of MDD at OMC, and at 2 and 4 percentage points over the OMC. The results of the laboratory tests will be used to identify the percent compaction and moisture content that results in a laboratory hydraulic conductivity of $1x10^{-8}$ cm/sec. A laboratory permeability of $1x10^{-8}$ cm/sec has been selected as a target permeability because data has shown that laboratory permeabilities are typically lower than can be achieved in the field using large scale construction techniques. The selection of a hydraulic conductivity one order of magnitude less than the required field conductivity is purely arbitrary and is not based on any existing study. However, this is a value that is quite often used in practice when comparing field and laboratory permeabilities. Using this target lab permeability provides a reasonable basis for identifying MMD and OMC values for field placement of clays to meet the acquired field permeability volume of $1x10^{-7}$ cm/s.

Test Pad Construction

Following completion of the laboratory testing program a test pad will be constructed on-site using the procedures and similar equipment to what will be used to construct the clay layer for the proposed TSF. Samples of the test pad will be collected and tested to confirm that material types are generally similar to those used in the laboratory testing program and to evaluate the field hydraulic conductivity of the clay layer.

The test pad dimensions will be dictated somewhat by the construction equipment to be used for pad construction. In order to provide sufficient area to represent actual construction conditions, the minimum test pad dimensions will be 75 feet wide, 100 feet long, and 1 foot thick. The test pad will be constructed in an area of the impoundment footprint that will have similar geotechnical conditions (e.g. moisture content, soil type, gradation, etc.) to the area where the impoundment will ultimately be constructed. However, since grading for the impoundment will not have begun at the time the test pad is constructed, it is anticipated that the test pad will be constructed at an elevation different than the final elevation of the liner system. Therefore, it is not expected that the test pad will ultimately be incorporated into the final impoundment construction.

The test pad area will be graded to provide a flat surface sloped at least 1 percent to facilitate positive drainage off of the test pad. The test pad subgrade will be scarified to a minimum depth of 8 inches and recompacted to 95 percent of MDD at a moisture content between OMC and 2 percentage points above OMC. The subgrade will again be graded flat, with at least a 1 percent slope, and the clay layer placed over the subgrade in lifts not exceeding 6 inches in compacted thickness.

Clay for the clay layer will be moisture conditioned by adding water and discing the clay. The clay will be allowed to hydrate for a minimum of 24 hours prior to compaction to help more evenly distribute the moisture throughout the clay. The clay layer then will be compacted to the minimum dry density and moisture content that displayed a hydraulic conductivity of $1x10^{-8}$ cm/s during the laboratory testing program. Within 24 hours of completion of the test pad, large block samples will be collected from the pad and sent to the laboratory for hydraulic conductivity testing.

Excavations resulting from the sample collection will be filled and compacted using additional clay material. Patches placed in the excavations will be compacted using a hand compactor in 6 inch lifts to the same dry density and moisture content used for the rest of the clay layer. The clay layer will then be covered with 30 mil thick plastic sheeting which will in turn be covered with a minimum 6 inch thick lift of loose site soil. The purpose of covering the test pad with plastic and soil is to prevent desiccation of the test pad in the event that laboratory testing indicates that the required field hydraulic conductivity has not been achieved or additional sample collection is desired. If necessary, the cover soil and plastic sheeting can be removed and additional compactive effort applied to the clay layer with minimal moisture conditioning.

Field Saturated Hydraulic Conductivity Testing

Sampling Procedures

Five locations on the test pad will be sampled, one in the center and the remaining 4 located near the corners of the test pad. The samples collected at the corners of the pad will be not be located closer than 10 feet from the edge of the test pad to avoid edge effects and damage from turning and reorienting the compaction equipment. In-situ nuclear density tests will be taken immediately adjacent to each sample location prior to collecting the sample. Field moisture and dry density testing will be tested in accordance with ASTM-D6938-07a.

Block samples of the clay layer will be collected by placing a soil trimming ring on the surface of the clay layer and excavating a trench around the ring the full depth of the clay layer. The soil trimming ring will consist of a 12-inch (30 cm) long section of 18-inch (45 cm) diameter PVC pipe with a beveled cutting shoe machined into the base. Soil will then be carefully hand trimmed until the ring can be pushed down over the soil column. When the trimming is at full depth, the specimen will be removed from the hole by pushing a flat-bladed spade into the underlying foundation soil at several locations. After the sample is removed from the hole, the ends of the sample will be trimmed flush with the soil trimming ring and sealed with heavy plastic sheeting taped to the PVC trimming ring. The samples will then be packaged and shipped to the laboratory for analysis.

Laboratory Testing

During sample preparation the field sample will be trimmed to obtain a 12-inch (30 cm) diameter and 6-inch (15 cm) thick laboratory sample. Cuttings from the trimming process will be analyzed for moisture content, particle size distribution, and Atterberg limits. Each sample will be placed in a large-scale flexible-wall permeameter manufactured by Trautwein Soil Testing. The 30 cm diameter by 15 cm thickness dimension has been shown by Benson et al. (1994) to be sufficient to capture the macropore characteristics of the clay layer.

If laboratory testing indicates that the required field hydraulic conductivity has not been achieved, additional compactive effort may be applied to the test pad in an attempt to reduce the hydraulic conductivity. The moisture content of the existing test pad would be tested to confirm that it is still within the required range of moisture contents. If testing indicates that additional moisture conditioning is required, this would be performed prior to application of the additional compactive effort. Samples would be obtained from different areas of the test pad to avoid the possibility of sample disturbance.

Testing During Clay Liner Construction

During construction of the TSF it is imperative that the clay layer be covered with the HDPE geomembrane as soon as possible to prevent desiccation of the clay soil. Therefore, the clay layer should be covered with the rest of the liner system immediately following compaction. The clay layer would be covered prior to completion of the testing program for field hydraulic conductivity. Uranium One is therefore, proposing that the test pad be used as the basis for demonstrating that the proposed construction methodologies and site soils can meet the required field hydraulic conductivities. Soil samples will be collected during the placement of the clay layer to confirm that the soil properties are within the range specified based on a successful test pad evolution. Testing proposed will include particle size distribution, Atterberg limits, and in-place soil density and moisture content. Provided these parameters are within the range established during the test pad program the resulting hydraulic conductivity should remain the same. Therefore, the test pad results will be used to establish material property and placement specifications to meet the required field hydraulic conductivity of $1x10^{-7}$ cm/s. Actual QA testing for the clay liner will consist of confirming the specified material properties and in-place moisture contents and densities are within the acceptable ranges that were shown to meet the $1x10^{-7}$ field hydraulic conductivity requirements for the test pads. This QA program will allow for quick covering of the clay liner and will avoid destructive testing of the in-place liner system after installation, which could compromise the overall performance of the liner. The specifications and QA program proposed will be outlined in the Technical Specifications and QA/QC plan as a future submittal.

There are several advantages of using large scale block samples to confirm the field saturated hydraulic conductivity. During facility operation the overburden stress on the liner system will increase due to the deposition of tailings over the liner system. Therefore, the loads expected during the life of the facility can be modeled by controlling the confining stresses applied to the sample and monitoring the effect of the confining stress on the hydraulic permeability of the clay layer. Previous studies have shown that increasing the confining stress on a soil sample will decrease the field hydraulic conductivity of the soil being tested (Daniel, 1993). The range of expected stress can be modeled in the triaxial cell and the hydraulic conductivity under representative conditions can be observed.

References

Benson, C., Hardianto, F., and Motan, E., 1994. “Representative specimen size for hydraulic conductivity of compacted clay,” *Hydraulic Conductivity and Waste Containment Transport in Soils: ASTM STP 1142*, S. Trautwein and D. Daniel, eds., ASTM , Philadelphia, Pa., p. 3-29.

Benson, C.H., Gunter, J.A., Boutwell, G.P., Trautwein, S.J., and Berzanskis, P.H., 1997. “Comparison of four methods to assess hydraulic conductivity,” *Journal of Geotechnical and Geoenvironmental Engineering*, 123(10):929-937.

Daniel, David E. 1993. *Geotechnical Practice for Waste Disposal*. Chapman & Hall, London, UK, p. 149.

Foster Wheeler Environmental Corporation, February 2002. “Rocky Mountain Arsenal, Enhanced Hazardous Waste Landfill Test Pads Program, Summary Report.

Geo-Smith Engineering, LLC (Geo-Smith), 2008. Personal Communication between Greg Smith, Geo-Smith Engineering, LLC with Dr. Craig Benson, Clean Harbors Environmental Services. April 15.

Golder Associates Inc. June 2006. “Final Report, Clean Harbors Environmental Services, Deer Trail Secure Cell No. 3, Test Fill Report, Deer Trail, Colorado.

Harding Lawson Associates (HLA), December 1997. “Final Test Fill Construction Program, Summary Report, Feasibility Study, Soils Support Program, Rocky Mountain Arsenal, Commerce City, Colorado.

Trast, J.M. and Benson, C.H., 1995. “Estimating field hydraulic conductivity of compacted clay,” *Journal of Geotechnical Engineering*, 121(10):736-739.

BASIS FOR INTERROGATORY:

As stated in Round 1 and 2 Interrogatories, the applicant proposes to use a double liner with leak detection in order to prevent migration of wastes out of the impoundment (sections 4 & 5, TMP). The applicant indicates that the double liner with the leak detection system design is the Best Available Technology (BAT) and comparable to similar facilities in the industry. However, there is insufficient information provided in the Construction Control Quality Assurance Plan (CCQAP) and only limited detailed plans and specifications are provided for the construction of Cell 1 and 2. The deficiencies in the CCQAP are addressed in this interrogatory, while the deficiencies in the plans and specifications are addressed in a separate interrogatory.

As presented in Round 2 of this Interrogatory, the requirement for the hydraulic conductivity of the clay liner is an in-place ***field*** *hydraulic conductivity of* $1x10^{-7}$ *cm/s or less. This is considered BAT for liner systems. Uranium One needs to provide a demonstration that the clay used for the bottom liner meets this requirement. In the response to this interrogatory in round 1, Uranium One stated that field permeability testing would prove too difficult, and preliminary laboratory testing indicated permeability’s in the* 10^{-8} *cm/sec range. Further justification is needed as to why field permeability testing has not been successfully completed, and as to the difficulty is performance of the testing.*

According to “Assessment and Recommendations for Improving the Performance of Waste Containment Systems” (see reference for Bonaparte, Daniel, and Koerner, 2002 below), the most effective means of testing permeability of a soil layer such as a clay liner is in-place with a sealed double-ring infiltrometer.

Another method used is a single-ring infiltrometer (see reference for Amoozegar and Warrick, 1989 below). However, since the single-ring infiltrometer is not as widely used or accepted as the double-ring method, the specific methods and procedure for the single-ring infiltrometer will need to be provided for DRC review and concurrence prior to its use. Of particular concern is the ability to test a large enough surface area of the clay liner that will provide reasonable results that represent the actual permeability of the clay layer. Field testing is used because is has been found that laboratory test methods are applied to a small and limited sample size(or area) that is not typically representative of the soil layer being evaluated. Extensive reviews of laboratory tests results (typically involving 75-mm-diameter samples of compacted clay materials) have shown a strong tendency to report smaller saturated conductivities for clay liners than are actually achieved in the field (Benson, Hardianto, and Motan 1994; Bonaparte, Daniel, and Koerner, 2002). For this reason the Division prefers the use of the field methods stated in the interrogatory.

The DRC believes that successful field permeability testing of the clay liner can be performed using "ASTM D5093-02 Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring. Another method can be used (such as a single-walled infiltrometer) provided the specific methods and procedures are provided for DRC review and concurrence.

REFERENCES:

Amoozegar, A, and A.W. Warrick. 1986. Hydraulic conductivity of saturated soils: field methods. American Society of Agronomy.

Bonaparte, Rudolph, David E. Daniel, and Robert M. Koerner, December 2002. Assessment and Recommendations for Improving the Performance of Waste Containment Systems. EPA/600/R-02/099.

Benson CH; Hardianto FS; and Motan ES, "Representative Specimen Size for Hydraulic Conductivity Assessment of Compacted Soil Liners," ASTM Specialty Technical Publication 23883S, January 1994.

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Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-20/03: LINER STRENGTH & COMPATIBILITY

INTERROGATORY STATEMENT:

The proposed design needs to include a concise and well-defined design basis that is then demonstrated to meet the respective criteria through technical evaluation, data, and calculations. Based on the information provided to date in support of the proposed tailings cell design the following need to be included:

1. *An evaluation of the impact of stress imposed by equipment, tailings, and liquid during all scenarios and phases of construction, operations and tailings placement on the liner system that could result in movement and degradation of the liner system. Please include an evaluation of the steepest slope where the liner will be subject to the highest stresses during all scenarios and phases of construction, operations and tailings placement. Explain what is meant (specifically) when stating that the slopes will be" relatively mild". In addition, please note that since the tailings will be placed in the cell via slurry, the statement that there will be no significant ponding of liquids against the exposed liner is not correct. Consider slurry and free liquids in the cell in the design and evaluating the stability of the liner system.*

   Response 1
   This response will be provided in a later submittal.

2. *An evaluation of the impacts of wind uplift forces and ballasting for wind uplift on the liner system while exposed to these forces.*

   Response 2
   Design calculations for wind uplift forces and ballasting are provided in Appendix F.4 of the attached Design Report.

3. *The following Clarifications are needed on the anchor trench design calculations provided in the 11/28/07 response to item #3 in Round 2 of this interrogatory*

   3.1. *How will the use of sand fill material that has an internal friction angle of 32° or greater be assured in the construction of the liner anchor system?*

   Response 3.1
   Updated liner anchorage design calculations are provided in Appendix F.3 of the attached Design Report. Although a friction angle of 32° or greater will be assured during construction of the liner system, a conservative friction angle of 28° was used for design calculations for the anchor trench. The construction QA/QC program, to be presented in the Technical Specifications of the Construction Documents, will include frequent index and shear strength testing to assure a friction angle of 32° or greater during construction of the liner system.

   3.2. *Proposed cell liner drawings showing the geometry of the cell slopes and layout of the drainage layer need to be provided. They need to include where the drainage layer will be placed (i.e., only on the cell floor, or on the floor and up the side slopes). This will be helpful in understanding the critical stress areas and the proposed anchor trench design.*

Response 3.2
Cell liner drawings are included in the attached Design Report.

3.3. *It appears that the anchor trench calculations have used an angle of shearing resistance for soil to HDPE for the liner upper and lower surface. This is appropriate for the liner upper surface, but the lower (under) surface of the upper liner is in contact with the geonet. Typically, the angle of shearing resistance between HDPE and geonet is less than the one between soil and HDPE. It appears that it would be appropriate to use the angle of shearing resistance between soil and HDPE for the upper surface, and between the HDPE and the geonet for the lower surface. This will increase the run out lengths and anchor trench depths.*

Response 3.3
This correction has been made. The revised calculations are provided in Appendix F.3 of the attached design report.

3.4. *Please include the basis (references) for the following:*

- *Allowable stress of 2100 psi*
- *Thickness of 0.06 inches*
- *Unit weight of soil of 100 lb/ft3*

Response 3.4
The references for these parameters are included in Appendix F.3 of the attached design report.

4. *"Response 5"to Round 2 of this Interrogatory provided by Uranium One mentioned the use of rub sheets and splash guards in areas where the tailings will be discharged to the cell. Here again, design drawings need to show where these features are needed. Also, please note that if the tailings are to be discharged to the cell so that they flow down the side slope on the liner, the resultant load on the liner needs to be evaluated to ensure that the liner system will not be compromised.*

Response 4
The need for splash guards or rub sheets to protect the primary liner where tailings are discharged over the liner down the side slopes will be evaluated and presented in the Operations Plan. This subject is addressed conceptually in the attached Design Report.

5. *Figure K-2 shows the anchor systems where side slopes do or do not have a drainage layer. Drawings clarifying where the drainage layer is being placed needed to be included.*

Response 5
Drawing L2 in the attached Design Report delineates the limits of the LCS drainage gravel layer.

BASIS FOR INTERROGATORY:

As stated in Round 1 Interrogatories, the Applicant's submission does not include sufficient information to allow a complete review of adequacy of the lining system design for meeting the requirements of 10 CFR 40, Appendix A, Criterion 5 A(2) which addresses cell liner requirements, or for meeting the criteria identified in R317-6-1, 1.3 for BAT, for double liner systems. Lacking is a complete evaluation of the stresses on the liner system under maximum loading conditions. These maximum loading conditions need to be defined as the design basis, then calculations need to be developed and provided that demonstrate the liner system is capable of maintaining the design integrity, configuration, and performance. Reference is made to the RMTP as being an important basis of the design. However, the revised plan, responses to Round 1 Interrogatories, and subsequent discussions with Uranium One indicate the tailings will be placed as slurry, and it is inferred that the RMTP will be used when and if developed. A concise and well-defined design basis needs to be included that is then demonstrated to meet the respective criteria through technical evaluation, data, and calculations.

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Hsuan, Y.G., Lord, A.E., and Koerner, R.M., 1991. "Effects of Outdoor Exposure on a High Density Polyethylene Geomembrane", in Geosynthetics ' 91, Atlanta, GA, pp. 287-302.

Koerner, R.M. , Hsuan, Y.G., and Koerner, G.R., 2005. "Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions", Geosynthetic Institute White Paper #6, June 7, 2005.

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INTERROGATORY R313-24-4-21/03: LINER SETTLEMENT

INTERROGATORY STATEMENT:

Please indicate the extent of settlement, differential settlement, and distortion in the cover that are allowed at the time of final closure. Demonstrate that allowable settlement, differential settlement, and distortion resulting tailings consolidation with time will not damage the final liner system. Justify the respective design criteria and tailings material properties used.

Response 1

This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

Uranium One's response to Round 2 of this Interrogatory stated that a response will be provided in the next submittal.

In response to Round 1 Interrogatory Uranium One explained that the liner subgrade will be the Entrata Sandstone, and therefore settlement of the soil (rock) under the cells is not of concern. In addition, the clay and sand layers placed at part of the liner system will be compacted and also will not pose a concern with settlement. However, not provided is an evaluation and demonstration of the potential settlement of the tailings themselves after cover placement. This is now of particular concern considering that the tailings will be placed in a slurry with high liquid content. Will any anticipated settlement from dewatering of the tailings via the leachate collection system (including differential settlement) impact the integrity of the cover system? How long before dewatering is complete and consolidation of the tailings is no longer of concern? What are the settlement tolerances of the cover system? The moisture content, and other physical properties of the tailings after cover placement, and their potential for consolidation, thereby impacting the cover needs to be considered in this evaluation.

REFERENCES:

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-22/03: LEACHATE COLLECTION AND DETECTION SYSTEM DESIGN

INTERROGATORY STATEMENT:

Please provide confirmation as to the adequacy of the geofabric for permeability (permittivity) as well as for filtration. There needs to be confirmation that the geofabric will not restrict water flow or allow for the infiltration of the surrounding sand into the stone bedding.

Please clarify the use of a perforated pipe with a sock where the pipe extends up slopes. Typically a solid pipe is used for the collection sump piping.

Response 1

Geofabric is no longer a component of the leachate collection and detection system. The pipes in the collection system will be bedded at the base of 18 inches of clean gravel that is covered by six inches of well-graded sand filter. The drainage gravel serves the following functions: (1) providing a continuous drainage layer at the base of the tailings to prevent build-up of head on the primary liner, (2) adding drainage capacity to Leachate Collection System, (3) preventing intrusion of tailings into the 0.25-inch slots in the perforated drainage pipe, (4) guarding the HDPE liner against penetration of stones or other objects, and (5) protecting the HDPE liner against damage from construction equipment. The gradation envelope that represents acceptable particle sizes for the drainage gravel is shown in Figure 7-1 of the Design Report. The drainage gravel will have a maximum particle size (D100) of 1 inch, in order to protect the integrity of the primary HDPE liner. The minimum particle size is designed to meet filter criteria with the pipe perforations of 0.25 inches, according to guidance given in the National Engineering Handbook, Part 633, Chapter 26 “Gradation Design of Sand and Gravel Filters” (USDA, 1994). The sand filter is designed to prevent migration of tailings material into the pore spaces of the drainage gravel.

The Tailings Reclamation and Decommissioning Plan (Plateau Resources and Hydro-Engineering, 2002) presented the gradation results from three tailings samples. These gradations are shown in Figure 7-1 of the Design Report. As the milling process that produced these tailings is similar to the process that will produce future tailings at the site, it is reasonable to assume that these gradations represent likely gradations of whole tailing samples of future tailings. As the tailings are discharged, tailings will segregate with the coarser fraction settling out close to the discharge point, and the finer fraction settling out at further locations. Therefore, it is likely that a finer gradation than that presented in the Tailings Reclamation and Decommissioning Plan will exist at discrete locations. In order to estimate this finer fraction, the gradation from sample T4 was adjusted to represent the finest 50% of the whole gradation (i.e. the smallest 50% of the tailings settle out at a location far from discharge point). This adjusted gradation is shown on Figure 7-1 of the Design Report. From this adjusted gradation, a gradation envelope for filter sand meeting filter criteria with the fine tailings was developed using criteria presented in National Engineering Handbook, Gradation Design of Sand and Gravel Filters. In addition, a gradation envelope for the drainage gravel that meets filter criteria with both the filter sand and 0.125-in slots in the perforated drain pipe is presented. These gradations are all shown in Figure 7-1 of the Design Report.

Perforated pipe for leachate collection and leak detection will extend across the tailings basin floor, but will not extend up the side slopes. The drainage gravel and sand filter are designed to prevent plugging of the perforated pipe. Therefore, a sock is not needed around the perforated pipe. The only piping that will extend up the internal slopes of the tailings basin are the solid riser pipes used to evacuate the sump areas.

REFERENCES

United States Department of Agriculture (1994) *National Engineering Handbook, Part 633*, Chapter 26, Gradation Design of Sand and Gravel Filters.

BASIS FOR INTERROGATORY:

BAT requires that leachate collection and detection systems be designed to resist clogging during the active life and post-closure period. The proper design of the Sand/Tailings interface is a critical point where, under the current design, clogging potential is viewed as the highest.

Uranium Ones 11/28/07 response to Round 2 of this interrogatory included revised text for Section 5.1.4.2 "Piping Structural Design" of the TMP. Review of this section identified the following concerns:

- *There is no confirmation as to the adequacy of the geofabric for permeability (permittivity) and for filtration. There needs to be confirmation that the geofabric will not restrict water flow or allow for the infiltration of the surrounding sand into the stone bedding.*
- *The text states that where the pipe extends up slopes that are greater than 4H:1V and beyond the drainage layers, a filter sock will be placed around the pipe. Isn't the function of piping above the drainage layer to allow for sump access and liquid transfer via a pump? Why use a perforated pipe with a sock? Why not a solid pipe?*

REFERENCES:

Joen, H.-Y. and Mlynarek, J. 2004. "Assessments of Long-Term Drainage Performance of Geotextiles". GeoQuebec: 57th Canadian Geotechnical Conference.

Keshian, B. and Rager, R.E. 1988. "Geotechnical Properties of Hydraulically Placed Uranium Mill Tailings". Hydraulic Fill Structures: specialty conference sponsored by the Geotechnical Engineering Division of the American Society of Civil Engineers. Colorado State University, Fort Collins, Colorado. August 15-18.

Koerner, G.R, Koerner, R.M., and Martin, J.P. 1993. "Field Performance of Leachate Collection Systems and Design Implications". Solid Waste Association of North America: 31st Annual International Solid Waste Exposition, pp. 365-380.

Koerner, R. M. 2005. Designing with Geosynthetics, Fifth Edition.

Luettich, S.M., Giroud, J.P., and Bachus, R.C. 1992. "Geotextile Filter Design Guide". Journal of Geotextiles and Geomembranes, Vol. 11, No. 4-6. pp.19-34.

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007.

Reinhart, D.R. et al. 1998. Assessment of Leachate Collection System Clogging at Florida Municipal Landfills. Report # 98-5. Florida Center for Solid and Hazardous Waste Management, Gainesville, FL. October 30, 1998.

Rowe, R.K. 2005. Long Term Performance of Containment Barrier Systems, Geotechnique, 55, No. 9, pp. 631-678.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-23/03: DIKE INTEGRITY

INTERROGATORY STATEMENT:

Please confirm that all slopes and friction failure surfaces--including the proposed liner interfaces--have been evaluated or are represented by the evaluation of the most critical slopes and surfaces. All scenarios and phases of construction, operations, and tailings placement must be considered. Provide such analyses for the Division's review. These analyses must include and/or consider the dikes between Cell 1 and Cell 2 and between Cell 1 and the Evaporation and Process Pond Cell (EPPC) and the conditions where the liner is assumed to have failed (e.g., worst case scenario).

Please provide a slope and seismic stability evaluation for Shootaring Canyon Dam, the Cross Valley Berm, the area between the Cell 1 and the EPPC, and any other dams/berms using a failed liner condition under a worst case scenario or similar.

Provide conclusive calculations, models, and statements demonstrating the applicability and adequacy of the existing or new slope stability analysis. Ensure that such calculations, models, and statements address all special conditions that would affect dike and liner system integrity that may exist between Cell 1 and Cell 2 and between Cell 1 and the EPPC.

> **Response 1**
> The evaluation of all friction surfaces, including the proposed liner interfaces, will be presented in Interrogatory R313-24-4-20/03 Liner Strength and Compatibility, Response 1. Final design parameters of the EPPC have not yet been developed; this condition will be evaluated when the EPPC design has been completed.
>
> Seepage and slope stability analyses for the Shootaring Canyon Dam (South Dam) the side slopes, and the divider berm are presented in the attached Design Report. The Cross Valley Berm, the North Dike, and the East Dike will be entirely removed during construction of the revised Tailings Storage Facility.

BASIS FOR INTERROGATORY:

The operating elevations of the tailings on each side of the dikes are important, since the effect of such operations have some failure potential. Therefore, proposed configurations of the dikes must be evaluated as part of the design criteria. The criteria must include the critical loading and elevation scenarios on both sides of the dikes. Later, these critical scenarios may also be used to propose the limited operating conditions by which the ponds on each side of the dikes may be operated.

In general, the response and revised text in Section 3 address part of the interrogatory statement from Round 1. Another analysis of seismic stability was conducted by Inberg-Miller Engineers [IME] (dated January 2007) with a Safety Factor of 1.18. However, this did not constitute a worst case scenario with a failed liner and leakage as required by Utah Administrative Code and URCR. The new analysis from IME 'assumed no phreatic surface will develop through the earthen dam.' The UDRC rule reads, 'In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment' R313-24-4.

Seismic and slope stability analyses were conducted by the applicant for the Shootaring Canyon Dam and the Cross Valley Berm (section 3 & Appendix A, TMP). The reference documents within the application do not address piping, however this may not be wholly applicable since the cells have double layers (liners) technology. The documents do contain a slope stability analysis for the Cross Valley Berm.

The information requested is needed to demonstrate the long-term stability of the final cover, especially in consideration of the cited passage of URCR on the presumption of leakage of the liner system during the active life of the impoundment.

REFERENCES:

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility," Dated December 2005, Revised April 2007.

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-24/03: BEST AVAILABLE TECHNOLOGY

INTERROGATORY STATEMENT:

Please provide the following:

1. *Estimation of anticipated leachate flow rates and maximum capacity in the leachate collection systems.*

   Response 1
   An estimation of anticipated leachate flow rates and the maximum capacity of the leachate collection system is discussed in Section 7.6.3 of the Design Report, with additional calculations in Appendix F.1 of the report.

2. *A demonstration that the leak detection system design in the final cell(s) will result in no more than 1-foot of head on the bottom liner at any time, and that the system is designed to handle the resultant flow.*

   Response 2
   The expected head on the bottom liner, anticipated flows, and the capacity of the Leak Detection System are discussed in Sections 7.4.1 and 7.4.2 of the Design Report, with additional calculations in Appendix F.1 of that report.

3. *Complete Liner system design and construction drawings (plans), as well as material and performance specifications. They are to be certified by a Professional Engineer licensed in the State of Utah, and shall include, but not be limited to, cell liner, leachate collection, leak detection, dewatering operations, tailings transfer and management, and storm water control layouts, cross sections, details, and profiles. They must include proposed elevations and horizontal coordinates at all key locations. The specifications must cover (but not limited to) all proposed components and materials, their respective material and equipment and installation requirements.*

   Response 3
   This response will be provided in a later submittal.

4. *An estimate of volumes and capacities of the cells as well as cut and fill quantities.*

   Response 4
   Estimates of cut and fill quantities and storage capacities are provided on Drawing P1.3 in the attached Design Report.

5. *Review of Uranium One's 11/28/07 response to Round 2 Interrogatories identified the following concerns"*

   - *Material properties specific to the pipe material and soil bedding are included in the demonstration. However, the source of these values is not included. It is typical with these types of demonstrations (calculations) to include a copy of the specific data basis such as material spec sheets, test results, references from literature, etc. This is important in order to fully understand what is being presented, in what context, and to document the basis.*

Response 5a

Analyses related to the load bearing capacity of buried pipe has been modified to reflect revised methodology as presented by Plastic Pipe Institute, updated pipe diameters, and selected Standard Dimension Ratio (SDR). A summary of the piping structural design is presented in Section 7.6.5 of the Design Report, with calculations and material properties included in Appendix F.2 of that report.

- *The pipe and soil material properties need to be carried through to the project QAP and technical specifications to ensure that what is installed and constructed meets or exceeds the performance as presented in the respective demonstration.*

Response 5b

The project QAP and technical specifications will be submitted at a later date.

BASIS FOR INTERROGATORY:

Review of the responses to Round 1 and 2 of this Interrogatory found that the following concerns remain:

1. *Estimation of anticipated leachate flow rates and maximum capacity in the leachate collection systems has not been identified in the submittal and must be provided. Estimation of the anticipated flows will enable the leachate management system to be properly designed to accommodate the full flow conditions and will ensure that the tailings are dewatered in a reasonable timeframe. This estimation should then also be included as part of the Leachate Monitoring, Operations, Maintenance, and Reporting Plan.*
2. *The leak detection system for the final cell configuration and design will function so that the head on the lower liner never exceeds 1-foot.*
3. *The liner system design and construction drawings and material and performance specifications need to be developed. These items are currently only addressed for the cover system, but are not included for the liner system. Provide drawings (plans) and specifications in sufficient detail so they could essentially be used for bidding and construction. They are to be certified by a Professional Engineer licensed in the State of Utah. The drawings shall include, but not be limited to, cell liner, leachate collection, leak detection, dewatering operations, tailings transfer and management, and storm water control layouts, cross sections, details, and profiles. They shall include proposed elevations and horizontal coordinates at all key locations. The specifications shall cover (but not limited to) all proposed components and materials, their respective material and equipment and installation requirements*

   In addition, design exercises such as estimating volumes and capacities and creating filling and grading plans in advance of waste generation are critical to a successful project since these exercises help to ensure that estimated volumes are considered and that adequate storage space is planned (even if the storage is temporary). It is common practice to prepare for the estimated contaminated soil volume with a contingency volume included (contingency amount would be based on the confidence in the primary volume estimate). If the contingency volume is not used, then clean or lower level contaminated material can be placed as general fill. These concepts would all be blended into the detailed design drawings and specifications.
4. *Uranium One included in Appendix J of the 11/28/07 response to Round 2 Interrogatories an evaluation demonstrating the adequacy of the buried HDPE pipe to withstand the load imposed due to its burial depth. A review of this demonstration resulted in the identification of some concerns that need clarification. They are:*

a. *Material properties specific to the pipe material and soil bedding are included in the demonstration. However, the source of these values is not included. It is typical with these types of demonstrations (calculations) to include a copy of the specific data basis such as material spec sheets, test results, references from literature, etc. This is important in order to fully understand what is being presented, in what context, and to document the basis.*

b. *The pipe and soil material properties need to be carried through to the project QAP and technical specifications to ensure that what is installed and constructed meets or exceeds the performance as presented in the respective demonstration.*

REFERENCES:

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Plateau Resources, Ltd., "Shootaring Canyon Uranium Processing Facility Environmental Report, Source Material License No. UT0900480", Dated January 2006.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-26/03: INFILTRATION AND CONTAMINANT TRANSPORT MODELING

INTERROGATORY STATEMENT:

Please provide sufficient information to demonstrate that the cover system will not experience some potential long-term degradation through one or more processes (as discussed below in the Basis For Interrogatory), when active institutional control is no longer in effect to maintain the cover system.

Provide additional information to identify and evaluate the potential effects of long-term degradation processes on the components of the final cover system.

Conduct and report additional (infiltration sensitivity) analyses to assess the potential affects of such cover system component degradation on long –term infiltration rates through the cover during the cover's design life.

Response 1

This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

The response provided to date (Response to Round 1) does not provide sufficient information to support the contention that the compacted clay layer in the cover system (and/or other layers in the cover system as well) would not experience some potential long-term degradation through one or more processes, under the scenario where there the active institutional controls period is no longer in effect to maintain the cover system. Additional information should be provided to identify and evaluate the potential effects of long-term degradation processes on the compacted clay layer and on other components of the final cover system. Additional (infiltration sensitivity) analyses should be conducted and modeling results from such analyses provided to assess the potential affects of such cover system component degradation on long –term infiltration rates through the cover during the cover's design life. Specific information that should be considered includes the following:

- *Additional information demonstrating that analyses of the closed facility's future performance have considered reasonably foreseeable degraded conditions that could occur within the final cover system after closure (e.g., up to several hundred years following closure) if the closed site were not actively maintained. For example, in the HELP Modeling simulations described in the December 2006 Tailings Reclamation Plan, it is not clear that the HELP Model simulations provided incorporate any reduction in the value of saturated hydraulic conductivity for either the fine sand layer or for the rock mulch capping layer to reflect potential (e.g., partial) clogging of these layers with windblown fines (rock mulch layer) or fines (sand drainage layer) that could invade these layers over time through ecological succession, or an increased value of saturated hydraulic conductivity of the radon barrier layer due to the effects of (e.g., moderately deep or possibly deeper-rooted) plant species. Other cover system physical parameters that could be affected over the long term due to environmental processes, such as porosity, field capacity, and wilting point of various cover layers, should be considered and incorporated as appropriate, into the infiltration analysis.*
- *A biointrusion assessment/analysis, including information regarding the potential for shallow and/or possibly deeper-rooted plant species to become established on the final cover system and an analysis to evaluate the effects of such vegetation on long-term infiltration rates. For example, it has not been demonstrated whether or not it is possible that native vegetation, including one or more deep-rooted species (such as black greasewood in particular, or other*

deeper-rooted species that might be present in Shootaring Canyon area) might become established on areas of the cover after the 100-year period of institutional control.

- *If the information compiled above indicates that establishment of moderately deep to deeper-rooted vegetation on the final cover system appears possible, please provide a sensitivity analysis in the HELP model to evaluate the effect of such deeper-rooted species becoming established on the final cover during the performance period on long-term infiltration rates through the cover. Phenomena to consider include a network of taproot/possible root decay –induced defects in the radon barrier layer and their effect on hydraulic conductivity of the radon barrier layer.*
- *A revised infiltration analysis that considers the potential for partial degradation of the 40-mil HDPE geomembrane, as a result of puncturing damage or other construction-related or post-construction static loading-related damage, if considered possible, as well as long-term deterioration of the HDPE geomembrane liner due to antioxidant depletion, oxidative induction (with resulting HDPE embrittlement and chain scission and environmental stress cracking), and other possible factors (e.g., biological agents).*
- *The possibility of stress cracking with the HDPE geomembrane has not been addressed in the HELP model. Information addressing the issue of potential stress cracking in the geomembrane and its effects on cover infiltration needs to be provided.*
- *A frost depth analysis should be performed to determine the maximum projected frost penetration depth within the final cover.*

REFERENCES:

Badu-Tweneboah, K., Tisinger, L.G., Giroud, J.P., and Smith, B.S., 1999, "Assessment of the Long-Term Performance of Polyethylene Geomembrane and Containers in a Low-Level Radioactive Waste Disposal Landfill," in Proceedings, Geosynthetics '99, Boston, Massachusetts, April 28-30, 1999.

DOE 2001. Disposal Cell Cover Moisture Content and Hydraulic Conductivity, Long-Term Surveillance and Maintenance Program Shiprock, New Mexico, Site, Grand Junction, Colorado. May 2001.

EPA 2002a. “Simulating Radionuclide Fate and Transport in the Unsaturated Zone: Evaluation and Sensitivity Analyses of Select Computer Models”. EPA/600/R-02/082. 2002.

EPA 2002b. U.S. Environmental Protection Agency 2002. Assessment and Recommendations for Improving the Performance of Waste Containment Systems. EPA/600/R-02/099. Cincinnati, Ohio. December 2002.

EPA 2004. “Technical Guidance for RCRA/CERCLA Final Covers”, USEPA - USACE Superfund Partnership Program Policy, Guidance, and Activities, Chapter 2 and Appendix B. http://hq.environmental.usace.army.mil/epasuperfund/geotech/

Hydro-Engineering, L.L.C. 2006. Ground-Water Monitoring of Shootaring Canyon Tailings Site - 2005.

Koerner et al. 2005. Koerner, R, Hsuan, Y.G., and Koerner, G. 2005. GRI White Paper #6 - on - Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions. Geosynthetic Institute, Folsom, Pennsylvania. June 7, 2005.

National Committee on Radiation Protection, National Bureau of Standards(NBS) Handbook 69 (1959), “Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure,” Superintendent of Documents, U.S. Department of Commerce, U.S. Government Printing Office, Washington, D.C., June 5, 1959.

Plateau Resources, Ltd., “Revised Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project”, Dated December 2006.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R317-6-2.1-27/03: GROUNDWATER MONITORING

INTERROGATORY STATEMENT:

Per discussions between Uranium One and the DRC and in accordance with the application requirements of the Utah Administrative Code R317-6, Uranium One needs to provide adequate documentation, justification, evaluation procedures, and modeling results that include a sound basis for the groundwater monitoring for the site. This includes a complete presentation and description of the existing hydrogeologic conditions, means of establishing background, and the evaluation of results as they compare to the respective limits. Based on the review of the information submitted to date, the following items need to be addressed by Uranium One:

1. ***BAT Monitoring Plan for Seepage Rate Monitoring and Verification**: Please provide a BAT monitoring plan which includes: (a) Justification or basis for the plan; (b) Best Available Technology and seepage control monitoring for the tailings impoundments; and (c) Information to verify that Engineering Controls are sufficient and will limit seepage to specified levels. It is recommended that Uranium One prepare a separate document (from the respective Groundwater Monitoring Plan) reflecting specific monitoring devices and types, monitoring frequency, and validation procedures to comply with laws, regulations and guidance.*

   Response 1
   This response will be provided in a later submittal.

2. ***Hydrogeologic Modeling and Groundwater Monitoring Well Designs and Network:** Please provide additional information, including groundwater modeling, information regarding estimated horizontal and vertical dispersion, groundwater-surface water interaction (relationship of groundwater flow systems to existing springs present in the area), and information adequately describing flow direction, gradient and spatial variability of groundwater flow, to ensure that potential contaminant flow paths and potential plume shape are described. Please provide information indicating how this information supports design of the monitoring well network including well locations, screen length and depth(s) of monitoring. Modeling needs to consider flow paths in the vadose zone, the perched aquifer and the main (lower) Entrada aquifer. It has been noted, for example, based on past monitoring and modeling at the facility that a low-permeability zone exists at the top of the main (lower) Entrada aquifer in the area near the main Tailings Dam. The impact of this condition on flow paths for potential releases from the tailings containment cells needs to be carefully examined and clarified.*

   Response 2a
   This response will be provided in a later submittal.

   Additionally, a review of the horizontal groundwater contour information on Figure 1, Proposed Ground Water Monitoring Locations, of the Draft Groundwater Monitoring Plan suggests that potential releases from the containment cells might flow to an area southwest of the proposed monitoring locations and therefore be missed by the monitoring network. In preparing the additional information requested in this interrogatory, Uranium One needs to demonstrate that the modeling assumptions that are used are conservative and/or are representative of field conditions.

   Response 2b
   This response will be provided in a later submittal.

3. ***Background Monitoring Plan for New POC Wells:*** *Please confirm the location of the POC monitoring wells and provide additional information concerning the approach for developing interim and final intrawell Groundwater Compliance Limits (GWCLs) for the POC monitoring wells. Please provide information to justify the duration of background sample collection and analysis, proposed sampling frequency, and procedures to be used for controlling or correcting for such seasonal and/or temporal correlation in the data, if necessary. Please clarify the ultimate use of the current (ongoing) background evaluation. For example, indicate whether the evaluation is being conducted to provide interim limits for downgradient operational POC wells based on two standard deviations above background as listed in R317-6-6.16 until specific intrawell background can be established. In order to conform to GWCL criteria previously established for this facility and GWCLs that have been established for other similar (licensed) facilities in Utah, final GWCLs should be determined as follows: (a) for constituents detected as a background concentration, the GWCL should not exceed the mean concentration in that well plus two standard deviations or 1.1 times the background (mean) concentration, whichever value is greater; and (b) for a contaminant not present in a detectable amount as a background concentration, the GWCL should not exceed 1.1 times the value of the groundwater quality standard Maximum Contaminant level (MCL)or the limit of detection, whichever value is greater.*

Response 3
This response will be provided in a later submittal.

4. ***Statistical Analysis of Groundwater Data****: Please provide the following with respect to the Draft Groundwater Monitoring Plan (Plan) dated 11/30/07 and the Shootaring Background Water Quality document (December 12, 2007):*

   a. *Additional information to further substantiate/verify the degree of homogeneity (lack of spatial variability) of groundwater quality within groups of groundwater monitoring wells. The Piper diagrams in the current statistical approach use only a limited list of ions. Additional information, including the distribution of trace elements detected in groundwater at the site, should also be considered, and a discussion of how those trace element concentrations relate to site subsurface (e.g., aquifer matrix geochemical) conditions should be provided, along with evidence to confirm that the background groundwater data are suitable for comparison to the site groundwater data. Parameters such as arsenic (previously detected at apparently elevated levels in wells RM-8 and RM-20), selenium (previously detected at apparently elevated levels in well RM20) and fluoride (previously detected at apparently elevated levels in wells RM8 and RM20) are examples of parameters (Plateau Resources, Ltd. 2006) that require further analysis. Uranium One may wish to consider other types of data analysis, for example, multivariate statistical techniques such as cluster analysis and/or Principal Component Analysis, wherein the distributions of additional parameters (possibly including, but not limited to, arsenic, uranium, molybdenum, barium, manganese, chromium, and nickel) in the site monitoring wells are analyzed. Uranium One may also wish to consider developing stiff diagrams as an additional means of deciphering patterns in groundwater quality at the site.*

Response 4a
This response will be provided in a later submittal.

   b. *Please provide a revised Plan that employs consistent terminology with respect to the different groundwater-bearing units present beneath the site.*

Response 4b
This response will be provided in a later submittal.

c. *Please add carbonate + bicarbonate, calcium, and nitrate + nitrite to the monitoring parameters list (Table 1 of Plan), or, alternatively, provide justification for not including these parameters in the Plan.*

Response 4c
This response will be provided in a later submittal.

d. *Please provide information indicating the relevance of the 2007 Final Rule (EPA 2007) that amends relevant previous EPA Final Rules that specify acceptable analytical methods for some monitoring parameters included in Table 1, including Ra-226, chloride, fluoride, nitrate, nitrite, and sulfate, to the Plan. Please revise the text on page 4 of the Plan and in Appendix 1, as necessary, to conform to the EPA 2007 Final Rule. This information should be included as an element of the Facility Quality Assurance Plan (QAP) and Groundwater Monitoring QAP.*

Response 4d
This response will be provided in a later submittal.

e. *Please include a description of the missing Appendices 1 through 3, and provide a copy of any missing Appendices.*

Response 4e
This response will be provided in a later submittal.

f. *Please revise the text of the Plan to reflect the correct ordering of the tables in the document. On Page 5 – "Test of Normality", 2nd paragraph: in the first sentence the order of the two tables as identified in the text is reversed.*

Response 4f
This response will be provided in a later submittal.

g. *Please provide an expanded discussion within the Plan (in reference to the discussion presented on p. 10 of the current Draft Groundwater Monitoring Plan entitled "Trend Analysis"), to include the following elements:*

i) *Identification of any seasonal variability as well as any temporal correlation in the data, and procedures for controlling or correcting for such seasonal and/or temporal correlation in the data, if necessary,*

ii) *Completing background sampling on a schedule that will ensure sample independence,*

iii) *Criteria for selecting statistical analysis methods for each parameter of interest in each well,*

iv) *Specific criteria, including data characteristics such as normality or lack of normality, for selecting the statistical analysis method(s) for analyzing accrued data and criteria and timetables for updating background groundwater quality statistics/concentrations as new data are obtained, and*

v) *Identification of any spatial variability of data when an inter-well data analysis method is used.*

Response 4g
This response will be provided in a later submittal.

h. *Please revise page 11 – "Frequency": 1st paragraph, second sentence, to change the word "down" to "downgradient". Please revise the text to reflect the correct term.*

Response 4h
This response will be provided in a later submittal.

i. *Please provide an expanded discussion within the Plan following the discussion presented on p. 11 of the current Draft Plan entitled "Frequency", under a heading entitled "Actions Taken if Monitoring Data Are Out of Control" or some other similar heading, of the specific timetable within which a verification (confirmation) sampling/analysis episode would occur following determination of initial evidence of an exceedance or evidence of a statistically significant trend in one or more parameter concentrations within a well.*

Response 4i
This response will be provided in a later submittal.

j. *Please revise the text in the first paragraph of the Plan to refer to ASTM D6312-98 instead of ASTM D6313-98.*

Response 4j
This response will be provided in a later submittal.

k. *Please provide additional information to evaluate the impact, if any, that the indicated lack of a normal or lognormal distribution of at least four of five monitoring parameters identified as process-related parameters, (i.e., K, Na, Unat, and $SO4^{-2}$) – see Tables 1 and 2 of the Plan – has on the selection and application of statistical analysis method(s) for these parameters, including the compilation of time-series plots/future intrawell statistic analysis. Please also provide information to assess whether the highest concentrations of several parameters (e.g., Na, Unat, Cl^-, Fl^-, NO3 + NO2, $SO4^{-2}$, TDS, Mg), as shown on the Probablility Plots in Figure 3 of the Shootaring Background Water Quality document, might represent different water quality populations.*

Response 4k
This response will be provided in a later submittal.

l. *Please provide additional information regarding the values of "n" shown in Tables 1 and 2. It appears that "n" represents the number of samples in each parameter data set; however, this information is not explicitly stated. The values of "n" given for the various parameters, assuming that "n" represents the number of samples, also seem to be very large.*

Response 4l
This response will be provided in a later submittal.

5. ***Proposed Groundwater Monitoring Approach****: Please provide responses to the following concerns regarding the proposed groundwater monitoring approach presented to date. These concerns were expressed in Round 2 of this Interrogatory, and Uranium One stated that responses will be provided in the next submittal.*

   a. *Please provide a proposed sampling and analysis plan for monitoring of the seep (or spring) located south of the mill site near Ant Knolls (as shown on Figure 1-1 of the revised Tailings Management Plan). Please also provide information to indicate whether sampling and analysis of springs or seeps located northwest of the mill site and proposed Cells 1 and 2 and the spring or seep located northeast of proposed Cells 1 and 2 (e.g. Lost Spring) would be conducted, for example, for comparison purposes. Alternatively, please provide justification for not monitoring these seep/spring locations.*

      Response 5a
      This response will be provided in a later submittal.

   b. *Please provide rationale for selecting parameters for groundwater sampling and analysis as listed in Section 7 and in Appendix D of the Revised Tailings Management Plan (Plateau Resources, Ltd. And Hydro-Engineering, LLC 2007), including parameters to be used as key indicators of performance. Please provide additional information/rationale to support not specifying requirements for analysis of any parameters (e.g., Radium-228 and gross alpha) identified in R317-6-2.1, as applicable parameters for sampling and analysis.*

      Response 5b
      This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

A teleconference was held on December 19, 2007, amongst Uranium One, the Utah Division of Radiation Control, and URS Corporation. Three "Draft" Documents prepared by Uranium One were discussed during the teleconference; (1) A Conceptual Tailings Storage Facility Design; (2) A document entitled "Draft Shootaring Groundwater Monitoring Plan" (November 30, 2007); and (3) A document entitled "Shootaring Background Water Quality (December 12, 2007)." During the teleconference, it was discussed and agreed that the groundwater monitoring plan will be based on a two-part strategy. The first line of groundwater compliance will be based on Best Available Technology and seepage control monitoring from the tailings impoundments. As discussed during the teleconference, Uranium One will develop a monitoring strategy to verify that seepage onto the leak detection layer is limited to 200 gallons per day per acre (allowable design leakage rate) as referenced the March 17, 1999 Ground Water Quality Discharge Permit for the facility. It will also include the limitation of 3-feet of head on the upper primary liner as specified in the December 28, 1998 DRC and DWQ Statement of Basis for the permit. The second line of groundwater compliance will encompass the use of a monitoring well network designed for early detection of contamination that could be potentially released from the tailings impoundments.

Based on the discussed strategy and application requirements of Utah Administrative Code R317-6, this interrogatory is intended to ensure that Uranium One plans and prepares adequate documentation, evaluation procedures and modeling regarding BAT monitoring, hydrogeologic flow descriptios for the *site, and statistical background and downgradient analysis of groundwater data in compliance with applicable laws, regulations, and guidance.*

The proposed statistical analysis method provided in the Draft Groundwater Monitoring Plan includes the construction and use of control charts and intra-well data analysis for determining statistically significant trends in groundwater quality. The use of control charts (Shewart-CUSUM approach), is not a preferred methodology of the DRC for final compliance determinations. As set forth in the Utah Administrative Code R-317-6-6.16.b.2, control charts can be used as a means to determine statistical significance. Trend evaluation is also an important element of an intrawell statistical method. DRC, however, requires the use of other means, such as a front-line determination of groundwater quality compliance, i.e. interwell average concentration + 2 standard deviations, for analysis of groundwater quality and comparison with Groundwater Compliance Limits (GWCLs). This methodology has been established for other (similar) licensed facilities in Utah.

In general, the current Draft Groundwater Monitoring Plan is difficult to follow in that it does not provide a clear decision tree or sufficient details regarding methods that would be followed for:

- *Conducting Exploratory Data Analysis (EDA) of the various data sets depending on the characteristics of the data,*
- *Correcting for seasonal variability as well as temporal correlation in the data, including procedures for controlling or correcting for such seasonal variability and/or temporal correlation in the data, if necessary,*
- *Completing background sampling on a schedule that will ensure sample independence*
- *Selecting statistical analysis methods for each parameter of interest in each well, and*
- *Updating background groundwater quality concentrations/statistics as new data are obtained.*

One or more flow charts depicting the EDA and statistical analysis method selection and application processes would be very beneficial in helping to understand the overall structure of the statistical analysis Plan. Decision criteria that would be used for selecting the method(s) to conduct an exploratory data analyses (EDA) of the data prior to selecting the statistical analysis method(s) should be better described.

Additionally, the proposal under this section indicates that groundwater samples will be collected during at least 8 sampling periods over a period of one year before constructing control charts. These samples need to be independent (not temporally correlated) samples (USEPA 1989, (Section 7); however, there is no information provided to allow an assessment to be made as to whether the samples collected would be independent samples. Uranium One needs to evaluate the potential for temporal variability of, and autocorellation among, the groundwater constituents (EPA 1989, Section2.4.2).

<u>Specific Basis for Specific Listed Interrogatory Items:</u>

1. *Figure 1, text of the Plan (all), and in the Uranium One U.S.A., Inc. Shootaring Background Water Quality document (December 12, 2007) – The legend refers to the water table contour for the Main Entrada Aquifer. The text of the document variously refers to the "lower (main) Entrada aquifer" (e.g., p. 3 and p. 5) or the "principal Entrada aquifer" (e.g., p. 5), while the Plan (e.g., p. 3 and Table 1) refers to the "Entrada Aquifer" (as a unit distinct from the "Perched Entrada Aquifer"). To avoid potential confusion, it is suggested that consistent terminology be used throughout the document.*

2. *On Page 3 and in Table 1, "Parameters to be Monitored", of the Plan, the list of parameters to be monitored does not include carbonate + bicarbonate, calcium, or nitrate + nitrite). Calcium and nitrate + nitrite are listed in Tables 4 and 5 as part of the compliance parameters for the perched aquifer and lower (main) Entrada aquifer. Additionally, calcium and carbonate + bicarbonate are parameters that are required for constructing Piper/trilinear diagrams, stiff diagrams, etc… that help*

characterize water quality and help distinguish between different water chemistries that might occur within different water-bearing units (Hem 1985, pp. 173-180). (Note: The distributions of other monitoring constituents such as certain trace elements should also be analyzed using one or more other multivariate statistical techniques, as a means of characterizing groundwater quality populations and patterns – see comments above).

3. *Page 4 – "Sampling and Analysis", and Appendix 1, of the Plan do not reference EPA's Final Rule (EPA 2007) that amends relevant previous EPA Final Rules that specify acceptable analytical methods for some monitoring parameters included in Table 1, including Ra-226, chloride, fluoride, nitrate, nitrite, and sulfate.*

4. *In the Table of Contents and page 4 of the Plan, Appendix 1, Appendix 2, and Appendix 3 are not described and Appendix 1 and Appendix 3 are not attached. Appendix 2 appears to be a Uranium One U.S.A., Inc. Shootaring Background Water Quality document (December 12, 2007), but without a description of Appendix 2 provided, this assumption cannot be confirmed.*

5. *On page 5 of the Plan, under the section entitled "Test of Normality", 2nd paragraph: in the first sentence the order of the two tables as identified in the text is reversed.*

6. *The section of the Plan entitled "Trend Analysis" is, in general, difficult to follow in that it does not provide a clear decision tree or sufficient details regarding methods that would be followed for performing/conducting the identified elements. This section does not include a discussion of seasonal variability and/or temporal correlation in the data, including procedures for controlling or correcting for such seasonal and/or spatial variability and temporal correlation in the data, if necessary. With respect to the acquisition of baseline groundwater quality data, for example, this section indicates that groundwater samples will be collected during at least 8 sampling periods to establish a groundwater quality data baseline, before construction of control charts is initiated. However, there is no timetable given as to the frequency at which these background samples would be collected. The samples collected during this time period must be independent (not temporally correlated) samples (USEPA 1989, (Section 7). From the information provided in this section, it is not clear how it will be ensured that the samples collected during this time period would be independent samples. Additional information needs to be provided indicating how Uranium One will ensure that these background samples are independent samples. Additionally, ASTM D6312-98 (ASTM 2005) indicates that, for ensuring sample independence, if the combined Shewart-CUMSUM control chart procedure is used, wells should typically be sampled no more frequently than quarterly during routine groundwater monitoring.*

   The need for preparing time series plots and evaluating seasonal effects, if sufficient data are available, should be discussed. The need for identifying that baseline data do not show any evidence of an increasing trend should also be discussed. The use of control charts for a given well is appropriate only if it is assumed that there is no evidence of contamination or an increasing trend in a parameter concentration with time in that well. Procedures potentially applicable to addressing sample independence and seasonality include the (Seasonal) Kendall test/Mann-Kendall test, Time and/or Lag Plots, Sens Slope Estimator, Wilcoxon Rank Sum test, Wald- Wolfowitz test, etc… (see, e.g., USEPA 1989, Section 7; USEPA 1992, Sections 2 and 3; USEPA 2006, Sections 4.3 and 4.8).

   Use of the combined Shewart-CUMUSUM control chart procedure is also recommended only if the constituents are detected in at least 25 % of the samples (ASTM 2005), whereas a non-parametric Prediction Limits /Poisson Prediction Limit approach is recommended if the detection frequency is less than 25% and greater than 0% and there are at least 13 background samples. Additional information should be provided to indicate the criteria that would be used for selecting the most appropriate statistical analysis method for various monitored constituents and monitored wells. One *or more flow charts depicting the statistical analysis method selection and application processes would be very beneficial in helping to understand the overall structure of the statistical analysis plan. These flow charts should include decision criteria that would be used for selecting the method(s) to conduct initial analyses of the data as well as decision criteria that would be used for selecting the appropriate statistical analysis method(s) which are in compliance with EPA guidance. Included should be the recognition that compliance is established by the appropriate comparison of results to criteria in R317-6.16.*

7. *On page 11 of the Plan in the section entitled "Frequency", 1st paragraph, second sentence, the word "down" should instead be "downgradient".*

8. *On page 11 of the Plan in the section entitled "Frequency", the discussions presented in the 2nd and 3rd paragraphs address actions that would be taken in the event of an exceedance or evidence of a statistically significant trend in one or more parameter concentrations within a well. These discussions should be presented under a heading entitled "Actions Taken if Monitoring Data Are Out of Control" or under some similar context. In the 2nd paragraph, it is indicated that if an exceedance of any COC in one or more downgradient wells is confirmed through a re-sampling at that well, the well in question would be re-sampled and re-analyzed for the COC's that exceeded compliance criteria. No timetable (i.e. maximum number of days lapsed) is provided for conducting such a verification sampling event. In the 2nd paragraph, it is also indicated that if re-sampling and analysis confirms an exceedance for a COC, UDEQ would be promptly notified and monthly sampling and analysis for the wells yielding the exceedance would begin (for all compliance COCs) until values below the criteria are obtained from two consecutive months (after which a quarterly sampling and analysis schedule would be resumed). Such a complete COC analysis regime could occur in response to evidence indicating that a release had occurred from the tailings containment cell(s). However, no specific timetable (i.e. maximum number of days lapsed) is provided for initiating monthly sampling following the confirmation of such evidence of an exceedance.*

9. *In the 3rd paragraph, it is indicated that if control charts indicate a statistically significant increasing trend over three sampling events for any process-related COC (i.e., K. Mg, Na, Unat, and sulfate), quarterly sampling and analysis would be accelerated to monthly, the UDEQ would be advised in writing of such a trend, and a similar increasing trend for any other COC would not trigger an accelerated sample and analysis schedule unless it is accompanied by a concomitant increase in the conservative process-related COCs. This information seems to be in conflict with information presented in the 2nd paragraph as described above. It is therefore recommended that this paragraph be revised.*

10. *The ASTM Standard (ASTM 2005, p. 12) suggests that when large intra-well background databases are available (e.g., more than 3 years worth of semi-annual monitoring data) obvious cyclic or trend patterns can be removed from both the baseline data and from future data that would plotted on a control chart. Additionally, the discussion presented in the last section of the Plan does not include sufficient information regarding how and when the baseline data would be updated by including newer data that are shown to be not out of control and how and when control charts would be updated. The ASTM Standard (ASTM D6312-98) suggests that updating of baseline data may be done at a time interval of 1 or 2 years, after which a new trend analysis should be performed to ensure that no gradual upward or downward trends are observed. These updated parameters could then be used to construct updated control charts. Additionally, there is no discussion of whether, or under which criteria, truncated baseline data sets might be used for constructing such updated control charts.*

11. *The correct ASTM Standard Method is ASTM D6312-98.*

12. *Use of the combined Shewart-CUMSUM control chart approach assumes that the data are independent and normally distributed, or that natural log or square-root transformation of the data prior to analysis would be adequate (ASTM 2005, p. 11). Uranium One needs to provide additional information to address how the results presented in the columns entitled "Distribution" in Tables 1 and 2 of the Background Water Quality document would or would not be consistent with use of the combined Shewart-CUMSUM control chart approach for those parameters which are listed as having neither a normal nor lognormal distribution.*

13. *The meaning of "n", and the reasonableness of the stated n values, cannot be confirmed based on the information provided.*

REFERENCES:

ASTM D 6312. "Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs". ASTM, West Conshohocken, PA.

Davis, J.C., 2002, Statistics and Data Analysis in Geology: New York, John Wiley & Sons, Inc., 638 p.

Everitt, B.S., 1993, Cluster Analysis (Third Edition): NewYork, Arnold, London, and Halsted Press, 170 p.

Everitt, B.S., and Dunn, G., 2001, Applied Multivariate Data Analysis (Second Edition): New York, Oxford University Press, 352 p.

Johnson, R.A., and Wichern, D.W., 2002, Applied Multivariate Statistical Analysis (Fifth edition): Upper Saddle River, New Jersey, Prentice Hall, 767 p.

Hem, J.D. (1985) Study and Interpretation of the Chemical Characteristics of Natural Water. United States Geological Survey Professional Paper 2254.

Hydro-Engineering, LLC. Ground Water Monitoring of Shootaring Canyon Tailings Site – 2005. February 2006.

NRC 2003. NUREG-1620, Rev. 1, "Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978." Washington, DC: NRC 2003.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd. Ground-Water Monitoring of Shootaring Canyon Tailings Site – 2005. Hydro-Engineering, L.L.C, February 2006.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

USEPA (United States Environmental Protection Agency), 1989, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Office of Solid Waste, Waste Management Division, USEPA, Washington, DC 20460.

USEPA. 1992. Statistical Analysis Of Ground-Water Monitoring Data At RCRA Facilities - Addendum To Interim Final Guidance, Office of Solid Waste, Waste Management Division, USEPA, Washington, DC 20460. July 1992.

USEPA 2001. 40 CFR Parts 9, 141, and 142, National Primary Drinking Water Regulations; Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring; Final Rule. January 22, 2001.

USEPA. 2006. Data Quality Assessment: Statistical Methods for Practitioners, EPA QA/G-9S. EPA/240/B-06/003. Office of Environmental Information, Washington, D.C. Download from: http://www.epa.gov/quality/qs-docs/g9s-final.pdf

USEPA 2007. 40 CFR Part 122, 136, et al. Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; National Primary Drinking Water Regulations; and National Secondary Drinking Water Regulations; Analysis and Sampling Procedures; Final Rule. Federal Register, March 12, 2007.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

Uranium One USA, Inc., "DRAFT Shootaring Ground Water Monitoring Plan", November 30, 2007.

Utah Department of Environmental Quality. Ground Water Quality Discharge Permit. Permit #UGW170003, issued January 14, 2004.

Utah Department of Environmental Quality. Division of Radiation Control. Radioactive Material License UT 0900480, Amendment # 2.

Ward, J.H., 1963, Hierarchical Grouping to Optimize an Objective Function: Journal of the American Statistical Association, v. 58, p. 236–244.

INTERROGATORY R317-6-6.3F-28/03: INFORMATION ON EFFLUENT DISCHARGE RATES

INTERROGATORY STATEMENT:

Estimate the leakage through the secondary liner in similar fashion to the method used to calculate leakage through the primary liner (Section 5.1.4.7 of the TMP). Prepare the estimate using assumptions of head based on the intended operating conditions within the secondary containment sumps (i.e., head caused by one day of leakage and reasonable assumptions as to the leakage through the liner into the underlying subgrade. State and justify the estimated discharge quality and quantity. State the estimated leakage rate for each of the areas, recognizing that the impoundments each will be lined with secondary containment, and that the ore pad will allow greater leakage through the clay liner

Please provide the maximum daily leachate (gpd) and discharge rate (gpm) in each discharge or combination of discharges. Include in this information any discharge that may result from leakage through the tailings cells liner systems, the ore pad liner, and the Evaporation and Process Pond Cell. Please provide the appropriate calculations for each discharge. Also, please state the expected concentrations of pollutants in each discharge and the basis for the determination.

Response 1

This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

Uranium One must provide the above requested information on all discharges of pollutants that impact or have the potential to impact ground water. This information must include all discharges or potential discharges associated with effluent discharge, storage, and liner systems.

REFERENCES:

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY PR R317-6-6.3G-29/03: SURFACE WATER CONTROLS

INTERROGATORY STATEMENT:

Please provide information on how surface water run-on and run-off controls will be applied to control the migration of contaminants from the site and associated operations. This is to include a hydraulic analysis for surface water flow and control that could impact the site during milling operations. The analysis needs to be the same level of detail as provided for the Tailings Reclamation and Decommissioning Plan (Section 6.3), and include:

- *How (specifically) surface water flow from contaminated areas will be handled separately from surface water from non-contaminated areas.*
- *How impounded water will not alter or compromise the groundwater flow directions in the Upper Entrada Aquifer.*
- *Layout of flow patterns for surface water controls*
- *Design and details of surface water control structures and respective flow rates*
- *Design basis*
- *Operation and maintenance involved*

Please justify statements that infer that no storm water will impact "waters of the State" in consideration that surface water will be impounded and has the potential to impact groundwater. This justification could be combined with a response to Interrogatory R317-6-6.3F-28/03.

Response

Summary responses are given for individual bullet items, and a more detailed discussion of hydraulic analysis procedures is included as Attachment F, along with calculations. We believe that the following responses will demonstrate to the DRC's satisfaction that no contaminants will be discharged from the site via surface water.

Statement: *How (specifically) surface water flow from contaminated areas will be handled separately from surface water from non-contaminated areas.*

Response

In general, potentially contaminated surface runoff will be routed to lined tailings disposal facilities, where it will be impounded and ultimately evaporated. Clean water will also discharge to these facilities, but via separate conveyance systems. Some clean water (from outside the restricted area) will discharge offsite. Potentially contaminated surface water will be impounded only within the tailings disposal facility, and will not leave the site.

During Phase I, potentially contaminated water from the mill/ore storage site will be routed either to the South Cell, or to the existing tailings impounded behind the small dam located north of the existing cross-valley berm. A portion of the unrestricted mill site area will flow onto restricted area, and be commingled with potentially contaminated water, after which it will be treated as contaminated and routed to the tailings. Clean surface water from the bluffs adjacent to the South Cell will be routed to the South Cell to make up for evaporation within the cell. Any clean surface water arriving from areas north of the South Cell will simply continue present flow patterns, leading to retention, infiltration, or evaporation from portions of the valley floor north of the proposed divider berm. Clean surface water from the southern and eastern portions of the mill site lying outside the restricted area will be routed via roadside ditches and culverts to the canyon lying east of the bluff on which the mill sits.

At the beginning of Phase II, any residues from the runoff directed into existing tailings area will be removed, along with the existing tailings, and placed into the South Cell. During Phase II operations, potentially contaminated mill site runoff will be routed to the tailings impoundments, generally following the same flow paths as Phase I. Clean surface water from the bluffs adjacent to the cells will be routed into the appropriate tailings impoundment cell. Clean surface water from north of the North Cell will be conveyed to the North Cell via a rock-lined ditch, and retained within the North Cell. Clean surface water east of the mill will continue to drain into the east canyon, as in Phase I.

Statement: *How impounded water will not alter or compromise the groundwater flow directions in the Upper Entrada Aquifer.*

Response

Surface runoff will no longer be impounded in any designed facilities separately from the tailings, and all potentially contaminated surface water will be directed to lined tailings disposal facilities. During Phase I, the status quo will be maintained, wherein offsite drainage from areas north of the site will be retained on the valley floor, with the same potential for infiltration or evaporation as has existed in the past. During Phase II, offsite drainage arriving from the north will be retained in the tailings. The response to Interrogatory R317-6-6.3F-28/03 will address the potential for migration of leachate from the tailings impoundments.

Statement: *Layout of flow patterns for surface water controls*

Response

Surface water flow patterns are described in general terms in the first response, above. See Section 8.0 and Drawings P1.9 and P2.8 of the Design Report for more detail.

Statement: *Design and details of surface water control structures and respective flow rates*

Response

Design calculations and flow rates are provided in Attachment F to these Interrogatories and in Appendix G of the Design Report. Design drawings are provided as part of the Design Report. There are three principal surface water control structures used on the site: trapezoidal ditches (plain earth or riprap-lined), concrete fords, and culverts.

Statement: *Design basis*

Response

Flow rates for minor drainage controls (ditches, culverts, and concrete fords) were computed using the 100-year rainfall intensity, and conservative assumptions of runoff coefficients (C=0.90, uniformly). Given the relative rarity of large rainfall events in the region, and the ongoing presence of personnel over the 18-year operational life of the project, the 100-year event was judged to be adequate for surface water controls. Because all potentially contaminated surfaces naturally drain towards the tailings, failure of any of the controls would only result in discharge of eroded sediment or debris into the tailings facility, but would not risk environmental contamination.

Freeboard for the tailings impoundment was based on the simultaneous occurrence of the Probable Maximum Flood series (per Regulatory Guide 3.11), along with 100-year wind and wave effects.

More discussion on the design basis is provided in Section 8.0 of the Design Report. Calculations are provided in Attachment F to these Interrogatories and in Appendix G of the Design Report.

Statement: *Operation and maintenance involved*

Response

Ongoing maintenance of minor flow controls will generally involve spot-fixes of observed minor erosion, and removal of rockfall and sediment from ditches. Daily, monthly and quarterly inspections as per SOP A-3. Further information regarding ongoing maintenance during operations will be provided in the Operations Plan as a future submittal.

Because all collected water will be impounded within the tailings cells, the implications of surface water impoundment on “Waters of the State” are addressed in the response to Interrogatory R317-6-6.3F-28/03.

Attachments:

Surface Water Drainage and Erosion Protection Methods and Details

Calculations and Supporting Information

BASIS FOR INTERROGATORY:

The response to Round 2 was that the response to this submittal will be provided in the next submittal.

Uranium One’s response to Round 1 Interrogatory referred to Section 5.1.6 of the TMP that includes a limited summary of the surface water controls to be implemented during operation. No detailed information on the design and sizing of these controls was included, nor were there details on how water from contaminated areas will be kept and handled separately from water from non-contaminated areas. The same type of hydraulic analysis that was done for the Tailings Reclamation and Decommissioning Plan for storm water control after cell closure (Section 6.3) needs to be performed for the storm water control during mill operation.

In addition, the statement is made that no storm water will leave the site as surface discharge. However, water will be impounded and could be discharged to groundwater (see Interrogatory R317-6-6.3F-28/03). According to R313-6-6.3G, the operator is required to determine that discharges will not affect “waters of the State” which includes groundwater.

Discussions held with Uranium One in December 2007 on the revised cell design (regarding Tetra Tech memo 12/13/07 p. 3)_ indicated that storm water retained within the bermed areas will be pumped into a division channel and then flow offsite. Please include how it will be demonstrated and confirmed that water pumped from contaminated areas will meet the State's requirements for surface discharge.

REFERENCES:

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-33/03: POST-CLOSURE DRAINAGE AND EROSION CONTROLS AND POSTCLOSURE MAINTENANCE

INTERROGATORY STATEMENT:

In accordance with UAC R317-6-6.3.S, please provide a plan for closure and post-closure maintenance that discusses post-closure maintenance requirements and identifies measures that will be taken to prevent groundwater contamination during the facility's closure and postclosure phases and to minimize the need for active maintenance following closure. Maintenance of the cover and erosion control systems should also be addressed.

Please provide analyses and discussion of the long-term performance of the cover system considering wind erosion, slope stability, settlement, seismic events, etc. Please describe and provide a basis for the demonstration period during the interim period of site transfer to the custodial party. Please demonstrate that the cover system will remain effective for 1000 years, to the extent achievable, and for a minimum of 200 years and require minimal maintenance following closure.

Response 1

This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

The response to Round 2 was that the response to this submittal will be provided in the next submittal.

The licensee should demonstrate that the cover system and other closure design control features will remain effective for 1000 years, to the extent achievable, and for a minimum of 200 years and require minimal maintenance following closure without posing risks due to the release of radiological and potentially hazardous constituents.

The following portion of the 1st Round Interrogatory on Rock Cover (Interrogatory R313-24-4-17/01) is combined and moved to this section - Post-Closure Drainage and Erosion Controls and Post-Closure Maintenance; please provide analyses (or modeling) and discussion of the long-term performance of the cover system and associated erosion controls following closure. Section 6.0 of the Tailings Reclamation and Decommissioning Plan (Hydro-Engineering, L.L.C. 2006) discusses the design of the drainage and erosion control systems for reclamation, however, the section does not appear to thoroughly address post-closure performance required to demonstrate with reasonable assurance that the integrity of the cover system will be maintained and will control radiological and non-radiological hazards for a minimum of 200 years, and to extent achievable, for 1,000 years. Section 6.0 and prior responses indicate that the primary concern for disruption of the cover is erosion by water with the cover designed to accommodate a Probable Maximum Flood (PMF).

In review of information provided in December 2007 from Uranium One on the revised cell design, it was noted that the final cover surface water drainage is to the east into a drainage channel that flows to the south and offsite. However, it appears that the elevations and grading for this channel needs refinement. It is uncertain how the final cell cover surface flow will be transferred into the ditch and then around the dam to the south (in the south east corner of the cell area). Please ensure that the grading design for the final storm water control demonstrates adequate drainage ability and capacity.

REFERENCES:

Plateau Resources, Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December 2005, Revised December 2006.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility," Dated December 2005, Revised April 2007.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-34/03: RADON RELEASE MODELING

INTERROGATORY STATEMENT:

Please provide additional justification for the moisture content and dry density values proposed or, alternatively, more conservative values should be substituted in the modeling (refer to the discussion included in the Basis for Interrogatory).

Please provide adequate justification to support taking any credit for the presence of the HDPE geomembrane for reducing radon release in the long-term after the geomembrane's radon release barrier efficiency is essentially no longer effective.

Provide adequate justification for not completing a radon release simulation where the radon attenuation effects of the cover system layers overlying the radon barrier layer component of the cover are neglected, or include this simulation.

Response 1

This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

The response to Round 2 was that the response to this submittal will be provided in the next submittal.

In their response to Round 1 of this Interrogatory, Uranium One has not demonstrated that the (long-term) moisture content (24 percent) and dry density values (90 percent for Shootaring Canyon Dam-derived clay materials and 86 percent for alternate clay source-derived clay materials) specifically selected for use in the radon release modeling are sufficiently conservative to bound the range of uncertainty associated with the long-term values of moisture content and dry density that could occur in the radon barrier layer. Variations in the moisture content and dry density of the compacted clay cover layer could likely occur over its design life and such variations need to be considered in evaluations performed to estimate long-term radon emission rates through the cover system (DOE 1989, Section 7.1; EPA 2004, Section 2.3.2.2.8). Additional justification should be presented for the values proposed or, alternatively, more conservative values should be substituted.

Applicable/relevant guidance for estimating long-term moisture content and dry density values for radon barrier layers, including the need for considering possible variations in climate, consideration of physical processes that would be involved, and the possibility of using the –15-bar moisture content of the radon barrier material as a reasonable lower bound estimate of the long-term radon barrier layer moisture content for conducting a worst-case radon release model simulation, are given in NRC Regulatory Guide 3.64 (NRC 1989, pp. 3.64-2 through 3.64-9) and DOE (1989, pp.163-176).

The HDPE geomembrane will have a finite effective service life (see Interrogatory R313-24-4-26/01: INFILTRATION AND CONTAMINANT TRANSPORT MODELING above). Therefore the HDPE geomembrane would provide a measure of conservatism for the radon release modeling only during the active service life of that geomembrane. Adequate justification needs to be provided to support taking any credit for the presence of the HDPE geomembrane for reducing radon release in the long-term after the geomembrane's radon release barrier efficiency is essentially no longer effective.

In addition, Uranium One has not provided adequate justification for not completing a radon release simulation where the radon attenuation effects of the cover system layers overlying the radon barrier layer component of the cover are neglected. Performance of such an analysis case is consistent with precedence that has been used for many years on the UMTRA Project where materials above the radon barrier layer were not modeled (DOE 1989, p. 170). Radon release simulations completed for other *similar facilities designed and/or constructed in the State of Utah (Monticello tailings repository final cover system – Waugh and Richardson 1997, p. D-41; Moab tailings repository final cover system (Office of Environmental Management 2006) each included one or more simulation cases where the cover layers overlying the radon barrier layer were not included in the radon release modeling.*

REFERENCES:

DOE, 1989, "Technical Approach Document," Uranium Mill Tailings Remedial Action Project, Rev. II, Section 7.1, "Design of the Radon Barrier". U.S. Department of Energy, UMTRA-DOE/AL 050425.0002. Albuquerque, New Mexico. December 1989.

EPA 2004. "Draft Technical Guidance for RCRA/CERCLA Final Covers", USEPA - USACE Superfund Partnership Program Policy, Guidance, and Activities, Chapter 2. http://hq.environmental.usace.army.mil/epasuperfund/geotech/

Plateau Resources, Ltd.,"Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project", Dated December, 2005.

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility" Amended December, 2005, Revised April 2007.

Plateau Resources, Ltd., Responses to Round 1 TMP Interrogatories, April 2007

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-36/03: OPERATIONAL DUST CONTROL

INTERROGATORY STATEMENT:

Please provide written procedures, material specifications, and supporting detail on dust suppression and air monitoring methods to be used on the tailings piles and drying and packaging operations. Please state the reasonable requirements for dust suppression and monitoring for these operations.

Please provide specifications on the alternative reagents that might be used for dust suppression associated with both the tailings piles and the drying and packaging operations.

Include details on methods for dust suppression for interim covering a portion of a cell when not working in the area, and discuss the impact it will have the engineering properties of the tailings (long and short term), and state the justification for the impacts. Also, provide air monitoring requirements and ALARA evaluations performed for dust suppression to ensure that airborne effluent releases are reduced to levels as low as reasonably achievable.

Response 1

SOP AP-5 has been developed and is submitted with these responses as Attachment G. SOP AP-5 is in draft format. The final procedure will be submitted to the DRC after tailings disposal design is finalized and prior to the start of operations.

BASIS FOR INTERROGATORY:

The response to Round 2 was that the response to this submittal will be provided in the next submittal.

Sections 4.1.1 and 6.2 of the TMP briefly reference applying agents for dust suppression but do not provide sufficient information. The applicants' initial response stated "The RMTP methodology requires further evaluation and refinement, and the production of dust from the paste or moist tailings is not yet quantified. It will be necessary to conduct testing of the fluid extraction process, reduced moisture tailings properties, and available dust suppression agents prior to operation of the mill."

The Division requires a consideration of airborne effluent releases to ensure they are ALARA and that population exposures are reduced to the maximum extent reasonably achievable.

REFERENCES:

Plateau Resources, Ltd., "Tailings Management Plan for Shootaring Canyon Uranium Processing Facility," Dated December 2005, Revised April 2007.

Regulatory Guide 3.56, "General Guidance for Designing, Testing, Operating, and Maintaining Emission Control Devices at Uranium Mills," Task CE 309-4, USNRC, May, 1986.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

INTERROGATORY R313-24-4-37/03: COST ESTIMATES FOR DECOMMISSIONING AND RECLAMATION

INTERROGATORY STATEMENT:

***After all design changes are made** for the facility and its component equipment, structures, and systems pursuant to this and subsequent rounds of interrogatories, please respond to the following general and specific directives and requests:*

1. *Provide the basis for EACH quantity, duration, allowance, and lump sum identified in the cost estimates presented in Section 11 of the "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project – Revised 2006." This basis should be related in some way to the quantity of materials to be handled (based on relevant drawings) and a documented productivity for similar activities.*

   Response 1
   This response will be provided in a later submittal.

2. *Estimate and include the cost of providing an appropriate level of security at the facility during reclamation and decommissioning.*

   Response 2
   This response will be provided in a later submittal.

3. *Either (A) make a connection between the structures, components, and systems listed in the second paragraph of Section 8.0 and the cost estimate presented in Section 11.1* ***OR*** *(B) estimate and include the costs of decommissioning each of the structures, components, and systems listed in the second paragraph of Section 8.0*

   Response 3
   This response will be provided in a later submittal.

4. *Justify and provide references for unit costs used with quantity (hour, volume, area, etc) estimates shown throughout Section 11.*

   Response 4
   This response will be provided in a later submittal.

5. *Include an adder of 31.7 percent in salaries for individuals listed in Sections 11.1.18, 11.2.10, and 11.3.10 to account for total benefits provided to workers by the contractor, consistent with the information provided for construction workers in Table 5 of the report located at page 11 of http://www.bls.gov/news.release/pdf/ecec.pdf*

   Response 5
   This response will be provided in a later submittal.

6. *Justify OR revise and justify the allowance for Living Costs of $40, $67, and $66 per person per day in Sections 11.1.18, 11.2.10, and 11.3.10, respectively. Justify discrepancies between the crew sizes used in Sections 11.2.10 and 11.3.10 for calculating the allowance for Living Costs*

and the crew sizes stated in Item 1 of Sections 11.2 and 11.3, respectively, OR revise them to make them consistent.

Response 6
This response will be provided in a later submittal.

7. *Include in the cost of verifying that soils have been properly cleaned up the cost of remedial action support surveys (Section 11.1.16). Justify, on the basis of MARSSIM guidance, the estimate that final status surveys will require only 48 person-hours. Include in the estimate the costs of analyzing remedial action support and final status survey samples.*

Response 7
This response will be provided in a later submittal.

8. *Include the cost of excavating, hauling, spreading, and compacting sandy Interim/Grading material, clay cover material, and Rocky Soil Cover material from local borrow sites, lack of royalty notwithstanding, (Section 11.2.4).*

Response 8
This response will be provided in a later submittal.

9. *Justify that 44 bags of grout per well is adequate for the purposes of abandoning monitoring wells (Sections 11.2.8 and 11.3.8).*

Response 9
This response will be provided in a later submittal.

10. *Ensure that the costs of environmental monitoring are included in closure and decommissioning costs estimates as appropriate.*

Response 10
This response will be provided in a later submittal.

11. *Apply 25 percent of subtotal costs for contingency allowance in Tables 12-1-Cell-1 and 12-1-Cell-2, consistent with relevant NRC guidance on cost estimates supporting determination of financial assurances.*

Response 11
This response will be provided in a later submittal.

12. *Revise the Uranium One Management Overhead percentage allowed in Tables 12-1-Cell-1 and 12-1-Cell-2 to reflect the possibility that the Tailings Reclamation and Decommissioning Plan will be performed by an independent third-party contractor. This percentage should allow for:*

- *Labor Overhead and Profit*
- *Materials and Subcontract Overhead and Profit*
- *General Conditions*

- *Subcontract Administration and Engineering*
- *Construction Oversight*

Response 12
This response will be provided in a later submittal.

13. *Ensure that all revisions made in Section 11 and 12 are incorporated into other sections of the Tailings Reclamation and Decommissioning Plan and elsewhere in the License Amendment Request.*

Response 13
This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

The response to Round 2 was that the response to this submittal will be provided in the next submittal.

As examples of providing the bases for quantities, durations, allowances, and lump sums, consider the following.

- *Uranium One should explain the basis for estimating that the duration of the ore hopper demolition (Section 11.1.4) is two weeks. This duration should be related in some way to the quantities of materials to be handled and a documented productivity for similar activities.*
- *Two examples (from numerous instances) of needed explanations: Uranium One should explain why allowances of $500 per month for Miscellaneous Office Supplies and of $40,000 for the "Environmental Radiological & Other Required Surveying, Quality control & Testing Equipment" (Section 11.1.18) are adequate and appropriate. Where quantity of an individual cost item is readily identifiable (e.g., collecting and analyzing environmental monitoring samples and neutralization), the cost estimate should be identified and supported through reference to those quantities.*

Unit costs presented throughout Section 11 should be justified and referenced to published sources, such as R.S. Means Building Construction Cost Data.

The allowances for contingency, management, and overhead costs are too small and should be increased.

REFERENCES:

Plateau Resources Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project –2005; Garfield County, Utah", December 2005, Revised: December 2006.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

US Bureau of Labor Statistics, "Employer Costs for Employee Compensation – March 2007", http://www.bls.gov/news.release/pdf/ecec.pdf as of July 10, 2007.

US Nuclear Regulatory Commission. "NMSS Decommissioning Standard Review Plan," NUREG-1727, September 2000.

US Nuclear Regulatory Commission. "Revised Analyses of Decommissioning Reference Non-Fuel-Cycle Facilities," NUREG/CR-6477, December 2002.

INTERROGATORY R313-24-4-38/02: LONG TERM SURVEILLANCE COSTS

INTERROGATORY STATEMENT:

Justify OR revise and justify the allowance of $752,600 for DOE to provide Long Term Maintenance (as shown in Table 12-1-Cell-1 and 12-1-Cell-2). Base the allowance on EITHER:

1. *A detailed listing of activities and cost components (expressed as quantities with unit costs), together with an orderly estimate of associated costs, including an explanation of basis. This cost estimate should address planned and expected costs for a period of at least 100 years following reclamation and decommissioning and should consider a rate of return on secure financial instruments of 2 percent real.*

   Response 1
   This response will be provided in a later submittal.

2. *Justifying, including explanation of basis*
   - *A value that was acceptable to DOE in 1978,*
   - *That DOE still honors the 1978 basis for determining costs that should be covered for it providing Long Term Maintenance, and*
   - *Cost escalation from 1978 to 2007 using an appropriate construction cost index.*

   Response 2
   This response will be provided in a later submittal.

BASIS FOR INTERROGATORY:

The response to Round 2 was that the response to this submittal will be provided in the next submittal.

Although the response to Round 1 Interrogatory R313-24-4-38/01 might be reasonable, no basis is provided that allows intelligent evaluation of the allowance for the cost of Long Term Maintenance by DOE. The basis for estimating the present value of costs for DOE to provide long-term surveillance and maintenance should be clearly elaborated.

REFERENCES:

Plateau Resources Ltd., "Tailings Reclamation and Decommissioning Plan for Shootaring Canyon Uranium Project –2005; Garfield County, Utah", December 2005, Revised: December 2006.

Uranium One USA, Inc., "Shootaring Canyon Uranium Mill Amendment Request for Radioactive Material License No. UT 09004480, 2nd Round Interrogatory Responses", November 28, 2007.

ATTACHMENT A
SUPPORTING DOCUMENTATION FOR INTERROGATORY R313-24-4-05/03: DAILY INSPECTIONS OF WASTE TAILINGS

DRAFT

Inspections of Tailings or Waste Retention Systems

Procedure AP-3

Prepared by

Uranium One U.S.A.
3801 Automation Way
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May 27, 2008

Revision Draft

Prepared by: ______________________________ Date: ______________
Project Lead

Approved by: ______________________________ Date: ______________
Corporate Radiation Safety Officer

Approved by: ______________________________ Date: ______________
Mill Superintendent

REVISION HISTORY

Date	Version	Description	Author
June 4, 2007	2.1	Initial Draft	Kenneth R. Baker
June 13, 2007	2.2	Final	Toby Wright
September 26, 2007	2.3	Revised	Kenneth R. Baker
February 20, 2008	Draft	Issued as draft per suggestion by DRC	Kenneth R. Baker

THIS PROCEDURE IS BEING SUBMITTED IN DRAFT AS PART OF THE APPLICATION. REVISIONS TO THE PROCEDURE WILL BE DONE AFTER THE TAILINGS DISPOSAL DESIGN IS FINALIZED AND SPECIFIC CELL COMPONENTS CAN BE IDENTIFIED. THE PROCEDURE WILL USE THE ASSOCIATED DESIGN CRITERIA AS A GUIDE FOR EVALUATING PROPER PERFORMANCE OF EACH COMPONENT. A FINAL PROCEDURE WILL BE PROVIDED TO THE DRC FOR REVIEW PRIOR TO THE START OF OPERATIONS

CONTENTS

ACRONYMS, ABBREVIATIONS, AND INITIALISMS

CFR	Code of Federal Regulations
CRSO	Corporate Radiation Safety Officer
RSO	Radiation Safety Officer
UDRC	Utah Division of Radiation Control
UDEQ	Utah Department of Environmental Quality
SOP	Standard Operating Procedure

Standard Operating Procedure AP-3

Inspections of Tailings or Waste Retention Systems

1 PURPOSE

R313-24-4 of the Utah Administrative Code requires the documentation of daily inspections of tailings or waste retention systems and the immediate notification of the Executive Secretary of any failure in a tailings or waste retention system that results in a release of tailings or waste into unrestricted areas, or of any unusual conditions (conditions not contemplated in the design of the retention system) that if not corrected could lead to failure of the system and result in a release of tailings or waste into unrestricted areas. This procedure outlines the methods, equipment, and recordkeeping requirements needed to perform the inspections of tailings or waste retention systems at the Shootaring Canyon Mill Site.

Other related inspection and reporting requirements exist in the Groundwater Discharge Permit No. UGW170003. These requirements may change as the discharge permit is amended. While some of the requirements may in part duplicate those in R313-24-4, this SOP is not intended to assure compliance with the inspection, reporting, or other requirements in the Groundwater Discharge Permit.

2 DEFINITIONS

For the purposes of this procedure, waste or tailings is defined as liquid or solid materials that are a byproduct of the uranium milling process that have been placed in a disposal area. Waste retention systems include berms, liners, tanks, or other containers such that if breached, there is potential for uncontrolled release of waste material or tailings.

Immediate reporting to the Executive Secretary is defined as “within four hours of knowledge of the incident”.

3 APPLICABILITY

This procedure is applicable to managing the waste retention systems at the Shootaring Canyon mill site, as currently configured and to the site after milling operations have resumed.

4 DISCUSSION

A small quantity of tailings had been placed on a synthetic liner above a leachate collection system that drains to a collection sump. Currently, this sump is pumped after or during significant precipitation events with the liquids pumped to a lined evaporation pond placed within the disposal cell. The evaporation pond has been sufficient to evaporate all of the water collected to date. The containment of liquids within the disposal cell is assured by the South Dam which has been designed to contain runoff from the drainage area resulting from a maximum precipitation event as long as there exists a freeboard of 13 feet. This SOP covers the inspection of the South Dam, evaporation and process ponds, the management of the leak detection system (LDS), ore storage pads, areas of construction as well as the general area within the tailings disposal area.

A new tailings disposal facility has been designed and proposed for use once milling operations resume. The current tailings and cell liner will be removed and reconfigured. This SOP has been written to apply to the new facility as proposed.

This SOP will also apply during the construction of the new tailings facility, during which the integrity of the South Dam will be monitored. This SOP, however, in no way is a substitute for a construction quality control plan.

5 RESPONSIBILITY

The General Site Foreman, or equivalent, or his designee is responsible for the inspections as outlined in this procedure. The field inspector has the responsibility of immediately notifying the General Site Foreman of any significant abnormal findings. The General Site Foreman has the responsibility for further investigation and assuring that the information is given to the CRSO in a timely manner so that reportable incidents are reported to the Executive Secretary of the UDEQ-DRC according to the criteria and time schedules given in AP-4 and the Groundwater Discharge Permit. The General Site Foreman has the responsibility to take timely and appropriate corrective actions to correct the deficiencies.

Inspection reports will be submitted to the General Site Foreman with copies to the CRSO.

6 EQUIPMENT AND MATERIALS

- Note Pad
- Clip Board
- Calculator
- Pen
- Digital Camera
- Field Log Book or equivalent
- Forms AP-3A and\or AP-3B

7 PROCEDURE

All inspections will be conducted by competent individuals, normally an engineer or other technical person familiar with the construction, operation, and inspection of tailings impoundments. All observations shall be recorded and any item(s) that are out of normal (defined as not noted during the last inspection or any occurrence that is not within the range of expected observations) shall be recorded and reported to the General Site Foreman immediately. Where appropriate, the observation should be documented by taking a photograph. Problematic observations noted during inspections shall normally be followed up by the collection of additional data required to quantify the probability of an event or to assess the impact. Such data as underdrain liquid collection rates, seepage rates, and settlements will normally not be available to the inspector but may be required by qualified individuals conducting the technical evaluations.

7.1 Daily Inspections

Daily Inspections shall include if appropriate:

- Documentation of water levels and pumping volumes from each Leak Detection System (LDS) sub-sump on Form AP-3A. Water Levels should be measured to nearest 0.1 feet and flow rates should be measured to nearest 0.5 gpm or minimum whole meter unit.
- Pumping rates from the LDS sumps should be compared to approved Action Leakage Rates for each LDS sub-sump.
- Effluent LCS and LDS pipes should be examined for evidence of clogging, cracking, and erosion.
- LCS and LDS sumps and other components should be inspected for proper functioning. Report evidence of clogging, freezing, corrosion, cracking, or crushing of pipes; and erosion at the discharge point or any other conditions that would make sumps non functional.
- Compare LCS and LDS intake and discharge flow rates for evidence of leaks.
- Pond water elevations – record elevation of tailings solution to nearest 0.1 feet. For the South Dam, measure and calculate the height from the tailings solution to the top of the Dam (freeboard) and record. After cell construction, the minimum freeboard for the South Cell (as measured from the tailings solution to the top of the South Dam liner) is 6.5 feet for Phase I and 5.0 feet for Phase II. The minimum freeboard for the North Cell is 7.5 feet.
- If the tailings are placed as a paste, tailings elevation should be recorded. The tailings height relative to the lined impoundment perimeter and/or Dam crest should be recorded and assessed to ensure placement does not exceed design conditions.
- Slurry transport system– visually inspect pipes and pump intakes for obstructions due to sand clogging or ice accumulation. Inspect pipe couplings for leaks and report any leaks found.
- Visually inspect top of dams and earthen embankments for cracks (especially cracks running parallel with the crest of the dam), slumping and movement of embankment material. Report and document all cracks, slumps or movement;
- Visually inspect all lined evaporation ponds for evidence of exposed liner deterioration or leaks. Exposed liners should have no tears, holes, and should be well anchored. Inspect associated earthen berms for waste water seeps, cracks, slumps or movement.
- Visually inspect area for evidence of burrowing animals, livestock, and other large animals.

- Check safety and performance instrumentation for operability.
- Check Emergency Discharge Facility for Operability
- Visually check all operational areas for adequate performance of dust control measures. Areas are to include but are not limited to the tailings storage cells, ore storage areas, site roads, site areas of construction and new disturbance. Inspections should include performance of interim soil covers, spray systems, wind brakes, application of water or other agents as appropriate to ensure control of fugitive dust.
- Other related systems as appropriate

Results of daily inspections shall be documented on Form AP-3A or equivalent.

7.2 Monthly Inspections

Monthly Inspections shall include:

Visually inspect diversion channels for channel bank erosion, bed aggradation or degradation and siltation, obstruction to flow, undesirable vegetation, or any unusual or inadequate operational conditions. This inspection shall be documented in a field log book or equivalent.

7.3 Quarterly Inspections of the Main Tailing Dam and Other Instrumented Berms

Quarterly inspections shall include:

- Measure water elevation, if any, in piezometers located on South Dam or retention berms;
- Survey embankment settlement monuments (MM) installed on top and slope of South Dam, if any,
- Visually inspect for seepage along slope of dam
- Visually inspect slope for erosion, burrowing animals, springs, seeps, brush, and trees

Results of quarterly inspections shall be documented on Form AP-3B or equivalent. Notify the General Site Foreman immediately of an unusual occurrence or an occurrence that was not noticed during the last inspection.

7.4 Special Inspections and Response to Unusual Conditions

The General Site Foreman will authorize special inspections:

- After any unusual event such as significant earthquake, tornado, major flood or intense local rainfall;
- Upon discovery of an unusual condition.

Special inspections will be reported on Form AP-3A.

The General Site Foreman will evaluate any unusual conditions by personally inspecting the condition and/or soliciting the assistance of a qualified person. The RSO and CRSO will be advised of the results of the investigation and, if appropriate, the CRSO will notify the Executive Secretary in accordance with the requirements in R313-24-4 and R313-19-50 (See SOP AP-4). The CRSO may appoint a competent person to prepare a Technical Evaluation if warranted.

Measures required to immediately correct a problem will be discussed with the Executive Secretary, implemented, and documented. The General Site Foreman will implement appropriate corrective action and document the conditions and corrective actions on Form AP-3A or using another suitable format.

7.5 Reporting

R313-24-4 of the Utah Administrative Code requires the immediate (within four hours) notification of the Executive Secretary of any failure in a tailings or waste retention system that results in a release of tailings or waste into unrestricted areas, or of any unusual conditions (conditions not contemplated in the design of the retention system) that if not corrected could lead to failure of the system and result in a release of tailings or waste into unrestricted areas. Examples of such events include:

- Liquid levels exceeding the freeboard requirements for the South Dam or tailings cells.
- Questionable integrity of South Dam arising from damage from an earthquake or precipitation event
- Erosion or sedimentation filling of diversion channels making them potentially non-functional
- Loss of liquids from the evaporation and\or process ponds due to dike failure
- Evidence of leaks from tailings or evaporation and\or process ponds in excess of design parameters

In addition, all hazardous conditions or potentially abnormal hazardous conditions should be evaluated by the CRSO to determine whether notification of the Executive Secretary in accordance with R313-24-4 and R313-19-50 is required. See SOP AP-4.

Additional reporting requirements exist in the Groundwater Discharge Permit No. UGW170003. Reports of noncompliance must be made within twenty-four hours. Spill Reporting per UCA 19-5-114 of the Utah Water Quality Act requires the immediate reporting of any spill that comes into contact with the ground surface or ground water that causes pollution or has the potential to cause pollution to waters of the state. A follow-up written report is required within five days of the occurrence.

Measures required to immediately correct a problem will be discussed with the Executive Secretary, implemented, and documented.

7.6 Technical Evaluation and Annual Best Available Technology (BAT) Report

A competent individual will prepare an evaluation of the existing conditions. A competent individual will normally be an engineer or other technical person familiar with the construction, operation, and inspection of tailings impoundments. Evaluation of existing conditions should include storage capacities, water quality, and structural integrity. In addition, surface water and groundwater water quality data should be examined to look for trends that might indicate a changing condition.

This technical evaluation should be made annually unless changing conditions dictate more frequently. Technical evaluation reports shall be prepared for each technical evaluation and should include the inspection data collected since the last report. They shall be maintained at the project office until license termination. These technical evaluations may be included within, in whole or in part, the Annual Environmental Monitoring Report and\or the Annual Effluent Monitoring Report, required by the Radioactive Materials License No. UT 0900480 and the Ground Water Discharge Permit No. UGW170003.

Best Available Technology (BAT) Reports may include the inspection technical evaluations described above along with

- Completed inspection reports
- Engineering data compilations
- General project data
- As-build drawings and photographs
- Hydrologic and hydraulic data
- Test results
- Applicable correspondence
- Names of the inspector and responsible supervisor

8 QUALITY ASSURANCE

The General Site Foreman will assure quality by:

- Implementing a training program for field inspectors by an experienced professional
- Assigning experienced and competent professionals to perform technical evaluations
- Conducting an Annual Field Inspector Retraining Program
- Adherence to this SOP

9 RECORDS

The following forms will be completed and maintained in the project office with copies sent to the CRSO. These forms shall be retained for three years from the date of inspection.

- Form AP-3A Daily Inspection Form, Tailings and Waste Retention Systems
- Form AP-3B Quarterly Inspection Form, Tailings and Waste Retention Systems

10 REFERENCES

R313-24-4, 10CFR40.26(c)(2)

R313-24-4, 10CFR40 Appendix A(8)(a)

R317-6-6.3 (O)

Shootaring Canyon Mill Groundwater Discharge Permit No. UGW170003.

NRC Regulatory Guide 3.11.1, Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings. Revision 1, October 1980. Office of Standards Development, U. S. Nuclear Regulatory Commission, Washington, DC.

NRC Regulatory Guide 3.11. Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills, Revision 2, December 1977. Office of Standards Development, U. S. Nuclear Regulatory Commission, Washington, DC..

APPENDIX A

DAILY INSPECTION FORM

Form AP-3A

Form AP-3A

Inspection Form
Tailings, Ore Stockpiles, Waste Retention Systems, Other Areas Inspection

Daily Inspection ____ (yes or no) Special Inspection____: Reason for Inspection____

Field Inspector___________________________ Date of Inspection__________________________

South Dam

Inspections:

- Pond water feet from top of dam liner _________ft. Meas. Method:_________________
- Visual dam top; cracks yes/no comments ____
  slumps yes/no comments ____
  movement yes/no comments_______________________________________
- Livestock; evidence around dam yes/no comments__________________________________
- Visual inspection; toe seepage yes/no comments __________________________________
  slope seepage yes/no comments _________________________________
- Visual inspection; erosion yes/no comments ______________________________________
  burrowing animals yes/no comments______________________________
  springs yes/no comments ______________________________________
  seeps yes/no comments ____
  brush and trees yes/no comments_______________________________

Tailings and Ore Stockpiles

Tailings Impoundment Visual Inspections:

- Interim Cover; surface deterioration/cracks yes/no comments________________________
  Fugitive dust yes/no comments_____________________________________
  Performance of dust control system adequate (yes\no): _________________
- Surrounding areas; surface deterioration/cracks yes/no comments___________________
  Fugitive dust yes/no comments_____________________________________
  Performance of dust control system adequate (yes\no): _________________

- Slurry transport system– visually inspect pipes and pump intakes for obstructions due to sand clogging or ice accumulation. Inspect pipe couplings for leaks and report any leaks found. Obstructions yes/no comments____

  Leaks yes/no comments____

- Leak Detection System;
  - Sump 1 totalized pumping volume:____________Water Level (from TOC)________
  - Sump 2 totalized pumping volume:____________Water Level (from TOC)________
  - Sump 3 totalized pumping volume:____________Water Level (from TOC)________
  - Sump 4 totalized pumping volume:____________Water Level (from TOC)________

Ore stockpile Visual Inspections:

- Pile surfaces; surface deterioration/cracks yes/no comments____________________

  Fugitive dust yes/no comments_______________________________

  Performance of dust control system adequate (yes\no): _________________

- Surrounding areas; surface deterioration/cracks yes/no comments____________________

  Fugitive dust yes/no comments____________________________________

  Performance of dust control system adequate (yes\no): _________________

Roads Inspections:

- Fugitive dust yes/no comments____

  Performance of dust control system adequate (yes\no): _________________

Construction Areas Inspections:

- Fugitive dust yes/no comments____

  Performance of dust control system adequate (yes\no): _________________

Other Retention Systems

Retention system name__________________________________(may use one for each system)

Inspections:

- Pond water feet from top of berm liner _________ft
- Pond liners; exposed surface deterioration/cracks yes/no comments___________________
  Liner well-anchored yes/no comments_______________________________
- Visual berm top; cracks yes/no comments _______________________________________
  slumps yes/no comments _______________________________________
  movement yes/no comments ____________________________________
- Visual inspection; toe seepage yes/no comments__________________________________
  slope seepage yes/no comments _________________________________
- Visual inspection; erosion yes/no comments ______________________________________
  burrowing animals yes/no comments ____________________________
  springs yes/no comments _____________________________________
  seeps yes/no comments _______________________________________
  brush and trees yes/no comments _______________________________
  evidence of live stock/large animals yes/no comments_______________
- Visual inspection; Fugitive dust yes/no Comments________________________________
  Performance of dust control system adequate (yes\no): ______________

Under-drain pipes, if any - visually inspect for clogging, cracks, and erosion yes/no
Comments____
____
____

Corrective Actions

By:________________________________Date:________________________________

APPENDIX B

QUARTERLY INSPECTION FORM

Form AP-3B

AP-3B

Quarterly Inspection Form
Tailings and Waste Retention Systems Inspection Form

Field Inspector___________________________________ Date of Inspection___________________

Retention System (use one for each retention system)

South Dam ____

or

____

Inspections:

- Pond water feet from top of dam _________ft
- Visual dam top: cracks yes/no comments ____
  slumps yes/no comments ____
  movement yes/no comments _______________________________________
- Visual slope and toe: toe seepage yes/no comments _________________________________
  slope seepage yes/no comments ___________________________________
  erosion yes/no comments ____
  burrowing animals yes/no comments ______________________________
  springs yes/no comments ____
  seeps yes/no comments ____
  brush and trees yes/no comments _________________________________
- Livestock: evidence around dam yes/no comments __________________________________

:

- Piezometers: PZ1 water yes/no casing top to water level ___________ft
  PZ2 water yes/no casing top to water level ___________ft
  PZ3 water yes/no casing top to water level ___________ft
  PZ4 water yes/no casing top to water level ___________ft
  PZ5 water yes/no casing top to water level ___________ft
  PZ6 water yes/no casing top to water level ___________ft

- Embankment survey: MM1 X______________, Y ______________, Z _____________
MM2 X______________, Y ______________, Z _____________
MM3 X______________, Y ______________, Z _____________
MM4 X______________, Y ______________, Z _____________
MM5 X______________, Y ______________, Z _____________
MM6 X______________, Y ______________, Z _____________
MM7 X______________, Y ______________, Z _____________
MM8 X______________, Y ______________, Z _____________
MM9 X______________, Y ______________, Z _____________
MM10 X_____________, Y ______________, Z _____________
MM11 X _____________, Y ______________, Z _____________
MM12 X _____________, Y ______________, Z _____________

Other Observations:

Corrective Actions

By:_________________________________Date:__________________________________

ATTACHMENT B

SUPPORTING DOCUMENTATION FOR INTERROGATORY R313-24-4-06/03: MAINTAINING RECORDS

DRAFT

Radioactive Materials Tracking and Balance

Procedure HP-25

Prepared by

Uranium One U.S.A.
3801 Automation Way
Suite 100
Fort Collins, Colorado 80525

May 28, 2008

Revision 0

Prepared by: ____ Date: __________________
Project Lead

Approved by: ____ Date: __________________
Corporate Radiation Safety Officer

Approved by: ____ Date: __________________
Mill Superintendent

REVISION HISTORY

Date	Version	Description	Author
October 9, 2006	0.1	Initial Draft	Mike Madonia
December 5, 2006	0.2	Incorporate edits and format	Mike Schierman
October 9, 2007	0.3	Incorporate Regulatory Review edits	Ken Baker
February 19, 2008	Draft	Incorporate Regulatory Review Edits and Change to Draft per DRC suggestions.	Ken Baker

THIS PROCEDURE IS BEING SUBMITTED IN DRAFT AS PART OF THE APPLICATION. A FINAL PROCEDURE WILL BE PROVIDED TO THE DRC FOR REVIEW PRIOR TO THE START OF OPERATIONS

CONTENTS

ACRONYMS, ABBREVIATIONS, AND INITIALISMS

AEL	Analytical Environmental Laboratory
COC	Certificate of Conformance
CRSO	Corporate Radiation Safety Officer
EVW	Empty Vehicle Weight
GVW	Gross Vehicle Weight
KPA	Kinetic Phosphorescence Analyzer
MBTD	Mass Balance Tracking Database
NTEP	National Type Evaluation Program

Standard Operating Procedure HP-25

Radioactive Materials Tracking and Balance

1 PURPOSE

The purpose of this procedure is to identify processes to document the receipt, transfer and disposal of radioactive materials from the Shootaring Canyon Mill Site, and to identify a means to determine the total amount of radioactive materials present in key areas of the site.

2 DEFINITIONS

MBTD – Mass Balance Tracking Database - a database developed using standard versions of Microsoft Office^{TM} software such as Access^{TM} or Excel^{TM}; capable of systematically storing raw data related to radioactive material inventory, transfer and disposal; and containing queries to generate a variety of reports to support inventory management.

3 APPLICABILITY

This procedure is applicable to stored or stockpiled radioactive materials already present, newly received ore and other materials, produced yellowcake, offsite transfer of yellowcake and other products (for sale or otherwise), and tailings products disposed of at the Shootaring Canyon Mill Site.

4 DISCUSSION

This procedure describes the processes to:

1. Document and verify the receipt of radioactive materials contained in uranium ore or other source material,
2. Document and verify the amount of yellowcake produced and transferred offsite for commercial or other purposes,
3. Document and verify the amount of tailings placed in tailings impoundments,
4. Document and verify the amount of liquid discharged to the evaporation pond,
5. Maintain running totals of the inventory of radioactive materials on site; identify significant discrepancies in overall site uranium mass balance; and initiate corrective measures.

Under typical operating mode, the Shootaring Canyon Mill Site will receive uranium ore via truck delivery in preparation for placement into the ore sizing and grinding components of the mill. Under standard operating conditions, the majority of the uranium will be processed into yellowcake and transferred off site for sale and additional processing. It is necessary to verify and document the amount of uranium received and shipped, and that may be present at the site at a given time. Calculation of this “material balance” requires understanding of the amount of radioactive materials associated with ore that has been accepted and/or is in the milling process prior to packaging of yellowcake, yellowcake packages stored on site, minor quantities of uranium discharged with tailings and waste liquids, any previously stored or stockpiled materials, and to a lesser extent, air emissions. Data relating to radioactive material inventory will be entered into a mass balance tracking database (MBTD) that will be maintained by site Analytical Environmental Laboratory (AEL) personnel. When populated, the MBTD will be capable of being queried for material balance related information.

5 RESPONSIBILITY

It is the responsibility of the Corporate Radiation Safety Officer (CRSO) and the environmental staff to implement and follow this procedure.

6 EQUIPMENT AND MATERIALS

- NTEP Certified Truck Scale
- Calibrated Kinetic Phosphorescence Analyzer (KPA) Laboratory System or equivalent
- Site Inventory Mass Balance Tracking Database (MBTD)
- Uranium reference materials.
- Uranium ore, tailings, liquid, and yellowcake sample containers as required by AEL

7 PROCEDURE

7.1 Document and Verify Receipt of Uranium Ore and Other Radioactive Materials

1. Ensure that truck scale has a current NTEP Certificate of Conformance (COC), is under current calibration, and functioning properly.

2. Direct incoming ore truck (or comparable vehicle) onto truck scale and obtain gross vehicle weight (GVW).

3. For each incoming ore truck; identify delivering entity (company affiliation), date, time, vehicle ID number as available, and GVW. Record in MBTD. Note unique delivery ID number generated by MBTD.

4. Driver to designated ore dump pocket/handling zone and offload materials.

5. As necessary, direct truck to portal for surface contamination survey in accordance with SOP HP-9.

6. Direct driver to return to truck scale and collect empty vehicle weight (EVW) measurement. Record in MBTD.

7. Complete and provide driver with delivery ticket as shown in Form HP25-1. Retain hard copy of delivery ticket for permanent site records.

8. Collect sample of delivered ore for laboratory uranium, thorium, radium, and moisture analyses in accordance with AEL procedures and Analytical Laboratory Quality Assurance Program (QAP).

9. Label samples with unique delivery ID number generated by MBTD. For multiple truck shipments, record all delivery ID numbers. Deliver to site AEL.
10. AEL shall analyze ore samples for total uranium content per procedures and QAP. Upon quality review approval, record total uranium concentration in MBTD for delivery ID number(s).
11. For radioactive source or byproduct material other than uranium ore, the CRSO will be notified in advance of receipt, authorize and verify acceptance of material under license limitations, and enter receipt of material into tracking database.

7.2 Document and Verify the Amount of Yellowcake Produced and Transferred Offsite

1. Yellowcake product shall be packaged in DOT 7A 55-gallon drums or comparable containers.
2. Prior to yellowcake production ensure that adequate numbers of containers are obtained, inspected for integrity, removed from service as necessary, and coded with a unique identification number or bar code tracking number.
3. Production personnel shall fill containers with yellowcake product and seal following yellowcake sample collection to determine sample purity. AEL personnel will split or divide samples as necessary to support customer confirmation laboratory analyses.
4. Each container shall be weighed and the tare weight and gross weight entered with container tracking number into Form HP25-2. User shall verify that scale is calibrated and in proper working condition. Automatic scale data recording and logging systems will be used as available.
5. Each yellowcake sample collected for an individual container or lot of containers will be placed in a sample container and submitted to the AEL with Form HP25-2, which identifies all associated container tracking numbers. As possible, sampling personnel will collect an aliquot of yellowcake from each container. Sampling will be done according to SOP (*to be developed prior to start of operations*)
6. Sample containers shall be cleaned of removable yellowcake, labeled, and transferred to AEL.
7. AEL shall perform uranium analyses in accordance with laboratory procedures, and enter results and associated containers in MBTD. Form HP25-2 shall be retained for permanent site records.
8. Sealed, sampled containers will be transferred to designated yellowcake storage areas, labeled, and stored in a manner such that all containers associated with a lot are in proximity to one another.
9. On a bi-weekly basis, an inventory list identifying all yellowcake containers that should be currently present on site shall be generated from the MBTD. Confirmation of the inventory will be documented by a qualified field inspector within one day of list generation. Any

discrepancies regarding yellowcake inventory shall be noted and the Mill Superintendent informed.

10. Yellowcake purchase requests shall be forwarded to the Plant Sales Manager. The Plant Sales Manager shall complete Form HP25-3 – Yellowcake Purchase Ticket and provide copy to AEL. Form HP25-3 shall identify desired yellowcake quantity, estimated date of pick-up, sample splits and requirements for customer, and special considerations and requests.
11. AEL shall review sampling requests and assign on-site inventory for customer shipment; provide analytical data to customer; or transfer yellowcake samples to offsite customer laboratory.
12. Following AEL assignment of containers to customer order in conjunction with sampling requirements, the AEL shall provide the Mill Superintendent with all container tracking numbers, the estimated date of pickup or shipment, and any special handling requests.
13. The Mill Superintendent or designee shall tag all yellowcake containers associated with a customer purchase with unique identifying marks and basic information as noted in Section 7.2, step 11 above, and prepare a draft transportation manifest/bill of lading.
14. Upon arrival for pickup, customer representative is required to show credentials and demonstrate that vehicles are in safe, working condition prior to proceeding to yellowcake loading area. Required credentials include hazardous material training, Department of Transportation (DOT) required training, commercial driver’s license (CDL), training on the site emergency response plan, and other credentials as determined by the CRSO. The same requirement applies for delivery personnel under subcontract to Uranium One.
15. Designees of the Mill Superintendent shall remove customer-assigned yellowcake containers to the loading area and perform U.S. Department of Transportation (DOT) surveys in accordance with SOP HP-4.
16. Following DOT surveys, Mill Superintendent or designee shall complete the transportation manifest/bill of lading, sign and provide copies to driver and to AEL. Obtain driver signature for receipt. Original copies are to be filed in the permanent site record.
17. Verify that proper transportation placards are on vehicle in accordance with site procedures.
18. As necessary, allow driver and vehicle to use truck scale to determine EVW and GVW.
19. As necessary, direct truck to portal for surface contamination survey in accordance with SOP HP-9.
20. Following release of shipment, AEL personnel shall enter information from SOP HP-4 and the manifests into the MBTD.

7.3 Document and Verify the Amount of Tailings Placed in Tailings Impoundments

1. Execute tailings sampling and analyses procedure on a daily basis, or other frequency as determined by mill plant operator considering events such as changes in operational production rates, shut down, etc. Coordination with the mill operator is necessary to assure that a minimum of one sample is taken to represent non-changing conditions of the mill output. A new sample should be taken soon after it has been determined that a change in tailings output has occurred. The mill plant operator will determine the average tailings output of the mill over a period of time using operations data and SOP (*to be prepared and submitted for DRC review prior to operations*). These data along with data from the previous sample will be used by the MBTD to calculate the mass and activity of the tailings disposed.
2. Collect sample of tailings at dewatering press discharge and submit for moisture content, uranium, thorium, and radium analyses in accordance with AEL procedures (*to be prepared and submitted for DRC review prior to operations*).
3. Should the dewatering press not be in use or otherwise inactive, take one sample of tailings plus liquids at discharge/sampling port or other representative location in the discharge system.
4. For each sample collected, the sampling technician shall document on Form HP25-4 the sample identifier, date, and time that the sample was taken. The total tailings discharged shall be calculated by the MBTD from the duration between this sample and the previous sample and the flow rate from the previous sample. The disposal activity will be calculated by taking the product of the mass disposed and the radionuclide concentrations from the previous sample. Note: tailings quantities may require subtraction of liquid routed from dewatering process from total input tailings mass associated with gallons of discharge. Also, the MBTD will allow for subtracting the duration of periods where no tailings are discharged, such as for a shutdown of the mill.
5. Upon completion of laboratory analyses and quality assurance review, the AEL shall enter the sample results and data into the MBTD. Quality assurance review and retention of data forms shall be done according to SOPs (*to be developed for DRC review prior to operations).*

7.4 Document and Verify the Amount of Liquid Discharged to the Evaporation Pond

1. Execute liquid discharge sampling and analyses procedure on a daily basis, or other frequency as determined by mill plant operator due to changes in operational production rates, shut down, etc. This sampling process may be performed in conjunction with tailings sampling specified in Section 7.3. The data should be entered on the appropriate section of Form HP25-4.
2. Collect liquid sample(s) at dewatering press discharge to evaporation pond or other bypass points in discharge lines from the mill that are directed to the evaporation pond. Submit samples for total dissolved solids (TDS), uranium, thorium, and radium analyses in

accordance with AEL procedures and Analytical Laboratory Quality Assurance Program (QAP).

3. For each sample collected, the sampling technician shall document on Form HP25-4 the sample identifier, date, and time that the sample was taken. The total liquids discharged shall be calculated by the MBTD from the duration between this sample and the previous sample and the flow rate from the previous sample. The disposal activity will be calculated by taking the product of the volume disposed and the radionuclide concentrations from the previous sample. The MBTD will allow for subtracting the duration of periods where no tailings are discharged, such as for a shutdown of the mill.
4. Upon completion of laboratory analyses and quality assurance review, the AEL shall enter the sample results and information from Form HP25-4 data into the MBTD.

7.5 Maintain Running Totals of the Inventory of Radioactive Materials on Site

1. Information gathered in procedure steps 7.1 through 7.4 shall be entered into the MBTD and validated by trained individuals according to SOPs *(to be developed and submitted to DRC for review prior to operations*).
2. Through the operation of the mill, quantities of radioactive materials may be inadvertently introduced to systems or site areas and may not readily be removed until shutdown; thus they become static component of site inventory until cleanup. The location of and radiological inventory associated with these areas will be determined by the CRSO during implementation of the radiation protection program. These quantities and location attributes shall be entered into the MBTD.
3. Through operation of the mill, other sources of radioactive material may be received, stored and used at the site. Receipt, storage, use and disposal of these sources shall be authorized and supervised by the CRSO in accordance with the terms of the radioactive materials license. The quantities and source characteristics shall be entered into the MBTD. Records of receipt and disposition of these materials will be stored with the radioactive materials license and with the permanent record.
4. As desired, MBTD users shall be able to generate the following outputs:
   a. Total Uranium Inventory On Site
   b. Total Weight and Average Grade of All Ore Received
   c. Total Uranium Activity and Mass of Ore Received
   d. Total Weight and Activity of Yellowcake Sold and/or Transferred Offsite
   e. Total Weight and Activity of Yellowcake On Hand
   f. Total Uranium, Radium-226 and Thorium-230 Activity Contained in Tailings Cells and Evaporation Pond
   g. Total On-Site Radioactivity Associated with Non-Ore or Yellowcake Sources

5. The CRSO or their appointee may add or modify queries and outputs from the database to support the material tracking program. Modifications shall be subject to quality control reviews of calculations, modifications to stored data, and report output validity. An annual validation process for the MBTD shall be performed according to SOP*(to be developed and submitted for DRC review prior to operations*).

8 QUALITY ASSURANCE

Quality assurance will be maintained by following the above procedures. Prior to performing work, technicians will be trained and certified as competent in procedures by the CRSO and/or an independent auditor. Noncompliance will be documented and corrected.

9 RECORDS

The radionuclide inventory at the site will be determined from reports generated by the MBTD. The data base will be supported by production data, laboratory data, and data from forms in this SOP provided in Appendix A. These forms, or their equivalent, will be completed and maintained in the project files. The forms include the following.

- Form HP25-1, Uranium Ore Delivery Ticket
- Form HP25-2, Yellowcake Container Sampling and Tracking
- Form HP25-3, Yellowcake Purchase Ticket
- Form HP25-4, Tailings and Tailings Liquids Disposal Samples

These records, along with the MBTD, will be retained until the license is terminated according to Utah Administrative Code R13-12-51 and 10 CFR Part 40.61. Should the license be transferred to a new licensee, ownership of these records will also be transferred.

10 REFERENCES

Utah Administrative Code R13-12-51, Records.

10 CFR 40.61 Records.

APPENDIX A
RADIOACTIVE MATERIALS TRACKING FORMS

Form HP25-1

Uranium Ore Delivery Ticket

GENERAL DELIVERY INFORMATION

Date of Delivery:__________________ **Time of Delivery:_______________**

Delivering Company:_______________ **Scale ID Number________________**

Other Information:____

WEIGHT INFORMATION

Current Scale Certification/Calibration ? **Yes** **No**

Vehicle Number/Description:_________________________

Incoming Gross Vehicle Weight (GVW) in Pounds:____________________

Material Balance Tracking Database (MBTD) Number:__________________________

Outgoing Empty Vehicle Weight (EVW) in Pounds:______________________

CERTIFICATION

Uranium One Representative **Delivering Company Representative**

Name:_________________________ **Name:________________________**

Signature:______________________ **Signature:______________________**

Note: Copy to be provided to delivering company representative.

Form HP25-2

Yellowcake Container Sampling and Tracking

Container Number	Pass Inspection?	Tare Weight (lbs)	Filled Container Weight (lbs)	Scale ID Number	Scale Calibrated?

SAMPLE ID NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __

DATE:__________________

SAMPLE COLLECTED BY:________________________

SIGNATURE:_______________________

DATE RECEIVED IN AEL:___________________

Note 1: Sample ID shall include date in numeric form (010106) with no spaces, military time (1300, etc), and sequential sample number collected during day (ie., 01, 02, 03, etc.)

Note 2: Sample should include aliquot from each container as possible

Form HP25-3

Yellowcake Purchase Ticket

GENERAL PURCHASE AND ORDER INFORMATION

Purchasing Company:__________________ **Desired Pickup or Ship Date:_____________**

Company Contact:_____________________ **Telephone Number:_____________________**

Desired Quantity in Pounds:_____________ **Desired Container Type:_________________**

Requested Analytical Services and Reports:____

Special Packaging and Other Requests:____

Order Taken by:______________________ **Date:___________________________________**

AEL INVENTORY ASSIGNMENT

Allocated Container No(s):______________ **Allocated Container No(s):______________**

Total Weight in Pounds:________________ **Total Weight in Pounds:________________**

Yellowcake Sample ID No:______________ **Yellowcake Sample ID No:______________**

Allocated Container No(s):______________ **Allocated Container No(s):______________**

Total Weight in Pounds:________________ **Total Weight in Pounds:________________**

Yellowcake Sample ID No:_______________ **Yellowcake Sample ID No:_______________**

Total Weight All Allocated Containers in Pounds:____________________

Yellowcake ID No(s) Split for Outside Laboratory Analyses:____________

Analytical Laboratory Destination:_________________________________

Date and Time Sample Shipped:____________________________________

AEL Representative Name:____

Signature:____________________ **Date of Assignment:____________**

Form HP25-4

Tailings and Tailings Liquids Disposal Samples

Dewatered Tailings Sample

SAMPLE ID NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __

DATE: _________________TIME:________________

SAMPLE NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __ (PREVIOUS SAMPLE)

AVERAGE FLOW RATE _________________(FROM MILL OPERATOR)

SAMPLE LOCATION/DESCRIPTION____

SAMPLE COLLECTED BY:________________________

Tailings Liquid Sample

SAMPLE ID NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __

DATE: __________________TIME:________________

SAMPLE NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __ (PREVIOUS SAMPLE)

AVERAGE FLOW RATE _________________(FROM MILL OPERATOR)

SAMPLE LOCATION/DESCRIPTION____

SAMPLE COLLECTED BY:________________________

Other Sample (Describe:____)

SAMPLE ID NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __

DATE: __________________TIME:________________

SAMPLE NUMBER: __ __ __ __ __ __- __ __ __ __ - __ __ (PREVIOUS SAMPLE)

AVERAGE FLOW RATE _________________(FROM MILL OPERATOR)

SAMPLE LOCATION/DESCRIPTION____

SAMPLE COLLECTED BY:________________________

Comment____

____

ATTACHMENT C

SUPPORTING DOCUMENTATION FOR INTERROGATORY R313-24-1-14/03: MILLING OPERATIONS

2.0 PROCESS DESCRIPTION

2.1 Plant Description

The Shootaring Canyon Plant was constructed and then operated briefly in the spring and summer of 1982 before operations were suspended. It has never been restarted. The mill was not properly shut down and the countercurrent decantation (CCD) portion of the plant was dismantled, removed, and sold in 2002. Uranium One is evaluating the restart of the plant and therefore requires this feasibility study. It is desired by Uranium One to get this plant started as soon as possible, so the primary assumption is to employ the original design for the plant as the basis for the restart.

The plant was designed to process uranium ores. In the region, there can be significant vanadium in the ore, but the original designs did not include the concept of recovering vanadium. At this point in time, only the recovery of uranium is being considered until the plant gets into operation. Then, modifications to the plant to recover vanadium can be considered.

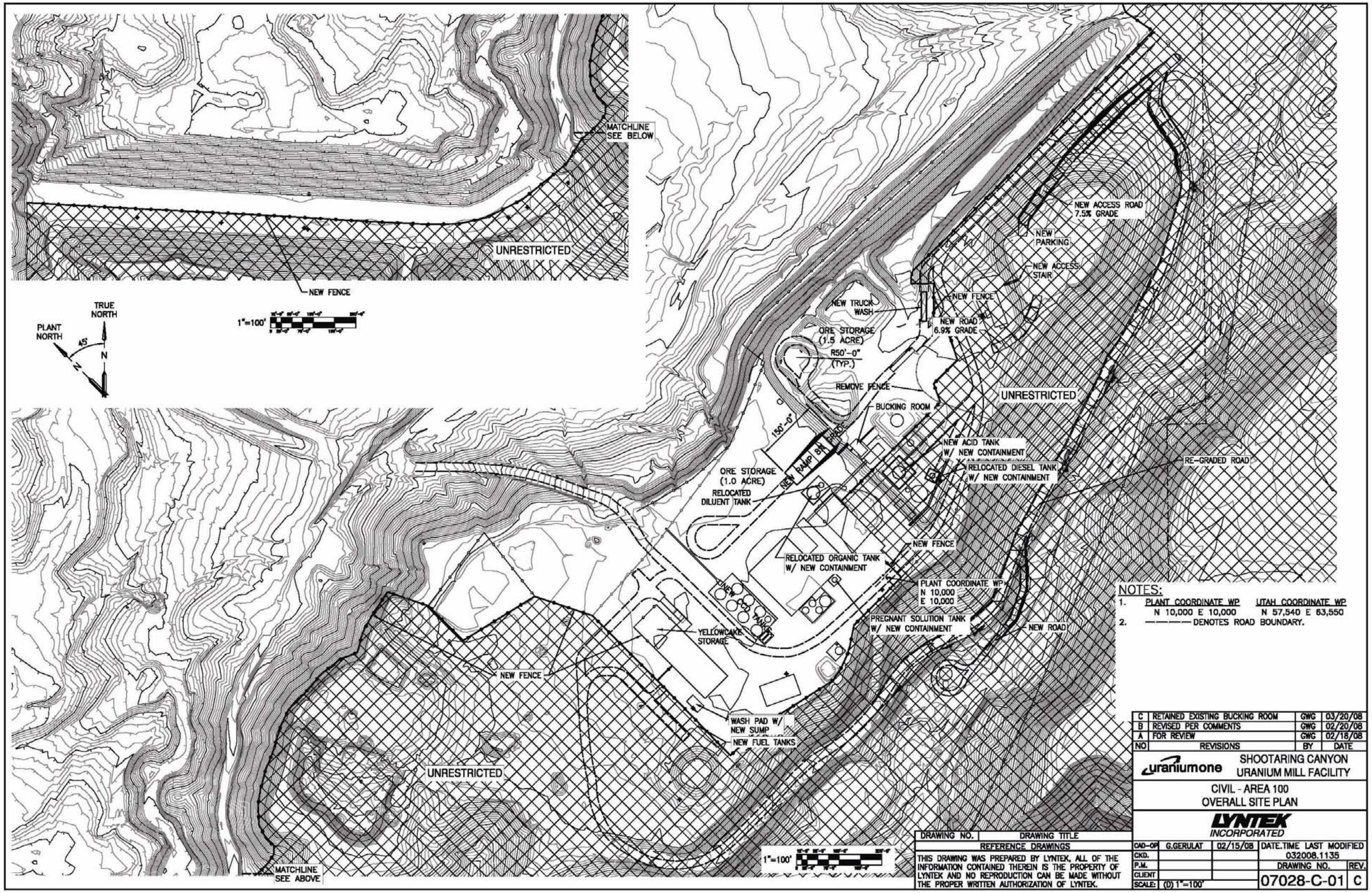
As refurbishment of the plant is considered, there are some areas wherein complete replacement of systems will be required. Of note is that the counter current decantation system has been removed and sold, so this circuit will have to be replaced. Other systems, for example, include the flocculation system, which requires replacement, updating of the control system, and attention to the feed water quality due to observed scaling in the feed piping systems.

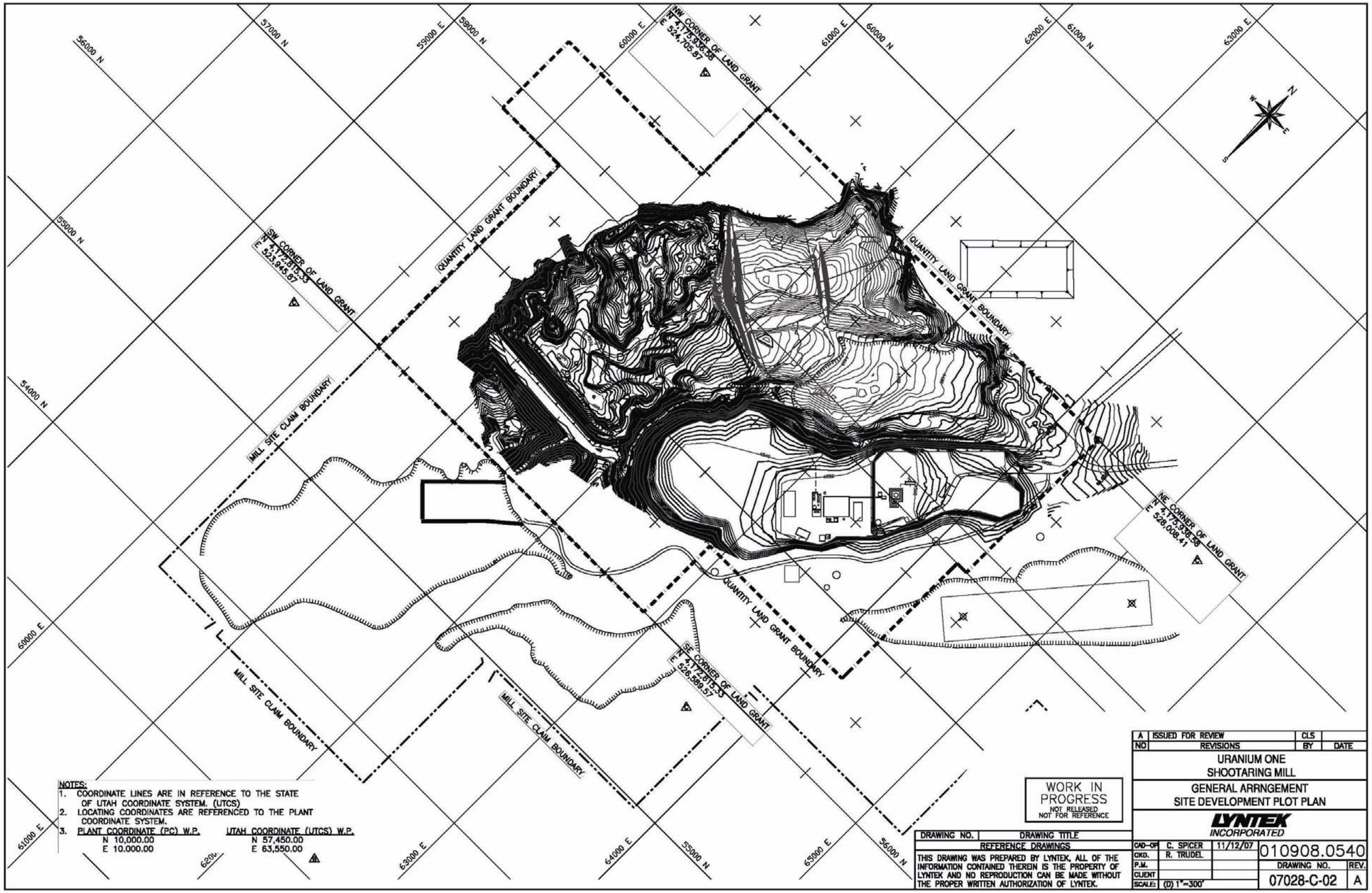
There are significant ore stockpiles yet remaining on the plant site. An internal Plateau Resources memorandum[1] indicates the mill has 94,191 tons averaging 0.132 percent uranium that can then be calculated to contain 248,664 pounds of U3O8.

JK Thamm internal correspondence to BO Fisher, November 24, 1986 and attachments

The plant is oriented along an axis striking northeast with a tailings facility located to the northwest. The topography and general site plot plan are shown in Figure 07028-C-01. The work in this study references the plant and the delivery system of the tailings stream to the tailings ponds as well as any other effluents to pond systems. The work relative to the tailings pond design is being performed by a separate Uranium One team. The costs included herein include the pumps and piping necessary for the transfer of these streams to and from the pond facilities. The batter limits for this work essentially include the primary access to the plant from the Tony M mine access road and the entire area shown in the plan view area of the plant area, excepting the pond facilities. A plan view of the ore pad, mill and processing facility is shown in Figure 07028-C-02.

Given the planned ore grades and mill production schedule, it is forecast that the mill will produce 1,053,000 lbs. of uranium per year. This is equivalent to about 3,000 lbs. per operating day, or 10.5 tons per week.


MATCHLINE SEE BELOW
UNRESTRICTED
NEW FENCE
TRUE NORTH
PLANT NORTH
45°
N
1"=100'
NEW ACCESS ROAD 7.5% GRADE
NEW PARKING
NEW ACCESS STAIR
NEW FENCE
NEW TRUCK WASH
NEW ROAD 6.9% GRADE
ORE STORAGE (1.5 ACRE)
R50'-0" (TYP.)
REMOVE FENCE
BUCKING ROOM
UNRESTRICTED
150'-0"
NEW RAMP 8% GRADE
NEW ACID TANK W/ NEW CONTAINMENT
RELOCATED DIESEL TANK W/ NEW CONTAINMENT
RE-GRADED ROAD
ORE STORAGE (1.0 ACRE)
RELOCATED DILUENT TANK
NEW FENCE
RELOCATED ORGANIC TANK W/ NEW CONTAINMENT
PLANT COORDINATE WP N 10,000 E 10,000
NEW TANKS
PREGNANT SOLUTION TANK W/ NEW CONTAINMENT
NEW ROAD
YELLOWCAKE STORAGE
NEW FENCE
WASH PAD W/ NEW SUMP
NEW FUEL TANKS
UNRESTRICTED
MATCHLINE SEE ABOVE
1"=100'
NOTES:
1. PLANT COORDINATE WP N 10,000 E 10,000 UTAH COORDINATE WP N 57,540 E 63,550
2. — — — — DENOTES ROAD BOUNDARY.
C RETAINED EXISTING BUCKING ROOM GWG 03/20/08
B REVISED PER COMMENTS GWG 02/20/08
A FOR REVIEW GWG 02/18/08
NO REVISIONS BY DATE
uraniumone
SHOOTARING CANYON URANIUM MILL FACILITY
CIVIL - AREA 100
OVERALL SITE PLAN
LYNTEK INCORPORATED
DRAWING NO. DRAWING TITLE
REFERENCE DRAWINGS
THIS DRAWING WAS PREPARED BY LYNTEK, ALL OF THE INFORMATION CONTAINED THEREIN IS THE PROPERTY OF LYNTEK AND NO REPRODUCTION CAN BE MADE WITHOUT THE PROPER WRITTEN AUTHORIZATION OF LYNTEK.
CAD-OP G.GERULAT 02/15/08
CKD.
P.M.
CLIENT
SCALE: (D) 1"=100'
DATE.TIME LAST MODIFIED 032008.1135
DRAWING NO. 07028-C-01
REV. C

56000 N
57000 N
58000 N
59000 E
60000 E
60000 N
61000 E
61000 N
62000 E
63000 E
55000 N
54000 N
60000 E
61000 E
6200
63000 E
64000 E
55000 N
65000 E
56000 N
N
E
S
W
NW CORNER OF LAND GRANT
N 4,175,936.58
E 524,705.87
SW CORNER OF LAND GRANT
N 4,172,815.33
E 523,945.87
NE CORNER OF LAND GRANT
N 4,175,936.58
E 528,008.41
SE CORNER OF LAND GRANT
N 4,172,815.33
E 526,589.57
QUANTITY LAND GRANT BOUNDARY
QUANTITY LAND GRANT BOUNDARY
QUANTITY LAND GRANT BOUNDARY
MILL SITE CLAIM BOUNDARY
MILL SITE CLAIM BOUNDARY
MILL SITE CLAIM BOUNDARY
NOTES:
1. COORDINATE LINES ARE IN REFERENCE TO THE STATE OF UTAH COORDINATE SYSTEM. (UTCS)
2. LOCATING COORDINATES ARE REFERENCED TO THE PLANT COORDINATE SYSTEM.
3. PLANT COORDINATE (PC) W.P. N 10,000.00 E 10.000.00
UTAH COORDINATE (UTCS) W.P. N 57,450.00 E 63,550.00
WORK IN PROGRESS
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THIS DRAWING WAS PREPARED BY LYNTEK, ALL OF THE INFORMATION CONTAINED THEREIN IS THE PROPERTY OF LYNTEK AND NO REPRODUCTION CAN BE MADE WITHOUT THE PROPER WRITTEN AUTHORIZATION OF LYNTEK.
A
ISSUED FOR REVIEW
CLS
NO
REVISIONS
BY
DATE
URANIUM ONE
SHOOTARING MILL
GENERAL ARRNGEMENT
SITE DEVELOPMENT PLOT PLAN
LYNTEK
INCORPORATED
CAD-OP
C. SPICER
11/12/07
CKD.
R. TRUDEL
P.M.
CLIENT
SCALE:
(D) 1"=300'
010908.0540
DRAWING NO.
REV.
07028-C-02
A

2.2 Process Design Criteria

The process design criteria are primarily based upon the original plant design. For the most part, because of the desire to place the plant into production as soon as possible, the design criteria mirror the original design criteria established for the plant. However, there are some significant differences to the original design. For example, because the CCD system has been removed, so updated designs can be employed. The most important change to the design criteria, however, results from the ore that is now conceived to be delivered to the plant.

It is now considered that ore will be delivered from the Frank M mine that is near the Shootaring Plant and the Velvet mine in Lisbon Valley near Monticello, Utah. The design criteria for the delivery of the ore assumes a 50 – 50 mix of ore with equal deliveries from each mine that will be mixed into an average and fed to the plant. The average uranium content of the Frank M ore is expected to be 0.12 percent with 0.33 percent U3O8 for the Velvet mine for an average of about 0.225 percent feed to the plant. Laboratory testing is currently being conducted on ore samples for each mine, but the current assumptions is that the acid requirement is 140 pounds of H_2SO_4 for one ton of mixed ore from the Frank M and Velvet mines. This is based upon the assumption 160 and 140lbs H_2SO_4 for the Frank and Velvet mines. Respectively, which is the best available estimate, contingent upon expectant metallurgical studies. Once the current testing has been completed and verified, this assumption must be revisited.

Table 2-1 provides the process design criteria.

Table 2-1 Design Criteria

JOB NO: 07028D SPEC. NO.: DC-07028D

FOR: DESIGN CRITERIA FOR SHOOTARING CANYON UPGRADE PROJECT

URANIUM ONE

TICABOO, UTAH

DESCRIPTION	NAME	DISCIPLINE	SIGNATURE	DATE:
PREPARED BY:		PROCESS ENGINEER.		
PRIME REVIEW		PROJECT MANAGER		
TECH. REVIEW		PROCESS ENGINEER		
TECH. REVIEW		PROCESS ENGINEER		
APPROVED. BY:		PROJECT MANAGER		
CLIENT				

REVISION DESCRIPTION	SECT. OR PAGES	REV NO.	REV. BY	APPROVALS			DATE
				Lyntek	Client	Check	

COMMENTS:

SOURCE CODE:

A = CRITERIA PROVIDED BY OWNER
B = PUBLISHED INFORMATION
C = ENGINEER RECOMMENDATION
D = VENDOR ORIGINATED CRITERIA
E = CRITERIA FROM PROCESS CALCULATIONS
F = ENGINEERING HANDBOOK DATA
G = ASSUMED DATA
H = MET LABORATORY TEST RESULT
J = ORIGINAL PROJECT DESIGN INFORMATION

ABBREVIATIONS AND NOMENCLATURE USED IN THIS DOCUMENT:

ft = Feet
ft^3/h = Cubic feet per hour
in = inches
g = Gram
g/l = Grams per liter
mg/l = Milligram per liter
lb = pounds
mph = miles per hour
t = Dry short tons
t/h = Dry short tons per hour
t/d = Dry short tons per day
t/y=Short tons per year
lb/d = Pounds per day
lb/ft^3 = Pounds per cubic foot
l = Liters
min = Minute
h = Hour
s=Second
y = Year
°F = Degree Fahrenheit
° = Angular degree

kW = Kilowatt
kWh = Kilowatt hour
kWh/t = Kilowatt hour per short ton
HP = Brake Horsepower
ppm = Parts per million
TBD = To Be Determined
P_{80} = 80% Passing
P_{100} = 100% Passing
S.G. = Specific Gravity
wt% = weight percent
Hg = mercury
S_s = mapped maximum considered earthquake, 5 percent damped, spectral response acceleration parameter at short periods
S_1 = mapped maximum considered earthquake, 5 percent damped, spectral response acceleration parameter at a period of 1 second

1.0 GENERAL

1.1 SITE LOCATION

The Shootaring Canyon Mill is located in Garfield County approximately 95 miles south-southwest of Green River Utah.

1.2 SITE CONDITIONS

	CRITERIA	SOURCE
Site Elevation		
Mean, ft	4550	B
Barometric Pressure		
Site Average, in Hg	25.3	B
Temperature		
Average Daily Maximum Temperature, °F	97	B
Average Daily Minimum Temperature, °F	-33	B
Design Frost Depth, in	30	B
Precipitation		
Average Yearly Precipitation, in	6	B
Maximum, 24 hr, in	1.8	B

1.3 STRUCTURAL DESIGN CRITERIA

	CRITERIA	SOURCE
International Building Code (IBC)		C
General Occupancy Category F-2 (Factory/Industrial Low Fire Hazard)		
Structural Occupancy Category II (Low Hazard)		
Type IIA Construction (Non-combustible)		
Mine Safety & Health Administration (MSHA) CFR 30		C
Seismic Information		
Seismic Design Category	C	B
Maximum Considered Earthquake (Ss)	35 % Gravity	B
Maximum Considered Earthquake (S1)	10% Gravity	B
Structural Design		
International Building Code (IBC)		C
Mine Safety & Health Administration (MSHA)		C

	CRITERIA	**SOURCE**
Wind Velocity		
Design Gust (3-second), mph	90	B
Mechanical Design		
International Mechanical Code (IMC) 2006 Edition		C
International Plumbing Code (IPC)		C
API 650 Welded Steel Tanks for Oil Storage		C
ASME B31.1-2006 Process Piping		C
ASME BPVC-VII-2007 Rules for Construction of Pressure Vessels		C
Electrical Design		
National Electric Code (NEC)		C
Low Voltage, V	460	C
Frequency, Hz	60	C

1.4 ORE CHARACTERISTICS

Type: Salt Wash Sandstone, Morrison formation		J
U_3O_8, wt% per dry ton	0.225	A
Average Percent Moisture, %	2.5	J
Specific Gravity (Dry Solids)	2.4	J

2.0 PLANT PRODUCTION

Average Daily Throughput, t/d	750	A
U_3O_8, Recovery (Nominal), %	90	A/J
U_3O_8 Production, lb/y	1,053,253	E
Plant Availability, %	95	J
Average Days Per Year Operation	350	A

3.0 PROCESS DESIGN

3.1 GRINDING

Type:	Semiautogenous (S.A.G.) closed circuit	J
Size:	12’ diameter X 6’-6” long	J
Days Operating per Week	7	A
Hours per Day	24	J
Availability, %	95	J
Grinding Mill Product, P_{100}, in	-5/8	J
Grinding Solid Fraction, wt.%	70	C
Grinding Slurry S.G.	1.79	E

3.2 CLOSED CIRCUIT CLASSIFICATION

	CRITERIA	SOURCE
Type:	DSM Screens	J
Recirculating Load, %	200	J
Product Undersize	28 mesh maximum	J

3.3 LEACH CIRCUIT

Number of Stages	2	J

3.3.1 First Stage

No. Agitated Leach Tanks	3	J
Tank Diameter, ft	14	J
Tank Height, ft	18	J
Effective Volume, gal	16,120	J
Residence Time, h	2	J
Slurry Solids, wt%	29	J
Agitation	mechanical –rubber covered agitators	J
H_2SO_4 Addition (Total) lbs/t of ore	70	J
Thickener Quantity	1	J
Thickener Diameter, ft	19.5	J
Thickener Height, ft	8.75	J
Solids Residence Time, min	55	J
Thickener Underflow Slurry Solids, wt%	50	J
Thickener Overflow Solids, ppm	200 maximum	J
Flocculant Addition, lbs/t of ore	0.06	J
Flocculant Strength, wt%	0.25	J

3.3.2 Second Stage

No. Agitated Leach Tanks	4	J
Tank Diameter, ft	20	J
Tank Height, ft	24	J
Effective Volume, gal	46,400	J
Residence Time, h	16	J
Slurry Solids, wt%	48.8	J
Agitation	mechanical –rubber covered agitators	J
H2SO4 Addition (Total) lbs/t of ore	70	J
Chlorate Addition, lbs/t of ore	1.707	J
Chlorate Strength, wt%	25	J
U3O8 Solubility, %	93	J

3.4 COUNTER CURRENT DECANTATION (CCD) CRITERIA

		SOURCE
Number of High Rate Thickener stages	5	D
Diameter, ft	26.25	D
Side Wall Height, ft	8	D
Number of High Density Thickener stages,	1	D
Diameter, ft	26.25	D
Side Wall Height, ft	28.2	D
Wash Ratio	2	J
Net Volume, ft3 (1st to 5th)	4,650	D
Net Volume, ft3 (6th)	15,550	D
Thickener Underflow Solid Fraction, wt.% (1st to 5th)	50	J,A
Thickener Underflow Solid Fraction, wt.% (6th)	up to 60	A
Thickener Underflow Slurry S.G. (1st to 5th)	1.41	E
Thickener Underflow Slurry S.G. (6th)	1.54	E
Inter-stage Mix Tank Residence Time, min	1.7	D
Flocculant Addition	TBD	D
Materials of Construction	2205 alloy	A

3.5 CLARIFICATION

3.5.1 Clarifier

Clarifier Diameter, ft	27	J
Clarifier Height, ft	18	J
Clarifier Capacity, gal	72,800	J
Retention Time, h	7	J
Clarifier Overflow Solids, ppm	<50	J
Underflow Rate, gpm	0.84	E
Overflow Rate, gpm	199	E

3.5.2 Sand Filters

Number	3	J
Type	Sand with automatic backwash	J
Hydraulic Capacity, gpm/ft2	5	J
Filtrate Solids, ppm	<10	J
Filtrate, U3O8	1.36	E
Filtrate Rate, gpm	199	E
Filter Area Required, ft2	38	E

3.6 SOLVENT EXTRACTION & STRIPPING CIRCUIT	CRITERIA	SOURCE
3.6.1 Extraction		
Aqueous Feed Rate, gpm	190	E
Organic Feed Rate, gpm	29	J
Mixer Organic to Aqueous Ratio (Organic recycle)	1.2/1	J
Number of Extraction Mixer/Settlers	4	J
Tanks (mixer volume), 4 each, fiberglass	980	J
Mixer Retention Time, min	2	E
Settler Area Required, gpm/ft2	1.25	J
Organic Composition		
Tertiary Amine, vol %	1 vol% per gpl U3O8 in Aq. Feed	B
Isodecanol, vol %	5	J
Diluent, vol %	Remainder	J
3.6.2 Strip		
Mixer Organic to Aqueous Ratio (Aqueous recycle)	4/1	J
Number of Extraction Mixer/Settlers	4	J
Tanks (mixer volume), 1 each, fiberglass	100	J
Mixer Retention Time, min	0.7	E
Settler Area Factor, gpm/ft2	1.25	J
Ammonia Consumption, lb/lb of U3O8	0.24	J
3.6.3 Scrub		
Organic to Aqueous Ratio (Aqueous recycle)	4	J
Settler Area Required, gpm/ft2	1.25	J
Number of Extraction Mixer/Settlers	1	J
Tanks (mixer volume), 1 each, fiberglass	100	J
3.6.4 Liquid Storage		
Pregnant Liquor Storage Capacity, two tanks, total gal	46,000	J
Recycle Raffinate Tank Capacity, gal	23,000	J
Barren Organic Tank Capacity, gal	4,100	J
Solvent Makeup Tanks Capacity, gal	380	J
Diluent Tank Capacity, gal	10,000	J
Pregnant Strip Solution Tank Capacity, gal	1,000	J
Barren Strip Solution Tank Capacity, gal	9,000	J

3.7 URANIUM PERCIPITATION

	CRITERIA	SOURCE
Precipitation Tank		
Number Required	3	J
Size (Based on 9 hour Retention Time), gal	470	J
Ammonia Consumption, lb/lb of U3O8	0.18	J
Precipitate Thickener		
Number Required	1	J
Size diameter/height, ft	12/4	J

3.8 URANIUM DEWATERING AND DRYING

Vacuum Drum Filters		
Number Required	2	J
Size diameter/length, ft	3/3	J
Other	each has a repulper	J
Moyno Pump Capacity, gpm	0.5 to 2.0	J
Multi-hearth Calciner		
Size diameter, ft	5	J
Number of stages	6	J
Maximum Operating Temperature, °F	1600	J
Wet Scrubber, each	1	J

3.9 URANIUM PACKAGING

Capacity, lbs of U3O8/h	232	J
Pulverizer Capacity, lbs of U3O8/h	270	J
Barrel Vibrator, each	1	J
Roller Conveyor, each	1	J
Weight Batch Scale, each	1	J
Packaged Uranium in 55 gal. Drums, no./day	3 to 4	E
U3O8 per drum, lb	800	C

2.3 Process Assumptions

The plant is designed with a set of primary process assumptions that guide the overall process design criteria and concept for the plant. The primary process assumptions are summarized below.

Principal Process Assumptions:

- Plant design conforms to the original plant design to allow immediate production

- The consideration for the addition of a vanadium circuit will be later

- The ore delivered to the mill will be sourced from the Frank M and the Velvet mines

- The ore delivery to the mill will be assumed to be identical to the original mill assumptions with the exception that the design ore grade will be 0.225 percent U3O8

- The CCD circuit will be generally designed per the original specifications

The design of the plant has been evaluated based upon a mass balance, which includes the assumptions defined above. The mass balance is shown in Table 2-2.

Table 2-2
Uranium One
Shootaring Canyon Mill Restart
Base Mass Balance (1)

	Stream No.	1	1A	1C	2	2A	2B	3	4	5	6		7	14	16	25	10	12	17	27	18	19	21
		Plant Feed	**Mill Feed**	**Water To Mill**	**Mill Discharge**	**O'Size Recycle to Mill**	**Pulp to Leach Feed Tanks**	**CCD O'Flow**	**CCD O'Flow to Leach Feed Surge Tanks**	**CCD O'Flow to Pre-Leach**	**SAG Mill Discharge to Pre-Leach**	**Total Feed to Pre-Leach**	**93% Sulfuric Acid to Pre-Leach**	**Sand Filter Backwash**	**Pre-Leach Thickener Underflow to Leach**	**Pre-Leach Thickener Overflow to Clarifier**	**Flocculant to Thickener**	**Flocculant to Clarifier**	**Clarifier U'Flow to Leach**	**Clarifier O'Flow to Sand Filters**	**93% Sulfuric Acid to Leach**	**Sodium Chlorate to Leach**	**Leach Discharge**
Gas or Vapor	lbs/hr																						
	S.G.																						
	SCFM																						
Solids	TPH	31.3	31.3		62.5	31.3	31.3				31.3	31.3		0.0	31.3	0.011	0.001	0.0002	0.011	0.2			31.3
	S.G.		2.4		2.4	2.4	2.4				2.4	2.4			2.4	2.4			2.4	2.4			2.4
	U_3O_8 lbs/hr		140.6		281.3	140.6	140.6				140.6	140.6			70.3					1.1			9.8
Liquid	TPH		1.30	12.1	26.8	13.4	13.4	66.8	17.9	49.0	31.3	80.2	1.18	0.09	31.3	50.2	0.37	0.06	0.21	49.4	1.18	0.11	32.7
	S.G.		1.0	1.0	1.0	1.00	1.00	1.06	1.06	1.06	1.00	1.06	1.82	1.07	1.00	1.05	1.00	1.00	1.07	1.05	1.82	1.07	1.0
	GPM		5.2	48.4	107.3	53.7	53.7	252.6	67.5	185.1	125.2	310.3	2.6	0.3	125.2	191.7	1.50	0.25	0.77	188.42	2.6	0.40	129.1
	U_3O_8 lbs/hr														70.3					128.5			130.8
Pulp	TPH		32.6	12.1	89.3	44.6	44.6	66.8	17.9	49.0	62.5	111.5	1.18	0.1	62.5	50.2	0.38	0.06	0.22	49.6	1.2	0.11	64.0
	S.G.		2.4	1	1.69	1.69	1.69	1.06	1.06	1.06	1.41	1.20	1.82	1.01	1.41	1.05		1.00	1.03	1.00	1.8	1.07	1.40
	GPM		54.3	48.4	211.6	105.8	105.8	252.62	67.5	185.1	177.4	373.6	2.6		177.4	191.7		0.25	0.85	198.3	2.6	0.40	183.4
	% Solids (ppm)		96.0%		70.0%	70.0%	70.0%				50.0%	28.0%		2.0%	50.0%	(200)			5.0%	0.5%			48.8%
	Temp, °F		50	50	125	110	110			157	125		80	153		137				153	80	80	176
	U_3O_8 lbs/hr		140.6		281.3	140.6	140.6				140.6	140.6			140.6								140.6

		22	23	41	30	48	3	55	42
		#2CCD Overflow	**CCD Feed**	**CCD Wash Feed**	**Total Flocculant to CCD**	**Tailings**	**CCD O'Flow**	**Raffinate from SX**	**Hot Make-Up Water**
Gas or Vapor	lbs/hr								
	S.G.								
	SCFM								
Solids	TPH	0.01	31.3			31.3			
	S.G.		2.4			2.4			
	U_3O_8 lbs/hr		9.8			9.84			
Liquid	TPH	65.5	98.3	65.5	0.644	32.3	66.8	49.4	16.2
	S.G.	1.05	1.0	1.04	1.0	1.0	1.06	1.05	1.00
	GPM	250.1	387.6	252.2	3.4	127.3	252.6	188.4	65.0
	U_3O_8 lbs/hr	0.580	130.8			2.6	128.5	0.3	
Pulp	TPH	65.5	129.5	65.5	337.8	63.6	66.8	49.4	16.2
	S.G.	1.05	1.2	1.04	1.0	1.40	1.06	1.05	1.00
	GPM	250.1	433.4	252.2	1353.2	181.6	252.6	188.4	65.0
	% Solids (ppm)		24.1%		0.25%	49.2%			
	Temp, °F		176	121	80		165	146	72
	U_3O_8 lbs/hr		140.6			12.39			

	Stream No.	27	15	60	55	64	77		82	83	84	72	87
		Sand Filter Feed	**Clarified SX Feed Solution**	**Barren Organic Feed to Uranium SX**	**Raffinate**	**Loaded Organic to Strip**	**Barren Strip Solution from Yellowcake Thickener**	**Total Ammonia to Strip**	**Pregnant Strip Solution to Precipitation Circuit**	**Air to Precipita tion**	**Ammonia to Precipitation**	**SX Scrub Bleed**	**Yellowcake Slurry**
Gas or Vapor	lbs/hr							30.8			23.1		
	S.G.												
	SCFM												
Solids	TPH	0.2											
	S.G.	2.4											
	U_3O_8 lbs/hr	1.1											128.2
Liquid	TPH	49.4	49.4	6.2	49.4		0.7		0.7			0.5	2.07
	S.G.	1.05	1.05	0.86	1.1		1.1		1.11			1.1	1.05
	GPM	188.4	188.4	29.0	188.4		2.7		2.7			1.7	7.9
	U_3O_8 lbs/hr	128.5	128.5		0.3	128.2			128.2				
Pulp	TPH	49.6	49.4	6.2	49.4		0.7		0.7			0.5	2.14
	S.G.	1.003	1.1	0.86	1.1		1.11		1.11			1.07	1.11
	GPM	198.3	188.4	29.0	188.4		2.7		2.7			1.75	
	% Solids (ppm)	0.5%	-										3.0%
	Temp, °F	153	155	125	146	152	100		100				
	U_3O_8 lbs/hr	129.6	128.5		0.3	128.2			128.2				128.2
	U_3O_8 gpl					8.8			94.9				

	Stream No.	91	10	106	101
		Yellowcake Thickener Underflow	**Flocculant to Yellowcake Thickener**	**Yellowcake Product**	**Water to Wet scrubber**
Gas or Vapor	lbs/hr				
	S.G.				
	SCFM				
Solids	TPH	0.06		0.06	
	S.G.			3.2	
	U_3O_8 lbs/hr	128.2		128.2	
Liquid	TPH	0.19	0.38		0.3
	S.G.	1.11	1.00		1.00
	GPM	0.65	1.50		1.13
	U_3O_8 lbs/hr				
Pulp	TPH	0.26	0.38	0.0	0.2
	S.G.	1.21	1	0.0	0.86
	GPM	0.85	1.50	0.0	1.0
	% Solids (ppm)	25.0%		-	
	Temp, °F	115		1250	125
	U_3O_8 lbs/hr	128.2		128.2	

Means input from the material balance by Mountain States Engineering ,1978, other inputs come from the design criteria sheet

Total Fresh Water Make Up, gpm	126.1	with 100% SX raffinate recycle
	163.8	with 80% SX raffinate recycle
	220.3	with 50% SX raffinate recycle
	314.5	with no SX raffinate recycle

2.5 Alternative Processes Considered

Within the scope of this work, the primary effort is to get the existing uranium mill up and operating as soon as possible. Uranium markets are now generating potential for profit that over ride most primary considerations such that it is paramount to get the mill producing as soon as possible. The CCD circuit has been designed with the following changes: No other alternative processes have been considered and the employment of a vanadium circuit will also be pushed into the future for consideration once the mill is up and operating, so there is opportunity for upside revenue potential. A feasibility study will be necessary, as current indications suggest the revenue earned may not be worth the capital expense.

2.6 Process Description

Process Overview

This section presents a description of the Shootaring Canyon uranium recovery process.

The Shootaring Canyon processing facility is expected to have an overall uranium recovery rate of 91.0 percent from an ore containing 0.12 percent uranium oxide (U_3O_8). Based on this anticipated recovery and an average processing rate of 750 tons per day (t/d) of ore, the facility will produce about 1,639 pounds per day (1b/d) of U_3O_8.

The ore processing consists of a single stage grinding circuit followed by sulfuric acid leach and counter current decantation (CCD) systems. The washed solids from the CCD are pumped to a tailings pond while the leachate is sent to a solvent extraction (SX) circuit where the uranium is recovered from the leachate. The uranium is precipitated from the SX strip solution with ammonia and recovered as dry Yellowcake. A detailed process description is provided below.

Stockpile Operations

It is assumed that the ore will be, delivered by 25-ton trucks from the Tony M mine and with 25-ton trucks with 12-ton pups from the Velvet mine. The mix ratio between the two mines is expected to be equal at 50 percent each. The ore will be weighed at the weigh station and proper delivery tickets and references obtained and recorded. The ore will then be dumped according to the ore storage plan. This plan will recognize the blending scheme for the two mines that is necessary due to the differences between the two ore characteristics. It is not conceived that there will be any direct dumping into the crushing circuit. All ore will be stockpiled prior to size reduction.

Ore Sampling

Plant samples to be collected for analysis will include 3 samples per day for the leach slurry (one/shift), 3 per day for the tailings slurry (one/shift), 3 samples from the feed belt (one/shift), at least one scheduled weekly CCD profile sample of each of the 6 CCD thickeners, special mill grab samples, and random environmental soil samples.

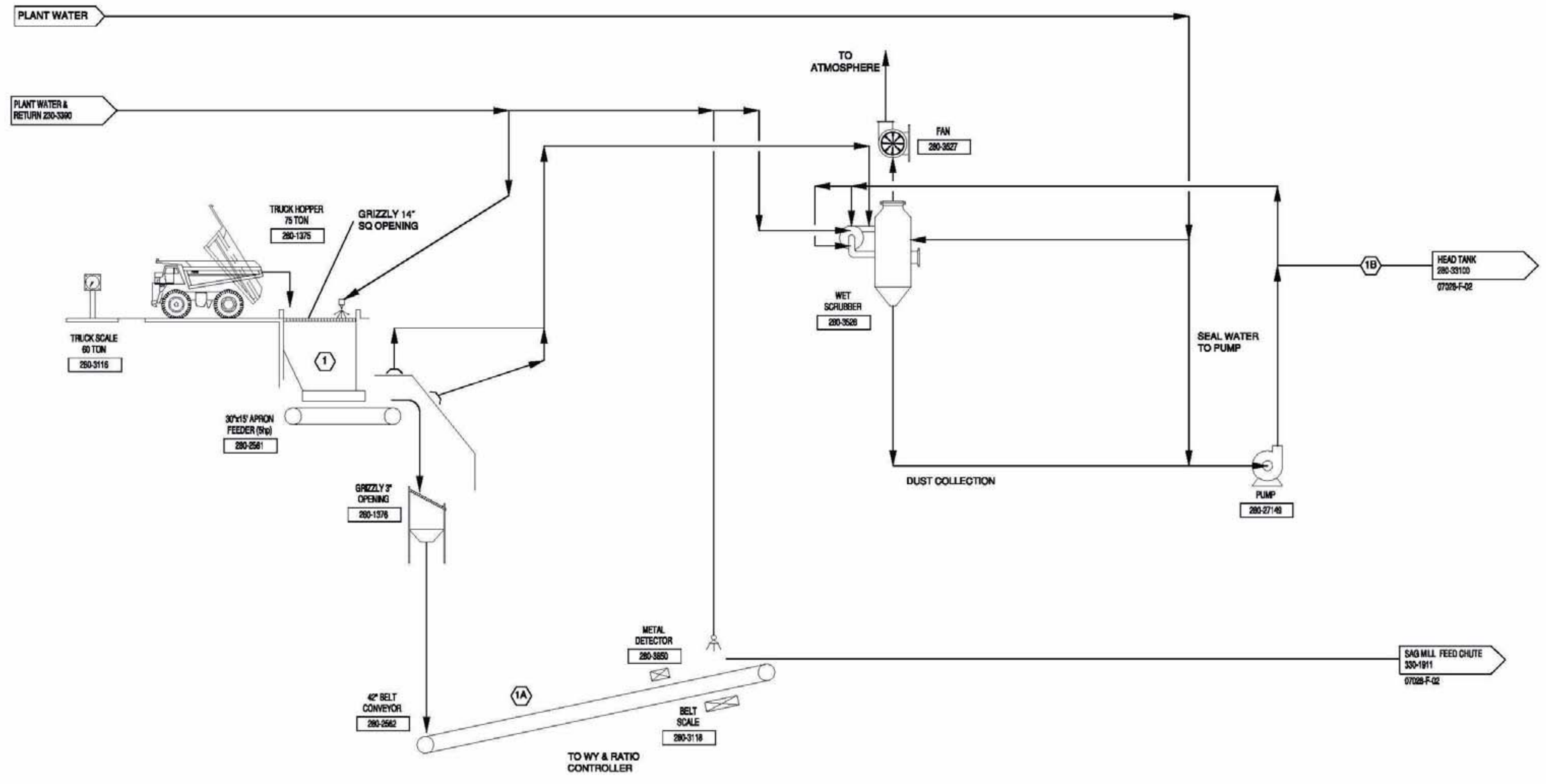
Grinding

The ore to be processed is a sandstone type that has the uranium compounds present as a coating on the sand grains and as filler in the intergranular spaces. Prior to leaching, the ore is ground to release the sand-sized particles so that the acid may intimately contact the uranium granular surfaces.

Referring to drawing 07028-F-01, the grinding process begins with loading of the ore through a stationary grizzly with 14-inch openings and into a 75-ton capacity hopper; occasional oversize pieces are broken in place. The hopper discharges the ore via a variable speed apron feeder onto a second stationary grizzly with 3-inch openings. The ore material passing through the grizzly discharges directly onto a 42-inch (in) wide, 316 feet (ft) long conveyor belt. The grizzly has a steep-sloping surface, and the oversize material rolls down onto the bedding surface formed by the undersize material already on the belt conveyor. The belt conveyor is equipped with a belt scale and associated electronics to measure the ore feed rate to the Semiautogenous Grinding (SAG) mill. Other equipment shown on the drawing includes a dust control system consisting of water spray nozzles to minimize dust generation and a dust capture hood/wet scrubber system.

Drawing 07028-F-02 shows the SAG mill. The mill slowly rotates while water is added to produce a slurry containing approximately 70 weight percent (wt %) solids. As the mill rotates, the impact of steel balls and larger ore pieces grind the smaller ore portions into sand-sized particles. The SAG mill is 12 ft diameter by 6 ft – 6 in long. It has a 250 horsepower (hp) drive with a speed reducer and drive mechanism. The design ore throughput is 750 t/d.

The slurry from the SAG mill is pumped to one of four DSM screens to remove oversize particles. The over sized particles from the screen gravity flows back to the SAG mill. The material passing through the screen gravity flows into a sump and is pumped to agitated wood stave leach feed surge tanks. Each tank has a 60,000-gallon capacity with an integral stave water system. Each tank agitator has two propellers with 50 hp gear reduced drives. The ball charge is expected to be 6 percent in the SAG Mill. Ball consumption is estimated at ¼ lb per ton of ore.



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SHOOTARING CANYON
URANIUM MILL FACILITY

PFD - AREA 280
CRUSHING SYSTEM

LYNTEK
INCORPORATED

DRAWING NO.	DRAWING TITLE

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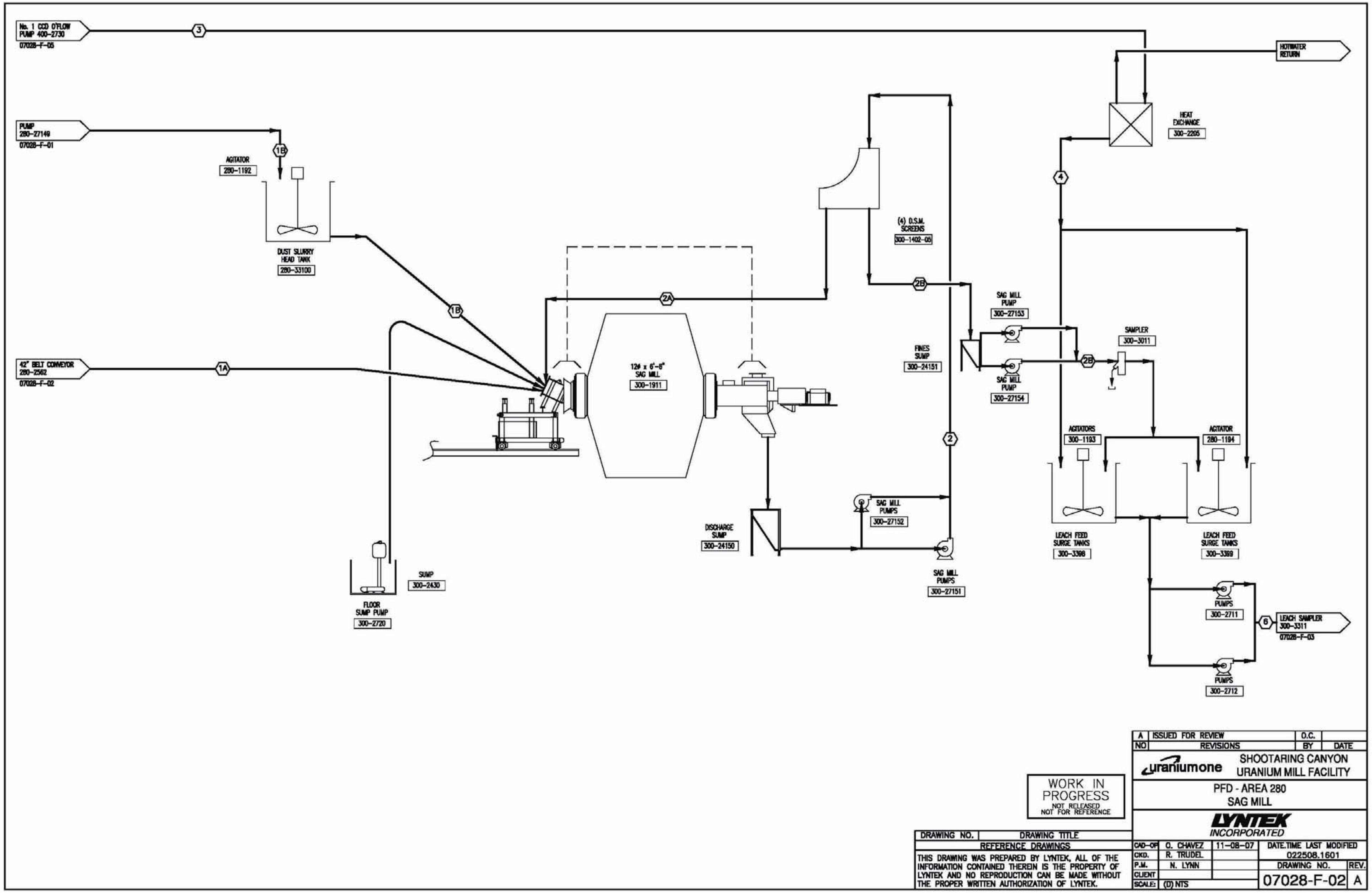
P.M.	N. LYNN		DRAWING NO. 07028-F-01
CLIENT			REV. A
SCALE:	(D) NTS		


No. 1 CCD O'FLOW PUMP 400-2730
07028-F-05
3
PUMP 280-27149
07028-F-01
1B
AGITATOR
280-1192
DUST SLURRY HEAD TANK
280-33100
1B
42" BELT CONVEYOR 280-2562
07028-F-02
1A
2A
12# x 6'-6"
SAG MILL
300-1911
FLOOR SUMP PUMP
300-2720
SUMP
300-2430
DISCHARGE SUMP
300-24150
SAG MILL PUMPS
300-27152
SAG MILL PUMPS
300-27151
2
(4) D.S.M. SCREENS
300-1402-05
2B
FINES SUMP
300-24151
SAG MILL PUMP
300-27153
SAG MILL PUMP
300-27154
2B
SAMPLER
300-3011
HOTWATER RETURN
HEAT EXCHANGE
300-2205
4
AGITATORS
300-1193
AGITATOR
280-1194
LEACH FEED SURGE TANKS
300-3398
LEACH FEED SURGE TANKS
300-3399
PUMPS
300-2711
PUMPS
300-2712
6
LEACH SAMPLER 300-3311
07028-F-03
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SHOOTARING CANYON
URANIUM MILL FACILITY
PFD - AREA 280
SAG MILL
LYNTEK
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07028-F-02
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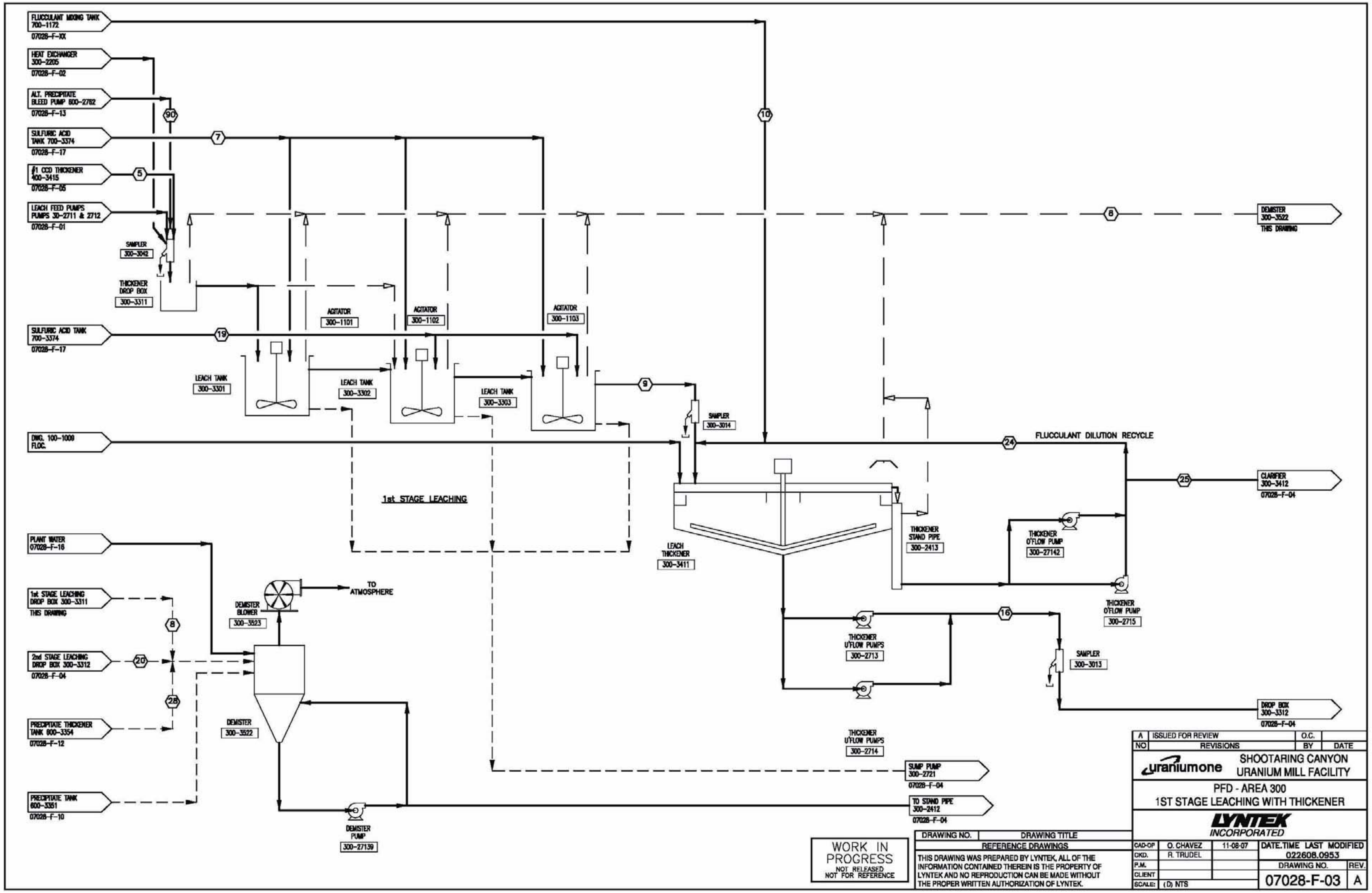
Leaching

Referring to drawings 07028-F-03 and 07028-F-04, the leaching circuit includes a two-stage leaching circuit with a primary decant thickener and clarifier located in between the leaching stages. The first stage, called primary leach, includes three agitated leach tanks connected in series followed by a thickener. The ore slurry from the leach feed surge tanks is pumped to the first stage leach tanks where it is mixed with the overflow from counter current decantation (CCD) thickener #1 and sulfuric acid/sodium chlorate to maintain required pH and EMF. The slurry flows out of the third leach tank into the primary leach thickener. The solids from the thickener are pumped to the second stage leach consisting of four additional agitated tanks where more sulfuric acid and sodium chlorate are added to complete the leach process. The overflow from the thickener is sent to a clarifier designed to remove suspended solids. The clarifier overflow containing the dissolved uranium is pumped through sand filters to remove any remaining solids and onto the SX circuit feed tank. The slurry solids, exiting the last leach tank, are diluted with overflow liquid from the 2nd thickener in the CCD circuit and pump fed to the first CCD thickener.

Countercurrent Decantation (CCD)

The CCD system is designed to wash the residual solids that exit the leach system. The wash is necessary to remove dissolved uranium that is entrained in the solids before the solids are discarded to the tailing pond. Referring to drawings 07028-F-05, 07028-F-0 6, and 07028-F-07 countercurrent washing of the leached pulp is carried out in six thickeners. The first five thickeners are high rate thickeners and the sixth thickener is a high density thickener.

Each thickener is equipped with a thickener rake, an overflow pump and an underflow pump since the thickeners are arranged at the same elevation so that both the underflows and the overflows require pumping. The leachate and solids are pumped from the 2nd stage leach system to the first CCD thickener. The solids settle to the bottom of the thickener and are pumped to the second CCD thickener while the relatively solid-free liquid overflows from the first CCD thickener and is pumped to the first stage leach circuit.


FLUCCULANT MIXING TANK 700-1172 07028-F-XX
HEAT EXCHANGER 300-2205 07028-F-02
ALT. PRECIPITATE BLEED PUMP 600-2782 07028-F-13
SULFURIC ACID TANK 700-3374 07028-F-17
#1 CCD THICKENER 400-3415 07028-F-05
LEACH FEED PUMPS PUMPS 30-2711 & 2712 07028-F-01
90
7
5
10
8
SAMPLER 300-3042
THICKENER DROP BOX 300-3311
AGITATOR 300-1101
AGITATOR 300-1102
AGITATOR 300-1103
SULFURIC ACID TANK 700-3374 07028-F-17
19
LEACH TANK 300-3301
LEACH TANK 300-3302
LEACH TANK 300-3303
9
SAMPLER 300-3014
DEMISTER 300-3522 THIS DRAWING
DWG. 100-1009 FLOC.
24
FLUCCULANT DILUTION RECYCLE
25
CLARIFIER 300-3412 07028-F-04
1st STAGE LEACHING
LEACH THICKENER 300-3411
THICKENER STAND PIPE 300-2413
THICKENER O'FLOW PUMP 300-27142
THICKENER O'FLOW PUMP 300-2715
PLANT WATER 07028-F-16
TO ATMOSPHERE
DEMISTER BLOWER 300-3523
1st STAGE LEACHING DROP BOX 300-3311 THIS DRAWING
8
2nd STAGE LEACHING DROP BOX 300-3312 07028-F-04
20
28
PRECIPITATE THICKENER TANK 600-3354 07028-F-12
DEMISTER 300-3522
PRECIPITATE TANK 600-3351 07028-F-10
DEMISTER PUMP 300-27139
16
THICKENER U'FLOW PUMPS 300-2713
SAMPLER 300-3013
DROP BOX 300-3312 07028-F-04
THICKENER U'FLOW PUMPS 300-2714
SUMP PUMP 300-2721 07028-F-04
TO STAND PIPE 300-2412 07028-F-04
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SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 300
1ST STAGE LEACHING WITH THICKENER
LYNTEK INCORPORATED
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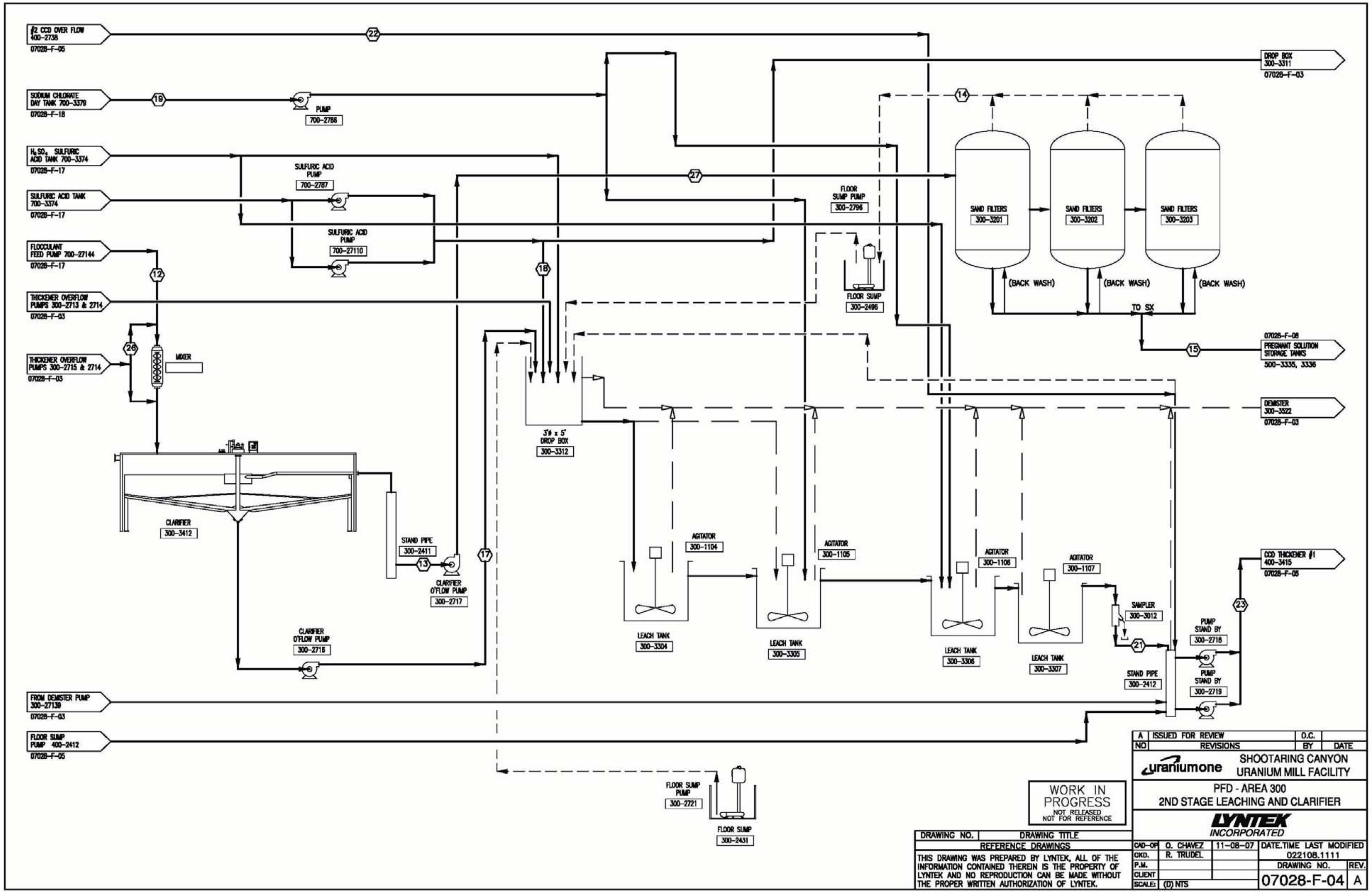
#2 CCD OVER FLOW
400-2738
07028-F-05
22
SODIUM CHLORATE
DAY TANK 700-3379
07028-F-18
19
PUMP
700-2786
H2SO4 SULFURIC
ACID TANK 700-3374
07028-F-17
SULFURIC ACID
PUMP
700-2787
SULFURIC ACID TANK
700-3374
07028-F-17
SULFURIC ACID
PUMP
700-27110
FLOCCULANT
FEED PUMP 700-27144
07028-F-17
12
THICKENER OVERFLOW
PUMPS 300-2713 & 2714
07028-F-03
26
MIXER
THICKENER OVERFLOW
PUMPS 300-2715 & 2714
07028-F-03
27
18
FLOOR
SUMP PUMP
300-2796
FLOOR SUMP
300-2496
14
SAND FILTERS
300-3201
SAND FILTERS
300-3202
SAND FILTERS
300-3203
(BACK WASH)
(BACK WASH)
(BACK WASH)
TO SX
DROP BOX
300-3311
07028-F-03
07028-F-08
PREGNANT SOLUTION
STORAGE TANKS
500-3335, 3336
15
DEMISTER
300-3522
07028-F-03
3'ø x 5'
DROP BOX
300-3312
CLARIFIER
300-3412
STAND PIPE
300-2411
13
CLARIFIER
O'FLOW PUMP
300-2717
17
CLARIFIER
O'FLOW PUMP
300-2716
AGITATOR
300-1104
LEACH TANK
300-3304
AGITATOR
300-1105
LEACH TANK
300-3305
AGITATOR
300-1106
LEACH TANK
300-3306
AGITATOR
300-1107
LEACH TANK
300-3307
SAMPLER
300-3012
21
STAND PIPE
300-2412
PUMP
STAND BY
300-2718
PUMP
STAND BY
300-2719
23
CCD THICKENER #1
400-3415
07028-F-05
FROM DEMISTER PUMP
300-27139
07028-F-03
FLOOR SUMP
PUMP 400-2412
07028-F-05
FLOOR SUMP
PUMP
300-2721
FLOOR SUMP
300-2431
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URANIUM MILL FACILITY
PFD - AREA 300
2ND STAGE LEACHING AND CLARIFIER
LYNTEK
INCORPORATED
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07028-F-04
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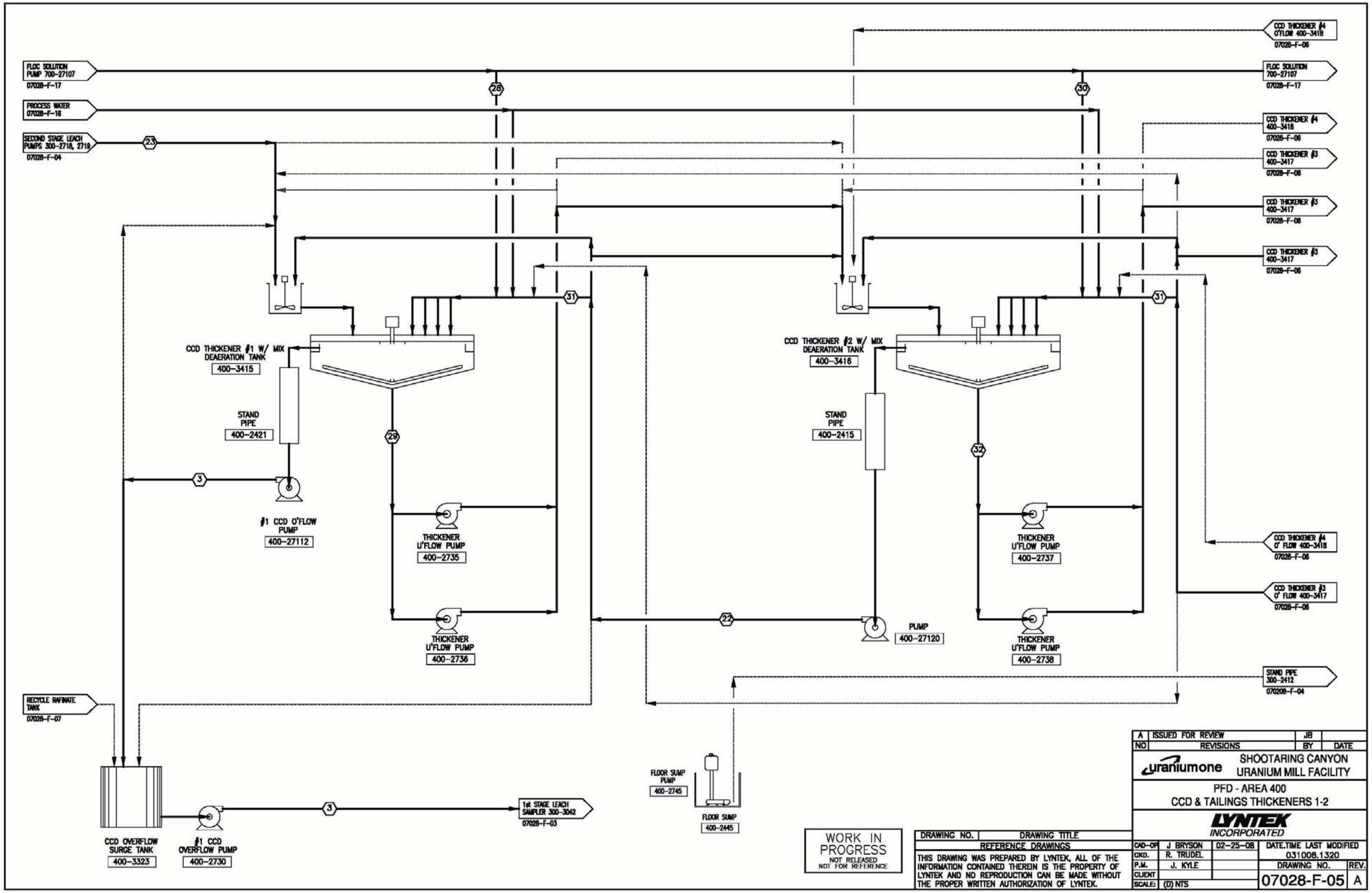
FLOC SOLUTION PUMP 700-27107
07028-F-17
PROCESS WATER 07028-F-16
SECOND STAGE LEACH PUMPS 300-2718, 2719
07028-F-04
23
28
30
31
CCD THICKENER #4 O'FLOW 400-3418
07028-F-06
FLOC SOLUTION 700-27107
07028-F-17
CCD THICKENER #4 400-3418
07028-F-06
CCD THICKENER #3 400-3417
07028-F-06
CCD THICKENER #3 400-3417
07028-F-06
CCD THICKENER #3 400-3417
07028-F-06
CCD THICKENER #1 W/ MIX DEAERATION TANK
400-3415
CCD THICKENER #2 W/ MIX DEAERATION TANK
400-3416
STAND PIPE
400-2421
STAND PIPE
400-2415
29
32
3
#1 CCD O'FLOW PUMP
400-27112
THICKENER U'FLOW PUMP
400-2735
THICKENER U'FLOW PUMP
400-2736
THICKENER U'FLOW PUMP
400-2737
THICKENER U'FLOW PUMP
400-2738
22
PUMP
400-27120
CCD THICKENER #4 O' FLOW 400-3418
07028-F-06
CCD THICKENER #3 O' FLOW 400-3417
07028-F-06
STAND PIPE 300-2412
070208-F-04
RECYCLE RAFINATE TANK
07028-F-07
FLOOR SUMP PUMP
400-2745
FLOOR SUMP
400-2445
CCD OVERFLOW SURGE TANK
400-3323
#1 CCD OVERFLOW PUMP
400-2730
3
1st STAGE LEACH SAMPLER 300-3042
07028-F-03
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SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 400
CCD & TAILINGS THICKENERS 1-2
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J BRYSON
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REV.
07028-F-05
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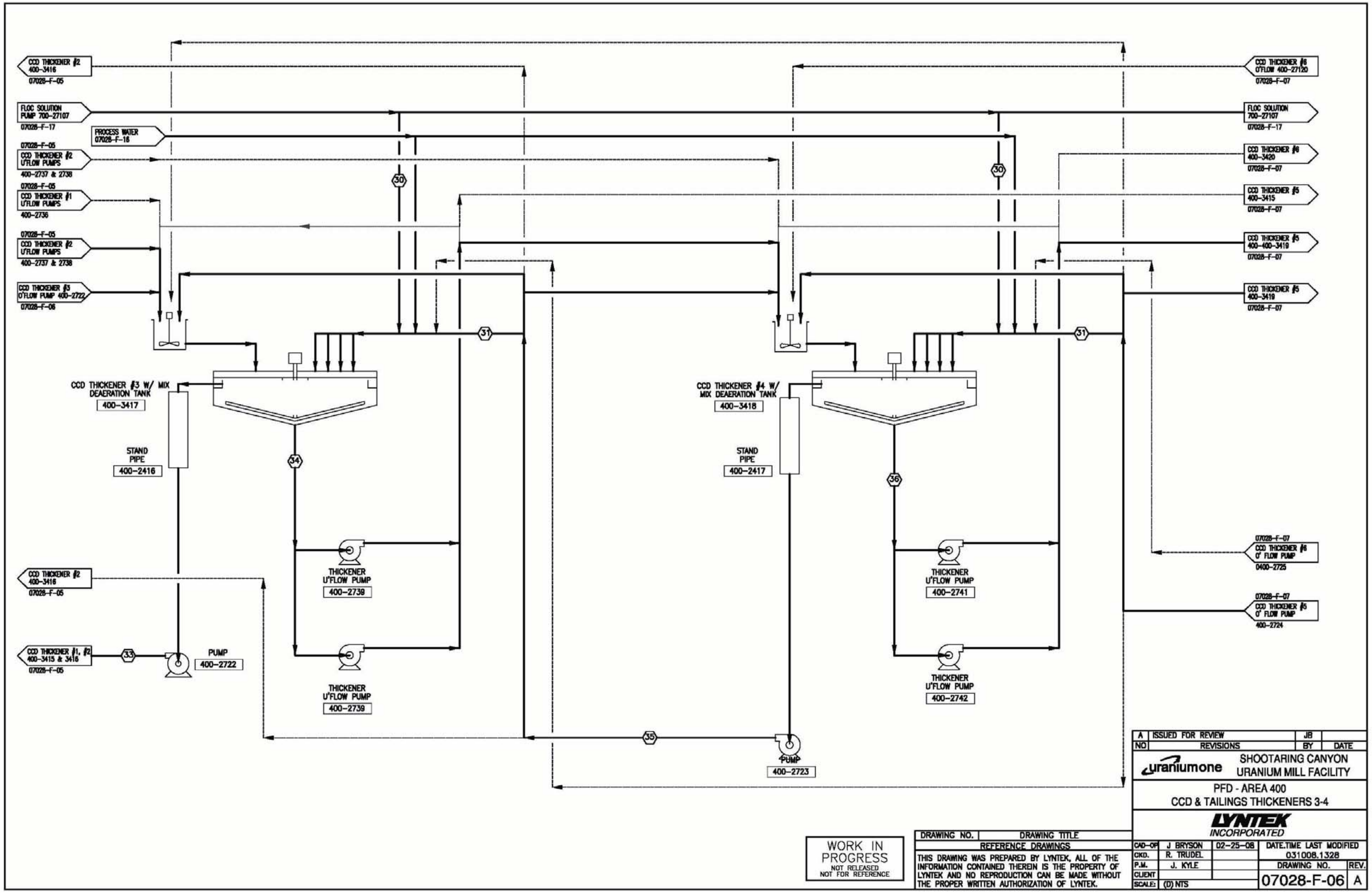
CCD THICKENER #2 400-3416 07028-F-05
FLOC SOLUTION PUMP 700-27107 07028-F-17
PROCESS WATER 07028-F-16
07028-F-05 CCD THICKENER #2 U'FLOW PUMPS 400-2737 & 2738
07028-F-05 CCD THICKENER #1 U'FLOW PUMPS 400-2736
07028-F-05 CCD THICKENER #2 U'FLOW PUMPS 400-2737 & 2738
CCD THICKENER #3 O'FLOW PUMP 400-2722 07028-F-06
CCD THICKENER #6 O'FLOW 400-27120 07028-F-07
FLOC SOLUTION 700-27107 07028-F-17
CCD THICKENER #6 400-3420 07028-F-07
CCD THICKENER #5 400-3415 07028-F-07
CCD THICKENER #5 400-400-3419 07028-F-07
CCD THICKENER #5 400-3419 07028-F-07
30
30
31
31
CCD THICKENER #3 W/ MIX DEAERATION TANK
400-3417
CCD THICKENER #4 W/ MIX DEAERATION TANK
400-3418
STAND PIPE
400-2416
STAND PIPE
400-2417
34
36
THICKENER U'FLOW PUMP
400-2739
THICKENER U'FLOW PUMP
400-2741
07028-F-07 CCD THICKENER #6 O' FLOW PUMP 0400-2725
07028-F-07 CCD THICKENER #5 O' FLOW PUMP 400-2724
CCD THICKENER #2 400-3416 07028-F-05
CCD THICKENER #1, #2 400-3415 & 3416 07028-F-05
33
PUMP
400-2722
THICKENER U'FLOW PUMP
400-2739
THICKENER U'FLOW PUMP
400-2742
35
PUMP
400-2723
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SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 400
CCD & TAILINGS THICKENERS 3-4
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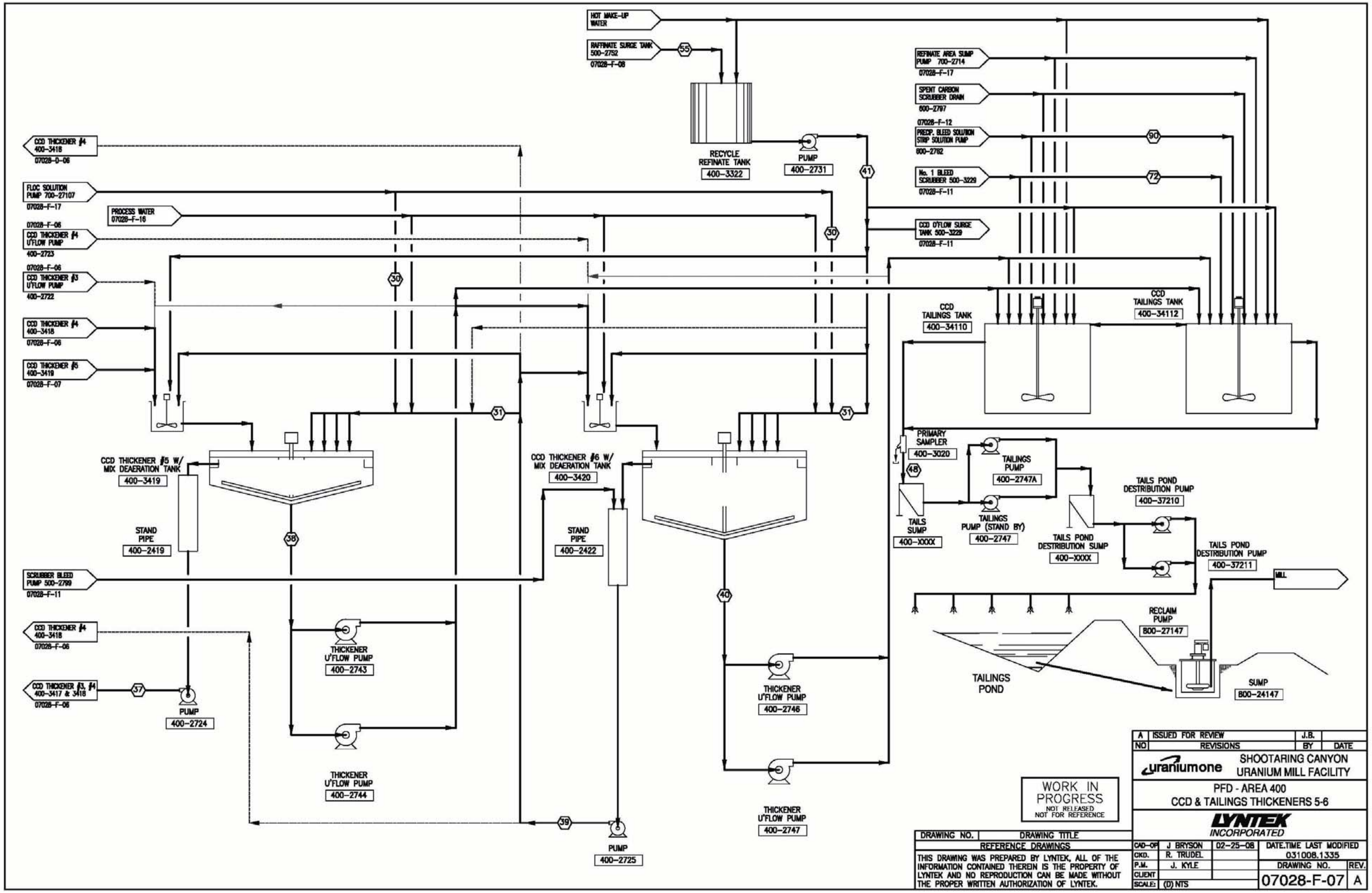
HOT MAKE-UP WATER
RAFFINATE SURGE TANK 500-2752 07028-F-08
55
RECYCLE REFINATE TANK
400-3322
PUMP
400-2731
41
REFINATE AREA SUMP PUMP 700-2714 07028-F-17
SPENT CARBON SCRUBBER DRAIN 600-2797 07028-F-12
PRECIP. BLEED SOLUTION STRIP SOLUTION PUMP 600-2792
90
No. 1 BLEED SCRUBBER 500-3229 07028-F-11
72
CCD O'FLOW SURGE TANK 500-3229 07028-F-11
CCD THICKENER #4 400-3418 07028-D-06
FLOC SOLUTION PUMP 700-27107 07028-F-17
PROCESS WATER 07028-F-16
07028-F-06
CCD THICKENER #4 U'FLOW PUMP 400-2723
07028-F-06
CCD THICKENER #3 U'FLOW PUMP 400-2722
CCD THICKENER #4 400-3418 07028-F-06
CCD THICKENER #5 400-3419 07028-F-07
30
30
31
31
CCD TAILINGS TANK
400-34110
CCD TAILINGS TANK
400-34112
CCD THICKENER #5 W/ MIX DEAERATION TANK
400-3419
CCD THICKENER #6 W/ MIX DEAERATION TANK
400-3420
STAND PIPE
400-2419
STAND PIPE
400-2422
38
40
PRIMARY SAMPLER
400-3020
48
TAILINGS PUMP
400-2747A
TAILS SUMP
400-XXXX
TAILINGS PUMP (STAND BY)
400-2747
TAILS POND DESTRIBUTION PUMP
400-37210
TAILS POND DESTRIBUTION SUMP
400-XXXX
TAILS POND DESTRIBUTION PUMP
400-37211
MILL
SCRUBBER BLEED PUMP 500-2799 07028-F-11
RECLAIM PUMP
800-27147
TAILINGS POND
SUMP
800-24147
CCD THICKENER #4 400-3418 07028-F-06
CCD THICKENER #3, #4 400-3417 & 3418 07028-F-06
57
PUMP
400-2724
THICKENER U'FLOW PUMP
400-2743
THICKENER U'FLOW PUMP
400-2744
THICKENER U'FLOW PUMP
400-2746
THICKENER U'FLOW PUMP
400-2747
39
PUMP
400-2725
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PFD - AREA 400
CCD & TAILINGS THICKENERS 5-6
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07028-F-07 A

The leached slurry solids enter the first thickener progresses in series from the first through the sixth thickener and finally to the tailings impoundment. Meanwhile, the wash solution, consisting of raffinate from the SX circuit, enters the sixth thickener and progresses in series flowing counter currently to the solids. The solution is pumped from the sixth thickener overflow to the fifth thickener and this is repeated until the liquid is pumped from the first thickener overflow to the first stage leach circuit. Flocculant solution is pumped to each thickener to assist with solid/liquid separation.

The purpose of the number six high rate thickener with its characteristic deep side wall and steep cone bottom provides for a higher underflow slurry density, therefore, less solution liquid is in the underflow slurry in order to maximize recovery and minimize soluble uranium losses to the tailings pond. Another reason for the high rate thickener is to give the added flexibility in operation reducing the impact of upsets during operation that can occur within the CCD washing circuit.

Slurry underflow from the sixth CCD Thickener is pumped to a tailings mix tanks for mixing with other solution streams or dilution water to reduce the percent solids and thereby making pumping of the slurry more manageable before going to the tailings pond. Overflow from the tailings mix tanks pass through a sampler before flowing into the final tailings sump and pump. Sampling at this point will monitor the performance of the plant.

Solvent Extraction (SX)

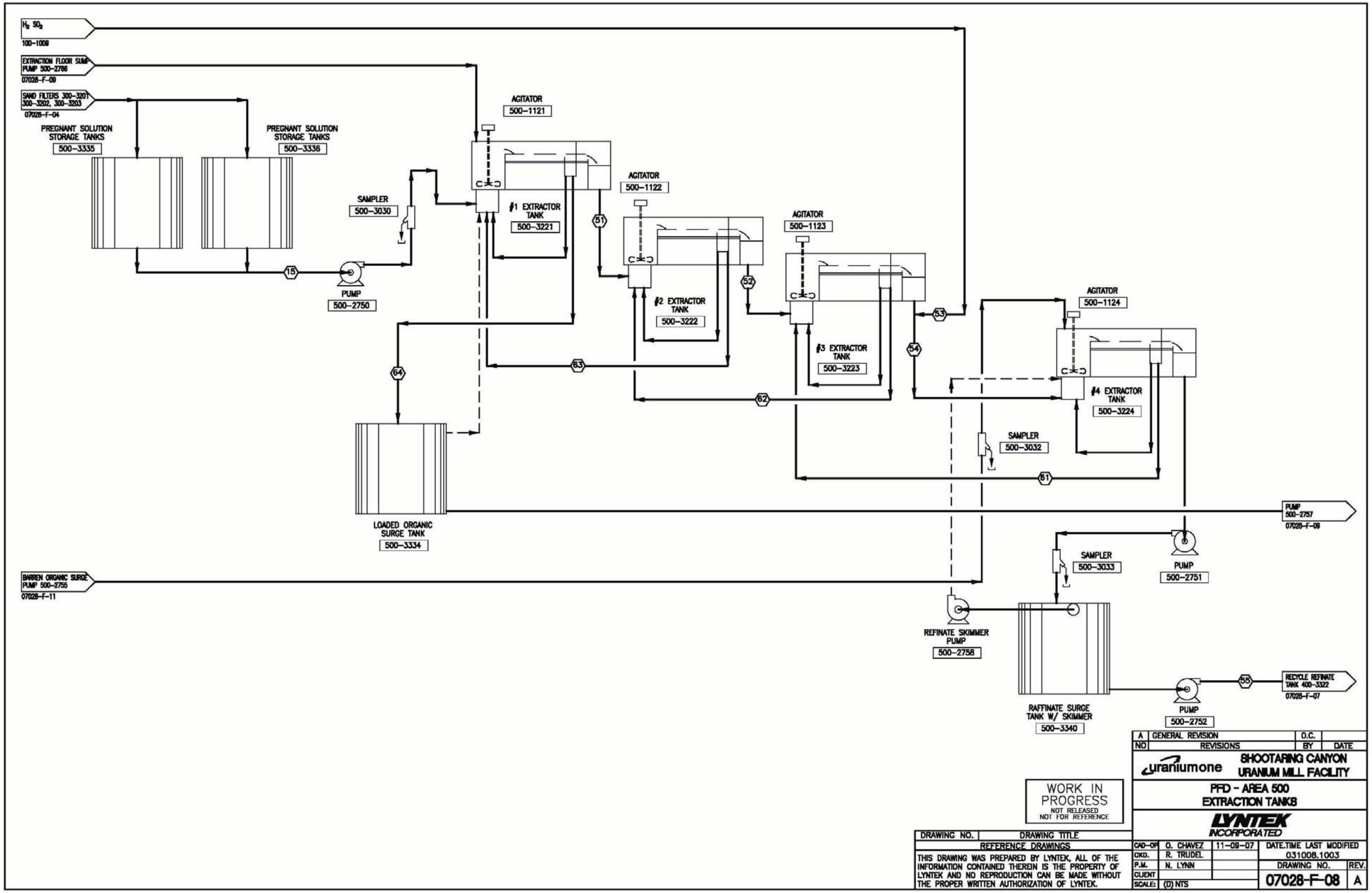
The primary purpose of the SX circuit is to concentrate the uranium bearing pregnant solution. Referring to drawings 07028-F-08, 07028-F-09, and 07028-F-11, the SX system consists of two unit operations. In the first operation, the uranium is transferred from the aqueous leach solution to an immiscible organic liquid by ion exchange. In the second operation, a reverse ion exchange process then strips the uranium from the organic solvent using aqueous ammonium sulfate.

The uranium SX system consists of four extraction mixer/settlers, four strip mixer/settlers and one organic scrub mixer/settler.

Extraction Stages

The pregnant solution is pumped from the storage tanks into the first extraction mixer where it is contacted with a tertiary amine flowing from the second stage extraction settler. Recycling organic from the settler portion of the extraction stage and combining it with the organic stream from the next succeeding extraction stage maintains the desired organic to aqueous ratio in each extraction mixer. Pump type mixer impellers are used to transport the liquids between the mixer/settlers. After mixing, the combined solution of organic and aqueous overflows from the mixer into the settler where the aqueous and organic phases separate. The uranium loaded organic flows to the loaded organic surge tank, while the aqueous phase flows to the 2nd extraction mixer, where it is contacted with the organic coming from the 3rd settler.

The combined solution of organic and aqueous overflows from the 2nd mixer into the settler where the phases separate. The organic phase flows to the 1st mixer while the aqueous phase flows to the 3rd mixer. The aqueous stream to the 3rd mixer is mixed with the organic stream from the 4th settler. The mixture overflows into the 3rd settler where they separate. The organic phase flows to the 2nd mixer while the aqueous phase flows to the 4th mixer. The aqueous stream to the 4th mixer is combined with barren organic fed from the barren organic tank. This mixture overflows into the 4th settler where they separate and the organic stream flows to the 3rd mixer while the aqueous stream flows to a raffinate surge tank. The raffinate is recycled back to the CCD circuit for washing the solids from leach.


H2 SO2
100-1009
EXTRACTION FLOOR SUMP PUMP 500-2786
07028-F-09
SAND FILTERS 300-3201 300-3202, 300-3203
07028-F-04
PREGNANT SOLUTION STORAGE TANKS
500-3335
PREGNANT SOLUTION STORAGE TANKS
500-3336
SAMPLER
500-3030
15
PUMP
500-2750
AGITATOR
500-1121
#1 EXTRACTOR TANK
500-3221
51
AGITATOR
500-1122
#2 EXTRACTOR TANK
500-3222
52
AGITATOR
500-1123
#3 EXTRACTOR TANK
500-3223
53
54
AGITATOR
500-1124
#4 EXTRACTOR TANK
500-3224
63
62
64
SAMPLER
500-3032
61
LOADED ORGANIC SURGE TANK
500-3334
PUMP 500-2757
07028-F-09
SAMPLER
500-3033
PUMP
500-2751
BARREN ORGANIC SURGE PUMP 500-2755
07028-F-11
REFINATE SKIMMER PUMP
500-2758
RAFFINATE SURGE TANK W/ SKIMMER
500-3340
PUMP
500-2752
55
RECYCLE REFINATE TANK 400-3322
07028-F-07
A
GENERAL REVISION
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uraniumone
SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 500 EXTRACTION TANKS
LYNTEK INCORPORATED
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CLIENT
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REV.
07028-F-08
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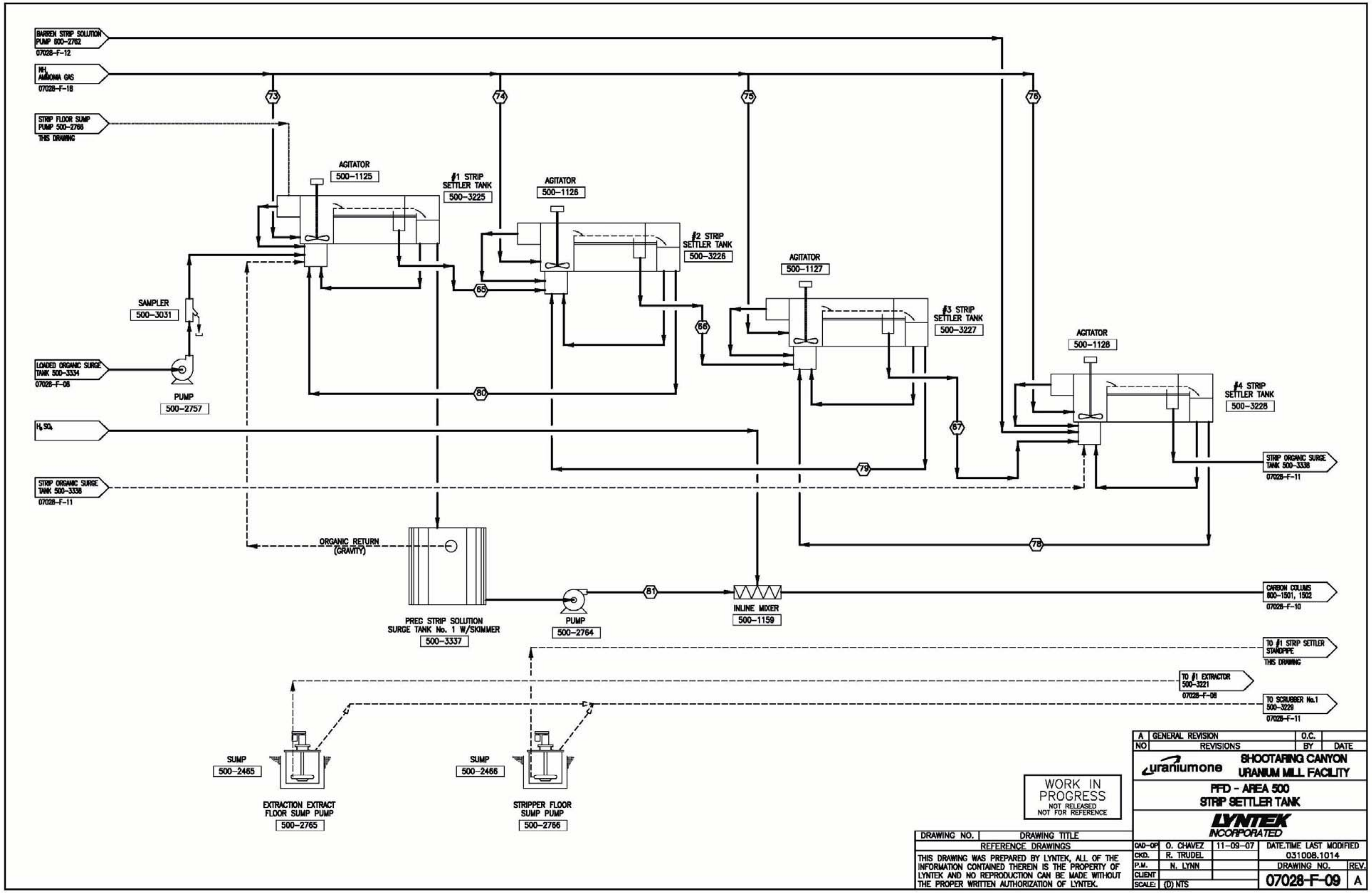
BARREN STRIP SOLUTION PUMP 800-2762
07028-F-12
NH3 AMMONIA GAS
07028-F-18
STRIP FLOOR SUMP PUMP 500-2766
THIS DRAWING
73
74
75
76
AGITATOR
500-1125
#1 STRIP SETTLER TANK
500-3225
AGITATOR
500-1126
#2 STRIP SETTLER TANK
500-3226
AGITATOR
500-1127
#3 STRIP SETTLER TANK
500-3227
AGITATOR
500-1128
#4 STRIP SETTLER TANK
500-3228
65
66
67
80
79
78
81
SAMPLER
500-3031
LOADED ORGANIC SURGE TANK 500-3334
07028-F-08
PUMP
500-2757
H2SO4
STRIP ORGANIC SURGE TANK 500-3338
07028-F-11
STRIP ORGANIC SURGE TANK 500-3338
07028-F-11
ORGANIC RETURN (GRAVITY)
PREG STRIP SOLUTION SURGE TANK No. 1 W/SKIMMER
500-3337
PUMP
500-2764
INLINE MIXER
500-1159
CARBON COLUMS 800-1501, 1502
07028-F-10
TO #1 STRIP SETTLER STANDPIPE
THIS DRAWING
TO #1 EXTRACTOR 500-3221
07028-F-08
TO SCRUBBER No.1 500-3229
07028-F-11
SUMP
500-2465
EXTRACTION EXTRACT FLOOR SUMP PUMP
500-2765
SUMP
500-2466
STRIPPER FLOOR SUMP PUMP
500-2766
WORK IN PROGRESS
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PFD - AREA 500
STRIP SETTLER TANK
LYNTEK INCORPORATED
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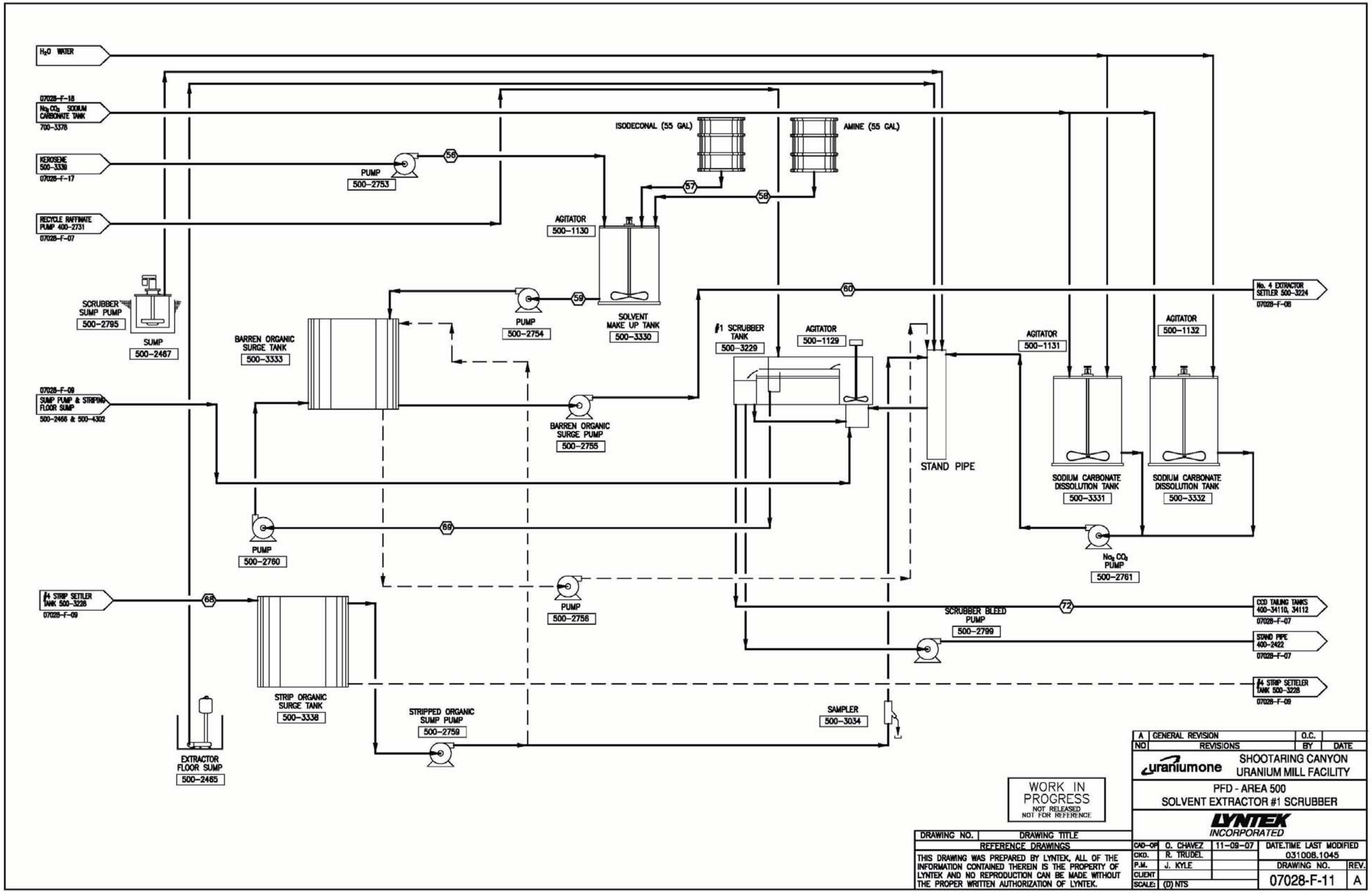
REV. A


H₂O WATER
07028-F-18
Na₂ CO₃ SODIUM CARBONATE TANK
700-3378
KEROSENE 500-3339
07028-F-17
RECYCLE RAFFINATE PUMP 400-2731
07028-F-07
PUMP
500-2753
56
ISODECONAL (55 GAL)
AMINE (55 GAL)
57
58
AGITATOR
500-1130
SCRUBBER SUMP PUMP
500-2795
SUMP
500-2467
BARREN ORGANIC SURGE TANK
500-3333
PUMP
500-2754
59
SOLVENT MAKE UP TANK
500-3330
60
No. 4 EXTRACTOR SETTLER 500-3224
07028-F-06
#1 SCRUBBER TANK
500-3229
AGITATOR
500-1129
AGITATOR
500-1131
AGITATOR
500-1132
07028-F-09
SUMP PUMP & STRIPING FLOOR SUMP
500-2466 & 500-4302
BARREN ORGANIC SURGE PUMP
500-2755
STAND PIPE
SODIUM CARBONATE DISSOLUTION TANK
500-3331
SODIUM CARBONATE DISSOLUTION TANK
500-3332
69
PUMP
500-2760
Na₂ CO₃ PUMP
500-2761
#4 STRIP SETTLER TANK 500-3228
07028-F-09
68
PUMP
500-2756
SCRUBBER BLEED PUMP
500-2799
72
CCD TAILING TANKS 400-34110, 34112
07028-F-07
STAND PIPE 400-2422
07028-F-07
#4 STRIP SETTELER TANK 500-3228
07028-F-09
STRIP ORGANIC SURGE TANK
500-3338
STRIPPED ORGANIC SUMP PUMP
500-2759
SAMPLER
500-3034
EXTRACTOR FLOOR SUMP
500-2465
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PFD - AREA 500
SOLVENT EXTRACTOR #1 SCRUBBER
LYNTEK INCORPORATED
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DRAWING NO. 07028-F-11
REV. A

*

Strip Stages

The uranium loaded organic is pumped from the loaded organic storage tank into the 1st strip mixer where it is contacted with an ammonium sulfate aqueous solution flowing from the 2nd stage extraction settler. Recycling aqueous from the settler portion of the 1st strip stage and combining it with the aqueous stream from the next succeeding strip stage maintains the desired organic to aqueous ratio in each extraction mixer. After mixing, the combined solution of organic and aqueous overflows from the mixer into the settler where the aqueous and organic phases separate. The uranium loaded aqueous stream flows into pregnant strip solution tank, while the organic phase flows to the 2nd strip mixer, where it is contacted with the organic coming from the 3rd settler.

The combined solution of organic and aqueous overflows from the 2nd mixer into the settler where the phases separate. The aqueous phase flows to the 1st mixer while the organic phase flows to the 3rd mixer. The organic stream to the 3rd mixer is mixed with the aqueous stream from the 4th settler. The mixture overflows into the 3rd settler where they separate. The aqueous phase flows to the 2nd mixer while the organic phase flows to the 4th mixer. The organic stream to the 4th mixer is combined with barren strip solution fed from the barren strip solution surge tank. This mixture overflows into the 4th settler where they separate and the aqueous stream flows to the 3rd mixer while the organic stream flows to the strip organic surge tank.

Pump type mixer impellers are used to transport the liquids between the mixer/settlers and ammonia is added each strip stage to control the pH.

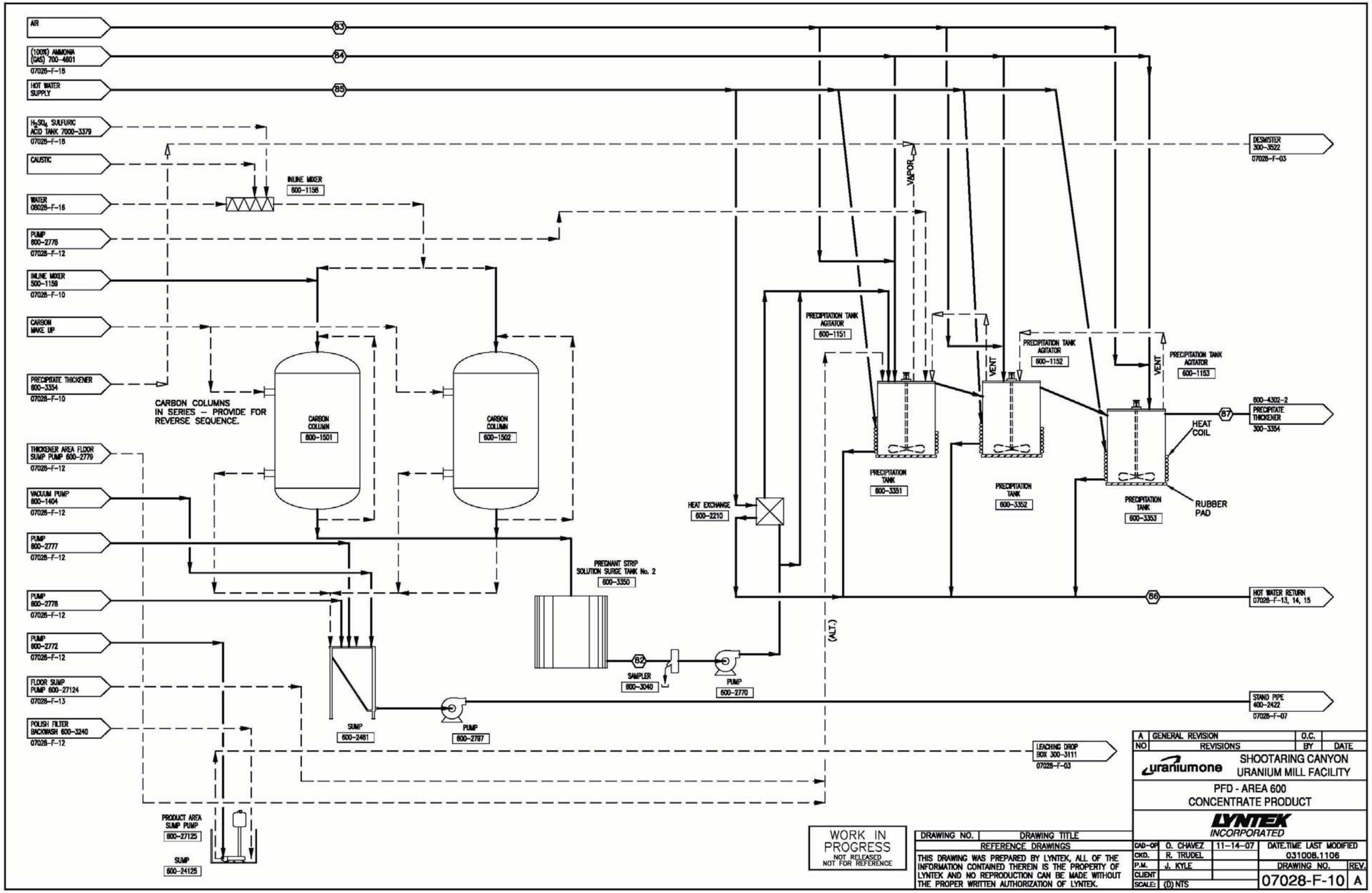
Scrub Stage

In order to prevent the build-up of co-extracted minerals such as molybdenum and vanadium in the recycled organic, some of the stripped organic is scrubbed with sodium carbonate in a single scrub mixer settler. The stripped organic is pump fed to a stand pie where it is combined with sodium carbonate. The pump type mixer impeller draws the mixture from the standpipe into the scrub mixer. The mixture overflows into the settler and the phases disengage. The scrubbed organic is pumped to the barren organic storage tank. Most of the aqueous phase is recycled back to the mixer to maintain a low organic to aqueous ratio in the mixer. The depleted sodium carbonate is sent from the scrub settler to the tailings impoundment.

Precipitation

Drawings 07028-F-10 and 07028-F-12 illustrate the process for producing the Yellowcake product. The pregnant aqueous ammonium sulfate strip solution from the first strip stage of the uranium SX is fed to carbon columns to remove entrained organic before it is sent to the precipitation process surge tank. The pregnant ammonium sulfate solution is then pumped through a heat exchanger to increase its temperature. The solution flows from the heat exchanger into the first of three agitated precipitation tanks that are also temperature controlled with hot water flowing through coils located around the outside of the tanks. Ammonia gas is injected into the reaction tanks to neutralize the solution and achieve the uranium precipitation reaction to produce uranium diuranate. The precipitated uranium and barren liquor gravity flow into the precipitate thickener. The thickener is large enough to accumulate the precipitate so that the downstream equipment including the washing, calcining and product packaging circuits can operate intermittently.

The barren ammonium sulfate solution overflow from the thickener is filtered and flows into the barren strip solution surge tank. Most of the barren solution is recycled back to the SX circuit for strip feed. In order to prevent contaminate buildup in the strip and precipitation circuits, part of the barren solution is sent to the tailings impoundment.


AIR
(100%) AMMONIA (GAS) 700-4601
07028-F-18
HOT WATER SUPPLY
83
84
85
H2SO4 SULFURIC ACID TANK 7000-3379
07028-F-18
CAUSTIC
WATER 08028-F-16
INLINE MIXER
600-1158
PUMP 600-2778
07028-F-12
INLINE MIXER 500-1159
07028-F-10
CARBON MAKE UP
PRECIPITATE THICKENER 600-3354
07028-F-10
CARBON COLUMNS IN SERIES – PROVIDE FOR REVERSE SEQUENCE.
CARBON COLUMN
600-1501
CARBON COLUMN
600-1502
THICKENER AREA FLOOR SUMP PUMP 600-2779
07028-F-12
VACUUM PUMP 600-1404
07028-F-12
PUMP 600-2777
07028-F-12
PUMP 600-2778
07028-F-12
PUMP 600-2772
07028-F-12
FLOOR SUMP PUMP 600-27124
07028-F-13
POLISH FILTER BACKWASH 600-3240
07028-F-12
SUMP
600-2481
PUMP
600-2797
PRODUCT AREA SUMP PUMP
600-27125
SUMP
600-24125
PREGNANT STRIP SOLUTION SURGE TANK No. 2
600-3350
82
SAMPLER
600-3040
PUMP
600-2770
HEAT EXCHANGE
600-2210
(ALT.)
VAPOR
VENT
VENT
PRECIPITATION TANK AGITATOR
600-1151
PRECIPITATION TANK AGITATOR
600-1152
PRECIPITATION TANK AGITATOR
600-1153
PRECIPITATION TANK
600-3351
PRECIPITATION TANK
600-3352
PRECIPITATION TANK
600-3353
HEAT COIL
RUBBER PAD
DESMISTER 300-3522
07028-F-03
87
600-4302-2
PRECIPITATE THICKENER
300-3354
86
HOT WATER RETURN 07028-F-13, 14, 15
STAND PIPE 400-2422
07028-F-07
LEACHING DROP BOX 300-3111
07028-F-03
WORK IN PROGRESS
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SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 600
CONCENTRATE PRODUCT
LYNTEK INCORPORATED
CAD-OP
O. CHAVEZ
11-14-07
CKD.
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P.M.
J. KYLE
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REV.
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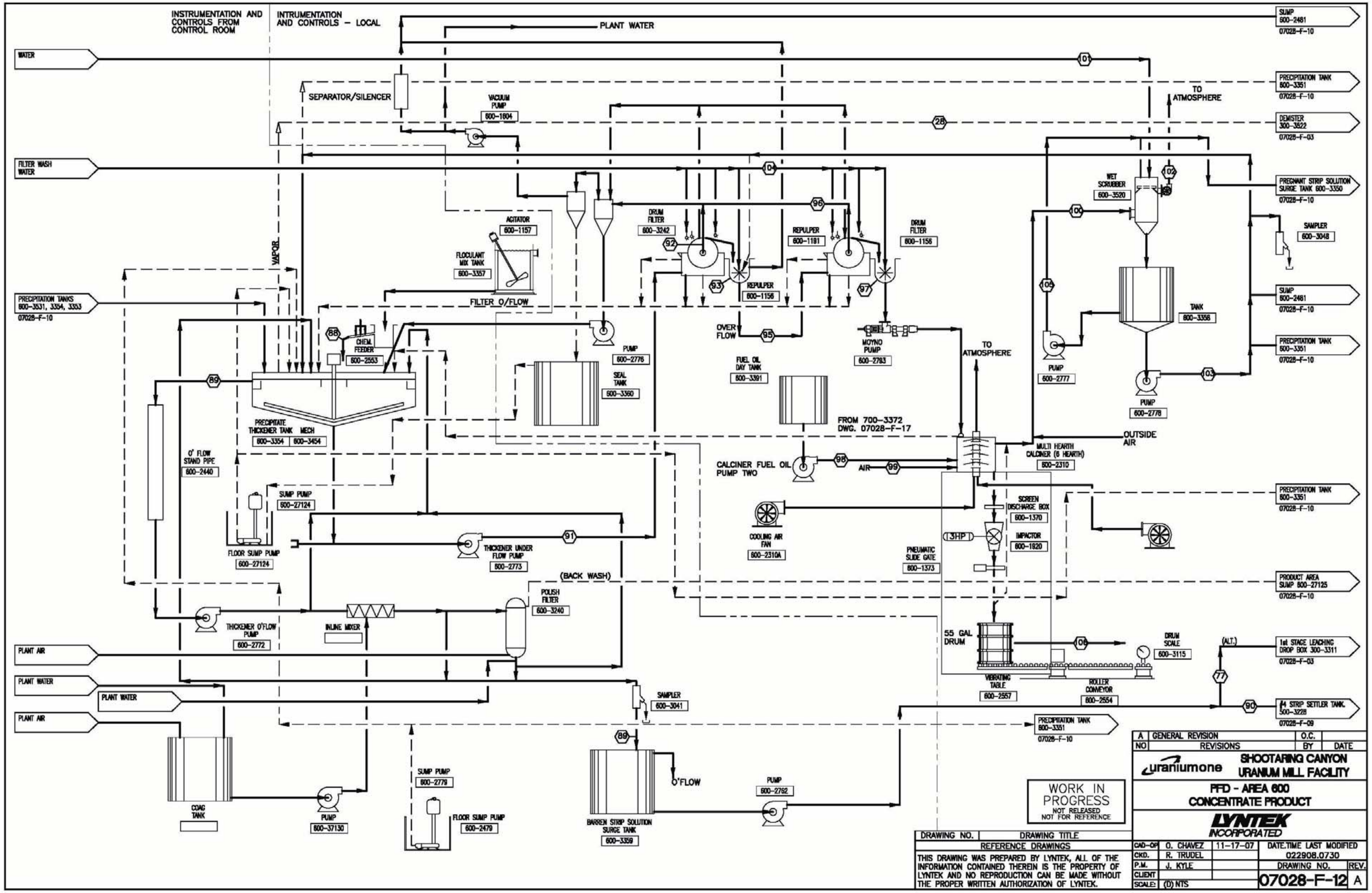
INSTRUMENTATION AND CONTROLS FROM CONTROL ROOM
INTRUMENTATION AND CONTROLS - LOCAL
PLANT WATER
WATER
SEPARATOR/SILENCER
VACUUM PUMP 600-1604
FILTER WASH WATER
VAPOR
AGITATOR 600-1157
FLOCULANT MIX TANK 600-3357
FILTER O/FLOW
PRECIPITATION TANKS 600-3531, 3354, 3353 07028-F-10
88
CHEM. FEEDER 600-2553
89
PRECIPITATE THICKENER TANK 600-3354
MECH 600-3454
O' FLOW STAND PIPE 600-2440
SUMP PUMP 600-27124
FLOOR SUMP PUMP 600-27124
THICKENER UNDER FLOW PUMP 600-2773
91
(BACK WASH)
POLISH FILTER 600-3240
THICKENER O'FLOW PUMP 600-2772
INLINE MIXER
PLANT AIR
PLANT WATER
PLANT WATER
PLANT AIR
SAMPLER 600-3041
COAG TANK
PUMP 600-37130
SUMP PUMP 600-2779
FLOOR SUMP PUMP 600-2479
89
BARREN STRIP SOLUTION SURGE TANK 600-3359
O'FLOW
PUMP 600-2762
PUMP 600-2776
SEAL TANK 600-3360
DRUM FILTER 600-3242
92
93
104
96
REPULPER 600-1156
REPULPER 600-1181
97
DRUM FILTER 600-1156
OVER FLOW
95
MOYNO PUMP 600-2783
FUEL OIL DAY TANK 600-3391
FROM 700-3372 DWG. 07028-F-17
CALCINER FUEL OIL PUMP TWO
98
AIR
99
TO ATMOSPHERE
MULTI HEARTH CALCINER (6 HEARTH) 600-2310
OUTSIDE AIR
COOLING AIR FAN 600-2310A
SCREEN DISCHARGE BOX 600-1370
3HP
IMPACTOR 600-1920
PNEUMATIC SLIDE GATE 600-1373
55 GAL DRUM
106
DRUM SCALE 600-3115
VIBRATING TABLE 600-2557
ROLLER CONVEYOR 600-2554
101
28
TO ATMOSPHERE
102
WET SCRUBBER 600-3520
100
105
PUMP 600-2777
TANK 600-3356
PUMP 600-2778
103
SAMPLER 600-3048
(ALT.)
77
90
SUMP 600-2481 07028-F-10
PRECIPITATION TANK 600-3351 07028-F-10
DEMISTER 300-3522 07028-F-03
PREGNANT STRIP SOLUTION SURGE TANK 600-3350 07028-F-10
SUMP 600-2481 07028-F-10
PRECIPITATION TANK 600-3351 07028-F-10
PRECIPITATION TANK 600-3351 07028-F-10
PRODUCT AREA SUMP 600-27125 07028-F-10
1st STAGE LEACHING DROP BOX 300-3311 07028-F-03
#4 STRIP SETTLER TANK. 500-3228 07028-F-09
PRECIPITATION TANK 600-3351 07028-F-10
WORK IN PROGRESS NOT RELEASED NOT FOR REFERENCE
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REV. A

Drying and Packaging

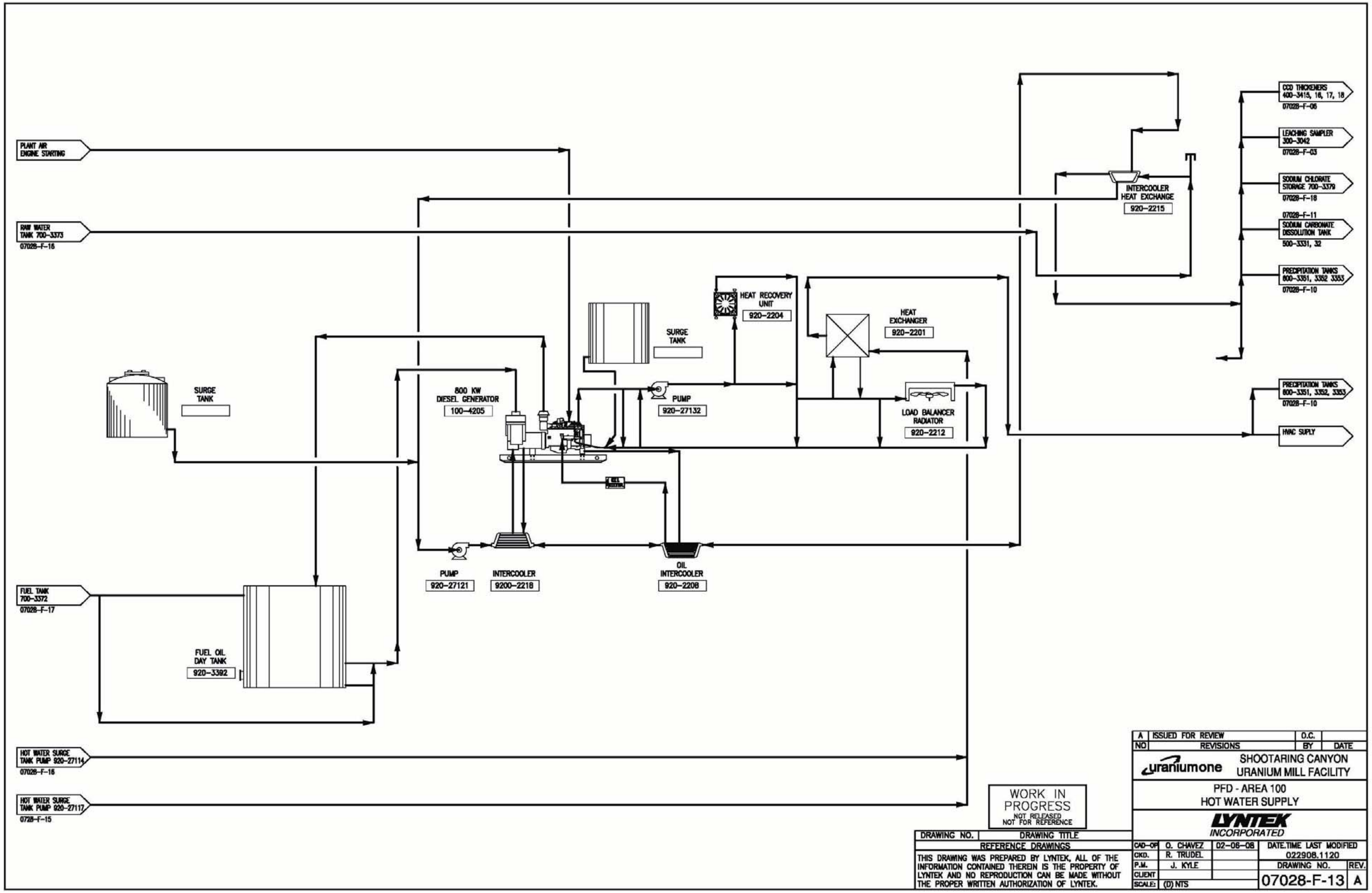
The precipitated uranium is pumped from the thickener underflow through two drum filter repulpers designed to remove entrained contaminants. The uranium diuranate solids are then pumped to a fuel oil fired calciner, a multi-hearth furnace, where the ammonia is driven off to produce Yellowcake. The Yellowcake then passes through a delumper and discharges into steel drums.

The washing, calcining and packaging circuits operates intermittently and product output from the plant will be approximately 15 to 16 barrels of yellow cake per week, each barrel holding approximately 750 lbs of product. Filled drums will be stored until a sufficient number have been assembled for shipment. It is expected that on average, about three weeks of uranium would be the optimum maximum inventory, which is about 48 barrels. A maximum of 64 barrels is assumed to be stored at the plant area. Shipment is expected every two weeks on a truck with 25-ton haulage capacity. The yellowcake will be hauled to Metropolis, Illinois, which is about a 1,500-mile haul.

Water Supply

The water supply for the plant is sourced from three water wells located east of the plant. See Drawing 07028-C-02 for the location of the water supply wells. Field investigations show significant scale buildup in the supply lines from the two supply wells. This scale buildup is significant considering the period of time for which the plant was operated. In order to address this issue, it is conceived that a reverse osmosis (RO) system be employed to remove calcium and other problem minerals from the water source.

The process water for the plant requires heating. The water is heated through the use of heat exchangers mounted on the enginators. The hot water supply systems are shown in Figures 07028-F-13, 07028-F-14, and 07028-F-15


PLANT AIR
ENGINE STARTING
RAW WATER
TANK 700-3373
07028-F-16
FUEL TANK
700-3372
07028-F-17
HOT WATER SURGE
TANK PUMP 920-27114
07028-F-16
HOT WATER SURGE
TANK PUMP 920-27117
0728-F-15
SURGE
TANK
800 KW
DIESEL GENERATOR
100-4205
SURGE
TANK
HEAT RECOVERY
UNIT
920-2204
PUMP
920-27132
HEAT
EXCHANGER
920-2201
LOAD BALANCER
RADIATOR
920-2212
INTERCOOLER
HEAT EXCHANGE
920-2215
PUMP
920-27121
INTERCOOLER
9200-2218
OIL
INTERCOOLER
920-2208
FUEL OIL
DAY TANK
920-3392
CCD THICKENERS
400-3415, 16, 17, 18
07028-F-06
LEACHING SAMPLER
300-3042
07028-F-03
SODIUM CHLORATE
STORAGE 700-3379
07028-F-18
07028-F-11
SODIUM CARBONATE
DISSOLUTION TANK
500-3331, 32
PRECIPITATION TANKS
800-3351, 3352 3353
07028-F-10
PRECIPITATION TANKS
800-3351, 3352, 3353
07028-F-10
HVAC SUPLY
WORK IN
PROGRESS
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URANIUM MILL FACILITY
PFD - AREA 100
HOT WATER SUPPLY
LYNTEK
INCORPORATED
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07028-F-13
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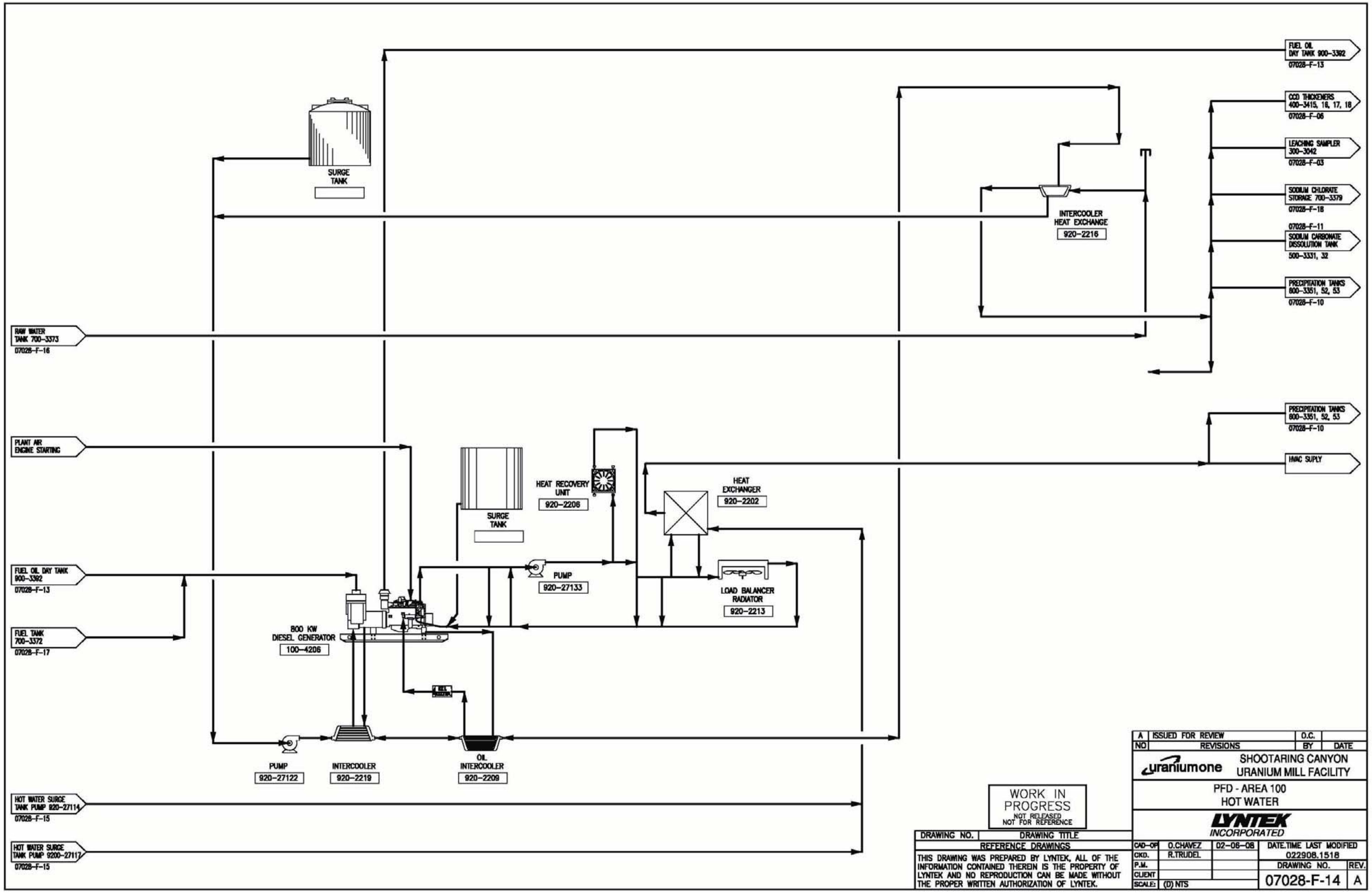
FUEL OIL DAY TANK 900-3392
07028-F-13
CCD THICKENERS 400-3415, 16, 17, 18
07028-F-06
LEACHING SAMPLER 300-3042
07028-F-03
SODIUM CHLORATE STORAGE 700-3379
07028-F-18
07028-F-11
SODIUM CARBONATE DISSOLUTION TANK
500-3331, 32
PRECIPITATION TANKS 800-3351, 52, 53
07028-F-10
PRECIPITATION TANKS 800-3351, 52, 53
07028-F-10
HVAC SUPLY
SURGE TANK
INTERCOOLER HEAT EXCHANGE
920-2216
RAW WATER TANK 700-3373
07028-F-16
PLANT AIR ENGINE STARTING
SURGE TANK
HEAT RECOVERY UNIT
920-2206
HEAT EXCHANGER
920-2202
PUMP
920-27133
LOAD BALANCER RADIATOR
920-2213
FUEL OIL DAY TANK 900-3392
07028-F-13
FUEL TANK 700-3372
07028-F-17
800 KW DIESEL GENERATOR
100-4206
PUMP
920-27122
INTERCOOLER
920-2219
OIL INTERCOOLER
920-2209
HOT WATER SURGE TANK PUMP 920-27114
07028-F-15
HOT WATER SURGE TANK PUMP 9200-27117
07028-F-15
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SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 100
HOT WATER
LYNTEK INCORPORATED
CAD-OP
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02-06-08
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DRAWING NO.
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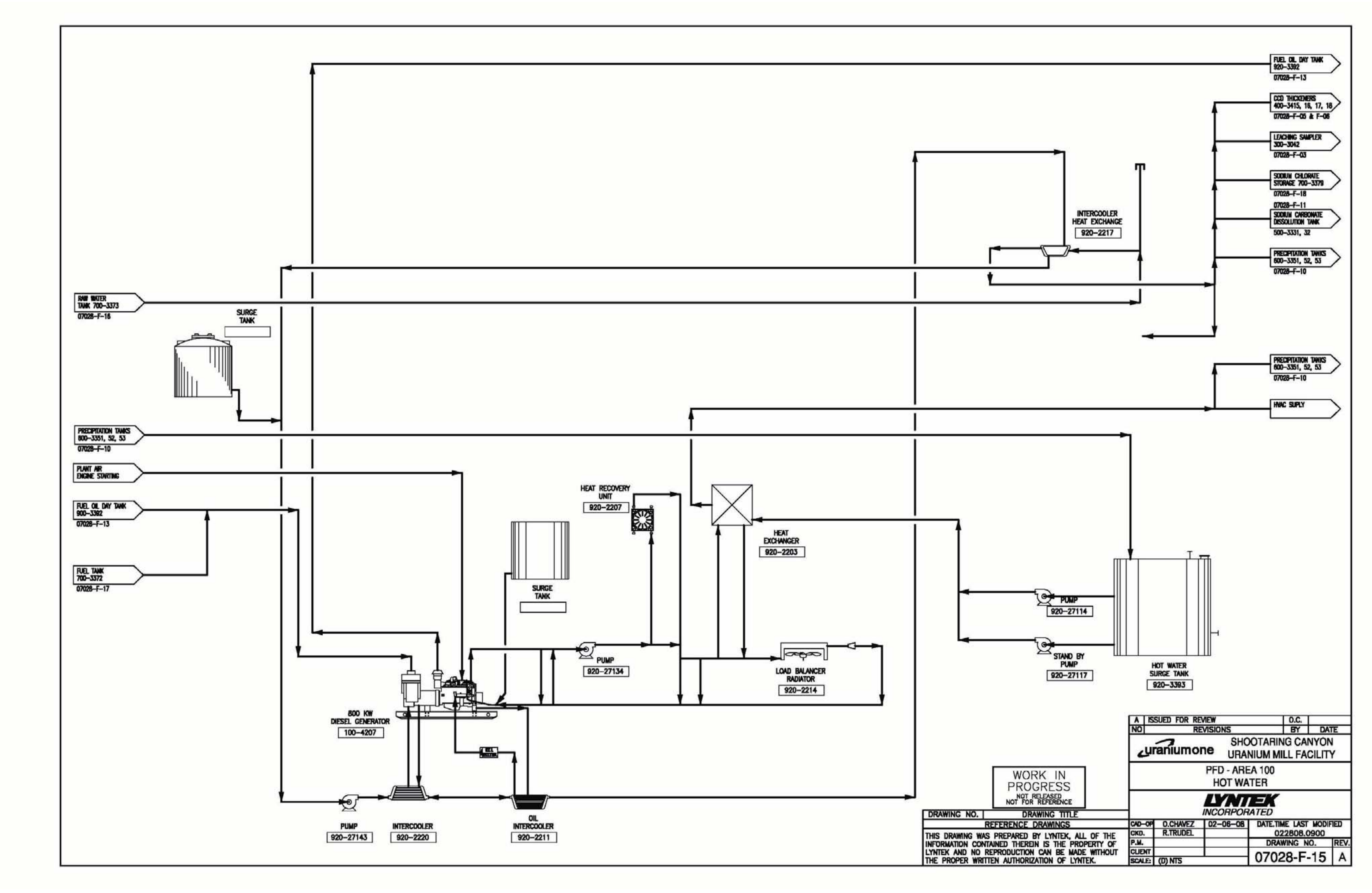
FUEL OIL DAY TANK
920-3392
07028-F-13
CCD THICKENERS
400-3415, 16, 17, 18
07028-F-05 & F-06
LEACHING SAMPLER
300-3042
07028-F-03
SODIUM CHLORATE
STORAGE 700-3379
07028-F-18
07028-F-11
SODIUM CARBONATE
DISSOLUTION TANK
500-3331, 32
PRECIPITATION TANKS
600-3351, 52, 53
07028-F-10
INTERCOOLER
HEAT EXCHANGE
920-2217
RAW WATER
TANK 700-3373
07028-F-16
SURGE
TANK
PRECIPITATION TANKS
600-3351, 52, 53
07028-F-10
HVAC SUPLY
PRECIPITATION TANKS
600-3351, 52, 53
07028-F-10
PLANT AIR
ENGINE STARTING
FUEL OIL DAY TANK
900-3392
07028-F-13
FUEL TANK
700-3372
07028-F-17
HEAT RECOVERY
UNIT
920-2207
HEAT
EXCHANGER
920-2203
SURGE
TANK
PUMP
920-27114
PUMP
920-27134
STAND BY
PUMP
920-27117
LOAD BALANCER
RADIATOR
920-2214
HOT WATER
SURGE TANK
920-3393
800 KW
DIESEL GENERATOR
100-4207
PUMP
920-27143
INTERCOOLER
920-2220
OIL
INTERCOOLER
920-2211
WORK IN
PROGRESS
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SHOOTARING CANYON
URANIUM MILL FACILITY
PFD - AREA 100
HOT WATER
LYNTEK
INCORPORATED
DRAWING NO. DRAWING TITLE
REFERENCE DRAWINGS
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07028-F-15 A

Potable water is provided from the three water wells, is stored in the well water storage tank, and then pumped to the raw water storage tank prior to being subjected to chlorine injection. It is then stored in the potable water storage tank where it is distributed by pumps for use. The fire water system is also supplied from the wells through the fuel oil driven main fire pumps that feed the main firewater loops within the plant and facility systems. The potable and fire water systems are shown in Figure 07028-F-16.

Plant Wastes and Effluents

Processed ore labeled “tailings” is the major waste generated by the Shootaring Canyon Uranium Ore Processing Facility. Tailings disposal includes permanent placement into an impoundment that utilizes a natural depression located adjacent to the plant site.

The plant and its support facilities also produce other liquid and solid wastes and effluents that are either recycled in the various process operations or discharged to the tailings impoundment or to a sanitary waste leach field.

Gaseous emissions and dust are discharged from eight stacks to promote dispersion.

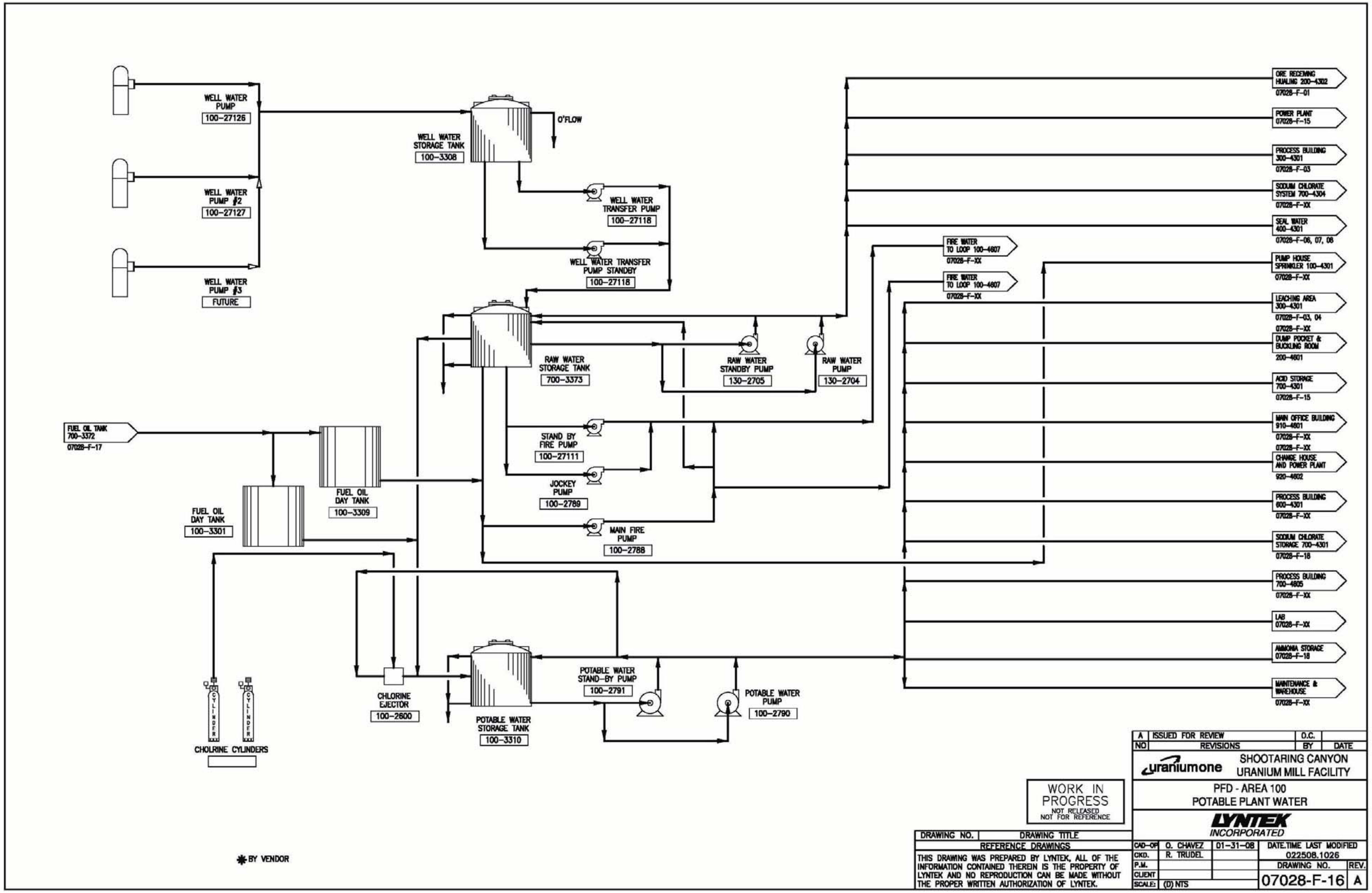
Controls for Plant Wastes and Effluents

Control systems have been incorporated into the plant design to minimize emissions from the plant. Volatile fuels and reagents are stored in closed tanks to minimize the escape of vapors to the atmosphere. Most unit operations are conducted inside buildings or closed vessels. Process vents from vessels are passed through wet dust collectors or demisters to remove dust, mists, and gaseous pollutants.

Buildings housing various plant operations have concrete floors sloped to sumps to collect spillage. Spilled materials are pumped back into the appropriate processing circuit. The building floors are curbed or recessed so that they can contain the volume of any single process tank in the event of a tank rupture. Fuel oil, kerosene, and acid storage tanks are located in open areas, and are surrounded by impoundments capable of holding the volume of the enclosed tanks.

The surface water handling system, including storm water handling, evaporation ponds, and tailings pond is being concurrently designed by another Uranium One team. The requirements, including these costs are included in that body of work.

In the dump area, a wet scrubber will be used to control fugitive dust emissions. See Drawing 07028-F-01.


WELL WATER PUMP
100-27126
WELL WATER PUMP #2
100-27127
WELL WATER PUMP #3
FUTURE
WELL WATER STORAGE TANK
100-3308
O'FLOW
WELL WATER TRANSFER PUMP
100-27118
WELL WATER TRANSFER PUMP STANDBY
100-27118
RAW WATER STORAGE TANK
700-3373
RAW WATER STANDBY PUMP
130-2705
RAW WATER PUMP
130-2704
FIRE WATER TO LOOP 100-4607
07028-F-XX
FIRE WATER TO LOOP 100-4607
07028-F-XX
FUEL OIL TANK 700-3372
07028-F-17
FUEL OIL DAY TANK
100-3309
FUEL OIL DAY TANK
100-3301
STAND BY FIRE PUMP
100-27111
JOCKEY PUMP
100-2789
MAIN FIRE PUMP
100-2788
CHLORINE EJECTOR
100-2600
POTABLE WATER STORAGE TANK
100-3310
POTABLE WATER STAND-BY PUMP
100-2791
POTABLE WATER PUMP
100-2790
CYLINDER
CYLINDER
CHOLRINE CYLINDERS
✱ BY VENDOR
ORE RECEIVING HUALING 200-4302
07028-F-01
POWER PLANT 07028-F-15
PROCESS BUILDING 300-4301
07028-F-03
SODIUM CHLORATE SYSTEM 700-4304
07028-F-XX
SEAL WATER 400-4301
07028-F-06, 07, 08
PUMP HOUSE SPRINKLER 100-4301
07028-F-XX
LEACHING AREA 300-4301
07028-F-03, 04
07028-F-XX
DUMP POCKET & BUCKLING ROOM
200-4601
ACID STORAGE 700-4301
07028-F-15
MAIN OFFICE BUILDING 910-4601
07028-F-XX
07028-F-XX
CHANGE HOUSE AND POWER PLANT
920-4602
PROCESS BUILDING 600-4301
07028-F-XX
SODIUM CHLORATE STORAGE 700-4301
07028-F-18
PROCESS BUILDING 700-4805
07028-F-XX
LAB 07028-F-XX
AMMONIA STORAGE 07028-F-18
MAINTENANCE & WAREHOUSE
07028-F-XX
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SHOOTARING CANYON URANIUM MILL FACILITY
PFD - AREA 100
POTABLE PLANT WATER
LYNTEK INCORPORATED
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Tailings Handling System

Tailings from the ore processing operation are discharged to a dammed impoundment located about 500 feet southwest the plant. The impoundment has been designed with a net capacity of about 2,600 acre-feet that is sufficient for 15 years operation with a plant throughput of 1,000 tons of dry ore per day, 365 days per year operation. At the end of 15 years the tailings in the impoundment will cover an area of approximately 70 surface acres. The impoundment is fenced to exclude livestock.

The tailings management system design for the Shootaring Canyon project incorporates best available technology. The tailings are stabilized within a few days to a few weeks of their placement in the impoundment. In order to accomplish this, a drainage system was installed in the bottom of the impoundment. A prescribed tailings placement procedure will be followed to facilitate the drainage. As a result of this procedure, no deep concentrations of the tailings slimes are expected to form within the impoundment. Therefore it will be possible to reclaim the tailings disposal area shortly after it is filled to its ultimate level.

2.7 Site Layout Considerations

The site layout needs to be modified to restrict the area where radiation controls need to be implemented. During January and February of 2008 this area was modified to establish a tighter perimeter so that those working out of the area of potential contact and contamination would not be required to go through radiation safety exercises. This has been done in order to focus the concentration of radiation safety programs on the areas that truly need the focus.

Lyntek recommends that the modification of the ore truck travel route through the property to reduce the area of potential contamination. In addition, an equipment wash down bay has been added, which is absolutely necessary to enable equipment to be transported from the site for repair and other purposes.

2.8 Ore Handling

The ore is delivered to the plant by over-the-road haulage trucks. It is expected that twenty to twenty five ton end-dump trucks will be employed from the Frank M mine and with the same style of truck with 12 ton pups from the Velvet mine. The ore will then be stockpiled according to grade, ore ownership if tolling arrangements are in effect, or other ore characteristics that dictate segregation or blending considerations. The feed ore stockpile will then be loaded by a 3 cubic yard front-end loader into the ore feed pocket located before the crushing and grinding circuit. Ore is then fed to the SAG mill.

2.9 Uranium Recovery

The Shootaring Canyon processing facility is expected to have an overall uranium recovery rate of 91.5 percent from an average ore containing 0.224 percent uranium oxide (U_3O_8). Based on this anticipated recovery and an average processing rate of 750 tons per day (t/d) of ore, the facility will produce about 3,088 pounds per day (1b/d) of U_3O_8 according to mass balance calculations.

ATTACHMENT D

SUPPORTING DOCUMENTATION FOR INTERROGATORY R313-24-4-16/03: SEISMIC HAZARD CHARACTERIZATION

Seismic Hazard Analysis for Shootaring Canyon Uranium Processing Facility

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Revised April 8, 2008

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1.0 INTRODUCTION

The Shootaring Canyon Uranium Processing Facility is currently in Standby status. Uranium One, Inc. is proposing to convert the present license to Operational status. This seismic hazard analysis has been prepared to characterize the peak horizontal ground acceleration (PGA) for use in seismic stability analyses of the facility.

1.1 Project Location

The site is located in a sparsely populated area of Garfield County, southeastern Utah, approximately 50 miles south of Hanksville, Utah (see Figure 1). A small town, Ticaboo, is located 2.6 miles south of the site. For the purposes of these analyses, the central location of the facility has coordinates of 37.72°N latitude and 110.70°W longitude.

1.2 Previous Work

Seismicity of the Shootaring site has been discussed in several previous consultants' reports. The Tailings Management Plan (Plateau Resources, Ltd et al., 2007) included results of several tailings stability and deformation analysis in Appendix A of the referenced report. Appendix A.1 includes results from a January 9, 1997 pseudostatic analysis of the Shootaring Canyon Dam. The analysis was performed using a horizontal seismic coefficient of 0.19 g based on a published report by Lawrence Livermore National Laboratories (Bernreuter et al., 1995). Appendix A.5 includes a June 14, 1999 deformation analysis on the Shootaring Canyon Dam. The analyses were performed using a peak acceleration of 0.33 g based on a U.S. Geological Survey (USGS) Peak Acceleration Map. Specific references for the map were not provided in the Tailings Management Plan (Plateau Resources Ltd, et al., 2007), but as will be discussed in Section 1.2.2, it is assumed that the peak acceleration corresponds to a 1 percent probability of exceedance in 50 years.

1.2.1 Lawrence Livermore National Laboratories

Lawrence Livermore National Laboratories (Bernreuter et al., 1995) performed a seismic hazard analysis for the Shootaring Canyon site as part of a study of all Title II sites performed for the U.S. Nuclear Regulatory Commission (NRC). The purpose of the study was to evaluate the seismic design assumptions for mining sites where uranium tailings are being stored by performing simplified deterministic and probabilistic analyses. Results of this study concluded that the PGA using deterministic methods is 0.3 g (median plus one sigma) and using probabilistic methods is 0.19 g for an annual probability of exceedance (PE) of $1x10^{-4}$.

The deterministic analysis concentrated on three faults of the Bright Angel fault system. The three faults evaluated include the fault closest to the site, and then two larger, but more distant, faults of the system. This analysis concluded that the closest fault (4 km long, located 9 km from the site) has the greatest potential impact on the site. Attenuation equations used in the analysis were not specified.

The probabilistic analysis considered the pattern of random earthquakes occurring in an undefined source zone around the site. Earthquake catalogs from the past 30 years (presumably from 1965 to 1995) were used to estimate a recurrence model for the area. The three faults of the Bright Angel fault system were not incorporated into their probabilistic analysis.

1.2.2 USGS

The source of the Peak Acceleration Map presented in the Tailings Management Plan, Appendix A.4 (Plateau Resources, Ltd. et al., 2007) was not referenced in Appendix A.4. A reproduction of this map is presented for convenience in Appendix A of this report. The map appears to be similar to interactive maps available from the USGS National Seismic Hazard Mapping Project (NSHMP) website using 1996 NSHMP data (USGS, 2007a), also shown in Appendix A. However, the peak acceleration contours shown in Appendix A.4 are higher than the peak accelerations shown on the website for either a 2 percent or 10 percent probability of exceedance in 50 years. Although a peak acceleration contour map showing 1 percent probability of exceedance is not currently available on the USGS website, it is assumed that at some point, this interactive map was available and it is this map that was presented in Appendix A.4. This assumption is supported by data obtained from the USGS National Seismic Hazard Mapping Project (NSHMP) website for 1996 Interactive Deaggregations (USGS, 2007a). Using the site location coordinates and a return period of 4975 years (which corresponds to a 1 percent probability of exceedance in 50 years), the mapping project reports an acceleration of 0.34 g. Therefore, it is assumed that the value of 0.33 g is an interpolated value from a map provided by NSHMP corresponding to a 1 percent chance of exceedance in 50 years, using 1996 data.

In 2002, the NSHMP was updated. Using 2002 data (USGS, 2007b), the peak acceleration at the site for a return period of 4975 years is reported as 0.32 g. The hazard is almost entirely (99.2 percent) attributed to background seismicity within the Colorado Plateau around the site. It should be noted that for purposes of assigning attenuation models for the NSHMP, the USGS drew a boundary between the central and eastern United States (CEUS) and western United States (WUS). The Shootaring Canyon site is located just within this CEUS boundary area. For areas within this CEUS boundary, attenuation relations of Toro et al. (1997), Frankel et al. (1996), Atkinson and Boore (1995), and Campbell (2002) were used. The output for this data is included in Appendix A.

2.0 REGIONAL PHYSIOGRAPHIC AND TECTONIC SETTING

The Shootaring Canyon site is located within the Colorado Plateau physiographic province in southeastern Utah. The Colorado Plateau is a broad, roughly circular region of relative structural stability within a more structurally active region of disturbed mountain systems. Broad basins and uplifts, monoclines, and belts of anticlines and synclines are characteristic of the plateau (Kelley, 1979). Igneous intrusions have formed several mountains, such as the Henry Mountains near the facility. However, most of the topographic relief in the Colorado Plateau is the result of erosion of deep canyons rather than upstanding mountain ranges (Thornbury, 1965).

The site is located near the southern end of the Henry Mountains' structural basin. The basin contains sedimentary rocks ranging from Mesozoic to Cenozoic in age, which are cut by the Tertiary intrusives forming the Henry Mountains, including Mt. Ellsworth. Fault development in the area is associated with the intrusive igneous centers of the Henry Mountains. These faults commonly have a northeasterly or northwesterly strike and do not generally extend far from the intrusive bodies. Faults are not known to exist within the project.

The interior of the Colorado Plateau is characterized by low heat-flow (Bodell and Chapman, 1982) and a thick (45 km) crust (Keller, Braile, and Morgan, 1979), as compared to the surrounding Basin and Range Province and Rio Grande rift. The transition zone between the interior and the surrounding provinces may be as wide as 100 to 150 km (Zoback and Zoback, 1989). This data suggest a weakening of the sides of the plateau lithosphere. Such weakening is consistent with the normal faulting along the margins of the plateau. The source of the relative stability of the Colorado Plateau thus is probably related to the cooler interior that has been stronger than the surrounding regions (Morgan and Swanberg, 1985).

The contemporary seismicity of the Colorado Plateau was investigated by Wong and Humphrey (1989) based on seismic monitoring. Their study characterized the seismicity of the plateau as being of small to moderate magnitude, of a low to moderate rate of occurrence with earthquakes widely distributed. Seismicity in the plateau appears to be the result of the reactivation of pre-existing faults not expressed at the surface but favorably oriented to the tectonic stress field. Very few earthquakes can be associated with known geologic structures or tectonic features in the plateau. The generally small size of the earthquakes and their widespread distribution is consistent with a highly faulted Precambrian basement and upper crust, and a moderate level of differential tectonic stresses. Earthquakes in the plateau generally occur within the upper 15 to 20 km of the upper crust (Smith, 1978, Wong and Chapman, 1986) although events have occurred as deep as 58 km (Wong and Humphrey, 1989). The predominant mode of tectonic deformation within the plateau appears to be normal faulting on northwest- to north-northwest-striking faults, with some localized occurrences of strike-slip displacement on northwest- or northeast-striking planes at shallow depths. The contemporary state of stress within the plateau is characterized by approximately northeast-trending extension (Wong and Humphrey, 1989).

3.0 SEISMICITY

3.1 Earthquake Catalogs

This seismic hazard analysis for the site included a review of historic earthquakes which have occurred within 200 miles of the site. Catalogs from the USGS NSHMP for the Western United States (WUS) and Central and Eastern United States (CEUS) (Mueller et al., 1997) were used. These catalogs, compiled by the USGS for their study, included removal of duplicate events as well as aftershocks and foreshocks related to the primary earthquake events in order to obtain a catalog of independent events. The database includes historical seismic events over the period from 1787 through December 2001. The WUS and CEUS catalogs were supplemented with events occurring between January 2002 and September 2007 by searching the National Earthquake Information Center (NEIC) database, also maintained by the USGS. This supplemental search resulted in three additional earthquakes. The catalog searches were limited to events with moment magnitude (Mw) greater than or equal to 4.0. A total of 114 events are included in the record. Earthquake activity is relatively diffuse and generally of small magnitudes, as shown in Figure 1. The earthquakes are tabulated in Appendix B.1.

The largest event is estimated in the WUS catalog to have an Mw of 6.5. This event occurred near Richfield, Utah on November 14, 1901. The epicenter is approximately 105 miles northwest of the site, within the Intermountain seismic belt (ISB), a seismically active zone between the western border of the Colorado Plateau, and the Basin and Range physiographic province.

The event closest to the site had an epicenter about 20 miles southeast of the site. This earthquake, which occurred on August 22, 1986, had an Mw of 4.0. As discussed in Wong and Humphrey (1989), this event is the largest earthquake known to have occurred in southeastern Utah. The focal mechanism for the earthquake exhibited normal faulting on northwest-striking fault planes.

In addition to the evaluation of significant earthquakes (Mw>4) as described above, a search of low magnitude events (Mw>2.4) within 80 miles of the site was also conducted using the NEIC database. These events are shown in Figure 2 and are tabulated in Appendix B.2.

4.0 SEISMIC HAZARD ANALYSIS

Seismic hazard analyses are typically conducted using one of two methods: (1) deterministic analysis or (2) probabilistic analysis. In the deterministic analyses, the ground motions from the maximum credible earthquake (MCE) associated with capable faults are attenuated to the site. A capable fault is defined by the United States Nuclear Regulatory Commission (NRC), in Appendix A to Part 100—Seismic and geologic siting criteria for Nuclear Power Plants, as a fault that has exhibited one or more of the following characteristics: 1) movement at or near the ground surface at least once within the past 35,000 years, or movement of a recurring nature within the past 500,000 years; 2) macroseismicity (magnitude 3.5 or greater) determined with instruments of sufficient precision to demonstrate a direct relationship with the fault; or 3) a structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other. The ground motions from the MCE associated with the fault are attenuated to the site using established attenuation equations. In deterministic analyses, typically median plus one sigma ground motions are reported.

Background, or floating, earthquakes are typically evaluated deterministically by placing the largest earthquake that can be assumed to occur unassociated with a known fault at a distance of 15 km from the site. In areas of low seismic activity, deterministic analyses tend to significantly overestimate ground accelerations.

In probabilistic analyses, ground motions and the associated probability of exceedance are estimated in order for the amount of risk associated with the design ground motion to be evaluated. As specified by the U.S. Environmental Protection Agency (EPA) Promulgated Standards for Remedial Actions at Inactive Uranium Processing Sites (40 CFR 192), the controls of residual radioactive material are to be effective for up to 1,000 years, to the extent reasonably achievable and, in any case, for at least 200 years. For the purpose of the seismic hazard evaluation, a 10,000-year return period is adopted for evaluating long-term stability of the facility. The probability that the 10,000-year event will be exceeded within a 200- to 1,000-year design life is between 2 and 10 percent. This is consistent with the International Building Code (IBC, 2006) which specifies designing for ground motions associated with a 2 percent probability of exceedance in a 50-year design life, or a return period of approximately 2,500 years. Similarly, a 2,500-year return period is appropriate during operational conditions, considering a design life of 50 years.

Seismic hazard analysis was performed using software EZ-FRISK, version 7.25 (Risk Engineering, Inc, 2008).

4.1 Seismic Sources

4.1.1 Active Faults

Quaternary faults were identified using the USGS Quaternary Fault and Fold database (USGS et al. 2006). Faults within 200 miles of the site are shown in Figure 1. A tabulated list of the faults is included in Appendix C.1. NRC documentation in 10 CFR Appendix A to Part 40 and 10 CFR Appendix A to Part 100 gives specific criteria for faults that should be considered as follows:

Table 1 Minimum Criteria for Considering Faults (NRC 10 CFR Part 100, Appendix A)

Distance from site (miles)	Minimum length of fault to be considered (miles)
0 to 20	1
20 to 50	5
50 to 100	10
100 to 150	20
150 to 200	40

All faults from the Quaternary Fault and Fold database that met these minimum requirements were considered as seismic sources for the deterministic seismic hazard analysis. This is a conservative approach, as the definition of a Quaternary fault is movement within the past 1.8 million years, and the definition of an active fault, as described in Section 4.0, is between 35,000 and 500,000 years. The MCE associated with each fault was calculated based on correlations between fault length and magnitude, as developed by Wells and Coppersmith (1994).

For the probabilistic analysis, faults that are included in the USGS Quaternary fault and fold database and have the potential to produce peak ground accelerations of 0.05 g or greater (based on deterministic methods) were selected for further evaluation in the probabilistic model. These criteria resulted in the inclusion of the following seven faults:

1) Bright Angel fault system, Fault 1, (2514),
2) Bright Angel fault system, Fault 2, (2514);
3) Bright Angel fault system, Fault 3, (2514);
4) Needles fault zone, (2507);
5) Shay graben, (2513);
6) Aquarius and Awapa plateau faults, (2505); and
7) Thousand Lakes fault (2506).

These faults are shown in Figure 2. These faults were not considered in the USGS NSHMP because their activity in the Quaternary is suspect, or because their movement in the mid to late Quaternary did not meet the USGS definition of an active fault.

The three faults of the Bright Angel fault system are included in the hazard analysis due to their proximity to the site and potential impacts. This fault system is classified as Class B in the Quaternary fault and fold database (USGS et al, 2006). The definition of Class B faults is geologic evidence that demonstrates the existence of Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A. The fault system is described as an expansive area of poorly understood suspected Quaternary faults in the Colorado Plateau. The faults are entirely within bedrock, thus Quaternary deformation can not be proven. Focal mechanism studies by both Brumbaugh (2005) and Wong and Humphrey (1989) indicate that within the Colorado Plateau, northwest striking normal faults are compatible with the modern state of stress of northeast-trending extension of the plateau, and northeast trending faults tend to not be active. Based on this data, the northeast trending faults of the Bright Angel fault system (labeled Fault 1 and 3 on Figure 2) will be assigned a low probability of seismogenic activity (0.10). Although Quaternary deformation has not been proven (USGS et al., 2006) and USGS did not consider this fault system to be active in the NSHMP, the northwest-trending Fault 2 will be assigned a higher probability of seismogenic activity of 0.50 because it is oriented favorably to the stress field.

The Needles fault zone has been removed from the probabilistic analysis because it is a structure resulting from salt movement that does not extend deeper than the evaporites of the Paradox Formation and is not considered seismogenic (Wong et al. 1996, Huntoon, 1982).

The Shay Graben faults have been assigned a lower probability of seismogenic activity (0.10) due to evidence for late-Quaternary deformation being associated with salt-dissolution collapse (Wong et al. 1996, Oviatt, 1988).

Descriptions of the faults (USGS et al. 2006) are included in Appendix D. Additional uncertainties in the fault characteristics are incorporated into the probabilistic analysis by representing the possible scenarios with a weight value. In general, the mean value is given a weight of 0.6, with the mean plus or minus one standard deviation values each given a weight of 0.2. The parameters used in the probabilistic analysis are described below, and are summarized in Appendix C.2.

Fault dips were assumed to vary between 40 and 80 degrees, with a mean value of 60 degrees. This is consistent with the NSHMP, which assumes a dip of 60 degrees for most normal faults within the western U.S., and with previous seismic hazard analyses in the Colorado Plateau (Wong et al., 1996). Fault depths were assumed to vary between 12 and 20 km, with a mean value of 15 km, as is typical in western U.S. (Wong and Chapman, 1990). Maximum magnitudes for the faults were estimated based upon the empirical relationship developed by Wells and Coppersmith (1994) for surface rupture length, with an uncertainty of 0.3 corresponding to the standard error in the Wells and Coppersmith (1994) relationship. The recurrence relationships for the faults were modeled using both Gutenberg-Richter exponential and normal magnitude recurrence models. The exponential model was given a weight of 0.2 and the normal magnitude model was given a weight of 0.8 in the analysis. Slip rates are used to characterize rates of fault activity. However, very limited data was available regarding slip rates, and the USGS fault and fold database categorizes all the 7 considered faults as simply having a slip-rate less than 0.2 mm per year. Slip rates were therefore modeled as being between 0.005 and 0.2 mm per year, similar to rates of activity assigned to many faults of questionable quaternary activity in the Rio Grande Rift area east of the Colorado Plateau (Wong et al., 2004).

4.1.2 Background Event

Many earthquakes occur that are not associated with a known structure. These events are termed background events, or floating earthquakes. Evaluation of the background event allows for potential low to moderate earthquakes not associated with tectonic structures to contribute to the seismic hazard of the site. The maximum magnitude for these background events within the Intermountain U.S. ranges between local magnitude (M_L) 6.0 and 6.5 (Woodward-Clyde 1996). Larger earthquakes would be expected to leave a detectable surface expression, especially in arid to semiarid climates, with slow erosion rates and limited vegetation. In seismically less active areas such as the Colorado Plateau, the maximum magnitude associated with a background event is assumed to be 6.3, consistent with that used in seismic evaluations performed for uranium tailing sites in Green River (DOE 1991a, pg. 26), and Grand Junction (DOE 1991b, pg. 71).

The hazard from background earthquakes is assessed using two approaches, each given equal weight in the probabilistic analysis. The first approach uses areal source zones and assumes a uniformly distributed seismicity within the zone. The second approach uses gridded seismicity which retains a degree of stationarity using 0.1 degree latitude and longitude grid spacing, as used by USGS for the NSHMP (Frankel et al. 1996).

The earthquake magnitude and recurrence interval of an areal source zone were assessed by looking at the earthquake record within 200 miles of the site, filtered to include only events with Mw values equal or greater than 4.0, as described in Section 3.1. The entire 200-mile radius circle about the site was evaluated as a source zone with uniformly distributed seismicity. As shown in Figure 1, the NW quadrant of the 200-mile radius circle has a high concentration of Quaternary faults and historical earthquake events. This zone corresponds to the Intermountain Seismic Belt (ISB), an area of significant earthquake activity. Including these events is conservative, as the recurrence interval of events in the remaining portion of the circle, including around the site, is overestimated.

In computation of background seismicity recurrence, all events know to be associated with faults considered in the hazard analysis should be removed from the analysis. On November 14, 1901, an earthquake with an estimated Mw of 6.5 occurred in Sevier County at an approximate location of 38.7° latitude and -112.1° longitude. As shown in Figure 2, this location is close to several Quaternary faults (Joseph Flats area faults and syncline - 2468, Elsinore fault - 2470, Dry Wash fault and syncline - 2496, Annabella graben - 2472, and Sevier fault northern portion - 2355). The earthquake record shows a total of 9 earthquakes with Mw equal or greater than 4.0 in this immediate area. The Mw 6.5 event has been removed from the background analysis since it is likely related to one of these structures, and an event of this magnitude will likely have a surface expression. For conservatism, the other eight events of lesser magnitude have been retained in the analysis.

The earthquake recurrence of the source zone was described by the truncated-exponential form of the Gutenberg-Richter relationship of log N = a – bM using the maximum likelihood procedure by Weichert (1980). The completeness periods for various magnitudes were estimated by Mueller et al. (1997). Table 2 gives the completeness period dates and the number of earthquakes during each period. Figure 3 shows the temporal distribution of earthquakes within the study area, and Figure 4 shows the recurrence curve.

Table 2 Completeness Periods and Event Counts Used in Recurrence Calculations

Magnitude Range (Mw)	Completeness Period	Number of Earthquakes
4.0-4.9	1/1963 - 8/2007	56
5.0-5.9	1/1930 - 8/2007	22
6.0-7.0	1/1850 - 8/2007	1

A study by Wong et al. (1996) also evaluated the recurrence of background events within the Colorado Plateau. The areal source zone is the interior portion of the plateau, as shown in Figure 1. The recurrence relationship developed for that study is shown on Figure 4. The relationship developed by Wong et al. (1996) is a robust analysis which limits the source zone to that most seismically similar to the project site. However, the seismicity record goes only through 1994. Therefore, the recurrence relationship for the 200-mile radius about the site is retained in the analysis because it incorporates events through 2007. The two recurrence relationships are evaluated in the hazard analysis with equal weight.

4.2 Attenuation Relations

Attenuation of ground motions from the location of a seismic event to the site was calculated using attenuation relations. Due to the absence of abundant strong ground motion records, no specific attenuation relation exists solely for Utah; thus, several attenuation relations from other areas were considered for use at the site. For the purposes of this study, the following three attenuation relationships were used: Spudich et al. (1999), Abrahamson and Silva (1997), and Campbell and Bozorgnia (2007). The empirical attenuation relations are appropriate for soft rock sites in the western U.S. An important consideration in the selection of appropriate attenuation relationships is that the area is located in an extensional tectonic regime where fault type is predominately normal. Spudich et al. (1999) was developed from an extensional earthquake database. Abrahamson and Silva (1997) and Campbell and Bozorgnia (2007) include normal faulting factors in the relations. The hazard was truncated at three standard deviations about the median value of each of the three attenuation relationships. Results from each relationship, along with the lognormal mean of the three relations are reported in Table 3.

4.3 Peak Ground Acceleration

Based on deterministic methods, the median plus one sigma ground motion from the background event results in a PGA of 0.24 g. Seven faults are identified as potentially capable of producing site PGA of 0.05 g or greater, and are summarized in Table 3.

Table 3 PGA for Significant Faults, Deterministic Analysis

Source Name	ID No.	Distance from Site (km)	MCE	PGA Median (Median plus 1 sigma)			
				Spudich et al. (1999)	Abrahamson and Silva (1997)	Campbell and Bozorgnia (2007)	Lognormal mean
Background Event	---	15	6.3	0.12 (0.19)	0.20 (0.33)	0.13 (0.23)	0.15 (0.24)
Bright Angel, Fault 1	2514	9	5.8	0.14 (0.22)	0.20 (0.35)	0.16 (0.28)	0.16 (0.28)
Bright Angel, Fault 2	2514	13	6.2	0.13 (0.21)	0.21 (0.36)	0.14 (0.25)	0.16 (0.27)
Bright Angel, Fault 3	2514	35	6.7	0.07 (0.11)	0.10 (0.16)	0.07 (0.12)	0.08 (0.13)
Needles Fault	2507	60	6.8	0.04 (0.06)	0.06 (0.09)	0.04 (0.07)	0.05 (0.07)
Thousand Lake Fault	2506	90	7.0	0.03 (0.05)	0.04 (0.07)	0.03 (0.06)	0.03 (0.06)
Shay graben Fault	2513	88	6.9	0.03 (0.05)	0.04 (0.07)	0.03 (0.06)	0.03 (0.06)
Aquarius and Awapa Fault	2505	89	6.9	0.03 (0.05)	0.04 (0.06)	0.03 (0.05)	0.03 (0.05)

As compared to the background event, only the faults of the Bright Angel Fault Zone result in PGA values of comparable magnitude. However, the likelihood of any of these events occurring within the design life of the project can only be evaluated by looking at the probabilistic analysis.

Table 4 shows the seismic source contribution to the total mean hazard at a return period of 10,000 years (or 1x10^{-4} annual percent exceedance). The mean PGA is estimated to be 0.18 g. The total hazard curve is shown in Figure 5 and the source contribution is shown in Figure 6. As shown in Figure 6, at this frequency, the hazard is almost entirely contributed to the background event. Input to the EZ-FRISK analysis is included in Appendix E.

Table 4 Hazard Contribution to Total Mean Hazard for 10,000-year Return Period, Probabilistic Analysis

Source Name	ID No.	Distance from Site (km)	PGA
Background Event – Ext Gridded	---	---	0.07
Background Event – CO Plateau Int (Wong et al. 1996)	---	---	0.11
Background Event – 200-mile radius about site	---	---	0.13
Bright Angel, Fault 1	2514	9	<0.01
Bright Angel, Fault 2	2514	13	<0.01
Bright Angel, Fault 3	2514	35	<0.01
Needles Fault	2507	60	<0.01
Thousand Lake Fault	2506	90	<0.01
Shay graben Fault	2513	88	<0.01
Aquarius and Awapa Fault	2505	89	<0.01
Total Hazard	---	---	0.18

4.4 Amplification

Geologic maps of the area (Hackman and Wyant, 1973) indicate that the site is underlain by Lower Cretaceous Morrison and Upper Jurassic Summerville formation of sandstones, mudstones, and siltstones. As defined in Campbell and Bozorgnia (2003), the site is categorized as a firm rock site, based on underlying geologic unit consisting of pre-Tertiary sedimentary rock. As such, further amplification of ground motions due to underlying soils was not considered. If further investigations indicate that the materials within the upper 30 meters are not classified as firm rock, soil amplification should be considered.

5.0 RESULTS AND CONCLUSIONS

Based on the probabilistic analysis, a PGA (at an annual PE of $1x10^{-4}$) of 0.18 g should be used for long-term seismic stability analyses. The U.S. Department of Energy (DOE, 1989) recommends that a seismic coefficient of two-thirds of the peak acceleration be used to analyze long-term, pseudostatic stability analyses. Therefore, for long-term pseudostatic analyses, a seismic coefficient of 0.12 g is recommended.

The value of 0.18 g is lower than the 0.32 g from the USGS 2002 Interactive Deaggragations (USGS, 2007a). It is likely that the majority of the difference is a result of using different attenuation relationships. As discussed in Section 1.2.2, the site is very close to the border drawn by USGS between the WUS and CEUS zones. Because the site lies within the CEUS area, the USGS applied attenuation relations developed for the CEUS. However, it is the opinion of the author that using attenuation relations that are specific to normal extensional faulting is appropriate. This is supported by other studies done in the area (e.g. Wong et al. 1996, Halling 2002, Wong et al. 2004).

During operational conditions, designing for an annual PE of $4x10^{-4}$, or a 2500-year return period would correlate roughly to a 2 percent chance of exceedance in 50 years. Using this criterion, the PGA is 0.10 g and the seismic coefficient is 0.07 g.

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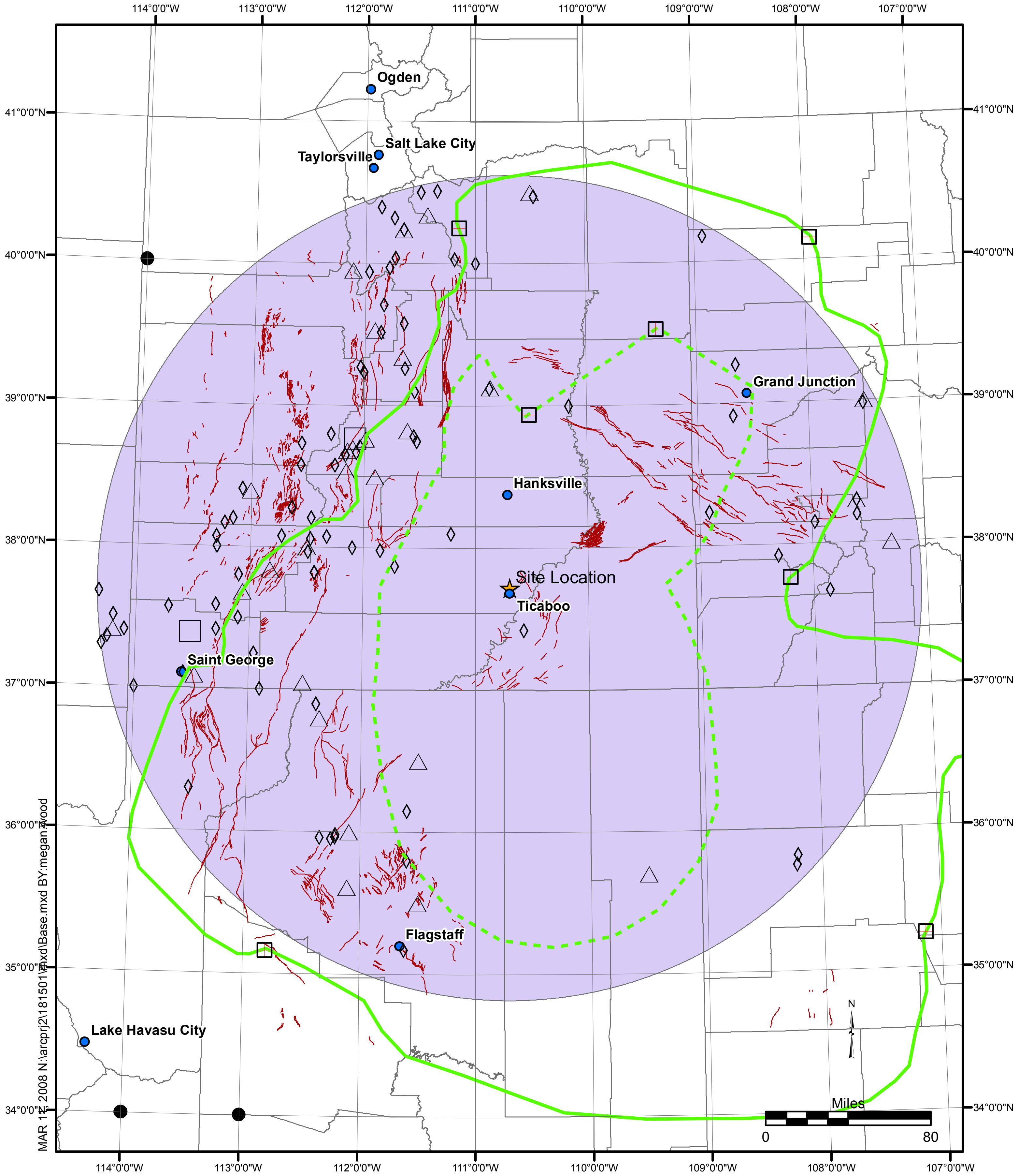


MAR 11, 2008 N:\arcprj\181501\mxd\Base.mxd BY:megan.wood

Earthquakes (Moment Magnitude)

- ◊ 4-4.9
- △ 5-5.9
- □ 6-6.9
- Quaternary Faults and Folds

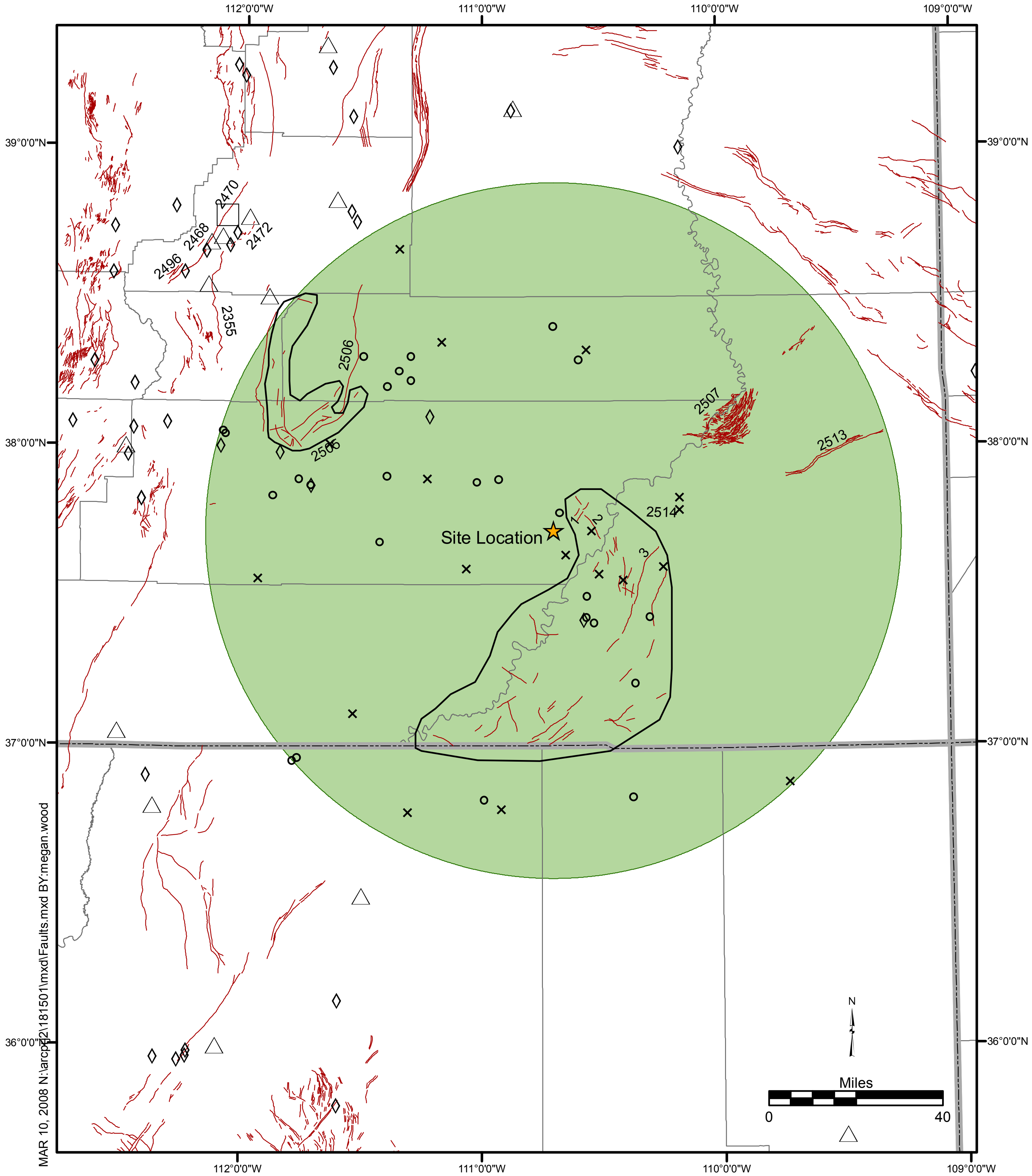
- 🟩 Colorado Plateau
- ⬚ Colorado Plateau Interior Seismic Zone

MAR 11, 2008

FIGURE 1

HISTORICAL EARTHQUAKES AND QUATERNARY FAULTS WITHIN 200 MILES OF SHOOTARING CANYON SITE

SHOOTARING 181501



MAR 10, 2008 N:\arcpd2\181501\mxd\Faults.mxd BY:megan.wood

Earthquakes (Moment Magnitude)

- × 2.4-2.9
- ○ 3-3.9
- ◇ 4-4.9
- △ 5-5.9
- □ 6-6.9

— Quaternary Faults and Folds

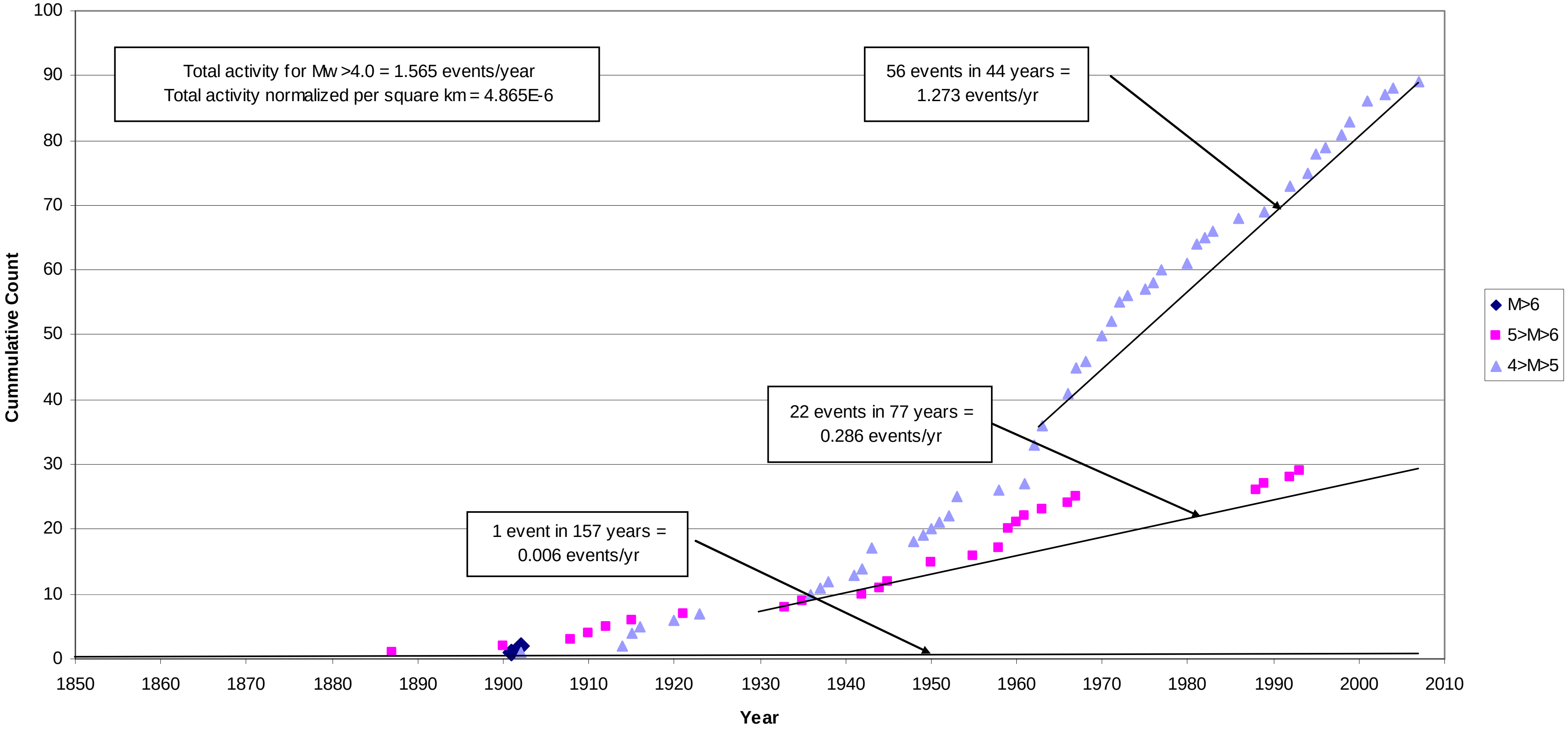
🟩 80 Mile Buffer

MAR 10, 2008

FIGURE 2

FAULTS DISCUSSED IN SEISMIC HAZARD ANALYSIS

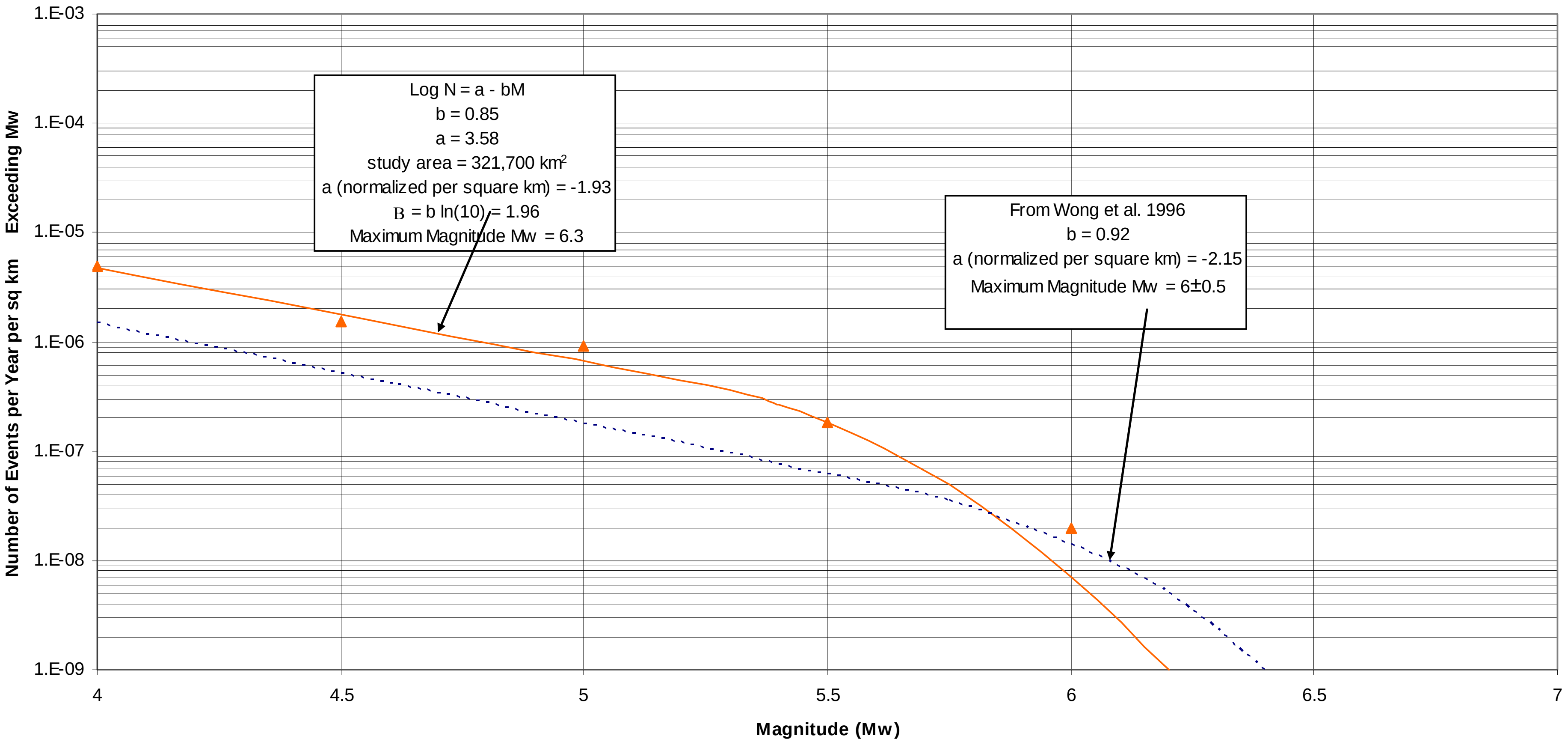
SHOOTARING 181501



Project No: 181692

April 2008

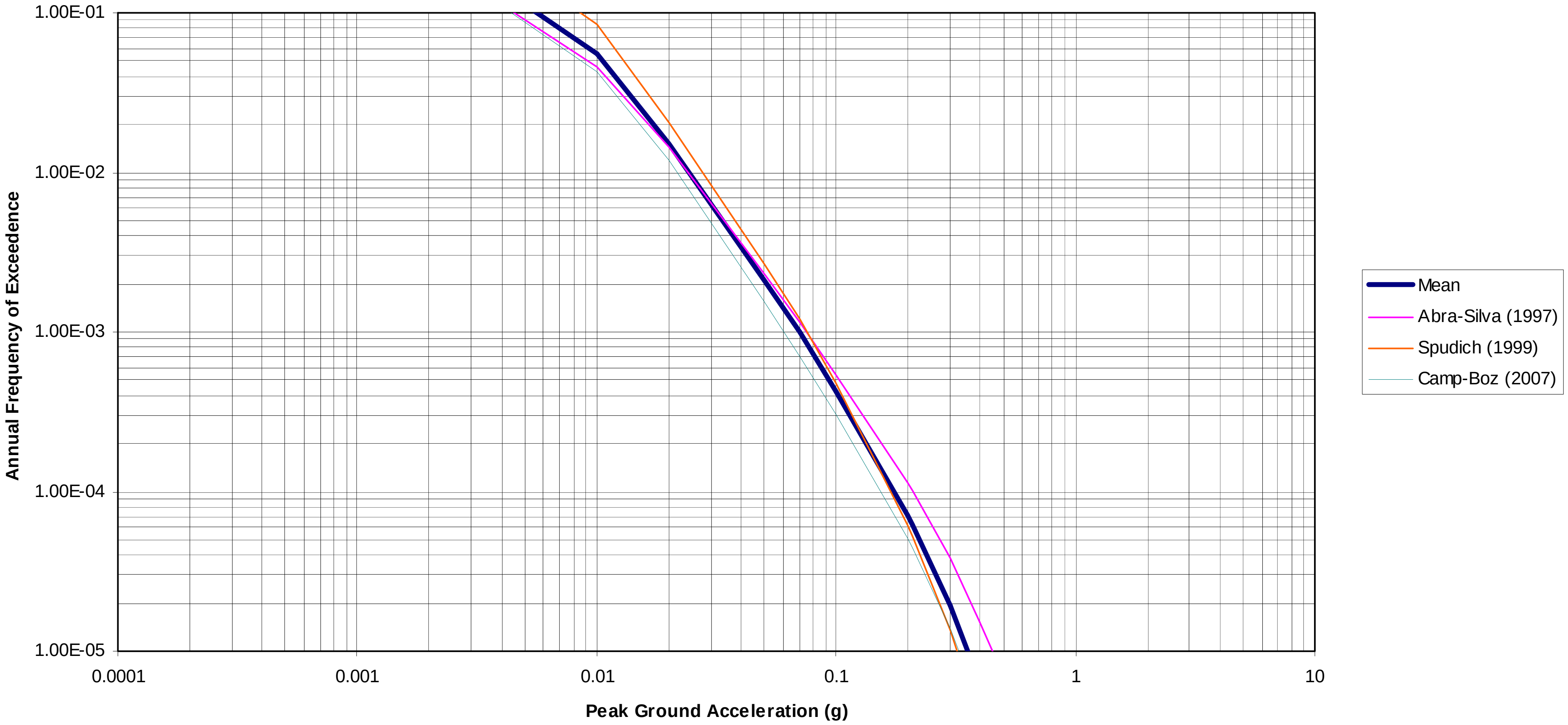
FIGURE 3
TEMPORAL DISTRIBUTION OF EARTHQUAKES WITHIN 200 MILES OF SHOOTARING CANYON SITE



Project No: 181692

April 2008

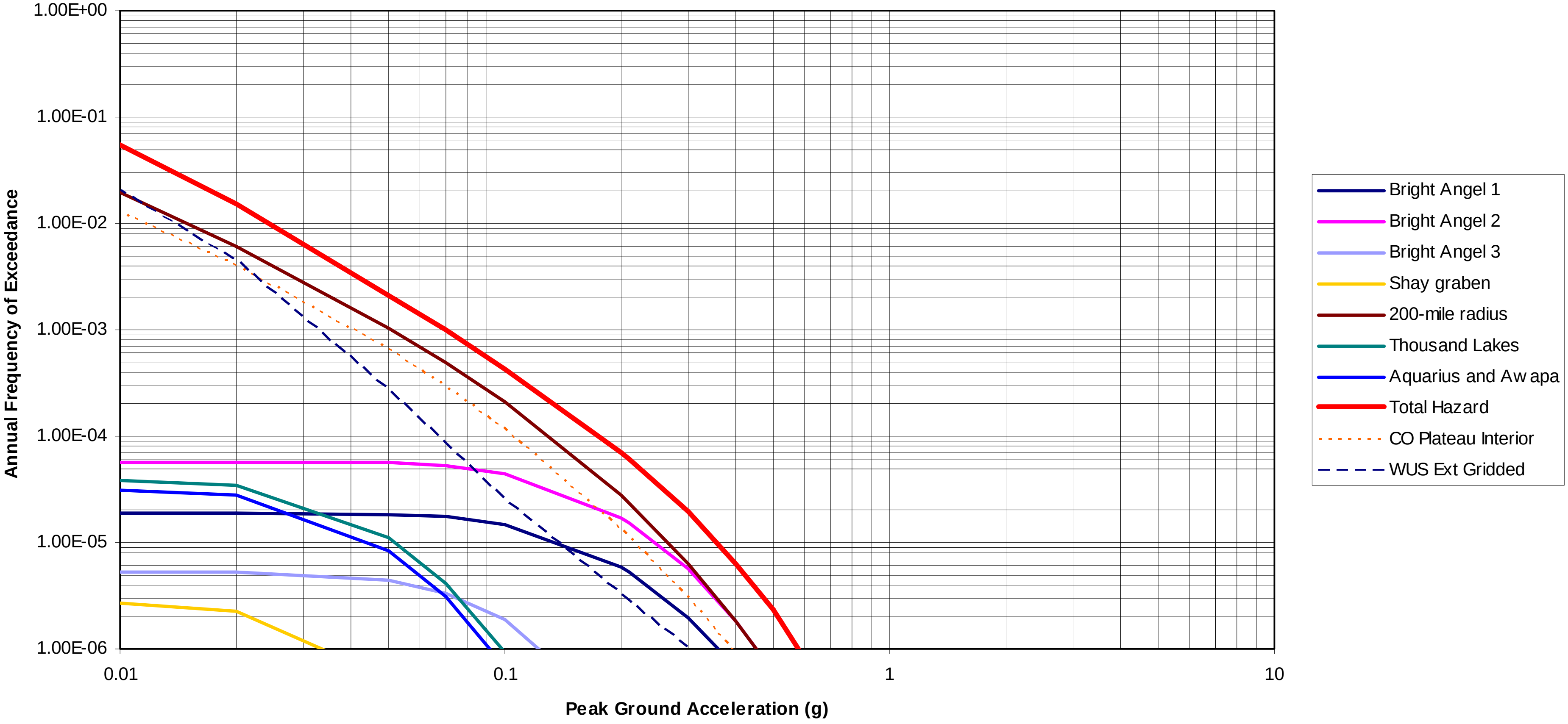
FIGURE 4
RECURRENCE CURVES FOR EARTHQUAKES
SHOOTARING CANYON SITE



Project No: 181692

April 2008

FIGURE 5
TOTAL SEISMIC HAZARD CURVE
SHOOTARING CANYON SITE



Project No: 181692

April 2008

FIGURE 6
SOURCE CONTRIBUTION TO TOTAL SEISMIC HAZARD
SHOOTARING CANYON SITE

APPENDIX A
DEAGGREGATION OF SEISMIC HAZARD FOR PGA FROM USGS NATIONAL SEISMIC HAZARDS MAPPING PROJECT

no fault-specific sources; site: NEHRP B-C boundary

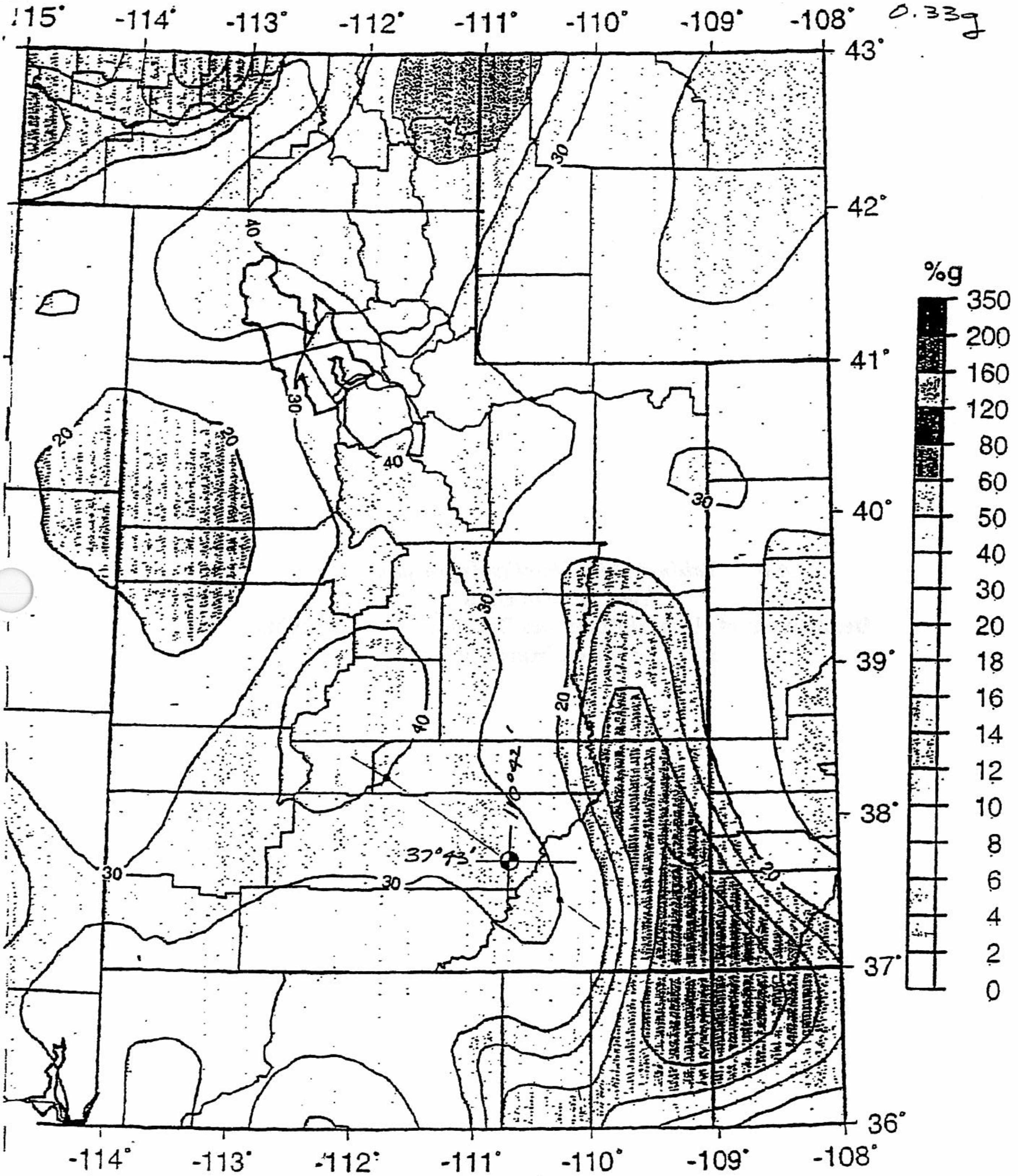
$\frac{23}{77} = 0.3$

U.S. Geological Survey

$0.3 \times 10 = 3$

National Seismic Hazard Mapping Project

0.33g



From Plateau Resources, Ltd et al. (2007),
Appendix A.5 Newmark Analysis, Letter Report, by Inberg-Miller
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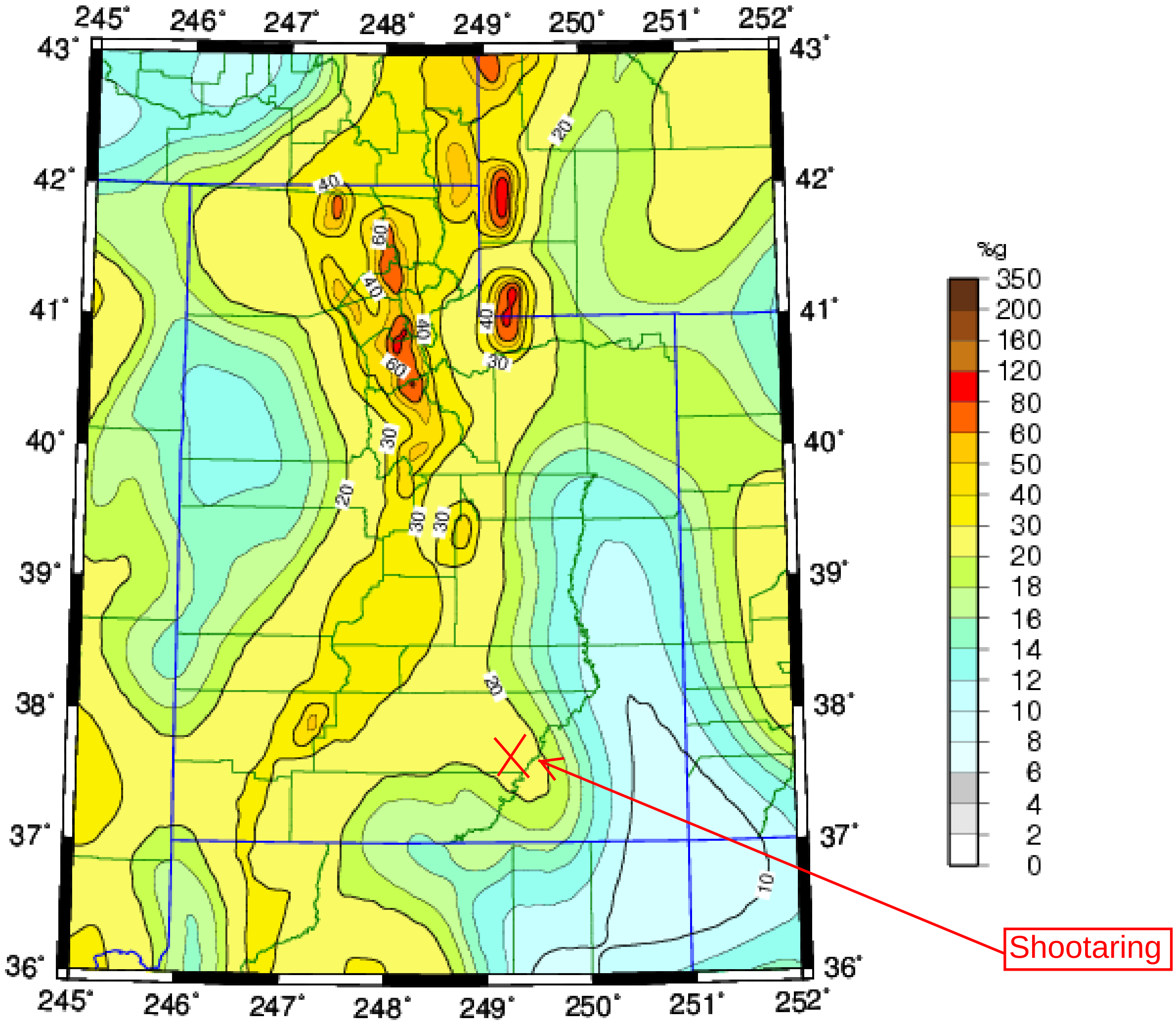
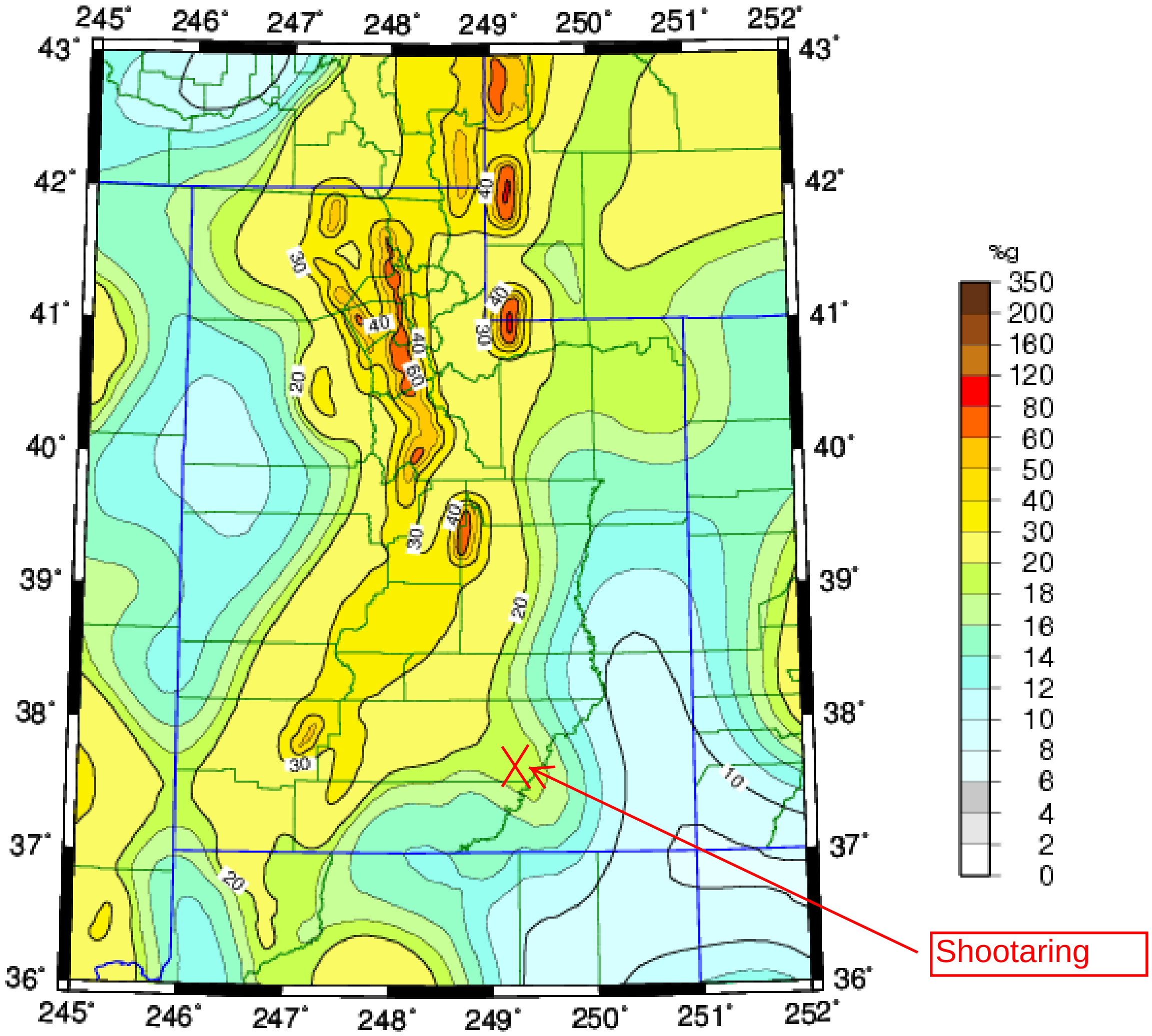
USGS National Seismic Hazard Mapping Project (1996)



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
U.S. Geological Survey
National Seismic Hazard Mapping Project

Albers Conic Equal-Area Projection
Standard Parallels: 29.5 and 45.5 degrees

USGS National Seismic Hazard Mapping Project (2002)



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
U.S. Geological Survey
National Seismic Hazard Mapping Project

Albers Conic Equal-Area Projection
Standard Parallels: 29.5 and 45.5 degrees

Deaggregation of Seismic Hazard for PGA & 2 Periods of Spectral Accel.
Data from U.S.G.S. National Seismic Hazards Mapping Project, 2002 version

```
PSHA Deaggregation. %contributions. site: Shootaring  long: 110.700 W., lat: 37.720 N.
USGS 2002-03 update files and programs. dM=0.2. Site descr:ROCK
Return period: 4975 yrs. Exceedance PGA =0.3227    g.
#Pr[at least one eq with median motion>=PGA in 50 yrs]=0.00478
DIST(KM) MAG(MW) ALL_EPS EPSILON>2  1<EPS<2 0<EPS<1 -1<EPS<0 -2<EPS<-1 EPS<-2
   11.0   4.60   6.015   0.739   2.631   2.261   0.368   0.016   0.000
   27.0   4.61   0.266   0.266   0.000   0.000   0.000   0.000   0.000
   12.0   4.80  13.152   1.476   5.427   5.169   1.031   0.049   0.000
   29.9   4.80   0.580   0.580   0.000   0.000   0.000   0.000   0.000
   12.3   5.03  11.236   0.788   4.426   4.679   1.251   0.092   0.000
   29.7   5.03   1.448   0.986   0.462   0.000   0.000   0.000   0.000
   12.8   5.21   4.981   0.306   1.750   2.237   0.639   0.049   0.000
   29.9   5.22   0.971   0.499   0.472   0.000   0.000   0.000   0.000
   13.3   5.40   8.620   0.393   2.670   4.115   1.356   0.085   0.001
   31.3   5.40   2.355   0.972   1.383   0.000   0.000   0.000   0.000
   55.4   5.41   0.070   0.070   0.000   0.000   0.000   0.000   0.000
   13.0   5.62   4.794   0.153   1.145   2.418   1.016   0.060   0.002
   30.6   5.62   2.361   0.595   1.467   0.300   0.000   0.000   0.000
   57.6   5.63   0.124   0.124   0.000   0.000   0.000   0.000   0.000
   14.4   5.81   5.249   0.159   1.222   2.641   1.130   0.094   0.004
   33.1   5.80   2.273   0.512   1.468   0.293   0.000   0.000   0.000
   58.3   5.82   0.208   0.193   0.014   0.000   0.000   0.000   0.000
   15.4   6.01   4.942   0.133   1.060   2.434   1.183   0.127   0.004
   35.6   6.01   1.738   0.294   1.168   0.276   0.000   0.000   0.000
   57.8   6.01   0.255   0.188   0.067   0.000   0.000   0.000   0.000
   81.6   6.02   0.067   0.067   0.000   0.000   0.000   0.000   0.000
   14.3   6.21   4.533   0.086   0.802   2.099   1.360   0.180   0.005
   34.2   6.21   2.512   0.283   1.395   0.834   0.000   0.000   0.000
   59.7   6.22   0.393   0.235   0.157   0.000   0.000   0.000   0.000
   85.3   6.23   0.086   0.084   0.002   0.000   0.000   0.000   0.000
   14.4   6.42   3.253   0.050   0.503   1.420   1.085   0.189   0.005
   34.5   6.42   2.209   0.177   1.010   0.968   0.054   0.000   0.000
   60.6   6.42   0.475   0.185   0.291   0.000   0.000   0.000   0.000
   88.3   6.42   0.089   0.082   0.007   0.000   0.000   0.000   0.000
  115.2   6.43   0.061   0.061   0.000   0.000   0.000   0.000   0.000
   14.2   6.59   2.058   0.033   0.290   0.850   0.738   0.144   0.004
   34.4   6.59   1.603   0.102   0.623   0.809   0.069   0.000   0.000
   58.6   6.60   0.338   0.084   0.246   0.008   0.000   0.000   0.000
   84.0   6.59   0.129   0.083   0.045   0.000   0.000   0.000   0.000
  119.6   6.60   0.076   0.072   0.003   0.000   0.000   0.000   0.000
   14.8   6.79   3.162   0.033   0.393   1.296   1.177   0.254   0.008
   36.0   6.78   2.185   0.126   0.759   1.169   0.131   0.000   0.000
   60.1   6.79   0.603   0.113   0.445   0.045   0.000   0.000   0.000
   85.0   6.79   0.219   0.101   0.119   0.000   0.000   0.000   0.000
  115.5   6.80   0.124   0.081   0.042   0.000   0.000   0.000   0.000
   14.9   6.98   1.734   0.012   0.194   0.712   0.656   0.155   0.005
   36.3   6.98   1.226   0.059   0.341   0.666   0.147   0.012   0.000
   60.5   6.98   0.418   0.056   0.286   0.076   0.000   0.000   0.000
   85.7   6.97   0.153   0.047   0.106   0.000   0.000   0.000   0.000
  115.0   6.95   0.066   0.033   0.033   0.000   0.000   0.000   0.000
  126.8   7.00   0.071   0.040   0.031   0.000   0.000   0.000   0.000
   63.6   7.16   0.055   0.007   0.035   0.012   0.000   0.000   0.000
   62.8   7.32   0.055   0.005   0.031   0.019   0.000   0.000   0.000
```

```
Summary statistics for above PSHA PGA  deaggregation, R=distance, e=epsilon:
 Mean src-site R=   20.3 km; M= 5.63; eps0=   0.07. Mean calculated for all sources.
Modal src-site R=   12.0 km; M= 4.80; eps0=   0.31 from peak (R,M) bin
Gridded source distance metrics: Rseis Rrup and Rjb
 MODE R*=  13.6km; M*= 4.80; EPS.INTERVAL: 1 to 2 sigma  % CONTRIB.=  5.427

Principal sources (faults, subduction, random seismicity having >10% contribution)
Source Category:              % contr.   R(km)    M   epsilon0 (mean values)
Midwest/CEUS gridded              99.20    20.4   5.62    0.07
Individual fault hazard details if contrib.>1%:
******************** Intermountain Seismic Belt***********************************
```

Deaggregation of Seismic Hazard for PGA & 3 Periods of Spectral Accel.
Data from U.S.G.S. National Seismic Hazards Mapping Project, 1996 version

```
PSHA Deaggregation. %contributions. site: Shootaring  long: 110.7000 W., lat: 37.7200 N.
Return period: 4975yrs. Exceedance PGA=0.3396090g. Computed annual rate=.20093E-03
DIST(KM) MAG(MW) ALL-EPS EPSILON>2  1<EPS<2 0<EPS<1 -1<EPS<0 -2<EPS<-1 EPS<-2
  11.7   4.84  25.886   5.081  12.688   8.053   0.064   0.000   0.000
  37.1   4.86   1.119   1.119   0.000   0.000   0.000   0.000   0.000
  57.5   4.87   0.096   0.096   0.000   0.000   0.000   0.000   0.000
  11.0   5.24  20.617   1.336   7.575  10.030   1.675   0.000   0.000
  29.5   5.26   7.455   3.431   3.938   0.086   0.000   0.000   0.000
  58.5   5.29   0.365   0.365   0.000   0.000   0.000   0.000   0.000
  11.8   5.70  13.565   0.580   3.236   7.129   2.591   0.029   0.000
  31.2   5.73   9.444   2.048   5.774   1.622   0.000   0.000   0.000
  59.5   5.76   0.983   0.924   0.059   0.000   0.000   0.000   0.000
  88.3   5.78   0.102   0.102   0.000   0.000   0.000   0.000   0.000
  12.3   6.22   7.887   0.307   1.494   3.448   2.414   0.224   0.000
  32.9   6.24   9.304   0.874   4.602   3.700   0.129   0.000   0.000
  60.6   6.27   1.872   0.940   0.931   0.000   0.000   0.000   0.000
  88.7   6.28   0.297   0.292   0.005   0.000   0.000   0.000   0.000
 112.7   6.29   0.167   0.167   0.000   0.000   0.000   0.000   0.000
  13.1   6.79   0.222   0.038   0.084   0.078   0.022   0.000   0.000
  73.0   6.76   0.080   0.028   0.052   0.000   0.000   0.000   0.000
  89.0   6.75   0.089   0.046   0.043   0.000   0.000   0.000   0.000
 113.5   6.75   0.055   0.044   0.011   0.000   0.000   0.000   0.000
  89.4   7.09   0.051   0.011   0.041   0.000   0.000   0.000   0.000

Summary statistics for above PSHA PGA  deaggregation, R=distance, e=epsilon:
 Mean src-site R=   19.7 km; M= 5.45; e0=   0.51; e=  1.22 for all sources.
Modal src-site R=   11.7 km; M= 4.84; e0=   0.79 from peak (R,M) bin
Primary distance metric: EPICENTRAL
 MODE R*=  12.1km; M*= 4.83; EPS.INTERVAL: 1 to 2 sigma  % CONTRIB.= 12.688

Principal sources (faults, subduction, random seismicity having >10% contribution)
Source:                       % contr.  R(km)   M   epsilon0 (mean values)
CEUS gridded seismicity,Frankel   61.52    19.9  5.44   0.42
CEUS gridded seismicity,Toro att  37.51    19.7  5.45   0.65
```

APPENDIX B
EARTHQUAKE EVENTS NEAR SHOOTARING CANYON SITE

APPENDIX B.1

EARTHQUAKE EVENTS WITH MAGNITUDE GREATER OR EQUAL TO 4.0 OCCURRING WITHIN 200 MILES OF SHOOTARING CANYON SITE

Appendix B.1: Earthquake events with Magnitude greater or equal to 4.0 occurring within 200 miles of Shootaring Canyon site

Source:
Open-File Report 97-464 "Preparation of Earthquake Catalogs for the National Seismic-Hazard Maps: Contiguous 48 States" by Charles Mueller, Margaret Hopper, and Arthur Frankel.
Western US Moment Magnitude Catalog

WUS > 4 Mw
BOLD data is more recent than January 1996

Magnitude (Mw)	Longitude (degree, west)	Latitude (degree, north)	Depth (km)	Year	Month	Day	Hour	Minute	Second	Catalog
5.7	-112.522	37.047	0	1887	12	5	15	30	0	DNAG
5.7	-112.114	39.952	0	1900	8	1	7	45	0	DNAG
6.5	-112.083	38.769	0	1901	11	14	4	39	0	DNAG
4.3	-112.639	38.279	0	1902	7	31	7	0	0	DNAG
6.3	-113.52	37.393	0	1902	11	17	19	50	0	DNAG
5	-113.007	38.393	0	1908	4	15	0	0	0	DNAG
5	-112.149	38.682	0	1910	1	10	13	0	0	DNAG
5.7	-111.5	36.5	0	1912	8	18	21	12	0	DNAG
4.3	-113.713	37.572	0	1914	12	14	5	30	0	DNAG
5	-111.655	40.239	0	1915	7	15	22	0	0	DNAG
4.3	-111.781	39.972	0	1916	2	5	6	25	0	DNAG
4.3	-113.573	37.106	0	1920	11	26	0	0	0	DNAG
5.2	-112.1	38.7	0	1921	9	29	14	12	0	USHIS
4.3	-113.233	38.166	0	1923	5	14	12	10	0	DNAG
5	-112.827	37.842	0	1933	1	20	13	10	0	DNAG
5	-112.1	36	0	1935	1	10	8	10	0	DNAG
4.3	-113.5	36.3	0	1936	1	22	3	38	0	SRA
4.3	-112.958	37.25	0	1936	5	9	10	25	0	DNAG
4.7	-113.3	38	0	1936	9	21	6	20	0	USHIS
4.3	-112.433	37.822	0	1937	2	18	4	15	0	DNAG
4	-114	37	0	1938	12	28	4	37	36	DNAG
4	-114.3	37.3	0	1941	5	6	3	11	42	CDMG
4.3	-111.65	39.58	0	1942	6	4	22	4	0	DNAG
5	-113.065	37.682	0	1942	8	30	22	8	0	DNAG
4	-114.1	37.4	0	1943	3	6	20	14	30	SRA
4.3	-112.26	38.58	0	1943	11	3	9	30	0	DNAG
4	-114.25	37.35	0	1943	11	6	3	55	0	CDMG
5	-111.986	38.765	0	1945	11	18	1	15	0	DNAG
4.3	-111.637	39.263	0	1948	11	4	13	18	0	DNAG
4.7	-113.1	37.5	0	1949	11	2	2	29	29	CDMG
4.3	-111.729	40.038	0	1950	5	8	22	35	0	DNAG
5	-111.9	38.5	0	1950	11	18	1	15	0	DNAG
4.3	-111.655	40.239	0	1951	8	12	0	26	0	DNAG
4.3	-111.86	40.396	0	1952	9	28	20	0	0	DNAG
4.3	-111.5	40.5	0	1953	5	24	2	54	29	DNAG
4.3	-112.433	37.822	0	1953	10	22	3	0	0	DNAG

Appendix B.1: Earthquake events with Magnitude greater or equal to 4.0 occurring within 200 miles of Shootaring Canyon site

5	-107.3	38	0	1955	8	3	6	39	42	DNAG
5	-111.44	40.341	0	1958	2	13	22	52	0	DNAG
4.3	-111.833	39.711	0	1958	11	28	13	30	39	DNAG
5	-112.5	38	0	1959	2	27	22	19	52	DNAG
5.6	-112.37	36.8	0	1959	7	21	17	39	29	USHIS
5	-111.5	35.5	0	1959	10	13	8	15	0	USHIS
5	-111.66	39.34	0	1961	4	16	5	2	39.3	DNAG
4.3	-114.333	37.667	0	1961	9	26	21	46	20	CDMG
4.7	-107.6	38.2	25	1962	2	5	14	45	51.1	USHIS
4.4	-112.9	37	21	1962	2	15	9	6	45.1	SRA
4.5	-112.4	36.9	26	1962	2	15	7	12	42.9	USHIS
4.5	-112.1	38	33	1962	6	5	22	29	45	USHIS
4.4	-114.2	37.5	0	1962	7	8	15	58	6	CDMG
4.3	-111	40	33	1962	9	7	8	47	19	DNAG
5	-111.91	39.53	7	1963	7	7	19	20	39.6	USHIS
4	-111.19	40.03	7	1963	7	9	20	25	25.8	SRA
4	-111.55	39.1	7	1966	4	23	20	20	53.3	SRA
4.2	-111.85	37.98	7	1966	5	20	13	40	47.9	SRA
5.4	-114.2	37.4	33	1966	9	22	18	57	36.5	USHIS
4.4	-111.6	35.8	34	1966	10	3	16	3	50.9	SRA
4.2	-113.16	38.2	7	1966	10	21	7	13	48.9	SRA
4.2	-112.3	38.8	33	1967	6	22	21	51	29.9	DNAG
4.2	-111.6	36.15	33	1967	9	4	23	27	46.2	SRA
5.6	-112.16	38.54	7	1967	10	4	10	20	12.8	USHIS
4	-112.04	39.27	7	1968	1	16	9	42	52.1	SRA
4	-113.082	38.407	0	1970	3	30	15	15	52.7	DNAG
4.1	-111.72	37.87	7	1970	4	18	10	42	11.5	SRA
4.2	-112.47	38.06	7	1970	5	23	22	55	23.2	SRA
4.1	-113.1	37.8	7	1971	11	10	14	10	23	SRA
4.5	-112.17	38.65	7	1972	1	3	10	20	38.9	USHIS
4.3	-112.07	38.67	7	1972	6	2	3	15	48.2	SRA
4.5	-111.35	40.51	7	1972	10	1	19	42	29.5	USHIS
4.6	-111.97	39.94	5	1980	5	24	10	3	36.3	SRA
4.3	-111.74	40.32	1	1981	2	20	9	13	1.2	USHIS
4.4	-113.3	37.59	1	1981	4	5	5	40	39.7	USHIS
4.3	-111.62	35.17	0	1981	12	6	9	9	20.3	DNAG
4.3	-112.04	38.71	5	1982	5	24	12	13	26.6	USHIS
4	-112.565	38.577	0	1983	12	9	8	58	40.7	SRA
4.6	-112.009	39.236	1	1986	3	24	22	40	23.4	USHIS
5.3	-111.614	38.824	10	1989	1	30	4	6	22.7	USHIS
4	-112.257	35.952	5	1989	3	5	0	40	30.8	PDE
4	-112.355	35.96	5	1992	3	14	5	13	31.6	PDE
4.4	-111.554	38.783	0	1992	6	24	7	31	20.2	PDE
4	-112.219	35.982	5	1992	7	5	18	17	29.9	PDE
5.7	-113.472	37.09	15	1992	9	2	10	26	20.9	PDE
5.3	-112.112	35.611	10	1993	4	29	8	21	0.8	PDE
4.1	-112.327	38.078	5	1994	9	6	3	48	37.6	PDE

Appendix B.1: Earthquake events with Magnitude greater or equal to 4.0 occurring within 200 miles of Shootaring Canyon site

4	-112.223	35.964	5	1995	4	17	8	23	46.2	PDE
4	-113.294	37.416	5	1995	6	8	8	29	16.5	PDE
4.5	**-112.467**	**38.206**	**5**	**1998**	**1**	**2**	**7**	**28**	**29**	**PDE**
4.1	**-112.49**	**37.97**	**2**	**1998**	**6**	**18**	**11**	**0**	**40**	**PDE**
4.2	**-112.727**	**38.077**	**5**	**1999**	**10**	**22**	**17**	**51**	**15.6**	**PDE**
4	**-111.53**	**38.75**	**2**	**1999**	**12**	**22**	**8**	**3**	**31**	**PDE**
4.1	**-112.56**	**38.73**	**0**	**2001**	**2**	**23**	**21**	**43**	**50**	**PDE**
4.4	**-111.521**	**38.731**	**3**	**2001**	**7**	**19**	**20**	**15**	**34**	**PDE**

Appendix B.1: Earthquake events with Magnitude greater or equal to 4.0 occurring within 200 miles of Shootaring Canyon site

Source:

Open-File Report 97-464 "Preparation of Earthquake Catalogs for the National Seismic-Hazard Maps: Contiguous 48 States" by Charles Mueller, Margaret Hopper, and Arthur Frankel.

Central/Eastern US Bodywave Magnitude Catalog

CEUS > 4 mb

BOLD data is more recent than January 1996

Magnitude (mb)	Longitude (degree, west)	Latitude (degree, north)	Depth (km)	Year	Month	Day	Hour	Minute	Second	Catalog
5	-107.5	39	0	1944	9	9	4	12	20	DNAG
5	-109.5	35.7	0	1950	1	17	0	51	0	DNAG
5.3	-110.5	40.5	0	1950	1	18	1	55	51	USHIS
4.3	-110.163	38.997	0	1953	7	30	5	45	0	DNAG
5.5	-107.6	38.3	49	1960	10	11	8	5	30.5	USHIS
4.3	-111.22	38.1	7	1963	9	30	9	17	39.3	SRA
4.2	-107.6	38.3	33	1966	9	4	9	52	34.5	SRA
4.4	-107.51	38.98	33	1967	1	12	3	52	6.2	SRA
4.1	-107.86	37.67	33	1967	1	16	9	22	45.9	SRA
4	-108.31	37.92	33	1970	2	3	5	59	35.6	SRA
4	-108.68	38.91	5	1971	11	12	9	30	44.6	SRA
4.1	-108.65	39.27	5	1975	1	30	14	48	40.3	SRA
4.6	-108.212	35.817	0	1976	1	5	6	23	33.9	SNMX
4.2	-108.222	35.748	0	1977	3	5	3	0	55.8	SNMX
4.8	-110.47	40.47	6	1977	9	30	10	19	20.4	USHIS
4	-110.574	37.42	5	1986	8	22	13	26	33.3	SRA
5.4	-110.869	39.128	10	1988	8	14	20	3	3.9	USHIS
4.5	-107.976	38.151	10	1994	9	13	6	1	23	PDE
4.1	-108.925	40.179	5	1995	3	20	12	46	16.3	PDE
4.2	**-110.878**	**39.12**	**0**	**1996**	**1**	**6**	**12**	**55**	**58.6**	**PDE**

Appendix B.1: Earthquake events with Magnitude greater or equal to 4.0 occurring within 200 miles of Shootaring Canyon site

Source: NEIC Earthquake search

FILE CREATED: Mon Sep 17 20:44:04 2007
Circle Search Earthquakes= 649
Circle Center Point Latitude: 37.720N Longitude: 110.700W
Radius: 320.000 km
Catalog Used: PDE
Data Selection: Historical & Preliminary Data

BOLD data is more recent than January 1996

Magnitude (Mw)	Longitude (degree, west)	Latitude (degree, north)	Depth (km)	Year	Month	Day	Hour	Minute	Second	Catalog
4.6	**-111.857**	**39.516**	**0**	**2003**	**4**	**17**	**1**	**4**	**19**	**PDE**
4.1	**-108.915**	**38.236**	**0**	**2004**	**11**	**7**	**6**	**54**	**59**	**PDE**
4.1	**-113.305**	**38.071**	**7**	**2007**	**8**	**18**	**13**	**16**	**31**	**PDE-Q**

APPENDIX B.2

EARTHQUAKE EVENTS WITHIN 80 MILES OF SHOOTARING CANYON SITE

Appendix B.2 Earthquake events within 80 miles of Shootaring Canyon Site

Source: NEIC Earthquake Search Results
UNITED STATES GEOLOGICAL SURVEY
EARTHQUAKE DATA BASE

FILE CREATED: Wed Mar 5 16:19:19 2008
Circle Search Earthquakes= 19
Circle Center Point Latitude: 37.720N Longitude: 110.700W
Radius: 129.000 km
Catalog Used: PDE
Data Selection: Historical & Preliminary Data
Catalog Used: USHIS
Data Selection: Significant U.S. Earthquakes (USHIS)
Catalog Used: SRA
Data Selection: Eastern, Central and Mountain States of U.S. (SRA)

	Date			COORDINATES		DEPTH	Magnitude (Mw)
CATALOG SOURCE	YEAR	MO	DA	LAT	LONG	km	
SRA	1885	12	17	38.3	-111.5		3.0
SRA	1896	10	14	38.4	-110.7		3.0
SRA	1935	10	6	37.9	-111.4		3.7
SRA	1943	8	14	38.2	-111.4		3.7
SRA	1955	3	27	38.3	-111.3		3.7
SRA	1962	3	16	36.88	-109.72		2.4
USHIS	1962	6	5	38	-112.1	33	4.5
SRA	1962	8	19	38.05	-112.09	7	3.2
SRA	1963	9	30	38.1	-111.22	7	4.3
SRA	1966	5	20	37.98	-111.85	7	4.1
SRA	1967	2	1	37.83	-110.17	7	2.5
SRA	1967	5	8	37.79	-110.17	7	2.7
SRA	1968	2	23	37.6	-110.24	7	2.8
SRA	1968	9	24	38.04	-112.08	7	3.6
SRA	1969	8	19	37.64	-110.65	7	2.6
SRA	1970	4	18	37.87	-111.72	7	3.7
SRA	1972	7	13	37.56	-111.94	7	2.9
SRA	1976	11	19	38.66	-111.35	7	2.5
SRA	1976	12	28	38.35	-111.17	7	2.5
SRA	1977	8	12	36.79	-110.92	7	2.6
SRA	1977	9	21	37.11	-111.54	7	2.7
SRA	1977	11	29	36.82	-110.99	7	3.0
SRA	1979	4	30	37.88	-111.02	7	3.8

SRA	1979	10	23	37.89	-110.93	7	3.5
SRA	1981	4	9	37.72	-110.54	2	2.7
SRA	1981	5	29	36.83	-110.37	1	3.0
SRA	1981	9	10	37.5	-110.56	2	3.1
SRA	1982	4	17	38.22	-111.3	9	3.0
SRA	1982	8	25	38.01	-111.64	7	2.7
SRA	1983	1	27	37.778	-110.674	7	3.3
PDE	1983	5	3	38.288	-110.592	7	3.0
PDE	1983	8	4	37.556	-110.409	7	2.7
SRA	1983	12	15	37.575	-110.51	3	2.8
PDE	1986	5	14	37.429	-110.561	5	3.2
PDE	1986	8	22	37.42	-110.574	5	4.0
SRA	1986	11	7	37.43	-110.297	1	3.0
PDE	1988	8	8	37.894	-111.23	15	2.8
PDE	1991	1	26	37.681	-111.429	9	3.3
PDE	1991	6	25	37.209	-110.358	1	3.0
PDE	1997	10	20	37.834	-111.879	10	3.1
PDE	1998	3	29	38.25	-111.35	3	3.2
PDE	2002	9	22	36.78	-111.31	1	2.9
PDE	2002	9	26	37.41	-110.53	3	3.0
PDE	2003	4	17	39.516	-111.857	0	4.4
PDE	2003	7	8	36.95	-111.79	6	3.3
PDE	2003	11	7	36.96	-111.77	9	3.1
PDE	2003	12	29	38.324	-110.56	4	2.9
PDE	2005	4	8	37.593	-111.066	6	2.8
PDE	2005	8	20	37.89	-111.77	0	3.2

APPENDIX C
QUATERNARY FAULTS AND FOLDS WITHIN 200 MILES OF SHOOTARING CANYON SITE

APPENDIX C.1
DETERMINISTIC CHARACTERISTICS

Appendix C.1: Quaternary faults and folds within 200 miles of Shootaring Canyon site - Deterministic Characteristics

Name of Fault	ID Number	Age of Most Recent Prehistoric Deformation (ya)^1	Slip-rate (mm/yr)	Fault Length (km)	Fault Type	Distance from site to surface trace of fault, (km)	MCE^2	PGA									
								Spudich et al. (1999) for rock sites		Abrahamson and Silva (1997) for normal faults		Campbell and Bozorgnia (2003) corrected		Campbell and Bozorgnia (2007)		Lognormal Mean	
								Mean	Mean +1SD	Mean	Mean +1SD	Mean	Mean +1SD	Mean	Mean +1SD	Mean	Mean +1SD
Random Earthquake						15	6.3	0.12	0.19	0.20	0.33	0.14	0.23	0.13	0.23	0.15	0.24
Fault 1, Bright Angel Fault Zone (Class B)	2514	Class B	<0.2	4.0	N	9	5.8	0.13	0.22	0.20	0.35	0.17	0.28	0.16	0.28	0.16	0.28
Fault 2, Bright Angel Fault Zone (Class B)	2514	Class B	<0.2	10.0	N	13	6.2	0.13	0.21	0.21	0.36	0.16	0.25	0.14	0.25	0.16	0.27
Fault 3, Bright Angel Fault Zone (Class B)	2514	Class B	<0.2	23.0	N	35	6.7	0.07	0.10	0.10	0.16	0.08	0.12	0.07	0.12	0.08	0.13
Needles fault zone (Class B)	2507	Class B	<0.2	28.5		60	6.8	0.04	0.06	0.06	0.09	0.05	0.07	0.04	0.07	0.05	0.07
Thousand Lake fault	2506	<750,000	<0.2	48.3		90	7.0	0.03	0.05	0.04	0.07	0.04	0.06	0.03	0.06	0.03	0.06
Shay graben faults (Class B)	2513	Class B	<0.2	39.5		88	6.9	0.03	0.05	0.04	0.07	0.03	0.05	0.03	0.06	0.03	0.06
Aquarius and Awapa Plateaus faults	2505	<1,600,000	<0.2	35.7		89	6.9	0.03	0.05	0.04	0.06	0.03	0.05	0.03	0.05	0.03	0.05
Paunsaugunt fault	2504	<1,600,000	<0.2	44.1		114	7.0	0.02	0.04	0.03	0.05	0.03	0.04			0.03	0.04
Sevier/Toroweap fault zone, Sevier section	997a	<130,000	0.2-1	88.7		142	7.3	0.02	0.04	0.03	0.05	0.03	0.04			0.03	0.04
Moab fault and Spanish Valley faults (Class B)	2476	Class B	<0.2	72.4	N	137	7.2	0.02	0.03	0.03	0.05	0.03	0.04			0.03	0.04
West Kaibab fault system	994	<1,600,000	<0.2	82.9	N	152	7.3	0.02	0.03	0.03	0.05	0.03	0.04			0.03	0.04
Wasatch monocline (Class B)	2450	<1,600,000	<0.2	103.5		164	7.4	0.02	0.03	0.03	0.05	0.03	0.04			0.02	0.04
Joes Valley fault zone, west fault	2453	<15,000	0.2-1	57.2		137	7.1	0.02	0.03	0.03	0.05	0.02	0.04			0.02	0.04
Southern Joes Valley fault zone	2456	<750,000	<0.2	47.2		137	7.0	0.02	0.03	0.03	0.04	0.02	0.04			0.02	0.04
Central Kaibab fault system	993	<1,600,000	<0.2	71.5	N	157	7.2	0.02	0.03	0.03	0.04	0.02	0.04			0.02	0.04
Salt and Cache Valleys faults (Class B)	2474	Class B	<0.2	57.9	N	147	7.1	0.02	0.03	0.03	0.04	0.02	0.04			0.02	0.04
Lisbon Valley fault zone (Class B)	2511	<1,600,000	<0.2	37.5		134	6.9	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Sevier fault	2355	<1,600,000	<0.2	41.3	N	139	7.0	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Sevier Valley-Marysvale-Circleville area faults	2500	<750,000	<0.2	34.9		137	6.9	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Ten Mile graben faults (Class B)	2473	Class B	<0.2	34.6	N	137	6.9	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Joes Valley fault zone, east fault	2455	<15,000	0.2-1	56.6		159	7.1	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Markagunt Plateau faults (Class B)	2535	<750,000	<0.2	56.4		162	7.1	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Paradox Valley graben (Class B)	2286	<1,600,000	<0.2	56.4	N	162	7.1	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Sevier/Toroweap fault zone, northern Toroweap section	997b	<130,000	<0.2	80.9		182	7.3	0.02	0.03	0.03	0.04	0.02	0.03			0.02	0.03
Eminence fault zone	992	<1,600,000	<0.2	36.0		155	6.9	0.02	0.03	0.02	0.04	0.02	0.03			0.02	0.03
Price River area faults (Class B)	2457	<1,600,000	<0.2	50.9	N	174	7.1	0.02	0.02	0.02	0.04	0.02	0.03			0.02	0.03
Bright Angel fault zone	991	<1,600,000	<0.2	66.0	N	193	7.2	0.01	0.02	0.02	0.03	0.02	0.03			0.02	0.03
Sevier Valley faults and folds (Class B)	2537	<130,000	<0.2	23.6		145	6.7	0.02	0.02	0.02	0.03	0.02	0.03			0.02	0.03
Big Gypsum Valley graben (Class B)	2288	Class B	<0.2	33.1		160	6.8	0.01	0.02	0.02	0.03	0.02	0.03			0.02	0.03
Valley Mountains monocline (Class B)	2449	<1,600,000	<0.2	38.6		174	6.9	0.01	0.02	0.02	0.03	0.02	0.03			0.02	0.03
Ryan Creek fault zone	2263	<1,600,000	<0.2	39.5	N	181	6.9	0.01	0.02	0.02	0.03	0.02	0.03			0.02	0.03

Appendix C.1: Quaternary faults and folds within 200 miles of Shootaring Canyon site - Deterministic Characteristics

Name of Fault	ID Number	Age of Most Recent Prehistoric Deformation (ya)[1]	Slip-rate (mm/yr)	Fault Length (km)	Fault Type	Distance from site to surface trace of fault, (km)	MCE[2]	PGA									
								Spudich et al. (1999) for rock sites		Abrahamson and Silva (1997) for normal faults		Campbell and Bozorgnia (2003) corrected		Campbell and Bozorgnia (2007)		Lognormal Mean	
								Mean	Mean +1SD	Mean	Mean +1SD	Mean	Mean +1SD	Mean	Mean +1SD	Mean	Mean +1SD
Tushar Mountains (east side) fault	2501	<1,600,000	<0.2	18.5		148	6.5	0.01	0.02	0.02	0.03	0.02	0.02			0.02	0.03
Beaver Basin faults, eastern margin faults	2492a	<15,000	<0.2	34.2		175	6.9	0.01	0.02	0.02	0.03	0.02	0.02			0.02	0.03
Beaver Basin faults, intrabasin faults	2492b	<15,000	<0.2	38.9		184	6.9	0.01	0.02	0.02	0.03	0.02	0.02			0.02	0.03
Joes Valley fault zone, intragraben faults	2454	<15,000	<0.2	34.0		181	6.9	0.01	0.02	0.02	0.03	0.02	0.02			0.02	0.02
Unnamed faults east of Atkinson Masa	2269	<1,600,000	<0.2	41.1	N	194	7.0	0.01	0.02	0.02	0.03	0.02	0.02			0.02	0.02
Gunnison fault	2445	<15,000	<0.2	42.0	N	197	7.0	0.01	0.02	0.02	0.03	0.02	0.02			0.02	0.02
White Mountain area faults	2451	<1,600,000	<0.2	16.4		157	6.5	0.01	0.02	0.02	0.03	0.01	0.02			0.01	0.02
Main Street fault zone	1002	<130,000	<0.2	87.3	N	266	7.3	0.01	0.02	0.02	0.03	0.01	0.02			0.01	0.02
Mineral Mountains (west side) faults	2489	<15,000	<0.2	36.6		203	6.9	0.01	0.02	0.02	0.03	0.01	0.02			0.01	0.02
Clear Lake fault zone (Class B)	2436	<15,000	<0.2	35.5		215	6.9	0.01	0.02	0.02	0.02	0.01	0.02			0.01	0.02
Hurricane fault zone, Anderson Junction section	998c	<15,000	0.2-1	42.2		233	7.0	0.01	0.02	0.02	0.02	0.01	0.02			0.01	0.02
Wasatch fault zone, Nephi section	2351h	<15,000	1-5	43.1		240	7.0	0.01	0.02	0.02	0.02	0.01	0.02			0.01	0.02
San Francisco Mountains (west side) fault	2486	<750,000	<0.2	41.4		238	7.0	0.01	0.02	0.02	0.02	0.01	0.02			0.01	0.02
Cricket Mountains (west side) fault	2460	<15,000	<0.2	41.0		238	7.0	0.01	0.02	0.02	0.02	0.01	0.02			0.01	0.02
Wah Wah Mountains (south end near Lund) fault	2485	<130,000	<0.2	40.2		239	6.9	0.01	0.02	0.01	0.02	0.01	0.02			0.01	0.02
Hurricane fault zone, southern section	998f	<1,600,000	<0.2	66.6	N	282	7.2	0.01	0.02	0.02	0.02	0.01	0.02			0.01	0.02

[1] ya = years ago

[2] Wells and Coppersmith, 1994

Class B=Geologic evidence demonstrates the existence of Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.

Fault Type: N=normal, R=reverse

APPENDIX C.2
PROBABILISTIC CHARACTERISTICS

Appendix C.2: Quaternary faults and folds capable of generating 0.05 g or greater at Shootaring Canyon site - Probabilistic Characteristics

Name of Fault	ID Number	Age of Most Recent Prehistoric Deformation (ya)[1]	Probability of Activity	Dip [2] (degrees)	Maximum Seismogenic Depth [2] (km)	Rate of Activity (mm/yr) [2]	MCE[2,3]
Fault 1, Bright Angel Fault Zone (Class B)	2514	Class B	0.1	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	5.8 (0.6) 5.5 (0.2) 6.1 (0.2)
Fault 2, Bright Angel Fault Zone (Class B)	2514	Class B	0.5	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	6.2 (0.6) 6.5 (0.2) 5.9 (0.2)
Fault 3, Bright Angel Fault Zone (Class B)	2514	Class B	0.1	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	6.7 (0.6) 7.0 (0.2) 6.4 (0.2)
Needles fault zone (Class B)	2507	Class B	0	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	6.8 (0.6) 7.1 (0.2) 6.5 (0.2)
Thousand Lake fault	2506	<750,000	1	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	7.0 (0.6) 7.3 (0.2) 6.7 (0.2)
Shay graben faults (Class B)	2513	Class B	0.1	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	6.9 (0.6) 7.2 (0.2) 6.6 (0.2)
Aquarius and Awapa Plateaus faults	2505	<1,600,000	1	60 (0.6) 40 (0.2) 80 (0.2)	15 (0.6) 12 (0.2) 20 (0.2)	0.02 (0.6) 0.2 (0.2) 0.005 (0.2)	6.9 (0.6) 7.2 (0.2) 6.6 (0.2)

[1] ya = years ago

[2] Number in parentheses represents weights for each parameter

[3] Wells and Coppersmith, 1994

Class B=Geologic evidence demonstrates the existence of Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.

APPENDIX D

DESCRIPTION OF FAULTS WITHIN PROJECT AREA, FROM USGS ET AL. 2006

Complete Report for Bright Angel fault system (Class B) No. 2514

Brief Report ||**Partial Report**

Compiled in cooperation with the Utah Geological Survey

citation for this record: **Black, B.D., and Hecker, S., compilers, 1999, Fault number 2514, Bright Angel fault system, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 10/15/2007 12:30 PM.**

Synopsis	Expansive area of poorly understood suspected Quaternary faults in the Colorado Plateau near the junction between the Colorado and San Juan Rivers. Owing to uncertainties in the timing of fault movement, we consider these faults to be Class B structures.
Name comments	**Fault ID Comments:** Refers to fault number 15-1 in Hecker (1993 #642).
County(s) and State (s)	GARFIELD COUNTY, UTAH KANE COUNTY, UTAH SAN JUAN COUNTY, UTAH
AMS sheet(s)	Escalante
Physiographic province(s)	COLORADO PLATEAUS
Reliability of location	Good Compiled at 1:500,000 scale. *Comments:* Mapped or discussed by Hintze (1963 #4991), Shoemaker and others (1978 #2155), and Woodward-Clyde Consultants (1982 #5025). Fault traces from 1:250,000-scale geologic mapping of Hintze (1963 #4991).
Geologic setting	Diffuse area of bedrock faults of varying orientation in the Monument upwarp/Glen Canyon area of the Colorado Plateaus in southeastern Utah.
Length (km)	102 km.
Average strike	N6°W
Sense of movement	Normal

Dip	*Comments:* Varies.
Paleoseismology studies	
Geomorphic expression	Faults are entirely within bedrock, thus Quaternary deformation can not be proven. The geometry and orientation of the faults are similar to known or questionable Quaternary structures in the San Francisco volcanic field in Arizona (Menges and Pearthree, 1983 #2073). A drainage system in the Cataract Creek basin in Arizona(?) appears to be older than movement on the fault system. Fold activity in the region is possible, although uncertain. Owing to uncertainties in the timing of fault movement, we consider these faults to be Class B structures.
Age of faulted surficial deposits	Jurassic, Quaternary(?)
Historic earthquake	
Most recent prehistoric deformation	Quaternary (<1.6 Ma) *Comments:* Based on geometry and orientation, and antecedent drainage.
Recurrence interval	
Slip-rate category	Less than 0.2 mm/yr
Date and Compiler (s)	1999 Bill D. Black, Utah Geological Survey Suzanne Hecker, U.S. Geological Survey
References	#642 Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., 6 pls., scale 1:500,000. #4991 Hintze, L.H., compiler, 1963, Geologic map of southwestern Utah: Utah State Land Board, 1 sheet, scale 1:250,000. #2073 Menges, C.M., and Pearthree, P.A., 1983, Map of neotectonic (latest Pliocene-Quaternary) deformation in Arizona: Arizona Bureau of Geology Mineral Technology Open-File Report 83-22, 48 p., scale 1:500,000. #2155 Shoemaker, E.M., Squires, R.L., and Abrams, M.J., 1978, Bright Angel and Mesa Butte fault systems in northern Arizona, in Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the Western Cordillera: Geological Society of America Memoir 152, p. 341-367. #5025 Woodward-Clyde Consultants, 1982, Geologic characterization report for the Paradox Basin study region, Utah study areas, volume II, Gibson Dome: Technical report to Battelle Memorial Institute, Office of Nuclear Waste Isolation, under Contract ONWI-290, variously paginated, scale 1:340,000.

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Complete Report for Needles fault zone (Class B) No. 2507

Brief Report ||Partial Report

Compiled in cooperation with the Utah Geological Survey

citation for this record: **Black, B.D., DuRoss, C.B., and Hecker, S., compilers, 2004, Fault number 2507, Needles fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 10/31/2007 04:12 AM.**

Synopsis	Poorly understood diffuse zone of suspected Holocene faulting along the Colorado River, which may have formed from gravity tectonics and salt flowage. Because of their possible non-seismogenic origin, we considered these features to be Class B structures.
Name comments	**Fault ID Comments:** Refers to fault number 18-11 in Hecker (1993 #642).
County(s) and State(s)	GARFIELD COUNTY, UTAH SAN JUAN COUNTY, UTAH WAYNE COUNTY, UTAH
AMS sheet(s)	Salina Moab Escalante
Physiographic province(s)	COLORADO PLATEAUS
Reliability of location	Poor Compiled at 1:340,000 scale. *Comments:* Mapped or discussed by Baker (1933 #4973), McGill and Stromquist (1974 #5000), Stromquist (1976 #5011), Hite (1982 #4992), Huntoon (1982 #586; 1988 #4994), Woodward-Clyde Consultants (1982 #5025), Biggar (1987 #4975), and Oviatt (1988 #5006). Fault traces from 1:340,000-scale geologic mapping of Woodward-Clyde Consultants (1982 #5025).
Geologic setting	The Needles fault zone consists of a diffuse zone of east- to northeast-oriented normal faults along Cataract Canyon, in and adjacent to Canyonlands National Park, in the Paradox Basin of eastern Utah. Extensional faulting may have initiated by a combination of (1) gravitational slip of sedimentary strata on evaporite deposits (Huntoon, 1982 #586, 1988 #4994; Crider and others, 2002 #6759), (2) mobilization and down-dip flowage of

	evaporites toward the Colorado River (Baker, 1933 #4973, McGill and Stromquist, 1974 #5000; Stromquist, 1976 #5011), and/or (3) salt dissolution and collapse (Hite, 1982 #4992). The gravitational-slip model may explain the formation of the anticlines resulting from compression across the floors of Cataract Canyon and its deep tributary canyons (Huntoon, 1982 #586, 1988 #4994). Extension may have begun in the late Cenozoic, and is considered active today (Huntoon, 1988 #4994; Crider and others, 2002 #6759).
Length (km)	29 km.
Average strike	N10°E
Sense of movement	Normal
Dip	*Comments:* Varies.
Paleoseismology studies	
Geomorphic expression	The faults bound grabens of varying ages. Youthfulness of faulting is suggested by good preservation of an abandoned, pre-graben drainage network and persistence of grabens as closed depressions. Sinkholes, some which may be historical, in many closed graben valleys may have formed by opening of bedrock fissures or, alternatively, by periodic flushing of material from old fissures. Stream braiding and aggradation within the grabens also suggest recent (Holocene?) subsidence. Changes in drainage patterns from north to south and the relatively simple, linear pattern of grabens at the eastern margin of the area suggest graben formation has progressed northward and eastward, away from the river. The oldest grabens (closest to the river) are inferred to have begun forming between about 1.4 Ma (based on a conservatively high estimate of canyon incision) and 85 ka (extrapolated from a 65 ka age for shallow graben sediments located a quarter of the distance from the river to the eastern margin of the graben system). Thus, some grabens may have formed as early as during early Pleistocene time. The long-term rate of extension across the fault zone is estimated at 2-20 mm/yr, based on geodetic and satellite radar interferometry (InSAR) monitoring of the deformation (Crider and others, 2002 #6759).
Age of faulted surficial deposits	Holocene(?).
Historic earthquake	
Most recent prehistoric deformation	Latest Quaternary (<15 ka) *Comments:* Based on drainage disruption, 14C and TL ages, and soil development.
Recurrence interval	
Slip-rate category	Less than 0.2 mm/yr *Comments:* Development of extensional grabens from west to east has apparently occurred at accelerated rates of 5-14 mm/yr associated with downcutting episodes on the Colorado River, and the process may be ongoing. However, any slip rate associated with deep tectonic processes is probably <0.2 mm/yr.
Date and Compiler (s)	2004 Bill D. Black, Utah Geological Survey Christopher B. DuRoss, Utah Geological Survey Suzanne Hecker, U.S. Geological Survey
References	#4973 Baker, A.A., 1933, Geology and oil possibilities of the Moab District, Grand and San Juan Counties, Utah: U.S. Geological Survey Bulletin 841, 95 p.

#6759 Crider, J.G., Owen, S.E., and Marsic, S.D., 2002, Monitoring active deformation in the grabens of Canyonlands National Park: Online, Geological Society of America Abstracts with Programs, , accessed November 3, 2004.

#642 Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., 6 pls., scale 1:500,000.

#4992 Hite, R.J., 1982, Task 1B--Geology, technical progress report for the quarter 1 July-30 September, 1982: Unpublished consultant's report for Battelle Memorial Institute, Office of Nuclear Waste Isolation, ONWI-9.

#4994 Huntoon, P., 1988, Late Cenozoic gravity tectonic deformation related to the Paradox salts in the Canyonlands area of Utah, in Doelling, H.H., Oviatt, C.G., and Huntoon, P.W., eds., Salt deformation in the Paradox region: Utah Geological and Mineral Survey Bulletin 122, p. 79-93.

#586 Huntoon, P.W., 1982, The Meander anticline, Canyonlands, Utah--An unloading structure resulting from horizontal gliding on salt: Geological Society of America Bulletin, v. 93, p. 941-950.

#5000 McGill, G.E., and Stromquist, A.W., 1974, A model for graben formation by subsurface flow; Canyonlands National Park, Utah: Amherst, University of Massachusetts, Department of Geology and Geography Contribution No. 15, p. 79.

#5011 Stromquist, A.W., Jr., 1976, Geometry and growth of grabens, lower Red Lake Canyon area, Canyonlands National Park, Utah: University of Massachusetts Department of Geology and Geography Contribution 28, p. 118.

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Complete Report for Shay graben faults (Class B) No. 2513

Brief Report ||Partial Report

Compiled in cooperation with the Utah Geological Survey

citation for this record: **Black, B.D., and Hecker, S., compilers, 1999, Fault number 2513, Shay graben faults, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 10/31/2007 04:14 AM.**

Synopsis	Poorly understood suspected Quaternary faults that bound a graben on the northern side of Shay Mountain in eastern Utah. Because of their possible non-seismogenic origin, we considered these features to be Class B structures.
Name comments	**Fault ID Comments:** Refers to fault number 19-1 in Hecker (1993 #642).
County(s) and State (s)	SAN JUAN COUNTY, UTAH
AMS sheet(s)	Cortez Moab
Physiographic province(s)	COLORADO PLATEAUS
Reliability of location	Good Compiled at 1:170,000 scale. *Comments:* Mapped by Woodward-Clyde Consultants (1982 #5025). Fault traces from 1:170,000- scale mapping of Woodward-Clyde Consultants (1982 #5025).
Geologic setting	Northeast-trending graben-bounding faults along the northern side of Shay Mountain in the Paradox Basin of eastern Utah.
Length (km)	40 km.
Average strike	N66°E
Sense of movement	Normal
Dip	
Paleoseismology studies	

Geomorphic expression	The faults form scarps that bound and define a northeast-trending graben. The north Shay fault has generally poorer surface expression than the south fault and is less likely to have had Quaternary displacement. The south Shay fault exhibits dip-slip displacement totaling less than 100 m and is regarded as a possible seismotectonic feature. Because of their possible non-seismogenic origin, we considered these features to be Class B structures.
Age of faulted surficial deposits	Quaternary pediment gravels
Historic earthquake	
Most recent prehistoric deformation	Quaternary (<1.6 Ma) *Comments:* Based on escarpment morphology and estimated age of displaced pediment surfaces.
Recurrence interval	
Slip-rate category	Less than 0.2 mm/yr
Date and Compiler (s)	1999 Bill D. Black, Utah Geological Survey Suzanne Hecker, U.S. Geological Survey
References	#642 Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., 6 pls., scale 1:500,000. #5025 Woodward-Clyde Consultants, 1982, Geologic characterization report for the Paradox Basin study region, Utah study areas, volume II, Gibson Dome: Technical report to Battelle Memorial Institute, Office of Nuclear Waste Isolation, under Contract ONWI-290, variously paginated, scale 1:340,000.

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Complete Report for Thousand Lake fault (Class A) No. 2506

Brief Report ||Partial Report

Compiled in cooperation with the Utah Geological Survey

citation for this record: **Black, B.D., and Hecker, S., compilers, 1999, Fault number 2506, Thousand Lake fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 10/30/2007 01:53 PM.**

Synopsis	Poorly understood Quaternary fault that bounds the western side of Thousand Lake and the Boulder Mountains.
Name comments	**Fault ID Comments:** Refers to fault number 14-1 in Hecker (1993 #642).
County(s) and State(s)	GARFIELD COUNTY, UTAH SEVIER COUNTY, UTAH WAYNE COUNTY, UTAH
AMS sheet(s)	Delta
Physiographic province(s)	COLORADO PLATEAUS
Reliability of location	Good Compiled at 1:250,000 scale. *Comments:* Mapped or discussed by Smith and others (1963 #4582), Anderson and Barnhard (1986 #895), Harty (1987 #4580), and Sergent, Hauskins, and Beckwith (1991 #4581). Fault traces from 1:250,000-scale mapping of Williams and Hackman (1971 #4578).
Geologic setting	Long, generally north-trending, sinuous range-front fault along the west side of Thousand Lake and Boulder Mountains, west of Capitol Reef.
Length (km)	48 km.
Average strike	N10°E
Sense of movement	Normal
Dip	

Paleoseismology studies	
Geomorphic expression	Remnants of Fremont River strath terraces (presumably truncated by faulting) may date from early Wisconsin time (>30 ka to 130 ka) and correlate with terraces on the downthrown side of the fault (Smith and others, 1963 #4582), but supporting evidence appears tenuous (Harty, 1987 #4580; Sergent and others, 1991 #4581). Projection of the terrace profiles suggests about 85 m of vertical displacement during late Pleistocene (post-early Wisconsin) to Holocene time (Smith and others, 1963 #4582). The extent of possible late Quaternary faulting is unknown, but based on the estimated terrace displacement and the distribution of total post-Oligocene throw along the fault, Anderson and Barnhard (1986 #895) postulated that Pleistocene displacements may exceed 100 m along the northern portion of the fault.
Age of faulted surficial deposits	Middle to late Quaternary.
Historic earthquake	
Most recent prehistoric deformation	Middle and late Quaternary (<750 ka) *Comments:*
Recurrence interval	
Slip-rate category	Less than 0.2 mm/yr
Date and Compiler (s)	1999 Bill D. Black, Utah Geological Survey Suzanne Hecker, U.S. Geological Survey
References	#895 Anderson, R.E., and Barnhard, T.P., 1986, Genetic relationship between faults and folds and determination of Laramide and neotectonic paleostress, western Colorado Plateau-transition zone, central Utah: Tectonics, v. 5, p. 335-357. #2479 Dohrenwend, J.C., and Moring, B., C., 1993, Reconnaissance photogeologic map of late Tertiary and Quaternary faults in Nevada: Geological Society of America Abstracts with Programs, v. 25, no. 5, p. 31. #4580 Harty, K.M., 1987, Field reconnaissance of Thousand Lake fault zone: Utah Geological and Mineral Survey, memorandum, 2 p. #642 Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., 6 pls., scale 1:500,000. #4581 Sergent, Hauskins, and Beckwith, 1991, Report for final preliminary engineering geology, geoseismic, and geotechnical study, proposed Torrey Dam and Reservoir, approximately one mile west of Torrey, Utah, for Wayne County Conservancy District: Salt Lake City, consultant's report prepared for Utah Department of Natural Resources, Division of Water Resources, SHB Job No. E90-2027, 18 p. #4582 Smith, J.F., Jr., Huff, L.C., Hinrichs, E.N., and Luedke, R.G., 1963, Geology of the Capitol Reef area, Wayne and Garfield Counties, Utah: U.S. Geological Survey Professional Paper 363, 102 p. #4578 Williams, P.L., and Hackman, R.J., 1971, Geology, structure, and uranium deposits of the Salina quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591, scale 1:250,000.

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URL: http://gldims.cr.usgs.gov/webapps/cfusion/Sites/qfault/qf_web_disp.cfm
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TAKE PRIDE IN AMERICA

Complete Report for Aquarius and Awapa Plateaus faults (Class A) No. 2505

Brief Report ||Partial Report

Compiled in cooperation with the Utah Geological Survey

citation for this record: **Black, B.D., and Hecker, S., compilers, 1999, Fault number 2505, Aquarius and Awapa Plateaus faults, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 10/30/2007 01:54 PM.**

Synopsis	Poorly understood Quaternary(?) faults in the Aquarius and Awapa Plateaus.
Name comments	**Fault ID Comments:** Refers to fault number 14-2 in Hecker (1993 #642).
County(s) and State(s)	GARFIELD COUNTY, UTAH PIUTE COUNTY, UTAH WAYNE COUNTY, UTAH
AMS sheet(s)	Salina
Physiographic province(s)	COLORADO PLATEAUS
Reliability of location	Good Compiled at 1:250,000 scale. *Comments:* Mapped or discussed by Williams and Hackman (1971 #4578) and Luedke and Smith (1978 #4579). Fault traces from 1:250,000-scale mapping of Williams (1964 #2789) and Williams and Hackman (1971 #4578).
Geologic setting	Diffuse area of normal faulting in Tertiary and Quaternary volcanic rocks in the Aquarius and Awapa Plateaus near the eastern boundary of the Basin and Range province.
Length (km)	36 km.
Average strike	N19°E
Sense of movement	Normal
Dip	

Paleoseismology studies	
Geomorphic expression	Faults displace or define the margins of Tertiary to Quaternary (<5 Ma) basalts.
Age of faulted surficial deposits	Quaternary(?)
Historic earthquake	
Most recent prehistoric deformation	Quaternary (<1.6 Ma) *Comments:*
Recurrence interval	
Slip-rate category	Less than 0.2 mm/yr
Date and Compiler(s)	1999 Bill D. Black, Utah Geological Survey Suzanne Hecker, U.S. Geological Survey
References	#642 Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., 6 pls., scale 1:500,000. #4579 Luedke, R.G., and Smith, R.L., 1978, Map showing distribution, composition, and age of late Cenozoic volcanic centers in Colorado, Utah, and southwestern Wyoming: U.S. Geological Survey Miscellaneous Investigations Map I-1091-B, scale 1:1,000,000. #2789 Williams, P.L., 1964, Geology, structure, and uranium deposits of the Moab quadrangle, Colorado and Utah: U.S. Geological Survey Miscellaneous Geologic Investigations I-360. #4578 Williams, P.L., and Hackman, R.J., 1971, Geology, structure, and uranium deposits of the Salina quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Map I-591, scale 1:250,000.

APPENDIX E
EZ-FRISK SOFTWARE INPUT

```
                 ***********************************************
                 *****               EZ-FRISK              *****
                 ***** SEISMIC HAZARD ANALYSIS DEFINITION  *****
                 *****       RISK ENGINEERING, INC.        *****
                 *****          BOULDER, CO  USA           *****
                 ***********************************************

PROGRAM VERSION
  EZ-FRISK 7.25

ANALYSIS TITLE:
  Seismic Hazard Analysis Round Three Interrogatory

ANALYSIS TYPE:
  Single Site Analysis

SITE COORDINATES
  Latitude 37.72
  Longitude -110.7

HAZARD DEAGGREGATION
  Status: ON
  Period: PGA
  Amplitude: 0.21
  Bin Configuration
    Magnitude
      Scale:         Moment Magnitude
      Lowest Value:  5 Mw
      Highest Value: 9 Mw
      Bin Size:      0.1
    Distance
      Lowest Value:  0 km
      Highest Value: 102.5 km
      Bin Size:      2.5 km
    Epsilon
      Lowest Value:  -2.2
      Highest Value: 4.2
      Bin Size:      0.2

SOIL AMPLIFICATION
  Method: Do not use soil amplification

ATTENUATION EQUATION SITE PARAMETERS
  Vs30 (m/s): 760
  Z25 (km): 0

AMPLITUDES - Acceleration (g)
  0.0001
  0.001
  0.01
  0.02
  0.05
  0.07
  0.1
  0.2
  0.21
  0.3
  0.4
  0.5
  0.7
  1
  2
  3

PERIODS (s)
  PGA
  5.e-002
  0.1
  0.2
  0.3
  0.4
```

```
  0.5
  0.75
  1.
  2.
  3.
  4.

DETERMINISTIC FRACTILES

PLOTTING PARAMETERS
  Period at which to plot PGA: 0.0001

CALCULATIONAL PARAMETERS
  Fault Seismic Sources -
    Down dip integration increment       :   1 km
    Horizontal integration increment     :   1 km
    Number rupture length per EarthQuake :   4
    Include near-source directivity      :   NO
  Area Seismic Sources -
    Maximum inclusion distance           :   1000 km
    Vertical integration increment       :   3 km
    Number of rupture azimuths           :   3
    Minimum epicentral distance step     :   0.5 km
    Maximum epicentral distance step     :   10 km
  Background Seismic Sources -
    Maximum inclusion distance            :   400 km
    Default number of rupture azimuths    :   10
    Maximum distance for default azimuths :   20 km
    Minimum distance for one azimuth      :   70
  All Seismic Sources -
    Magnitude integration step           :   0.1 M
    Apply magnitude scaling              :   NO

ATTENUATION EQUATIONS

  Name: Abra.-Silva (1997) Rock USGS 2002
  Database: C:\Program Files\EZ-FRISK 7.25\Files\standard.bin-attendb
  Base: Abrahamson-Silva 1997
  Truncation Type: Trunc Sigma*Value
  Truncation Value: 3
  Magnitude Scale: Moment Magnitude
  Distance Type: Distance To Rupture

  Name: Abra.-Silva (1997) Rock USGS 2002 Gridded
  Database: C:\Program Files\EZ-FRISK 7.25\Files\standard.bin-attendb
  Base: Abrahamson-Silva 1997
  Truncation Type: Trunc Sigma*Value
  Truncation Value: 3
  Magnitude Scale: Moment Magnitude
  Distance Type: Distance To Rupture

  Name: Campbell-Bozorgnia (2008) NGA 3 sigma
  Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-attendb
  Base: Campbell-Bozorgnia 2008 NGA
  Truncation Type: Trunc Sigma*Value
  Truncation Value: 3
  Magnitude Scale: Moment Magnitude
  Distance Type: Distance To Rupture

  Name: Spudich 1999 Rock USGS 2002
  Database: C:\Program Files\EZ-FRISK 7.25\Files\standard.bin-attendb
  Base: Spudich 1997/99
  Truncation Type: Trunc Sigma*Value
  Truncation Value: 3
  Magnitude Scale: Moment Magnitude
  Distance Type: Horizontal Distance To Rupture

SEISMIC SOURCES

Name: Bright Angel Fault Zone - Fault 1
```

```
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.10000000
Deterministic Magnitude: 5.8

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  5.500000  6.100000  1.842100
5.800000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  5.500000  6.100000  1.842100
5.800000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  5.500000  6.100000  1.842100
5.800000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  5.500000  6.100000  0.000000
5.800000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  5.500000  6.100000  0.000000
5.800000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  5.500000  6.100000  0.000000
5.800000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    37.7529  -110.6010
    37.7824  -110.5760

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Bright Angel Fault Zone - Fault 2
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.50000000
Deterministic Magnitude: 6.2

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        15
```

```
Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  5.900000  6.500000  1.842100
6.200000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  5.900000  6.500000  1.842100
6.200000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  5.900000  6.500000  1.842100
6.200000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  5.900000  6.500000  0.000000
6.200000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  5.900000  6.500000  0.000000
6.200000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  5.900000  6.500000  0.000000
6.200000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    37.7711  -110.4590
    37.6928  -110.5040

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Bright Angel Fault Zone - Fault 3
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.10000000
Deterministic Magnitude: 6.7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
         120       120         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.360000  6.960000  1.842100
6.660000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.360000  6.960000  1.842100
6.660000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  1.000e-001  6.360000  6.960000  1.842100
6.660000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.360000  6.960000  0.000000
6.660000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.360000  6.960000  0.000000
6.660000  0.120000  0.000000  0.000000
```

```
           Normal  0.200000        Slip  1.000e-001  6.360000  6.960000  0.000000
6.660000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    37.3762  -110.4140
    37.6652  -110.2590

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Needles
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.00000000
Deterministic Magnitude: 6.8

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.500000  7.100000  1.842100
6.800000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.500000  7.100000  1.842100
6.800000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.500000  7.100000  1.842100
6.800000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.500000  7.100000  0.000000
6.800000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.500000  7.100000  0.000000
6.800000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.500000  7.100000  0.000000
6.800000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
```

```
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1900  -109.8600
    38.0400  -110.1600

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Shay graben
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.10000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
         120       120         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  1.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  1.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0400  -109.2800
    37.9100  -109.7200

Attenuation Equations for Source:
```

```
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Ext Gridded
Region: WUS - USGS2002 Bkgd
Category: Gridded Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Regions\USGS 2002 v210\Files\Background Data\usgs2002.xml-gridSsDb
Magnitude Scale: Moment Magnitude

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002 Gridded
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Aquarius and Awapa plateau 40_12
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          40        40         0       0.1        12

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200
```

```
Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Aquarius and Awapa plateau 40_15
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          40        40         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Aquarius and Awapa plateau 40_20
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
```

```
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.03990000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          40        40         0       0.1        20

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Aquarius and Awapa plateau 60_12
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        12

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
```

```
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl         Aw        Bw      Sigw         Aa         Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Aquarius and Awapa plateau 60_15
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.36000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
```

```
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Aquarius and Awapa plateau 60_20
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        20

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
```

```
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Aquarius and Awapa plateau 80_12
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          80        80         0       0.1        12

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma
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*******************************************

Name: Aquarius and Awapa plateau 80_15
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          80        80         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Aquarius and Awapa plateau 80_20
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 6.9

Fault Profile Parameters:
```

```
        Dip1      Dip2    Depth1    Depth2    Depth3
          80        80         0       0.1        20

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.600000  7.200000  1.842100
6.900000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.600000  7.200000  0.000000
6.900000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.0300  -111.7800
    38.1700  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Thousand Lakes 40_12
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          40        40         0       0.1        12

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
```

```
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl         Aw        Bw      Sigw         Aa         Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 40_15
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          40        40         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl         Aw        Bw      Sigw         Aa         Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
```

```
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 40_20
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          40        40         0       0.1        20

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
```

```
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 60_12
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        12

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1  Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 60_15
Region: Utah
Category: Fault Seismic Source
```

```
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.36000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 60_20
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          60        60         0       0.1        20

Magnitude Recurrence Distributions:
```

```
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 80_12
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          80        80         0       0.1        12

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
```

```
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 80_15
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.12000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          80        80         0       0.1        15

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl        Aw        Bw      Sigw        Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
```

```
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

*******************************************

Name: Thousand Lakes 80_20
Region: Utah
Category: Fault Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-faultdb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.04000000
Deterministic Magnitude: 7

Fault Profile Parameters:
        Dip1      Dip2    Depth1    Depth2    Depth3
          80        80         0       0.1        20

Magnitude Recurrence Distributions:
        ModelType    Weight    RateType        Rate    MinMag    MaxMag      Beta
Mean     Sigma    Delta1    Delta2
      Exponential       0.1        Slip  2.000e-002  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  5.000e-003  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
      Exponential  0.050000        Slip  2.000e-001  6.700000  7.300000  1.842100
7.000000  0.120000  0.000000  0.000000
           Normal  0.400000        Slip  2.000e-002  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  5.000e-003  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000
           Normal  0.200000        Slip  2.000e-001  6.700000  7.300000  0.000000
7.000000  0.120000  0.000000  0.000000

Rupture Length Parameters
          Al        Bl      Sigl         Aw        Bw      Sigw         Aa        Ba
Sigw
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000
    4.000000  0.000000  0.010000  4.000000  0.000000  0.010000  0.000000  0.000000
0.000000

Trace Coordinates:
  Latitude   Longitude
    38.1200  -111.5900
    38.5500  -111.5200

Attenuation Equations for Source:
```

```
  Name: Abra.-Silva (1997) Rock USGS 2002
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: 200-mile radius circle around Shootaring
Region: Utah
Category: Area Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-areadb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.25
Minimum Depth: 3 km
Maximum Depth: 20 km

Boundary Coordinates:
  Latitude   Longitude
  -109.6290    40.4976
  -109.5150    40.4693
  -108.4690    40.0373
  -107.6650    39.3720
  -107.1800    38.5446
  -107.0530    37.6406
  -107.2820    36.7494
  -107.8350    35.9565
  -108.2390    35.6021
  -108.6510    35.3360
  -109.4470    35.0011
  -110.7480    34.8185
  -111.8400    34.9685
  -112.8290    35.3814
  -113.6260    36.0196
  -114.1520    36.8545
  -114.3510    37.7207
  -114.1920    38.6220
  -113.6760    39.4386
  -112.8470    40.0860
  -111.7850    40.4946
  -109.6290    40.4976

Magnitude Recurrence Distribution:
  Minimum Magnitude: 4 Mw
  Maximum Magnitude: 6.3 Mw
  Activity Rate: 1.55
  Beta: 1.96
  Al: -4
  Bl: 0

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002 Gridded
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Name: Wong et al. 1996
Region: Utah
Category: Area Seismic Source
Database: C:\Documents and Settings\roslyn.stern\Local Settings\Application Data\Risk
Engineering\EZ-FRISK\Files\user.xml-areadb
Fault Mechanism: Normal
Magnitude Scale: Moment Magnitude
Probability of Activity: 0.25
Minimum Depth: 3 km
Maximum Depth: 20 km

Boundary Coordinates:
  Latitude   Longitude
  -112.0000    39.4000
```

```
  -108.6000    39.4000
  -108.6000    35.2000
  -112.0000    35.2000
  -112.0000    39.4000

Magnitude Recurrence Distribution:
  Minimum Magnitude: 3 Mw
  Maximum Magnitude: 6 Mw
  Activity Rate: 1.83
  Beta: 2.12
  Al: -4
  Bl: 0

Attenuation Equations for Source:
  Name: Abra.-Silva (1997) Rock USGS 2002 Gridded
  Name: Spudich 1999 Rock USGS 2002
  Name: Campbell-Bozorgnia (2008) NGA 3 sigma

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Echo File Creation Time: 09:55:42 Monday, March 10, 2008
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ATTACHMENT E

SUPPORTING DOCUMENTATION FOR INTERROGATORY R313-24-4-19/03: DOUBLE LINER SYSTEM CQAP PLAN AND SPECIFICATIONS

COMPARISON OF FOUR METHODS TO ASSESS HYDRAULIC CONDUCTIVITY

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ABSTRACT: A hydraulic conductivity assessment that was conducted on four test pads constructed to the same specifications with soil from the same source by four different contractors is described. The test pads had distinctly different field hydraulic conductivities, even though they were constructed with similar soil, to similar compaction conditions, and with similar machinery. Adequate hydration time was key in achieving low field hydraulic conductivity. More extensive processing was another factor responsible for low field hydraulic conductivity. Four different test methods were used to assess the hydraulic conductivity of each test pad: (1) sealed double-ring infiltrometers (SDRIs); (2) two-stage borehole permeameters; (3) laboratory hydraulic conductivity tests on large block specimens; and (4) laboratory hydraulic conductivity tests on small specimens collected in thin-wall sampling tubes. The tests were conducted independently by each of the writers. After the tests were completed, the results were submitted and compared. Analysis of the test results shows that the three large-scale test methods generally yield similar hydraulic conductivities. For two of the test pads, however, the hydraulic conductivities of the specimens collected in sampling tubes were significantly lower than the field hydraulic conductivities. Both of these test pads had high field hydraulic conductivity. Thus, there is little value in using small specimens to assess field hydraulic conductivity.

INTRODUCTION

Four test pads were constructed using a low plasticity clay prior to construction of an earthen cap for closure of a 14-hectare surface impoundment at a chemical plant in Pampa, Tex. The test pads were constructed by four different contractors using their own methods, but following specifications for the project that were developed by the project consultant. The four contractors were selected from prequalification questionnaires and submittal packages. Each contractor was hired to construct a test pad of specified size and thickness, using a clay soil available from a stockpile at the site. Selection of the contractor for the closure work was to be based on both a bid from the contractor and the performance of that contractor's test pad. In particular, the field hydraulic conductivity had to be $\leq 1 \times 10^{-9}$ m/s.

The hydraulic conductivity of each test pad was assessed immediately after construction (October to December 1992) using sealed double-ring infiltrometers (SDRIs) and laboratory tests on small, 71-mm-diameter specimens collected using thin-wall sampling tubes (i.e., Shelby tubes). The results of these tests were used for contractor selection. Comparative hydraulic conductivity measurements were made 10 months after test pad construction (August 1993) following regulatory approval based on the SDRI results. In the interim, each test pad was protected with a sheet of polyethylene and a 30-cm-thick sand layer. The comparative measurements were made in the field using two-stage borehole permeameters (TSBs), and in the laboratory on large block specimens and an additional set of small specimens collected in thin-wall sampling tubes. Long-term measurements were also made with the SDRIs in August 1993.

The tests were conducted in a blind manner by the following persons: SDRIs by Trautwein and Gunter; TSBs by Boutwell; blocks and second set of sampling tubes by Benson; and first set of sampling tubes by project consultant. After the hydraulic conductivity tests were complete, the data were submitted and distributed to the writers. This paper describes the construction of the test pads and the results of the hydraulic conductivity tests. To the writers' knowledge, this is the first time that these field-scale test methods have been simultaneously compared on multiple test pads, especially through blind testing.

TEST PADS

Soil

Soil for the test pads was excavated and stockpiled several years prior to construction. The soil is classified as CL in the Unified Soil Classification System (USCS), and is composed of 1% gravel, 85% fines, and 42% clay (2 μm fraction) (ASTM D 422). The liquid limit is 41 and the plasticity index is 23 (ASTM D 4318). X-ray diffraction showed that the clay fraction is predominantly mixed layers of smectite and illite, with 20–30% of the layers being illite. The specific gravity of solids is 2.70.

Compaction tests were conducted on the soil by the writers to define compaction curves corresponding to modified

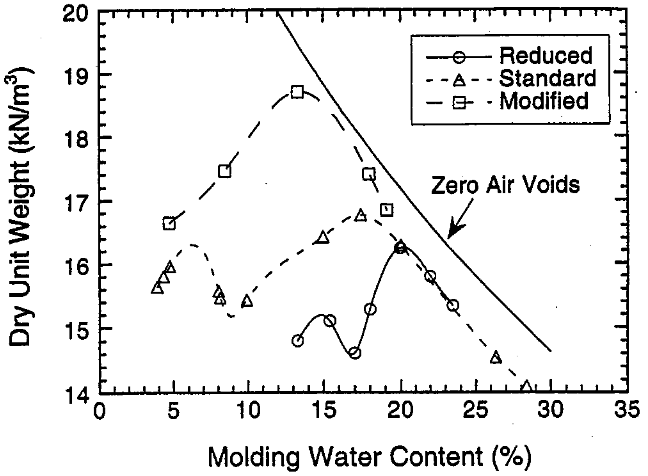

FIG. 1. Compaction Curves for Reduced, Standard, and Modified Proctor Effort

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(ASTM D 1557), standard (ASTM D 698), and reduced Proctor compactive effort. Reduced Proctor compaction is performed using the procedures described in ASTM D 698, except 15 blows are applied per layer (Daniel and Benson 1990). Results of the compaction tests are shown in Fig. 1. These compaction tests were conducted in 1993 and were not those used to control construction of the test pads. The compaction curves developed during construction exhibited significant scatter in optimum water content and maximum dry unit weight that was not consistent with the low variability of the soil. The scatter is evident in Fig. 2, which shows the optimum water content and maximum dry unit weight obtained from each compaction test performed during construction of the test pads. The initial saturation at optimum water content varied from 63–96%. In contrast, for the curves developed in 1993, the line of optimums corresponds to an initial, as-compacted saturation of 82% (Fig. 1) and the maximum dry unit weight increases linearly with the logarithm of compactive energy, both of which are characteristic of compacted clays used to build clay liners (Benson and Boutwell 1992).

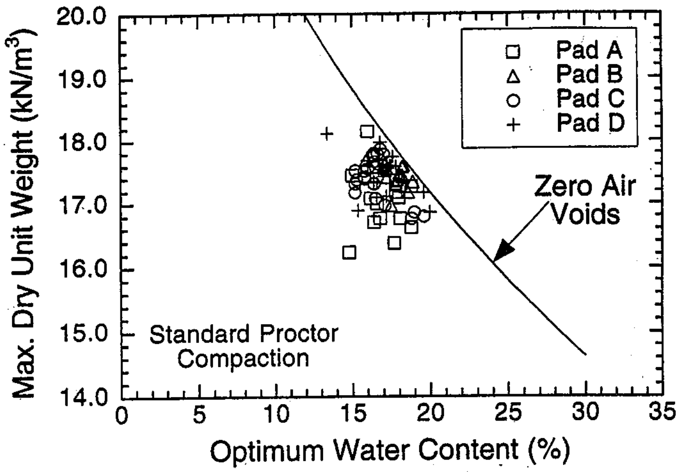


FIG. 2. Maximum Dry Unit Weights and Optimum Water Contents Measured During Construction

Specifications and Construction Testing

Three of the test pads were approximately 46 m long, 18 m wide, and 0.9 m thick as specified by the project consultant. Test pad B, however, was 22 m wide to accommodate wider construction equipment used by that contractor. Under each test pad, a free-draining sand underdrain at least 0.15 m thick was placed to provide a known hydraulic boundary condition for hydraulic conductivity computations.

The contractors were required to place the clay at a water content between optimum water content and 3% wet of optimum water content, and to a dry unit weight of at least 95% of standard Proctor (ASTM D 698) maximum dry unit weight. Each contractor was also informed that, if awarded the project, the methods used to construct the test pad would have to be used to construct the entire cap. Consequently, the contractors were cautious regarding the effort used when constructing the test pads.

Field measurements of water content and dry unit weight (ASTM D 2922 and D 3017) were conducted at a rate of one

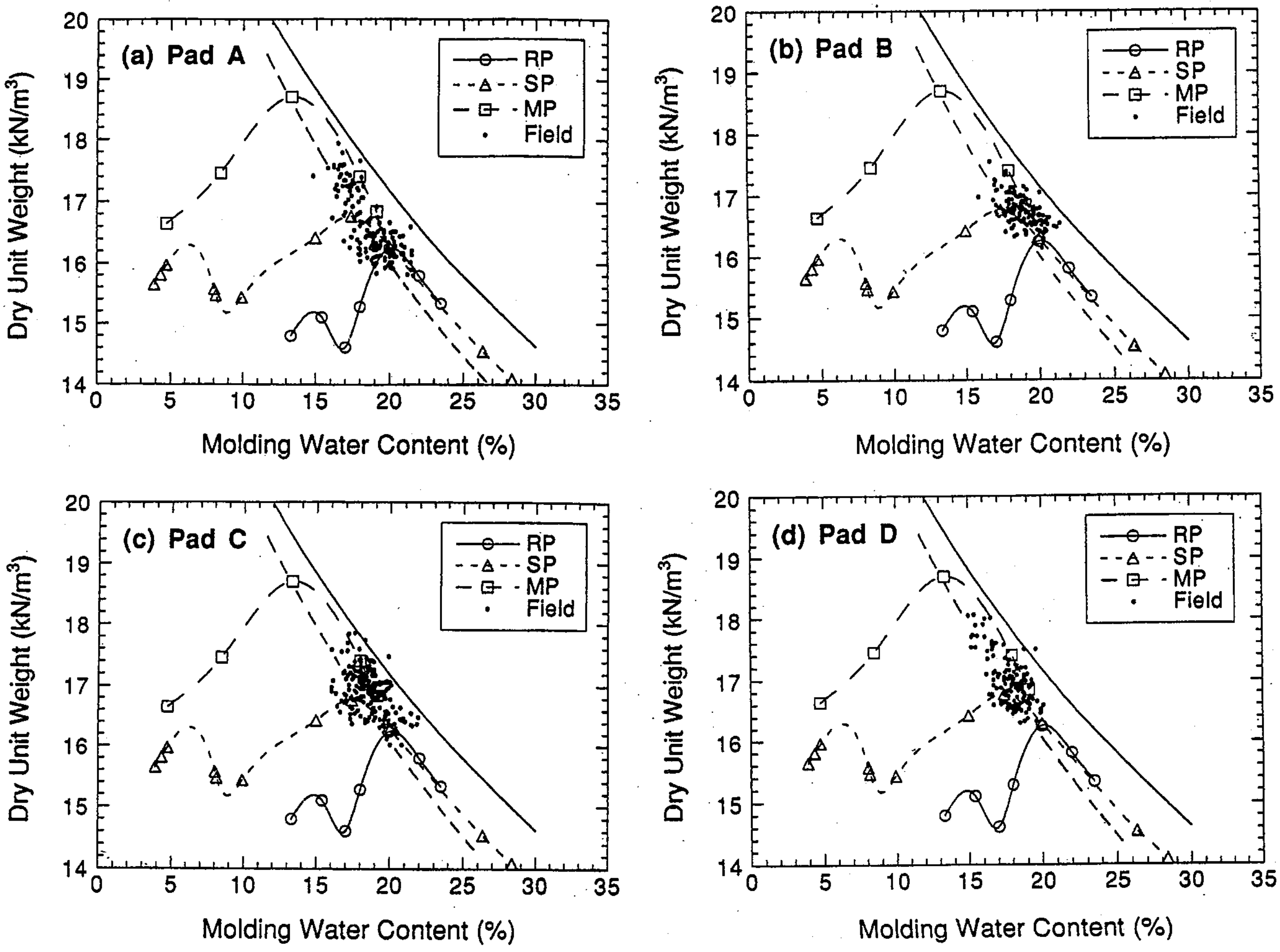


FIG. 3. Compaction Curves with Field Data: (a) Test Pad A; (b) Test Pad B; (c) Test Pad C; (d) Test Pad D

TABLE 1. Summary of Data Collected during Construction

Test pad (1)	Water Content (%)		Dry Unit Weight (kN/m³)		Initial Saturation (%)		Percent wet of line of optimums^c (8)	Liquid Limit		Plasticity Index	
	Mean (2)	Standard deviation (3)	Mean (4)	Standard deviation (5)	Mean (6)	Standard deviation (7)		Mean (9)	Standard deviation (10)	Mean (11)	Standard deviation (12)
A	18.72 (160)	1.43	16.58 (160)	0.50	84.60 (160)	4.58	75	41 (60)	2.8	23 (60)	1.7
B	18.88 (152)	1.05	16.72 (152)	0.25	87.31 (152)	4.12	86	42 (60)	1.7	22 (60)	1.8
C	18.63 (216)	1.16	16.87 (216)	0.37	88.35 (216)	5.37	84	43 (88)	3.4	24 (88)	2.0
D	17.83 (152)	1.10	16.97 (152)	0.40	85.87 (152)	4.63	73	40 (62)	1.9	22 (62)	1.7

Note: Numbers in parentheses indicate number of tests performed.

[a] Water content by ASTM D 2922.

[b] Unit weight by ASTM D 3017.

[c] Optimum water content = 17.5% (1993 standard Proctor compaction test).

test per 8 m^2 per lift. The data are shown in Figs. 3(a–d) (for pads A through D, respectively) with the writers' compaction curves; statistics describing the compaction data and index properties are summarized in Table 1.

All four test pads were compacted using a Caterpillar 815B tamping foot compactor (mass = 19,800 kg, foot length = 0.16 m). For all of the test pads, the field measurements of water content and dry unit weight indicate that compaction was primarily wet of the line of optimums and within specification based on the compaction curves developed during construction. Furthermore, the data indicate that the test pads were compacted to similar conditions (Fig. 3; Table 1). The only exception is test pad D, which was compacted at slightly lower water content, but to higher dry unit weight and similar initial saturation (Table 1). Construction was complete in late October 1992.

Construction Methods

Test Pad A

The contractor constructing test pad A began by discing and adding water to the clay on the stockpile. A conventional agricultural disc was used. The clay had been stockpiled for a number years and was very dry due to the climate in the Texas panhandle. The contractor added water to the stockpile and ran a disc over the soil for several hours each day. On the third day the contractor began transferring the processed clay from the stockpile to the test pad area. By the time the clay arrived at the test pad area, however, the soil was drier than optimum water content and required additional moisture conditioning.

On the first day of placement, a mixture of rain, sleet, and snow fell on the site for approximately 55 min. The contractor stopped work during the precipitation, but began work immediately after its end. The initial lift of clay was placed to an approximate thickness of 0.3 m to prevent the disc and compaction equipment from mixing the underlying sand drainage layer into the clay. Because additional water had to be added to the clay, four days were needed to achieve the required water content and dry unit weight for the first layer of the test pad.

Compaction of the second lift of clay was completed in one day; however, field testing showed the clay was too dry and the contractor had to disc, moisture condition, and recompact the clay. An additional day was required to moisture condition and recompact the second lift. Two additional days were required to complete the third lift, and the fourth lift was completed in one day.

Test Pad B

The contractor constructing test pad B used hydrated soil in the stockpile remaining from construction of test pad A. Clay from the stockpile was transported to the test pad area in dump trucks, where additional moisture conditioning was conducted. Placement of the first loose lift, moisture conditioning, and compaction occurred in approximately two days. The second, third, and fourth lifts were each completed in one day. Mixing of the soil was accomplished with a conventional agricultural disc.

Test Pad C

The contractor for test pad C began working the clay on top of the stockpile and adding water to moisture condition the soil before moving it to the test pad location. The contractor disced and added water to the clay stockpile for two days. More work was performed on the stockpile on the third day. On the fourth day, the contractor began transferring clay from the stockpile to the test pad location using paddle-wheel scrapers. The contractor spent approximately three and one-half days constructing the first 0.3-m lift.

After constructing the first lift, the contractor had used most of the stockpiled material that he had moisture conditioned. Therefore, the material for the remaining lifts was dry and had to be moisture conditioned on the test pad. The second and third lifts of clay each took approximately one day to complete, including moisture conditioning and compaction. The fourth lift took approximately two days to complete.

Test Pad D

The contractor for test pad D chose to use different equipment to mix the soil—a Caterpillar RR250 mixer. The contractors for the other test pads had all used a conventional agricultural disc for clod-size reduction and mixing. Mixers such as the RR250 are generally considered to be superior to a conventional agricultural disc for processing clay because it breaks the soil into much finer clods. Finer clods allow for better moisture conditioning.

The contractor began by using the RR250 mixer to mix soils and assist with moisture conditioning on the stockpile. This was conducted for approximately one-half day. Placement of the first 0.3-m-thick lift of soil was accomplished in one day.

The contractor used the mixer for one complete pass over the first lift. Further mixing of the soils was accomplished using a disc. Soil for the second, third, and fourth lifts was moisture conditioned on the pad. The second lift was also completed in one day. The third lift was completed in one-half day, while the fourth lift took one and one-half days. The mixer was used on each of these lifts for only one pass, while the remaining mixing was performed with the disc.

METHODS TO ASSESS HYDRAULIC CONDUCTIVITY

Sealed Double-Ring Infiltrometers

SDRI tests were initiated on each test pad in November 1992. Procedures described in ASTM D 5093 were followed.

The SDRIs (Fig. 4) had square inner and outer rings. The inner rings were made of fiberglass and had a width of 1.2 m. The outer rings were aluminum and were 3.7 m wide. Flow from the inner ring in each SDRI was monitored by measuring the change in weight of a flexible plastic bag. A meter stick was used to monitor depth of water in the outer ring (D_p). Three nests of tensiometers were used in each SDRI to monitor depth of the wetting front (D_f). Each nest contained three tensiometers, placed at depths of 0.15, 0.30, and 0.45 m. Swell measurements (Fig. 5) were made using a taut wire and caliper as suggested in Trautwein and Boutwell (1994). Details of the SDRI tests are in Christie and Gunter (1993).

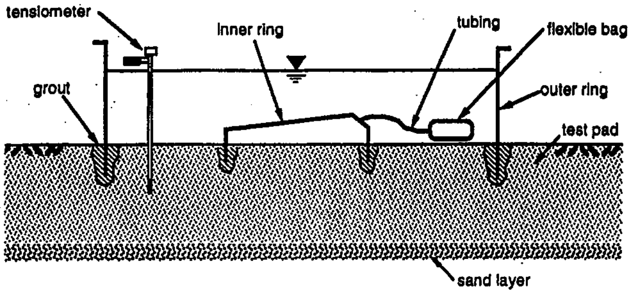


FIG. 4. Schematic of Sealed-Double Ring Infiltrometer (SDRI)

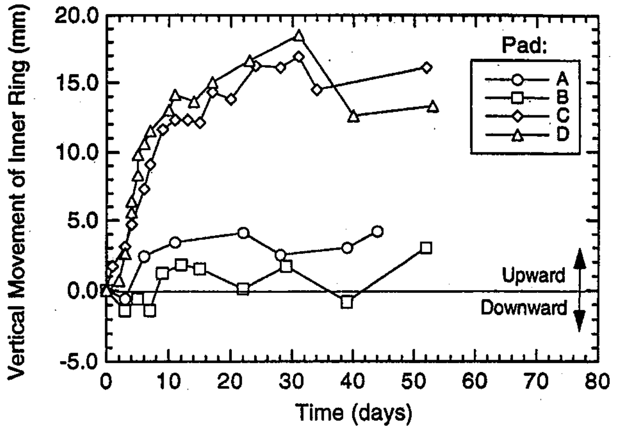


FIG. 5. Swell during SDRI Testing

Hydraulic conductivity was computed from the infiltration data using the wetting front method (Daniel 1989). Infiltration rate and hydraulic conductivity from the SDRIs are shown in Figs. 6(a–d). Data were collected from the SDRIs for 52 days. Water was left in the rings, however, so that long-term data could be collected later. The data show that the infiltration rate and computed hydraulic conductivity initially increased, and then gradually decreased. Little swell occurred during infiltration in test pads A and B, whereas approximately 15 mm of swell occurred in test pads C and D. Swell ceased for all test pads approximately 30 days after testing began.

Long-term data were collected in August 1993 prior to decommissioning of the SDRIs. At this time, the wetting front had passed the deepest set of tensiometers. Thus, to determine D_f, the tensiometer data for each SDRI (Fig. 7) were extrapolated using the procedure described in Wang and Benson (1995). The extrapolations indicate that D_f was near or had reached the base of each test pad by August 1993. Thus, D_f was assumed to equal the thickness of the test pad when computing the long-term hydraulic conductivity.

Hydraulic conductivities computed using the data collected through December 1992 and the data collected in August 1993 are summarized in Table 2. For test pads A, C, and D, the computed hydraulic conductivity had equilibrated towards the end of December 1992. Thus, the hydraulic conductivities for test pads A, C, and D reported in Table 2 are the average of the last three measurements. Because the computed hydraulic conductivity for test pad B was still decreasing in December 1992, the hydraulic conductivity for December 1992 (Table 2) is the average of the last two measurements in 1992, whereas

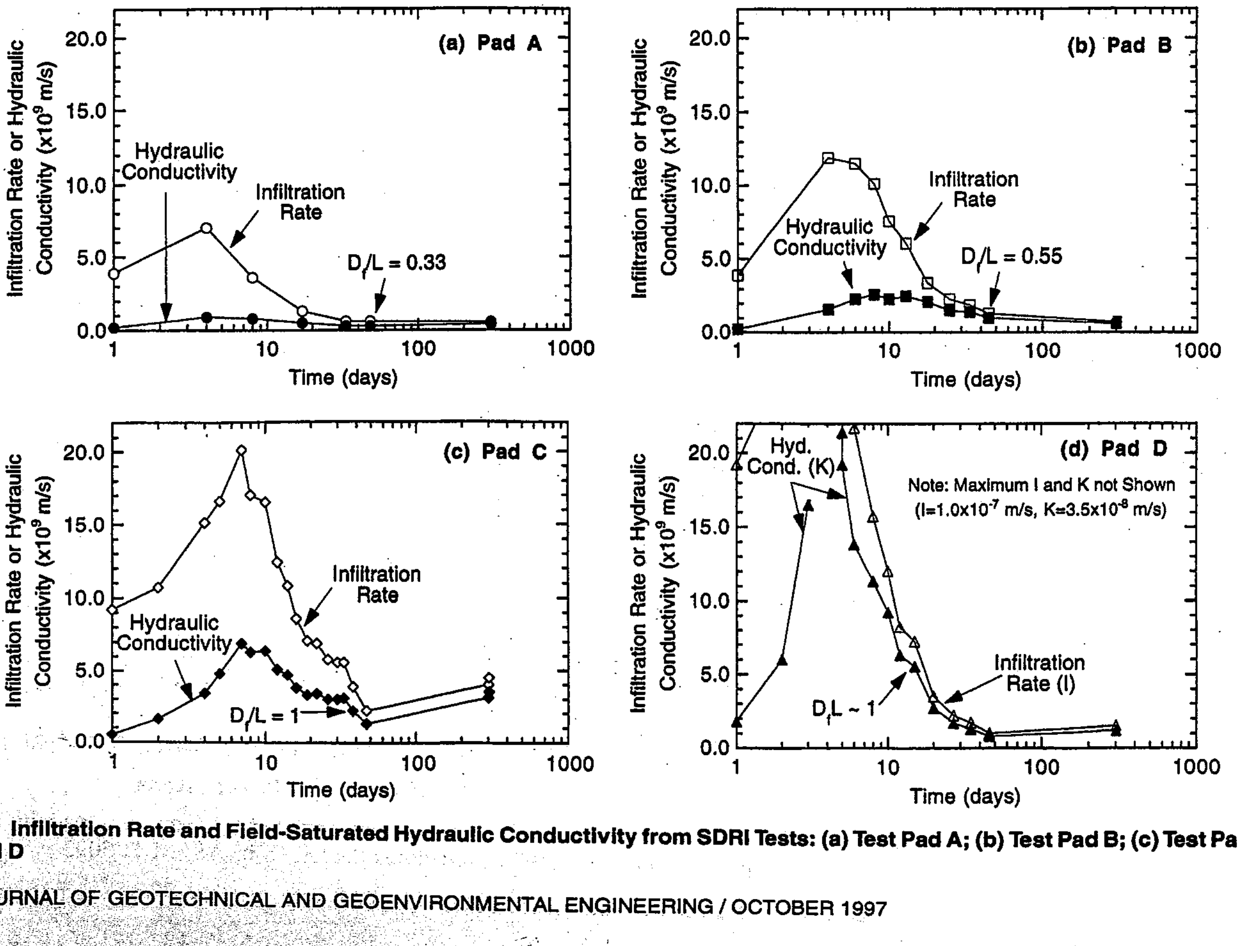


FIG. 6. Infiltration Rate and Field-Saturated Hydraulic Conductivity from SDRI Tests: (a) Test Pad A; (b) Test Pad B; (c) Test Pad C; (d) Test Pad D

TABLE 2. Summary of Hydraulic Conductivity Measurements

	Tube December 1992	Sampling Tube August 1993 (K_{ST})		Block (K_B)		Two-Stage Borehole (K_{TSB})		SDRI (K_{SDRI})	
Test pad (1)	K (m/s) (2)	K_{ST} (m/s) (3)	K_{ST}/K_{SDRI} (4)	K_B (m/s) (5)	K_B/K_{SDRI} (6)	K_{TSB} (m/s) (7)	K_{TSB}/K_{SDRI} (8)	December 1992 (m/s) (9)	August 1993 (m/s) (10)
A	3.9×10^{-10}	2.2×10^{-10} (0.21)	0.67	4.8×10^{-10}	1.4	2.1×10^{-10} (0.57)	0.63	3.6×10^{-10}	3.3×10^{-10}
B	7.0×10^{-10}	4.8×10^{-10} (0.25)	0.83	7.7×10^{-10}	1.3	3.2×10^{-9} (1.07)	5.3	1.3×10^{-9}	6.0×10^{-10}
C	3.8×10^{-10}	3.9×10^{-10} (0.31)	0.14	3.1×10^{-8}	12	7.5×10^{-10} (1.2)	0.29	2.2×10^{-9}	2.6×10^{-9}
D	3.5×10^{-10}	2.1×10^{-10} (0.32)	0.19	5.3×10^{-9}	4.8	1.1×10^{-9} (1.09)	1.0	1.3×10^{-9}	1.1×10^{-9}

Note: Numbers in parentheses are $\log_{10}$ standard deviations.
[a]Geometric mean hydraulic conductivity.

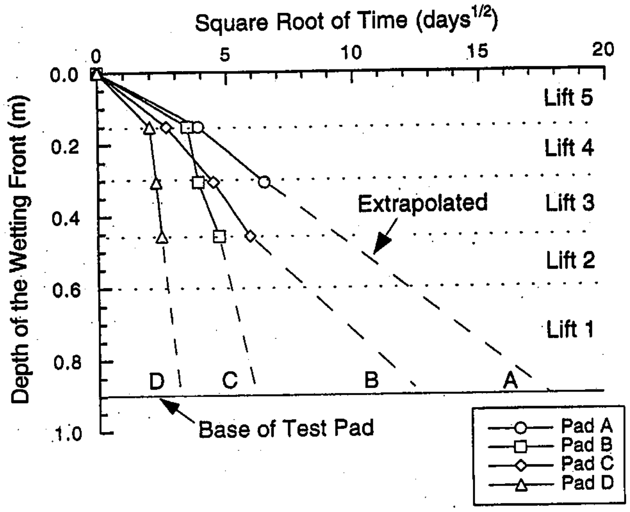


FIG. 7. Depth to Wetting Front during SDRI Testing

the hydraulic conductivity reported for August 1993 is the single measurement made in August 1993.

The hydraulic conductivities computed from the data collected in August 1993 are nearly identical to the hydraulic conductivities computed using data collected through December 1992, with exception of test pad B. For test pad B, the hydraulic conductivity determined using the SDRI test in August 1993 is two times lower than the hydraulic conductivity determined in December 1992 (Table 2). These results are consistent with the findings of Wang and Benson (1995), whose large-scale laboratory experiments showed that the wetting front method yields good estimates of field hydraulic conductivity when D_f is approximately one-half the thickness of the test pad. In the present study similar hydraulic conductivities were obtained for D_f as small as one-third the test pad thickness.

Two-Stage Borehole Permeameters

The two-stage borehole (TSB) tests were conducted during the period between August 23 and September 13, 1993. Six TSB permeameters were installed in each test pad. One TSB permeameter in each set had a sealed base and was used to determine changes in head caused by variations in temperature and barometric pressure. The other five TSB permeameters were used to measure hydraulic conductivity. This number of TSB permeameters is in accordance with recommendations by Koerner and Daniel (1993). A schematic of a typical TSB test installation is depicted in Fig. 8.

Unlike the other large-scale tests, the TSB permeameters had to be installed outside the boundaries of the SDRIs. Therefore, the material tested by the TSBs potentially had been subjected to environmental distress (e.g., desiccation and freeze-thaw cycling) during one summer and one winter, even though the test pads were protected by a layer of polyethylene and a layer of sand. The writers note that the maximum frost penetration for this site is approximately 0.6 m (Sowers 1979).

The methodology for installing and conducting the TSB tests followed recommendations by Trautwein and Boutwell (1994). The permeameters were constructed from plastic monitoring well casings having an inside diameter of 0.1 m. For stage 1 (Fig. 8), the TSB permeameters were set and sealed to depths between 0.40 and 0.46 m below the surface. The extensions for stage 2 (Fig. 8) were approximately 0.15 m long. Equations used to reduce the data for stages 1 and 2 are described in Trautwein and Boutwell (1994).

Complete details of the TSB tests are contained in Boutwell (personal communication, 1993). Vertical hydraulic conductivities determined from the TSB tests are summarized in Table 2. The hydraulic conductivities are more variable for pads B, C, and D, with logarithmic standard deviations exceeding those normally observed at other sites (Benson et al. 1994a; Trautwein and Boutwell 1994). This may be due to environmental effects to which the soil tested by the TSB permeameters had been subjected.

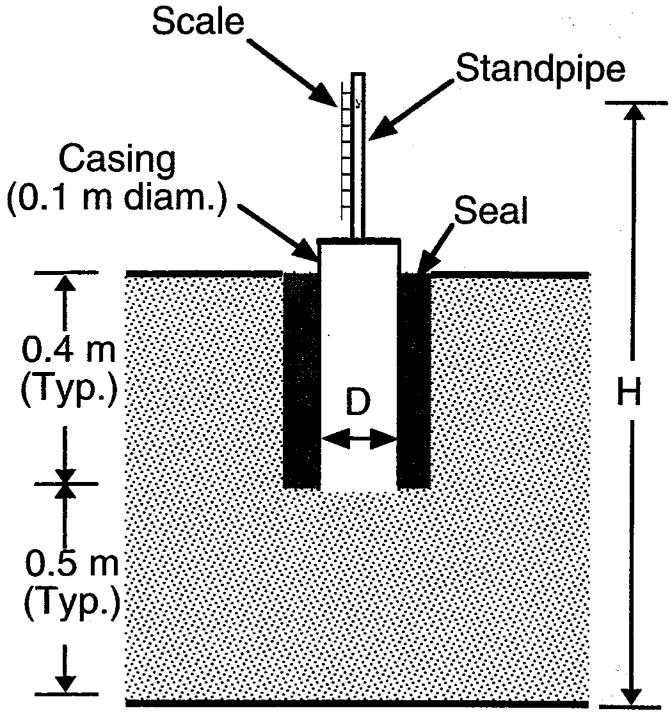
Block Specimens

Large undisturbed block specimens were collected in August 1993 from soil directly beneath the inner ring of each SDRI. The block specimens were collected following procedures described in Othman et al. (1994) and Benson et al. (1995). The trimming rings were 0.4 m in diameter and in height, and were constructed from a section of polyvinyl chloride (PVC) pipe. Soil collected in the rings was obtained from depths between 0.15 and 0.55 m. The upper 0.15-m-thick layer of soil was not sampled because it was very soft after being covered with water for 11 months.

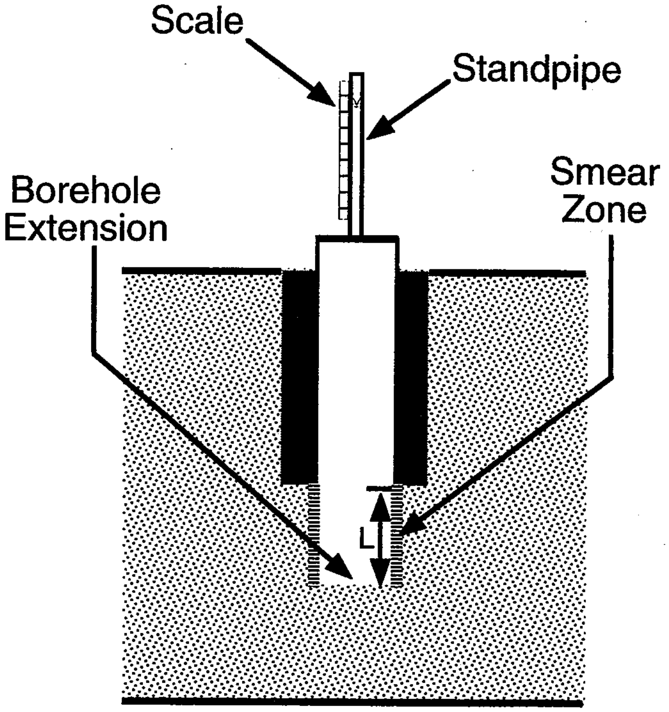
In the laboratory the specimens were trimmed to a diameter of 0.30 m and to heights ranging between 0.20 and 0.30 m. The trimmed specimens were placed in large-scale flexible-wall permeameters for hydraulic conductivity testing using procedures described in ASTM D 5084-Method C. The specimens were isotropically consolidated to an effective stress of 10 kPa and then permeated using a hydraulic gradient of 6. A backpressure of 280 kPa was applied. Results of the tests are tabulated in Table 2. Details of the testing procedures can be found in Benson (1993).

Specimens Collected in Sampling Tubes

After completion of the test pads in October 1992, one small specimen (71 mm diameter) was collected from each pad from a depth of approximately 0.3 m using a thin-wall sampling tube. The specimens were tested by a commercial laboratory



(a) Stage 1



(b) Stage 2

FIG. 8. Schematic of Two-Stage Borehole (TSB) Test

in flexible-wall permeameters using a hydraulic gradient of 60, but the effective stresses and backpressure were not reported. Also, the hydraulic conductivity of each specimen was determined from a single drop in head over one 24-hour period. Because of these vague testing conditions, the high hydraulic gradient used, and the short duration of testing, the writers believe that these hydraulic conductivities are not necessarily representative. Results of these tests are tabulated in Table 2.

Specimens were also collected in August 1993 using thin-wall sampling tubes from soil directly beneath the inner ring of the SDRIs. The tubes were pushed and then extracted by hand using a shovel. Soil collected in the tubes was obtained from depths between 0.1 and 0.6 m. Four specimens having a length of approximately 70 mm were obtained from each tube Trimming was only conducted on the ends of the specimens The ends were also scarified to eliminate smear. Flexible-wal permeameters were used for testing and procedures described in ASTM D 5084-Method C were followed. The specimens were tested using the same conditions employed for the block specimens. Results of the tests are tabulated in Table 2.

COMPARISON OF HYDRAULIC CONDUCTIVITY TEST RESULTS

Field and Large-Scale Laboratory Tests

Hydraulic conductivities measured using the four methods are compared in Fig. 9. The long-term hydraulic conductivities measured with the SDRIs are used as the basis for comparison because they represent the largest volume of soil tested. Fig. 9 includes lines corresponding to two standard deviations (2σ) from the 1:1 correlation line, which represents approximately 95% of the range of scatter due to spatial variability of the soil. The standard deviation that was used is the average of the standard deviations determined from the hydraulic conductivities of the second set of specimens collected in sampling tubes (Table 2). The standard deviations determined from the TSB tests were not considered because they may have been influenced by environmental stresses.

One outlier falls significantly above the upper 2σ line in Fig. 9, the block specimen from text pad C. This specimen had high hydraulic conductivity because it contained a macroscopic flow path, which did not grossly affect the hydraulic conductivity obtained from the SDRI, even though the specimen was collected directly beneath the inner ring. This suggests that replicate tests should be performed when block samples are used to assess hydraulic conductivity so that outlier data do not dominate the hydraulic conductivity assessment. Based on a statistical analysis, Trautwein and Boutwell (1994) recommend that five or more TSB tests should be conducted on a test pad, which should also be a reasonable number of block samples to test. Koerner and Daniel (1993) make a similar recommendation.

When the outlier for test pad C is excluded, the data indicate that the hydraulic conductivities of the block specimens are about two times those measured with the SDRIs, on average. The hydraulic conductivities measured with the TSBs are also about twice those measured with the SDRIs, on average. The

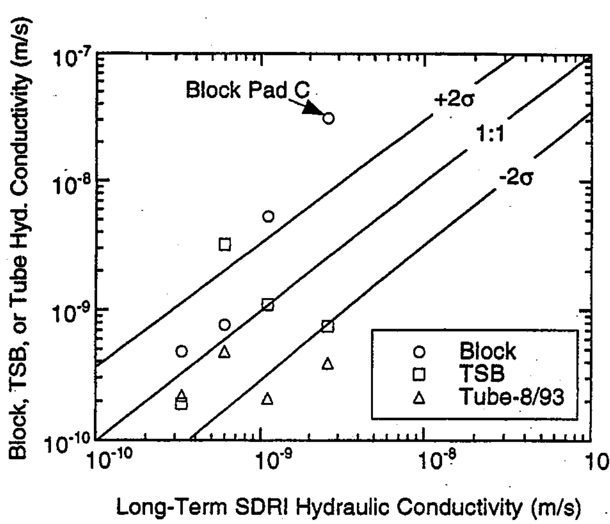


FIG. 9. Comparison of Hydraulic Conductivity Measurements

block specimens probably had higher hydraulic conductivity relative to the SDRIs because of two factors. First, the block specimens were backpressured, which yields higher hydraulic conductivity due to the higher degree of saturation obtained. Trast and Benson (1995) draw a similar conclusion in their comparison of hydraulic conductivities measured with SDRIs and tests on large block specimens. Second, the block specimens typically consist of one lift of soil, whereas the SDRI permeates multiple lifts of soil. Consequently, the SDRI should yield lower hydraulic conductivity because of the redundancy afforded by a multilift test pad (Benson and Daniel 1994; Benson et al. 1994b). Nevertheless, the writers believe that the differences in hydraulic conductivity are within the accuracy with which hydraulic conductivity generally can be assessed with any of the three large-scale methods.

Small-Scale Laboratory Tests

The small specimens removed in sampling tubes had similar or lower hydraulic conductivities than the long-term hydraulic conductivities measured with the SDRIs and the other large-scale test methods (Fig. 9; Table 2). The hydraulic conductivities measured with the SDRIs and on the small specimens were similar for test pads A and B, which had low long-term field hydraulic conductivity ($\leq 6 \times 10^{-10}$ m/s) as determined using the SDRIs. In contrast, the specimens removed from test pads C and D had hydraulic conductivities significantly lower than the long-term field hydraulic conductivities measured with the SDRIs.

Perhaps most significant is that the small specimens removed in 1993 with sampling tubes have similar hydraulic conductivity regardless of the test pad from which they were obtained, whereas the field hydraulic conductivities vary by more than an order of magnitude from test pad to test pad regardless of the assessment method (SDRIs, TSBs, or blocks). Furthermore, based on the hydraulic conductivities of these small specimens, it can be erroneously inferred that test pads C and D had acceptably low hydraulic conductivities ($\leq 10^{-9}$ m/s), when in fact their field hydraulic conductivities exceeded 10^{-9} m/s. This information, along with findings reported in other studies [e.g., Trautwein and Williams (1990); Benson and Boutwell (1992); Trautwein and Boutwell (1994); Trast and Benson (1995)], suggests that small specimens have little value for assessing the hydraulic conductivity of test pads. This is significant, because many hydraulic conductivity assessments currently rely solely on tests on small specimens.

FACTORS AFFECTING FIELD HYDRAULIC CONDUCTIVITY

The key question regarding the field hydraulic conductivity of the four test pads is: why do the long-term field hydraulic conductivities of the test pads differ by nearly an order of magnitude given that the contractors used soil from the same source, similar construction machinery, the same test pad thickness, the same compaction requirements, and similar molding water contents? Review of the data indicates that different hydration times is the most likely cause for the differences in field hydraulic conductivity. Processing time may also have affected the field hydraulic conductivity.

Hydration Time and Moisture Conditioning

The different methods used for moisture conditioning may have affected hydration and subsequent softening of the clods. The contractor for test pad A began adding moisture directly in the stockpile and allowed the soil to hydrate before compaction. The contractor for test pad C also added moisture in the stockpile, but only for the bottom lift. The contractors for test pads B and D added water only briefly prior to compaction, but the soil used for test pad B had been hydrated during moisture conditioning for test pad A.

The stockpile was extremely dry prior to construction. Thus, although the gross construction measurements made on each test pad indicated that a sufficient amount of water was added to the soil to wet it past the line of optimums, there may not have been sufficient time for the water to penetrate the clods and hydrate the clay. Consequently, for those test pads where little hydration time was permitted, the clay clods would have been more difficult to remold and the clay particles would have been more difficult to rearrange. Thus, the additional hydration time may have allowed the contractor for test pad A to achieve lowest field hydraulic conductivity. Also, the hydration of the soil for test pad B that occurred during construction of test pad A probably helped the contractor for test pad B to achieve lower field hydraulic conductivity.

The different swell and hydraulic conductivity data obtained from each test pad (Figs. 5 and 6) are consistent with different degrees of hydration. Test pads A and B received greater hydration prior to compaction and consequently exhibited less swell during infiltration. Also, the hydraulic conductivity computed with the wetting front method for test pads A and B decreases by less than a factor of 4 during testing, whereas the hydraulic computed for test pads C and D decreased by as much as a factor of 29. Wang and Benson (1995) show that when the wetting front method is used to calculate hydraulic conductivity, a larger decrease in hydraulic conductivity occurs when soils are drier prior to compaction. The larger decreases in hydraulic conductivity for test pads C and D may have also been caused by the greater swell that occurred in these test pads.

The ratios of large- to small-scale hydraulic conductivity (K_{SDRI}/K_{SS}, SDRI is large-scale, SS is laboratory test on small specimen) are also consistent with differences in hydration time. In an analysis of 29 case histories. Benson and Boutwell (1992) show that K_{SDRI}/K_{SS} is typically <2, and is almost always <4 for test pads that have more than 75% of the compaction data falling wet of the line of optimums. The ratios for test pads A and B (1.5, 1.2) meet this criteria. In contrast, the ratios for test pads C and D (7.1, 5.3) do not meet this criteria, but rather are more typical of test pads compacted dry of the line of optimums.

To evaluate the significance of hydration time, hydraulic conductivity tests were conducted on laboratory-compacted specimens prepared to the same gross water content and dry unit weight, but with different hydration times. To simulate the dry condition of the stockpile, soil was initially oven dried until it was very dry (water content ~2%). The soil was then crushed by hand past the 20-mm sieve to simulate the large clods that exist in the field. Although clods are usually larger than 20 mm in the field, Benson (1994) shows that specimens prepared using 20-mm clods have hydraulic conductivity similar to that existing in the field, even for compaction dry of the line of optimums.

The dry crushed soil was moistened with tap water using a spray bottle. Enough water was added to compact the soil 2% wet of optimum. After adding the water, the moistened soil was split into four equal volumes that were allowed to hydrate for different amounts of time (0, 12, 24, and 48 hours). After hydration, the specimens were compacted using procedures described in ASTM D 698. The number of blows was adjusted, however, so that the dry unit weight of each specimen had the same dry unit weight as a specimen hydrated for 24 hours (e.g., specimen compacted per ASTM D 698, Fig. 1). This simulates the field condition, where the number of compactor passes is adjusted until the desired dry unit weight is achieved. After compaction the specimens were permeated in

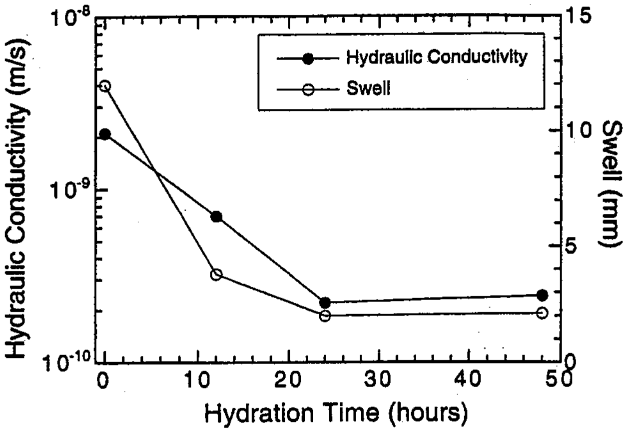


FIG. 10. Effect of Hydration Time on Hydraulic Conductivity and Swell

the compaction molds using rigid-wall permeameters equipped with swell rings. Methods described in ASTM D 5856 were followed.

Results of the tests are shown in Fig. 10. Hydraulic conductivity and swell are sensitive to hydration time, with higher hydraulic conductivity and greater swell obtained for compaction immediately after hydration (hydration time = 0 days). These results are similar to those obtained in the field, that is, higher field hydraulic conductivity and greater swell were obtained when the soil was compacted immediately after applying water. In addition, remnant clods were readily visible in the laboratory specimens with lower hydration time, whereas the specimens with longer hydration times (≥24 hours) appeared monolithic.

These results suggest that adequate hydration time is essential for initially dry clays. In the absence of more definitive data, the hydration criterion in ASTM D 698 (≥24 hours for CL soils, ≥48 hours for CH soils) is recommended for constructing clay liners using initially dry clay. Even longer hydration times may be needed in some cases, because field clods are typically larger than those used in ASTM D 698. In contrast, shorter hydration times are probably adequate when making small adjustments to the water content of moist clays. A more definitive method to determine the necessary hydration time is through testing using the procedure previously described. Regardless of the method used, however, clods should be inspected for adequate hydration prior to compaction.

Processing and Compaction Time

The contractor for test pad A may have achieved the lowest field hydraulic conductivity because he spent more time working the soil for each lift. The contractor for test pad A spent approximately two days working, discing, compacting, and watering each lift of soil. In contrast, the other contractors achieved placement, moisture conditioning, discing, and compaction of each lift in a day or, in some cases, as little as one-half day. The longer period of working the soil and the additional passes with the disc resulted in clods of smaller size and more homogeneous lifts, which should result in lower hydraulic conductivity.

CONCLUSIONS AND RECOMMENDATIONS

This paper has described a side-by-side blind comparison of four test methods used to assess hydraulic conductivity. The tests were conducted on four test pads, which were constructed with soil from the same source using the same specifications, but by four different contractors. Furthermore, the test pads were compacted to similar water contents and dry unit weights based on gross measurements made using normal quality control test procedures. Nevertheless, the test pads had different field hydraulic conductivities. Based on a comparison of these hydraulic conductivities, the following conclusions are drawn

Blind comparison of the three field-scale test methods used to assess field hydraulic conductivity shows that similar hydraulic conductivities are obtained regardless of test method Furthermore, the methods yield similar hydraulic conductivities for test pads devoid of macroscopic defects (i.e., test pads with scale-independent hydraulic conductivity, A and B) or test pads containing macroscopic defects (i.e., test pads with scale-dependent hydraulic conductivity, C and D). When the outlier for test pad C (block) is ignored, the block sampling method yields hydraulic conductivities about two times higher than the long-term hydraulic conductivity measured with the SDRIs on average. The hydraulic conductivities measured with the TSBs are also about twice the long-term hydraulic conductivities measured with the SDRIs, on average.

The hydraulic conductivities obtained from laboratory tests on small specimens were similar, regardless of the test pad from which the specimens were obtained. For test pads A and B, the small specimens had hydraulic conductivities similar to the field hydraulic conductivities measured with the field-scale test methods. Test pads A and B had low field hydraulic conductivity, and were devoid of macroscopic defects. In contrast the small specimens from test pads C and D had hydraulic conductivities one order of magnitude lower than the field hydraulic conductivity measured with the field-scale test methods.

Apparently, small specimens are too small to adequately represent the network of pores controlling field-scale hydraulic conductivity. This phenomenon has been reported by other investigators, although not through blind side-by-side testing of test pads constructed with the same soil but with varying degrees of quality. Nevertheless, in practice hydraulic conductivity is still commonly assessed by testing small specimens. The data available to date indicate that small specimens have limited value for hydraulic conductivity assessment when the primary purpose is to determine if hydraulic conductivity $\geq 10^{-9}$ m/s exists. In fact, erroneous conclusions can be drawn if specimens of this type are used to assess field hydraulic conductivity. Consequently, tests on small specimens should not be used as the basis for hydraulic conductivity assessments.

Hydraulic conductivities determined from moderate-term SDRI data are representative of hydraulic conductivities obtained in the long-term when the wetting front has completely penetrated the test pad. This finding is consistent with results of large-scale laboratory tests reported by Wang and Benson (1995).

Hydration time had a significant impact on the field hydraulic conductivity. The test pads with short hydration time had higher field hydraulic conductivity and greater swell, both of which are indicative of poor hydration of clods. Similar results were obtained from laboratory tests on specimens prepared with different hydration times. The writers recommend that the hydration criterion in ASTM D 698 (≥24 hours for CL soils, ≥48 hours for CH soils) be followed when constructing clay liners using initially dry clay. In addition, clods should be checked for adequate hydration prior to compaction.

Different construction methods employed by different contractors can result in significantly different field hydraulic conductivities, even though the same specification is followed. Thus, it may be incorrect to infer that a test pad and liner have similar field hydraulic conductivity because they are compacted to the similar water content and dry unit weight. This problem is best alleviated through carefully written specifications and having the same contractor construct the test pad and liner.

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ESTIMATING FIELD HYDRAULIC CONDUCTIVITY OF COMPACTED CLAY

By John M. Trast[1] and Craig H. Benson,[2] Members, ASCE

ABSTRACT: Results of hydraulic-conductivity tests conducted in the field and laboratory are presented for soils collected from 11 compacted-clay test pads or liners. The field tests were conducted with sealed double-ring infiltrometers to define the field-scale hydraulic conductivity (K_F). The laboratory tests were conducted using large undisturbed block specimens (diameter ≥ 0.3 m) and small specimens collected in thin-wall sampling tubes (diameter = 71 mm). Results of tests at low effective stress showed that the hydraulic conductivity of the block specimens was similar to K_F at each site. The hydraulic conductivities of block specimens from sites where K_F exceeded 10^{-9} m/s decreased by a factor of 4 when the effective stress was increased from 10 to 44 kPa. In contrast, the hydraulic conductivities of specimens from the other sites were reduced only by a factor of 1.5 under the same increment of effective stress.

INTRODUCTION

Large-scale field tests are often conducted on test pads or trial sections to assess the field-scale hydraulic conductivity of compacted clay liners. During testing, the effective stress is typically low (~10 kPa) and is not necessarily representative of the effective stress that will exist when the actual liner is loaded with waste (50–300 kPa). As a result, the reported hydraulic conductivity may be higher than the hydraulic conductivity that will exist during operation and after closure of the facility. One method to extrapolate hydraulic conductivities measured in the field to higher levels of effective stress is to apply a reduction factor determined from results of laboratory tests conducted over a range of effective stresses (Environmental 1989). However, because specimens commonly used for laboratory testing can be too small to adequately represent the network of pores controlling flow at field scale (Benson et al. 1994), hydraulic conductivities estimated in this manner may not necessarily be representative of field conditions.

In this technical note, results are reported from hydraulic-conductivity tests conducted over a range of effective stresses. The tests were conducted in the laboratory, but used large undisturbed block specimens believed to be of sufficient size to capture the network of pores controlling flow at field scale. The block specimens were removed from test pads or compacted soil liners constructed at 11 sites throughout the United States.

METHODS

The ideal method to investigate the relationship between field-scale hydraulic conductivity (K_F) and effective stress (σ') is to conduct large field tests over a sequence of effective stresses. Conducting this type of test is not generally practical, because high costs and extensive testing time are required. Thus, in this study, the K_F-σ' relationship was investigated using laboratory tests on undisturbed specimens that were large enough to contain a network of pores representative of those existing in the field. It was assumed that the K_F-σ' relationship obtained in this manner is similar to the relationship existing in the field, but the writers acknowledge that this assumption has not been verified.

The specimen size was selected based on recommendations by Benson et al. (1994). They found that specimens having a diameter greater than or equal to 0.30 m and an aspect ratio (height/diameter) of 0.5 are large enough that their hydraulic conductivity is representative of field-scale conditions, even when macrostructure is present. In particular, specimens of this size were shown to have hydraulic conductivity comparable to the hydraulic conductivity measured with sealed double-ring infiltrometers (SDRIs) having an area of permeation greater than 1 m^2. SDRIs of this size are generally considered to measure the field hydraulic conductivity (Sai and Anderson 1990; Trautwein and Boutwell 1994).

Specimens having diameter greater than or equal to 0.30 m were collected from compacted clay test pads at 11 sites located throughout the United States. All of the test pads were built as part of construction operations; none of them were constructed for research purposes. Trast (1993) contains a detailed summary of the construction data for each site. Index properties and compaction data describing the soils are listed in Table 1. Smaller specimens were also collected in thin-walled sampling tubes with a diameter of 71 mm. In addition, SDRI tests were conducted at each site to verify that the large block specimens did yield consistent hydraulic conductivities.

Laboratory Hydraulic Conductivity Tests

The block specimens were removed from each site using a procedure described by Benson et al. (1994). In the laboratory, the specimens were trimmed to a diameter of 0.30 m and a height of approximately 0.15 m prior to hydraulic-conductivity testing. Large-scale flexible-wall permeameters capable of testing specimens with a diameter as large as 0.46 m were used for permeation. A detailed description of these permeameters can be found in Benson et al. (1994) and Trast (1993).

Procedures described in ASTM D 5084 were followed. The falling-headwater/rising-tailwater procedure (Daniel 1989) was employed to apply a hydraulic gradient of 4–5. Tap water from Madison, Wisconsin, was used as the permeant. A back-pressure of 140 kPa was applied.

The specimens were initially consolidated isotropically to an average effective stress of 10 kPa prior to the first stage of permeation to simulate the low effective stress assumed to exist during infiltration. Permeation was continued until the hydraulic conductivity was steady and inflow equaled outflow, ensuring that the specimens were essentially saturated. Each specimen was subsequently consolidated to effective stresses of 44, 78, 112, and 147 kPa, with hydraulic-conductivity tests being conducted at each effective stress.

Similar conditions and procedures were used to test the specimens collected in sampling tubes. However, not all of

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TABLE 1. Index Properties and Compaction Data

Soil (1)	S_i (2)	P_o (3)	*LL* (4)	*PL* (5)	*PI* (6)	Activity (7)	G_s (8)	Gravel (%) (9)	Sand (%) (10)	Fines (%) (11)	Clay (%) (12)	USCS (13)
A	83.1	60	70	32	38	0.58	2.80	0	6	94	65	CH
B	92.4	80	49	23	26	0.65	2.70	0	6	94	40	CL
C	87.7	84	27	12	15	0.54	2.75	2	24	76	28	CL with sand
D	85.4	57	35	16	19	0.46	2.80	3	8	89	41	CL
E	84.2	71	53	12	41	1.14	2.90	0	12	88	36	CH
F	88.6	81	67	21	46	0.87	2.80	0	6	94	53	CH
G	92.3	95	29	13	16	1.00	2.68	0	48	52	16	CL sandy
H	—[a]	—[a]	37	17	20	0.80	2.78	0	19	81	25	CL with sand
I	81.4	17	33	14	19	0.51	2.80	7	8	85	37	CL with sand
J	75.2	6	31	13	18	0.69	2.80	8	18	74	26	CL with sand
K	75.4	44	24	13	11	0.55	2.80	3	35	62	20	CL sandy

Note: S_i = initial saturation (at compaction); P_o = percent of water content–dry unit weight measurements falling wet of line of optimums; *LL* = liquid limit; *PL* = plastic limit; *PI* = plasticity index; G_s = specific gravity; USCS = Unified Soil Classification System; percentage of clay is the 2-μm fraction, and all other particle sizes are based on USCS definitions.

[a] Not available.

these specimens were tested at higher effective stresses. Thus, only the results of tests conducted at an average effective stress of 10 kPa are reported. Trast (1993) gives a summary of all test results.

Field Hydraulic Conductivity Tests

At least one SDRI was installed on each test pad either by the writers or by consultants employed by the owner of the facility. In the latter case, the data were interpreted independently by the writers. Square SDRIs were used at each site. The inner rings were 1.22–1.52 m wide, and the outer rings ranged from 2.44 to 3.66 m wide. Dimensional requirements stipulated in ASTM D 5093 were satisfied for all tests.

The field-scale hydraulic conductivity (K_F) was computed from infiltration rate (I) measured with the SDRIs using a simplified form of the Green-Ampt equation (Trautwein and Boutwell 1994), as follows:

$$K_F = [I/(D_p + D_f)/D_f] \quad (1)$$

In (1), D_p = depth of ponding; and D_f = depth of the wetting front, monitored with tensiometers. Detailed results of the SDRI tests and the data-reduction procedures can be found in Trast (1993).

When K_F is computed using (1), suction head at the wetting front is ignored, which in some cases results in an overestimate of K_F by as much as a factor of 6 (Wang 1993; Trast 1993). Furthermore, the impact of swelling on K_F is also ignored. The error resulting in K_F from these two factors depends on the matric suction, the depth of the wetting front, and the swell that has occurred. Thus, when analyzing the SDRI data, a range of hydraulic conductivities was determined that the writers believe accounts for these errors. A "best estimate" of the field hydraulic conductivity was also determined. For most of the sites, the range in hydraulic conductivity was small. However, for sites A, E, F, and H, where large matric suctions existed and significant swell occurred, the range of K_F varied by as much as a factor of 4.

RESULTS

Tests at Low Effective Stress

Results of hydraulic conductivity tests conducted at low effective stress (~10 kPa) are summarized in Table 2. This table includes results of the SDRI tests and the laboratory tests on specimens removed as blocks or with sampling tubes. For the SDRI tests, the aforementioned range is reported with the best estimate of the field hydraulic conductivity in parentheses. For the laboratory tests, a range representing the minimum and maximum measured hydraulic conductivities is reported, provided at least two tests were conducted. When more than two laboratory tests were conducted, the number in parentheses is the geometric mean of the test results.

Column 8 of Table 2 contains the ratio K_F/K_{ST}, which is the best estimate of the field-scale hydraulic conductivity (K_F) from the SDRI tests divided by the geometric mean hydraulic conductivity of the specimens collected in sampling tubes (K_{ST}). The ratio K_F/K_{ST} ranges from 0.6 to 23, indicating that scale-dependent hydraulic conductivity exists at some, but not all, sites.

A similar ratio computed using hydraulic conductivity of the block specimens, K_F/K_B, is listed in column 9. The ratio K_F/K_B ranges from 0.3 to 2.4; that is, the 0.3-m block specimens had essentially the same hydraulic conductivity as was measured with the SDRIs. Apparently, the large block specimens were of sufficient size to capture pore networks similar to those controlling flow in the field, even when scale-dependent hydraulic conductivity existed (i.e., K_F/K_{ST} is large). This result is consistent with the findings of Benson et al. (1994), and suggests that tests of this type may be a viable substitute for SDRI tests.

Tests at Higher Effective Stress

Results of tests conducted at higher effective stresses are presented in Figs. 1 and 2 in terms of the ratio $K_{\sigma'}/K_B$, where K_B = hydraulic conductivity of the block specimen at an effective stress of 10 kPa, and $K_{\sigma'}$ = hydraulic conductivity of the block specimen at an effective stress of σ'. By definition, $K_{\sigma'}/K_B = 1$ for $\sigma' = 10$ kPa. The data are categorized into two groups: $K_F > 1 \times 10^{-9}$ m/s (Fig. 1) and $K_F < 1 \times 10^{-9}$ m/s (Fig. 2).

The specimens with $K_F > 1 \times 10^{-9}$ m/s (Fig. 1) showed a rapid decrease in hydraulic conductivity when the average effective stress (σ') was increased from 10 to 44 kPa. This increment in effective stress reduced the hydraulic conductivity by a factor of 4 on average. An increase in stress of this magnitude is expected on placement of a leachate collection system and a typical first lift of waste. A more subtle decrease occurred as the effective stress was increased further. At the highest effective stress (147 kPa), the hydraulic conductivity was $0.1K_F$ on average. The upper bound for the ratio $K_{\sigma'}/K_F$ (shown in Fig. 1), which was "fit by eye," is defined by the following:

$$K_{\sigma'}/K_F = 1.0 - \alpha(\sigma' - 10), \text{ for } 10 \le \sigma' \le 44 \text{ kPa} \quad (2a)$$

TABLE 2. Results of Hydraulic Conductivity Tests at Low Effective Stress (~10 kPa)

	SDRI		Sampling Tube		Block			
Site (1)	Number of tests (2)	K (m/s) (3)	Number of tests (4)	K (m/s) (5)	Number of tests (6)	K (m/s) (7)	K_F/K_{ST} (8)	K_F/K_B (9)
A	1	2×10^{-10} to 8×10^{-10} $(5 \times 10^{-10\text{a}})$	2	2×10^{-10} 3×10^{-10}	2	3.0×10^{-10} 3.1×10^{-10}	2.0	1.7
B	1	1×10^{-9} to 3×10^{-9} $(2 \times 10^{-9})^{\text{a}}$	2	2.9×10^{-9} 3.5×10^{-9}	2	2×10^{-9} 3×10^{-9}	0.6	0.8
C	3	1×10^{-10} to 2×10^{-10} $(1.5 \times 10^{-10})^{\text{a}}$	2	1.3×10^{-10} 2.5×10^{-10}	3	1.5×10^{-10} to 2.5×10^{-10} $(1.9 \times 10^{-10})^{\text{a}}$	0.8	0.8
D	1	1×10^{-9} to 2×10^{-9} $(1.5 \times 10^{-9})^{\text{a}}$	1	2.5×10^{-10}	2	1.2×10^{-9} 2.0×10^{-9}	6.0	0.9
E	1	1.5×10^{-10} to 4×10^{-11} $(9 \times 10^{-11})^{\text{a}}$	2	1.5×10^{-11} 3.5×10^{-11}	4	3.5×10^{-11} to 7×10^{-11} $(3.8 \times 10^{-11})^{\text{a}}$	3.6	2.4
F	1	6×10^{-11} to 1×10^{-10} $(8 \times 10^{-11})^{\text{a}}$	2	8×10^{-11} 1×10^{-10}	2	7.0×10^{-11} 2.1×10^{-10}	0.9	0.6
G	1	8×10^{-11} to 1×10^{-10} $(9 \times 10^{-11})^{\text{a}}$	1	1.5×10^{-10}	4	5×10^{-11} to 3×10^{-10} $(1.2 \times 10^{-10})^{\text{a}}$	0.6	0.8
H	1	4×10^{-10} to 1×10^{-9} $(7 \times 10^{-10})^{\text{a}}$	1	3×10^{-11}	4	1×10^{-11} to 1×10^{-5} $(2.2 \times 10^{-9})^{\text{a}}$	23	0.3
I	1	1×10^{-9} to 2×10^{-9} $(1.5 \times 10^{-9})^{\text{a}}$	1	1.5×10^{-10}	2	1.2×10^{-9} 1.5×10^{-9}	10	1.1
J	1	1×10^{-9} to 2×10^{-9} $(1.5 \times 10^{-9})^{\text{a}}$	2	1.8×10^{-10} 2.2×10^{-10}	3	1.5×10^{-9} to 3.2×10^{-9} $(2.6 \times 10^{-9})^{\text{a}}$	7.5	0.6
K	6	1×10^{-9} to 3×10^{-9} $(2 \times 10^{-9})^{\text{a}}$	6	1×10^{-10} to 4×10^{-10} $(2.9 \times 10^{-10})^{\text{a}}$	5	1.2×10^{-9} to 3.5×10^{-9} $(2.6 \times 10^{-9})^{\text{a}}$	6.8	0.8

[a] Best estimate of field hydraulic conductivity.

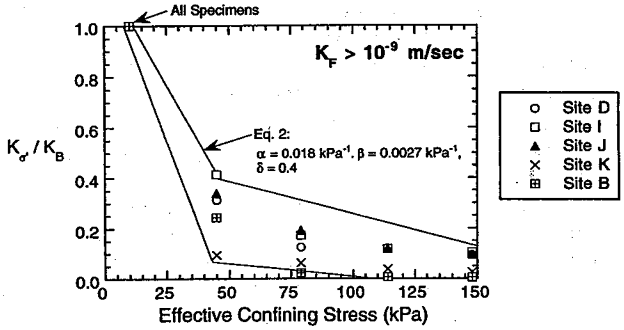

FIG. 1. Relationship between Hydraulic Conductivity and Effective Stress for Specimens with $K_F > 1 \times 10^{-9}$ m/s

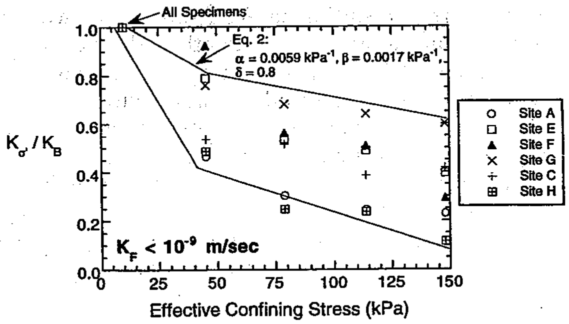

FIG. 2. Relationship between Hydraulic Conductivity and Effective Stress for Specimens with $K_F < 1 \times 10^{-9}$ m/s

$$K_{\sigma'}/K_F = \delta - \beta(\sigma' - 44), \text{ for } 44 \leq \sigma' \leq 147 \text{ kPa} \quad (2b)$$

Eq. (2), with $\alpha = 0.018$ kPa^{-1}, $\beta = 0.0027$ kPa^{-1}, and $\delta = 0.4$, can be used to conservatively estimate the hydraulic conductivity of these soils for various effective stresses.

The hydraulic conductivity of specimens with $K_F < 1 \times 10^{-9}$ m/s was less sensitive to increasing effective stress (Fig. 2), although the hydraulic conductivity still decreased more rapidly as the effective stress was increased from 10 kPa to 44 kPa than at higher effective stresses. Increasing the effective stress from 10 to 44 kPa reduced the hydraulic conductivity by a factor of 1.5 on average, whereas increasing the effective stress to 147 kPa reduced the hydraulic conductivity by a factor of 2.5. There was also substantially more variability in the hydraulic conductivity–effective stress relationship for these specimens. The hydraulic conductivity of these soils for various effective stresses can also be conservatively estimated using (2), with $\alpha = 0.0059$ kPa^{-1}, $\beta = 0.0017$ kPa^{-1}, $\delta = 0.8$.

The greater sensitivity of hydraulic conductivity to increasing effective stress observed for the specimens with $K_F > 1 \times 10^{-9}$ m/s was expected. Because these specimens have larger hydraulic conductivity, they contain larger pores. Furthermore, for all but one of the sites (site B) where $K_F > 1 \times 10^{-9}$ m/s, the hydraulic conductivity was scale-dependent, suggesting that a network of macropores was present at these sites (Benson et al. 1994). These larger pores are expected to collapse more readily under elevated effective stress. Consequently, a greater decrease in hydraulic conductivity occurs.

SUMMARY AND CONCLUSION

Results of hydraulic-conductivity tests conducted in the field and laboratory have been presented for soils collected from 11 compacted-clay test pads or compacted-clay liners. The field tests were conducted with sealed double-ring infiltrometers (SDRIs) to define the field-scale hydraulic conductivity (K_F). The laboratory tests were conducted using large undisturbed block specimens (diameter ≥ 0.3 m) and small specimens collected in thin-walled sampling tubes (diameter = 71 mm).

Results of tests at low effective stress showed that the hydraulic conductivity of the block specimens (K_B) was similar to K_F measured at each site. Thus, laboratory hydraulic-conductivity tests conducted on specimens of this size may prove to be a viable alternative to SDRI testing. In contrast, the hydraulic conductivity of the specimens collected in sampling tubes (K_{ST}) compared well to K_F for some cases, but for other sites K_{ST} was significantly lower than K_F.

The hydraulic conductivities of block specimens from sites where $K_F > 10^{-9}$ m/s were more sensitive to effective stress. On average, the hydraulic conductivity of these specimens decreased by a factor of 4 when the effective stress was increased from 10 to 44 kPa. The hydraulic conductivity of specimens from sites where $K_F < 10^{-9}$ m/s was reduced only by a factor of 1.5 under the same increment of effective stress. In either case, a conservative estimate of the hydraulic conductivity of these soils at various effective stresses can be made using (2), provided K_F is known.

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REPRESENTATIVE SPECIMEN SIZE FOR HYDRAULIC CONDUCTIVITY ASSESSMENT OF COMPACTED SOIL LINERS

REFERENCE: Benson, C. H., Hardianto, F. S., and Motan E. S., **"Representative Specimen Size for Hydraulic Conductivity Assessment of Compacted Soil Liners,"** Hydraulic Conductivity and Waste Contaminant Transport in Soil, ASTM STP 1142, David E. Daniel, and Stephen J. Trautwein, Eds., American Society for Testing and Materials, Philadelphia, 1994.

ABSTRACT: An alternative to field measurement of hydraulic conductivity is to conduct laboratory hydraulic conductivity tests on specimens large enough to simulate field-scale conditions. Laboratory tests can be performed rapidly using standard procedures and with accurate control of state of stress and gradient. The objective of this research program was to identify how large a specimen must be to yield field-scale hydraulic conductivity. This objective was accomplished through field testing, laboratory testing, and statistical modeling.

Hydraulic conductivity tests were conducted on test pads at four sites that represented construction conditions ranging from poor to excellent. One test pad was deliberately constructed using poor construction methods to demonstrate "worst case" conditions. Field tests were performed with sealed double-ring infiltrometers (SDRIs) having inner rings with widths of 0.61, 0.92, 1.2, or 1.5 m. Laboratory tests were performed on block specimens with diameters ranging from 0.07 m to 0.46 m.

For the range of construction conditions that were evaluated, the test results showed that hydraulic conductivity at or near field-scale can be measured using block specimens with a diameter of 0.30 m and a thickness of 0.15 m. A probabilistic model was designed to simulate macroscopic defects in compacted soil. Results obtained with the model supported the results of the experimental study.

KEYWORDS: representative specimen size, hydraulic conductivity, soil liner, clay liner, test pads, field-scale, in situ, sealed double-ring infiltrometer, block samples.

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INTRODUCTION

Compacted fine-grained soils are widely used in liners and covers for waste containment structures. Their primary purpose is to minimize flow. Hence, low hydraulic conductivity is of utmost importance (Daniel, 1987). To ensure a liner will have sufficiently low hydraulic conductivity, measurements are performed in the laboratory on specimens removed in thin-wall sampling tubes or in the field using in situ measurement techniques.

Several studies have shown that the field-scale hydraulic conductivity of compacted soil liners may differ significantly from hydraulic conductivity measured in the laboratory on small specimens (Daniel, 1984; Day and Daniel, 1985; Elsbury et al., 1988; Benson and Boutwell, 1992). For poorly built liners, the hydraulic conductivity of small specimens (diameter~0.07m) can be several orders of magnitude lower than the hydraulic conductivity measured using large-scale field tests. These studies have shown that defects which control flow at field-scale may be inadequately represented in small specimens.

Currently, many regulatory agencies require field tests to ensure an adequate volume of soil is permeated and the field-scale hydraulic conductivity is assessed. As will be shown, however, it is not essential that these tests be performed in the field; tests only need to be conducted on a specimen that is large enough to adequately represent macroscopic defects. In fact, field tests have practical and technical problems that limit their use in quality control. From a practical perspective, field tests usually require a long time to complete and are expensive. As a result, replicate measurements are not ordinarily performed and therefore the measurements cannot be analyzed statistically. Furthermore, for most field tests, the state of stress cannot be controlled and the hydraulic gradient cannot be measured with accuracy. As a result, hydraulic conductivity is usually estimated conservatively.

A logical alternative to field testing is to conduct hydraulic conductivity tests in the laboratory on specimens large enough to simulate field-scale conditions. Laboratory tests can be performed rapidly and with accurate control of the state of stress and gradient. Furthermore, methods to perform laboratory tests in flexible-wall permeameters have been refined in recent years and an ASTM standard is now available to ensure consistency among laboratories (ASTM D5084). In addition, laboratory tests are usually less expensive than field tests. Therefore, replicate measurements can be obtained to yield statistically significant results.

Before laboratory testing can be used as an alternative for field tests, the size of specimen that is necessary to adequately represent field-scale hydraulic conductivity under a variety of construction conditions must be identified. Herein, this size is referred to as the "Representative Specimen Size" (RSS). The objective of the research program described in this paper was to determine the RSS through field testing, laboratory testing, and statistical modeling.

BACKGROUND

Discrepancies Between Small and Large-Scale Measurements

Daniel (1984) presented three case histories regarding soil liners in central Texas where hydraulic conductivities were measured in the field and laboratory. Field tests were performed using ring infiltrometers and laboratory tests were performed on small undisturbed specimens. Daniel found that the field-scale hydraulic conductivity was generally 10-1000 times larger than the hydraulic conductivity obtained from laboratory tests. Daniel also noted that the liners were thin, construction was poorly documented, and little was done to prevent desiccation.

Based on these results, Daniel (1984) concluded that laboratory hydraulic conductivity tests may yield hydraulic conductivity lower than the hydraulic conductivity at field-scale because small, non-representative specimens are used for testing. He stated that small specimens are not likely to contain a representative distribution of desiccation cracks, fissures, slickensides, or other hydraulic defects that may be present in the field.

Day and Daniel (1985) reported similar findings. They performed hydraulic conductivity tests in the laboratory and field on two "prototype" soil liners. Laboratory tests were performed on hand-carved specimens, on specimens obtained with thin-wall sampling tubes, and on laboratory-compacted specimens. Field tests were performed with infiltrometers and underdrains. Two clays, designated Clay 1 and Clay 2, were used.

The overall hydraulic conductivity of each liner was computed from the rate of outflow measured with the underdrains and was found to be $9\text{x}10^{-8}$ m/sec for Clay 1 and $4\text{x}10^{-8}$ m/sec for Clay 2. Hydraulic conductivities measured with the underdrains were assumed to be the actual hydraulic conductivities of the liners. Field hydraulic conductivity tests were also performed using single-ring and double-ring infiltrometers. The single-ring infiltrometers had a diameter of either 0.56 m or 1.12 m. The double-ring infiltrometers had inner and outer rings with diameters of 0.30 m and 0.50 m. Hydraulic conductivities of 5×10^{-8} m/sec (Clay 1) and 3×10^{-8} m/sec (Clay 2) were obtained from the infiltration tests. These hydraulic conductivities are close to the hydraulic conductivities measured with the underdrains.

Block specimens removed from the liners were trimmed to a diameter of 0.10 m or 0.064 m. Flexible-wall permeameters were used to test the 0.10-m specimens whereas consolidation cells were used to test the 0.064-m specimens. Specimens obtained with thin-wall sampling tubes were tested in flexible-wall permeameters. Results of the laboratory tests showed that the average hydraulic conductivity for Clay 1 was 1×10^{-10} m/sec whereas the average value for Clay 2 was 3×10^{-11} m/sec. Thus, the laboratory-measured hydraulic conductivities were 2 to 3 orders of magnitude lower then the field-measured values. Day and Daniel (1985) concluded that the laboratory specimens were too small to incorporate macropores controlling field-scale hydraulic conductivity, whereas the volume of soil permeated with the ring infiltration tests was large enough to be representative of the entire liner.

Elsbury et al. (1988) have also shown that field-scale hydraulic conductivity may differ substantially from hydraulic conductivity measured on small specimens in the laboratory. They constructed a test pad with a high plasticity clay. The pad was compacted dry of standard Proctor optimum water content with a lightweight padfoot compactor.

Field measurements of hydraulic conductivity were conducted using an underdrain (4.9 m x 4.9 m) and 4 sealed double-ring infiltrometers (SDRIs). Laboratory tests were conducted on small specimens removed in thin-wall sampling tubes 0.07 m in diameter and on block specimens trimmed to a diameter of 0.15 m. The field-scale measurements of hydraulic conductivity obtained with the SDRIs and the underdrain were essentially the same. However, the average hydraulic conductivity of the 0.07-m specimens was 5 orders of magnitude lower than the field-scale hydraulic conductivity. The average hydraulic conductivity of the larger block specimens (diameter=0.15 m) was approximately 2 orders of magnitude lower than the field-scale hydraulic conductivity. Elsbury et al. (1988) concluded that these discrepancies occurred because the laboratory specimens were too small to capture macropores controlling flow at field-scale.

Similar Hydraulic Conductivity at Small and Large-Scale

Lahti et al. (1987) and Reades et al. (1990) have found close agreement between hydraulic conductivity measured in the laboratory and field for a liner at the Keele Valley Landfill. The liner was constructed with glacial till placed in 0.15 m lifts and compacted to achieve a dry unit weight in excess of 95% of standard Proctor maximum dry unit weight. Water content was maintained 2 to 3% wet of optimum water content. Based on the measurements of water content and dry unit weight, the average degree of saturation was found to be approximately 95%.

Specimens for laboratory testing were obtained using thin-wall sampling tubes having a diameter of 0.07 m. The specimens were extruded and tested for hydraulic conductivity using flexible-wall permeameters. All of the tests were conducted at a hydraulic gradient of 20 and an effective stress of 165 kPa. Measurements made during the construction seasons of 1983, 1984, and 1985 showed a geometric mean hydraulic conductivity of 7.1×10^{-11}, 8.2×10^{-11}, and 7.7×10^{-11} m/sec, respectively.

Field-scale hydraulic conductivity was computed from flow rates measured in six square underdrains, each with a width of 15 m. Three underdrains were installed below the liner and three were installed within the liner. Hydraulic conductivity computed from the underdrains averaged 9×10^{-11} m/sec, which is comparable to the hydraulic conductivity measured on the small laboratory specimens.

Lahti et al. (1987) and Reades et al. (1990) concluded that the hydraulic conductivity measured in the field and laboratory was similar because proper construction techniques were employed and quality control procedures were strictly followed. Heavy rollers were used and the water content was maintained wet of optimum. As a result, the pores controlling flow through the liner were very small and were adequately represented in small specimens.

Similar agreement between laboratory and field-measured hydraulic conductivity has been observed by Johnson et al. (1990). They constructed two test pads with a moderate plasticity clay. A heavy sheepsfoot compactor was used to compact the soil in 0.15-m lifts and the degree of saturation during compaction was maintained above the degree of saturation at optimum water content. Field hydraulic conductivity tests were conducted with sealed double-ring infiltrometers, Boutwell borehole permeameters, and underdrains. Laboratory tests were conducted in flexible-wall permeameters on specimens removed in thin-wall sampling tubes (diameter=0.07 m). The field-measured hydraulic conductivity was found to range between 0.6 to 2 times the laboratory-measured hydraulic conductivity. The close agreement between the laboratory and field measurements occurred because the soil was carefully compacted and devoid of macropores. As a result, the small specimens contained pores that were representative of the pores conducting flow at field-scale.

Synthesis

The case histories show that a large discrepancy can exist between hydraulic conductivity measured in the laboratory on small specimens and in the field using large-scale tests. A large discrepancy occurs when inadequate construction techniques are employed and macropores exist in the soil. Macropores, which control flow at field-scale, are inadequately represented in small specimens (diameter~0.07m) normally tested in the laboratory. In contrast, when proper construction methods are used, a dense mass devoid of macropores is obtained. As a result, the field-scale hydraulic conductivity is controlled by very small pores that are adequately represented in small specimens traditionally used for laboratory testing.

Thus, the RSS depends on the quality of construction, which directly impacts the size of the network of pores controlling flow at field-scale. Unfortunately, the quality of construction and the size of the network of pores controlling flow at field-scale are not known a priori. Hence, an RSS needs to be identified that is applicable to a wide range of construction conditions. The aforementioned case histories illustrate that a widely applicable RSS is likely to be larger than the commonly used thin-wall sampling tube (diameter=0.07 m) and smaller than or equal in size to infiltrometers (diameter=0.5 to 1.5m).

TEST SITES

Hydraulic conductivity tests were performed on test pads at four sites. Construction methods that were used varied from poor to excellent. One test pad was deliberately constructed poorly to define "worst case" conditions that would result in an upper bound on the RSS.

Site A

Soil used to construct the test pad at Site A was a sandy clay obtained from an alluvial deposit. Properties of the soil are summarized in Table 1.

The test pad at Site A was built with 5 lifts. Soil for the pad was sieved to remove clods and rocks with a diameter greater than 0.10 m. For the upper lift, a smaller sieve was used to reduce the maximum clod size to 0.02 m. Water was added as necessary to ensure that the water content was wet of optimum based on modified Proctor effort. A Caterpillar 825C tamping foot compactor was used for compaction. The compactor weighed 320 kN and had feet 0.19 m long. A minimum of six passes were used to compact each lift. The lower 4 lifts were approximately 0.13 m thick (after compaction) and the top lift was 0.10 m thick.

There was concern after construction that the different procedure used to compact the upper lift may confound comparisons to be made between measurements of hydraulic conductivity performed in the field and laboratory. However, the thin upper lift swelled and became soft during infiltration testing (described later). Thus, the upper lift probably had little impact on the test results.

Compaction tests were conducted to determine the relationship between water content, dry unit weight, and compactive effort. Three compactive efforts were used: modified Proctor (ASTM D1557), standard Proctor (ASTM D698), and reduced Proctor. The latter effort (reduced Proctor) is used to simulate light compactive effort. The weight and drop of the hammer are the same as standard Proctor, but only 15 blows per lift are applied (Daniel and Benson, 1990). Similar procedures were used to develop compaction curves for soils from Sites B-D.

Figure 1a shows the compaction curves and measurements of water content and dry unit weight performed during construction. The designer of the test pad planned for compaction "wet of optimum" to achieve low hydraulic conductivity. Construction of the pad was performed in accord with the designer's specifications; however, 60% of the field data points fell dry of the line of optimums (Fig. 1a).

TABLE 1--Summary of soil properties.

Site	LL	PI	% Gravel	% Sand	% Fines	% Clay	USCS Class
A	24	11	3	35	62	37	CL
B	32	14	1	14	85	44	CL
C	31	15	8	18	74	26	CL
D	30	17	0	48	52	16	SC-CL

Particle Size Definitions: Gravel>4.75 mm, 4.75 mm>Sand>0.075 mm, Fines<0.075 mm, Clay<2 μm

Site B

The test pad at Site B was deliberately compacted dry of the line of optimums at low compactive effort. These conditions are conducive to the formation of macropores and hydraulic conductivity that is scale-dependent (Benson and Daniel, 1990; Benson and Boutwell, 1992). These conditions were expected to represent a "worst case" that would require the largest specimen to obtain field-scale hydraulic conductivity.

Soil used to construct the test pad at Site B was a low plasticity clay obtained from a deposit of glacial till (see Table 1 for index properties). The first two lifts were compacted to a thickness of 0.15 m using a light-weight bulldozer (weight~35 kN). Each location received about 5 passes of the dozer. After the first two lifts were completed, it was apparent that even the light bulldozer was heavy enough to remold the clods in some locations. This occurred because some of the soil was too wet because of recent rains. Hence, to reduce the compactive energy, the remaining 0.30 m of soil was placed in one lift.

No effort was made to break down the clods prior to compaction. Clods ranged in size from small particles that would pass the No. 4 sieve to large chunks with diameters of 0.15 to 0.20 m. Some of the clods were broken down as the dozer spread the soil into lifts, but many of the clods remained intact and were only pressed together by the compactive effort.

Like the test pad at Site A, there was concern after construction that the different procedure used to compact the upper lift may confound comparisons to be made between measurements of hydraulic conductivity performed in the field and laboratory. However, the macropores were so extensive in each lift of this test pad, that the different compaction

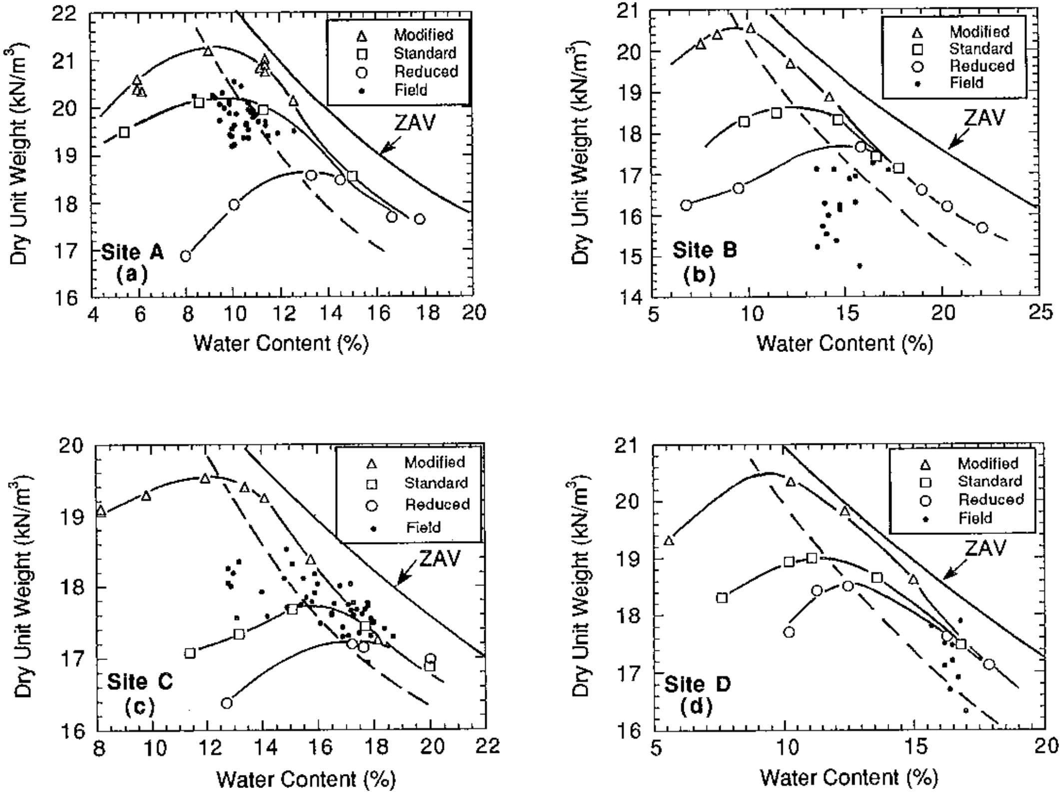

FIG. 1--Compaction curves and field data for Sites A-D.

procedures apparently had no effect on the test results (described later).

Compaction curves for Site B are shown in Fig. 1b with the measurements of water content and dry unit weight performed during construction. Figure 1b shows that 88% of the measurements of water content and dry unit weight fall dry of the line of optimums and that the compactive effort was low.

Site C

Soil used to construct the test pad at Site C was obtained from a deposit of glacial till. A summary of index properties of the soil is shown in Table 1.

The pad was constructed with six lifts each having a thickness of 0.15 m. Water was added if needed to ensure the water content remained above optimum based on modified Proctor effort. Compaction was performed using a Dynapac CA25 padfoot compactor having a weight of 90 kN and feet 0.11 m long. A minimum of four passes of the compactor were used for each lift.

Results of compaction tests performed on the soil from Site C are shown in Fig. 1c with measurements of water content and dry unit weight obtained during construction. Forty-three percent of the data points fall dry of the line of optimums even though the test pad was constructed in accord with the construction specifications.

Site D

The soil used to construct the test pad at Site D was a sandy marine clay. Index properties of the soil are summarized in Table 1.

The test pad was constructed in six lifts and each lift had a thickness of 0.15 m. A large bulldozer (weight=275 kN) was used for compaction. Compaction was controlled by ensuring that the degree of saturation at compaction exceeded the degree of saturation at optimum water content.

Compaction curves for the soil from Site D are shown in Fig. 1d with measurements of water content and dry unit weight performed during construction. Ninety-five percent of the measurements fall wet of the line of optimums.

TESTING PROCEDURES

To evaluate the relationship between hydraulic conductivity and size of specimen, experiments were conducted at various scales. Large scale tests (diameter > 0.6 m) were conducted in the field using sealed double-ring infiltrometers whereas smaller scale tests (diameter < 0.6 m) were conducted in the laboratory in a specially built large-scale flexible-wall permeameter.

Field Tests

Large-scale measurements of hydraulic conductivity were performed in the field with sealed double-ring infiltrometers (SDRIs) using the methods described in ASTM D5093. The inner and outer rings were square. For Sites A and B, the outer rings had a width of 2.45 m. The inner rings had widths of 0.61, 0.92, or 1.2 m so that different volumes of soil would be permeated. Two tests were performed for each size. At Sites C and D, only 1 SDRI was used. At both sites, the outer ring was

3.7 m wide and the inner ring was 1.5 m wide. All of the SDRIs met or exceeded dimensional requirements described in ASTM D5093.

Infiltration rate was measured with plastic bags connected to the inner ring via Tygon tubing. Double-sealing quick connects were used to join the plastic bags to the tubing. Infiltration rate (I) was determined from the change in weight of the bags (ΔW) using Eq. 1 (Daniel, 1989):

$$I = \frac{\Delta W}{\Delta t\, \gamma_w\, A} \qquad (1)$$

where Δt is the elapsed time between measurements of the bag weight, A is the horizontal cross-sectional area of the inner ring, and γ_w is the unit weight of water. The SDRI tests were deemed complete when the infiltration rate became steady.

Hydraulic conductivity (K) was computed from infiltration rate by (Daniel, 1989):

$$K = \frac{I}{i} \qquad (2)$$

In Eq. 2, i is the hydraulic gradient, which was computed using Eq. 3 (Daniel, 1989):

$$i = \frac{D_p + D_f}{D_f} \qquad (3)$$

where D_f is the depth to the wetting front and D_p is the depth of ponding.

Equation 3 ignores suction head at the wetting front, which can affect the hydraulic gradient and thus the hydraulic conductivity computed using Eq. 2. To avoid error caused by ignoring suction head, the tests at Sites A-C were continued until tensiometers installed between the inner and outer rings indicated that the wetting front passed through the test pad (Hardianto, 1992). Test pits were also excavated to confirm the depth to the wetting front. At Site D, however, the wetting front only penetrated about 0.20 m into the pad when the test was terminated. Thus, at Site D, the hydraulic conductivity (computed using Eqs. 2 and 3) may have been somewhat larger than the actual field-scale hydraulic conductivity.

Laboratory Tests

After the SDRI tests were complete, large specimens were removed as blocks from soil directly beneath each inner ring. The block specimens were shipped to the University of Wisconsin where they were trimmed and then permeated in a large-scale flexible-wall permeameter.

Sampling procedure

A trimming ring was used to carve and protect the block specimens. The ring was manufactured from PVC pipe and had an inside diameter of 0.58 m and a height of 0.3 m. A beveled cutting shoe was machined at the base of the ring. The trimming ring was similar to a consolidation ring, only much larger.

After the ring was placed on the soil, a trench was excavated surrounding the ring (Fig. 2a). Then, soil was carefully trimmed away until the ring could be moved downward over the soil with light effort

(Fig. 2b). The trimming procedure was similar to procedures used to trim specimens into rings for consolidation or direct shear testing. Trimming was continued until the upper edge of the ring was 0.05-0.10 m below the surface. The soil above the ring, which typically was very soft, was removed.

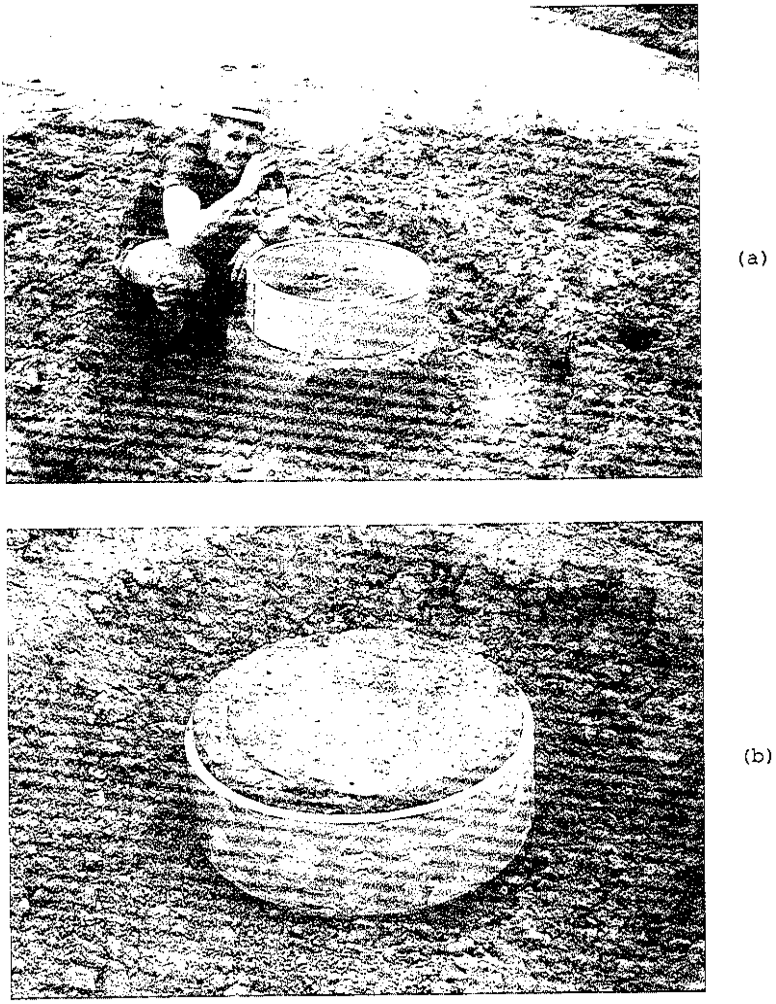

FIG. 2--Placement of ring on soil surface (a) and ring trimmed over specimen to be sampled (b).

When the trimming ring was at full depth, the specimen was separated from the underlying soil using one of the following procedures: (1) a sharpened steel plate was tapped into the soil with a hammer or (2) a flat-bladed shovel was pushed into the underlying soil at several locations. The latter method proved to be easier to implement and was less likely to cause disturbance. Afterwards, the specimen was transferred to a reinforced pallet and sealed with plastic wrap and duct tape.

Testing procedure

The rings were removed in the laboratory and soil was trimmed from the outer edge of the specimen until a diameter of 0.46 m was obtained. About 0.05 m of soil was also removed from the upper and lower surfaces. Afterwards, the upper and lower surfaces were scarified to eliminate smear.

Trimmed specimens were placed in the University of Wisconsin's large-scale flexible-wall permeameter which is similar in construction to flexible wall permeameters typically used in industry (e.g., Daniel et al., 1985), but much larger (Fig. 3). The permeameter was designed so that two specimens could be placed in the permeameter concurrently.

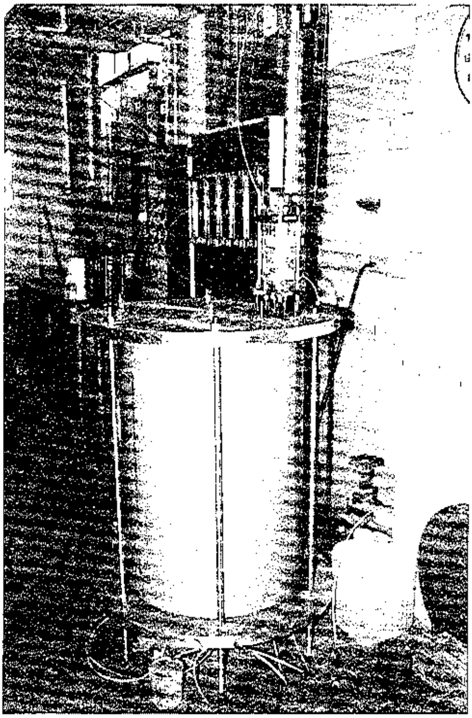

FIG. 3--Large-scale flexible-wall permeameter.

Hydraulic conductivity tests were conducted in accord with ASTM D5084 at an effective stress of 10 kPa and a hydraulic gradient between

3 and 5, but no backpressure was used. Permeation continued until inflow equaled outflow and the hydraulic conductivity was steady.

To evaluate the effect of specimen size, the specimens were repeatedly trimmed to smaller sizes and retested. At each size, the specimen was permeated until the hydraulic conductivity measurement became steady and inflow equaled outflow. Each block specimen was trimmed to diameters of 0.46, 0.30, 0.15, and 0.07 m with hydraulic conductivity measurements conducted at each size. Flexible-wall permeameters of various sizes were used to perform the hydraulic conductivity measurements.

Prior to performing the majority of tests, preliminary experiments were conducted to ensure that variations in aspect ratio (height/diameter) would not affect the scale-dependence of the measurements. Hydraulic conductivity tests were initially conducted on specimens having an aspect ratio of about 1.0. After equilibrium was reached, the specimens were trimmed to an aspect ratio of about 0.5 and their hydraulic conductivity was measured.

Results of the aspect ratio tests are shown in Table 2 for specimens from Site A. Specimens with an aspect ratio of 0.5 showed greater variability, but on average had similar hydraulic conductivity as the specimens having an aspect ratio of 1.0. Because aspect ratio did not have a consistent effect on hydraulic conductivity, an aspect ratio of approximately 0.5 was used for most of the laboratory tests. The exact size of each specimen is summarized in Benson and Hardianto (1992).

TABLE 2--Results of aspect ratio tests.

	Initial		Shortened			Average
Diameter (m)	Aspect Ratio	K (m/sec)	Aspect Ratio	K (m/sec)	K_{short}/K_{long}	K_{short}/K_{long}
0.15	1.13	$1x10^{-9}$	0.59	$6.0x10^{-10}$	0.6	1.3
			0.56	$2.0x10^{-9}$	2.0	
0.15	1.23	$1x10^{-9}$	0.56	$2.5x10^{-9}$	2.5	1.35
			0.63	$2.0x10^{-10}$	0.2	
0.01	1.13	$1x10^{-9}$	0.53	$3.5x10^{-10}$	0.35	0.35
					Average:	1.0

RESULTS OF FIELD AND LABORATORY TESTING

Results of the field and laboratory tests are shown in Fig. 4. Size of the specimens is described in Fig. 4 by "equivalent diameter," which is the diameter of a circle having area equal to the horizontal cross-sectional area that was permeated. Equivalent diameter was used as a common measure of specimen size to describe results obtained with SDRI tests (square cross-section) and laboratory tests (circular cross-section). Lines depicting trends in the data shown in Fig. 4 were fit by eye.

Site A

For Site A, hydraulic conductivity is related to equivalent diameter (Fig. 4a). The hydraulic conductivity of small specimens

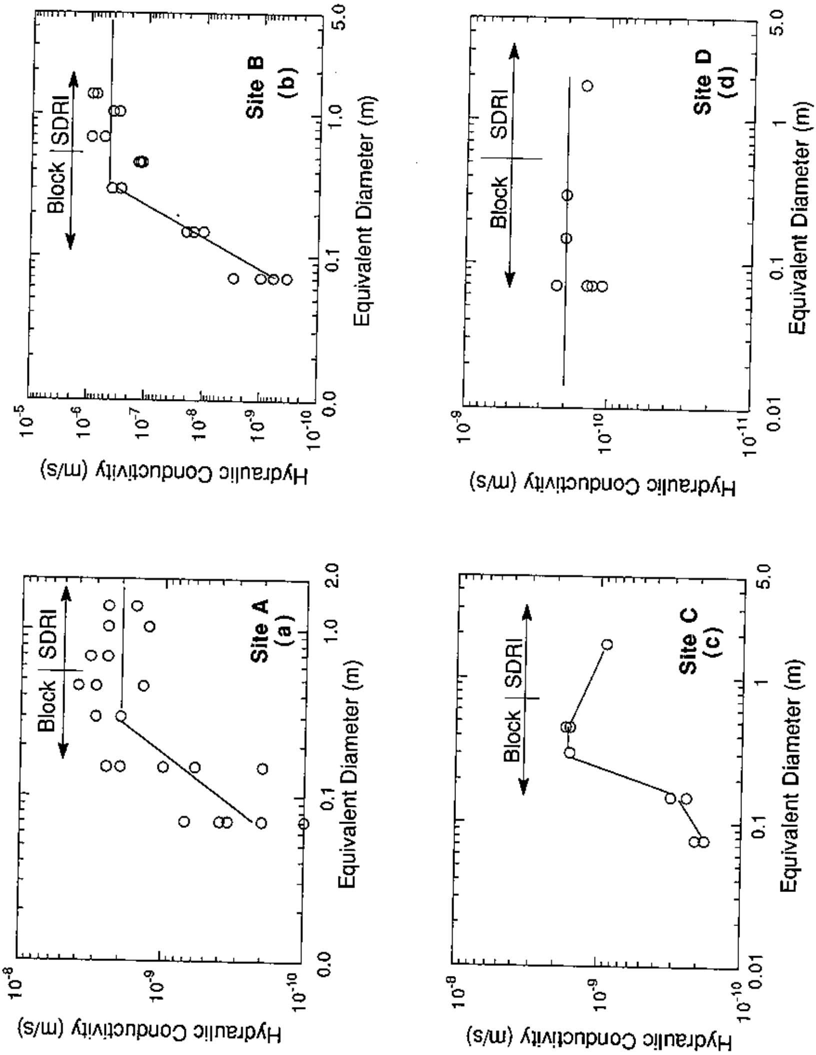

FIG. 4--Hydraulic conductivity-specimen size relationship for Sites A-D.

(diameter=0.07 m) is about one order of magnitude lower than the hydraulic conductivity measured with the SDRIs. An increase in hydraulic conductivity with increasing diameter is also apparent. However, for diameters equal to or greater than 0.30 m, hydraulic conductivity ceases to increase with further increase in diameter. To determine if the differences in hydraulic conductivity are statistically significant, a t-test was performed comparing the geometric mean hydraulic conductivity for each diameter. Results of the t-test showed that the geometric mean hydraulic conductivities are significantly different at the 5% level.

The trend of hydraulic conductivity with equivalent diameter that was observed at Site A was expected. The test pad at Site A was constructed slightly dry of the line of optimums, a condition conducive to the formation of macropores and scale-dependent hydraulic conductivities (Benson and Boutwell, 1992). Macropores existing in a specimen from Site A are evident in Fig. 5.

To confirm that macropores were carrying flow through the specimens, dye was introduced into one specimen after measuring its hydraulic conductivity at a diameter of 0.46 m. When the specimen was trimmed to smaller sizes, macropores through which the dye was flowing were evident. Trimming the specimens to smaller sizes eliminated some of these macropores and consequently the hydraulic conductivity decreased as the diameter of the specimen was reduced.

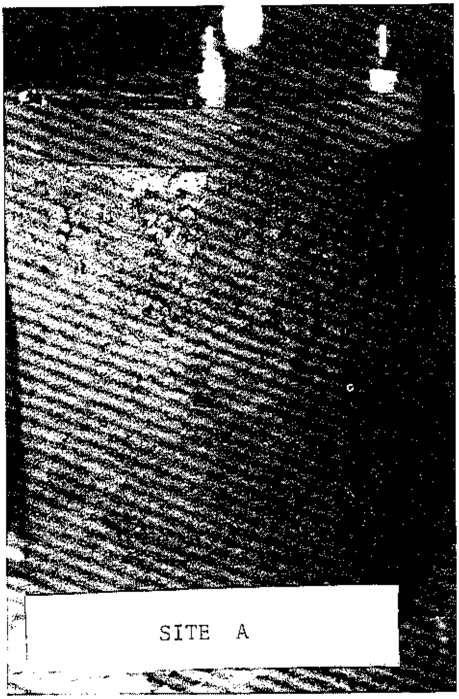

FIG. 5--Specimen from Site A showing macropores.

Site B

Results of field and laboratory tests from Site B are summarized in Fig. 4b. For Site B, hydraulic conductivity is also related to equivalent diameter. The small block specimens had hydraulic conductivity approximately 3 orders of magnitude lower than the large block specimens and the field tests.

The hydraulic conductivities of the block specimens with a diameter=0.46 m were slightly lower than the hydraulic conductivities measured with SDRIs. The lower values can be attributed in part to an artificial upper limit imposed by head losses in the permeameter. That is, the head loss in the tubes and valving was greater than the head loss in the specimen. Nevertheless, the results are similar to results obtained for Site A; for specimens having a diameter greater than 0.3 m, hydraulic conductivity near field-scale was measured.

Because Site B was deliberately constructed using procedures conducive to the formation of macroscopic defects, the large change in hydraulic conductivity with increasing diameter was expected. During installation of the SDRIs and removal of the block specimens, large macropores were observed. Dye studies showed that these macropores, which apparently controlled flow at field-scale, were inadequately represented in small (diameter < 0.30 m) specimens (Hardianto, 1992). Thus, the specimens were not representative of field-scale conditions. Trimming in the laboratory revealed that most of the macropores had an aperture width of about 1 to 3 mm. These pores were wider and longer than the pores observed in the specimens from Site A, as a result of the light compactive effort used during construction.

Site C

Results of the tests performed on specimens from Site C (Fig. 4c) show trends similar to those observed for Site A (Fig. 4a). For specimens with diameter exceeding 0.30 m, field-scale hydraulic conductivity was obtained. Like Site A, the test pad at Site C was constructed slightly dry of the line of optimums, a procedure conducive to the formation of macroscopic defects and scale-dependent hydraulic conductivities. Consequently, the small specimens (diameter=0.07 m) inadequately represented macroscopic features. Hence, their hydraulic conductivity did not represent field-scale conditions.

Figure 4c also shows that hydraulic conductivities measured on large block specimens (0.3 and 0.46 m diameter) were slightly larger than the hydraulic conductivity measured with the SDRI. The reason for this effect is not clear, but a similar trend is evident in the data from Site A and the modeling results presented later.

Site D

In contrast to the results obtained from Sites A-C, measurements of hydraulic conductivity at Site D showed no dependence on diameter. Examination of the liner during sampling and the specimens during trimming showed no presence of macroscopic features. Hence, hydraulic conductivity was not expected to depend on the diameter of specimen.

The lack of scale-dependence of hydraulic conductivity that was observed for Site D is a result of the construction methods that were employed. Compaction was achieved with a heavy compactor at water contents in excess of the line of optimums. Benson and Daniel (1990) have shown that large compactive effort, when combined with water content in excess of optimum, results in the elimination of macropores and interclod pores during compaction. As a result, the pores conducting flow are very small and are adequately represented in small and large specimens. Hence, the hydraulic conductivity does not vary with size of specimen.

Synthesis

The results of the testing program suggest that field-scale hydraulic conductivity can be assessed using laboratory tests on undisturbed block specimens having a diameter greater than 0.30 m. For the sites evaluated in this study, hydraulic conductivity measured on specimens of this size was similar to hydraulic conductivity measured using SDRIs. A variety of construction methods, ranging from very poor (Site B) to excellent (Site D), were used when compacting the test pads at these sites.

STOCHASTIC MODEL

Modeling of scale-dependent hydraulic conductivities was conducted concurrently with the experimental program. In this effort, a model of flow in compacted soil containing macropores was developed. Before modeling began, a literature review was conducted to determine if modeling techniques for flow in fractured rock could be adapted for flow in compacted soils. Two types of models were found to be widely used to simulate flow in fractured rock: dual continua models (e.g., Long et al., 1982; Andersson and Dverstorp, 1987; Berkowitz et al., 1988) and discrete fracture models (e.g., Snow, 1969; Neuzil and Tracy, 1981).

In dual continua models, the rock is assumed to consist of two continua that are joined hydraulically by a transfer function. One continuum represents the matrix and the other represents fractures. Typically, a finite difference or finite element algorithm (e.g., Long, et al., 1982) is used to link the continua together. In contrast, discrete fracture models (e.g., Neuzil and Tracy, 1981) ignore flow in the matrix and assume all flow occurs in the fractures. Laminar flow equations are used to compute flow rates in the fractures and continuity equations are written to join flows at the fracture intersections.

Approach for Compacted Soil Liners

The objective of this research program was to determine, via experiments and modeling, the size of specimen that is needed to represent field-scale hydraulic conductivity for a variety of construction conditions. In light of this objective, a simplified approach that combines the dual continua and discrete fracture methods was used. The macropores and the matrix were both treated as laminar flow media (i.e., using Darcian flow), but flow in the matrix and flow in the macropores was assumed to be uncoupled.

Figure 6 is a conceptual illustration of the model. A lift of soil is assumed to contain numerous interconnected macropores and a specimen with cross-sectional area A is sampled from the lift. The total flow rate (Q) through the specimen can be expressed as:

$$Q = Q_m + \sum_{i=1}^{N} Q_{p,i} \qquad (4)$$

where Q_m is the flow rate in the matrix, $Q_{p,i}$ is the flow rate in the i^{th} macropore that exits the base of the specimen, and N is the number of macropores that exit the base of the specimen. The flow rate in the matrix is computed based on the hydraulic conductivity of the soil that would be achieved for wet side compaction (K_w); i.e.,

$$Q_m = K_w \; i \; A \tag{5}$$

where i is the average hydraulic gradient and A is the cross-sectional area of flow. The cross-sectional area for matrix flow (A) was assumed equal to the gross area of the specimen because the contributions of the macropores to A are small.

The flow rate for the i^{th} macropore ($Q_{p,i}$) is also computed using Eq. 6. However, K_w is replaced by the hydraulic conductivity of the macropore, i is the hydraulic gradient along the macropore, and A is the cross-sectional area of the macropore.

The total flow rate is evaluated in terms of equivalent hydraulic conductivity (K) by:

$$K = \frac{Q}{i \; A} = K_w + \frac{1}{i \; A} \sum_{i=1}^{N} Q_{p,i} \tag{6}$$

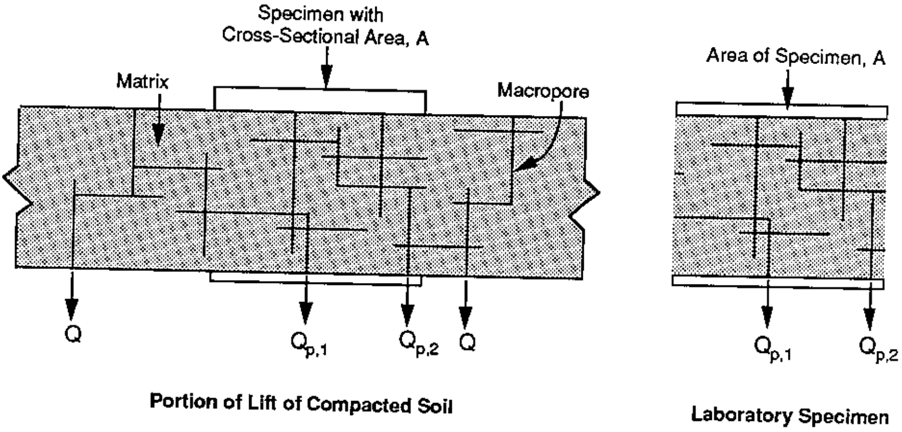

FIG. 6--Simulation of soil liner with defects.

Geometric Properties of Macropores

Little information is currently available to describe macropores in compacted soil liners. The greatest wealth of information has been collected by Elsbury et al. (1988), who describe a morphological study of a test pad that was very permeable ($K \sim 1 \times 10^{-6}$ m/sec). Thus, their results are likely to be representative of "worst case" conditions.

The report by Elsbury et al. (1988) contains photographs of dye stained macropores they found in the test pad. These photographs were used to characterize statistics of the length and size of macropores. All macropores were assumed to be horizontally or vertically oriented and a trace was made from each photograph based on this assumption (e.g., Fig. 7). From each trace, the length, orientation, and location of each macropore was obtained.

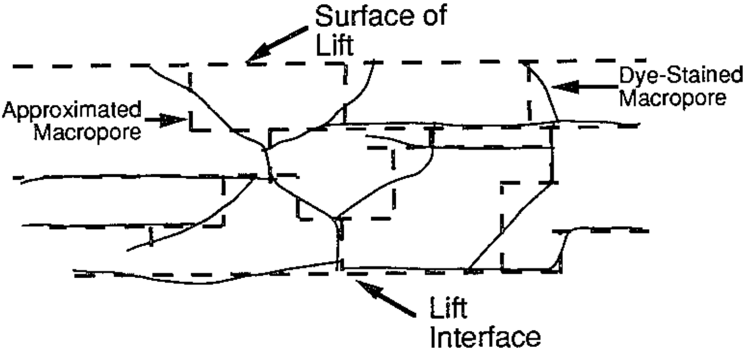

FIG. 7--Characterizing geometry of macropores from field observations.

Length of horizontal and vertical macropores

Horizontal macropores ranged in length from 0.03 m to 0.38 m with a mean 0.14 m. Vertical macropores were generally much shorter; they ranged in length from 0.02 to 0.06 m and had a mean length of 0.04 m. Aperture widths were virtually impossible to determine from the photographs; however, Elsbury et al. (1988) reported that the macropores were typically 0.001 to 0.003 m wide.

Histograms of macropore lengths were constructed to determine distributional forms that could be used to describe their variability (Fig. 8). Positive skew was evident in histograms for horizontal and vertical macropores. Hence, the lengths of the macropores were hypothesized as being log-normally distributed. To test this hypothesis, Filliben's probability plot correlation coefficient test was employed (Filliben, 1975). At a significance level of 0.05, the log-normal hypothesis was not rejected.

Location of intersections and number of vertical macropores

The photographs from Elsbury et al. (1988) were examined to develop a generating scheme based on how water infiltrating into a macropore at the surface forms a flow path through a soil liner. Figure 9a illustrates the process. Water first enters a vertical macropore at the surface of the soil and flows downward until it reaches a horizontal macropore. When water reaches the end of the vertical macropore, it stops (i.e., it reaches a dead end) or it spreads laterally in a horizontal macropore until another vertical macropore (or several vertical macropores) is found. This process is repeated until the water reaches the bottom of the lift.

To determine if probability distributions could be used to describe this process, the locations of intersections of horizontal and

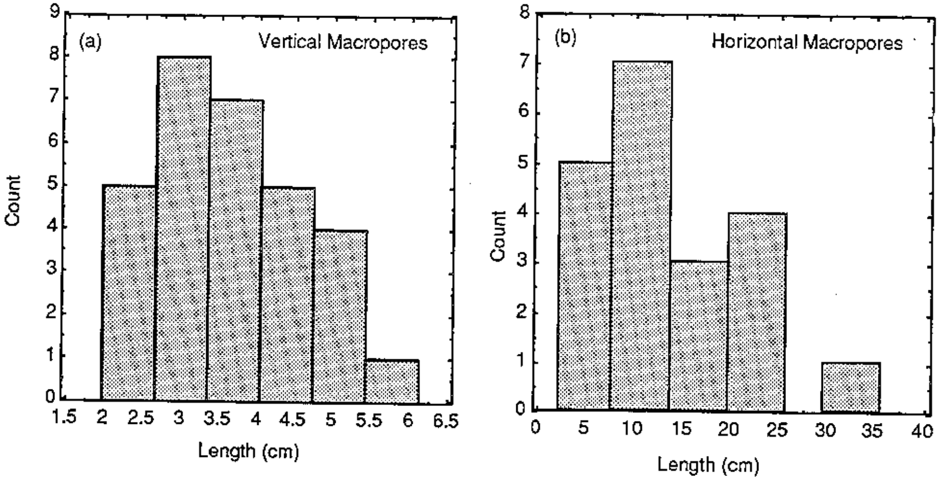

FIG. 8--Histograms of macropore lengths: (a) vertical and (b) horizontal.

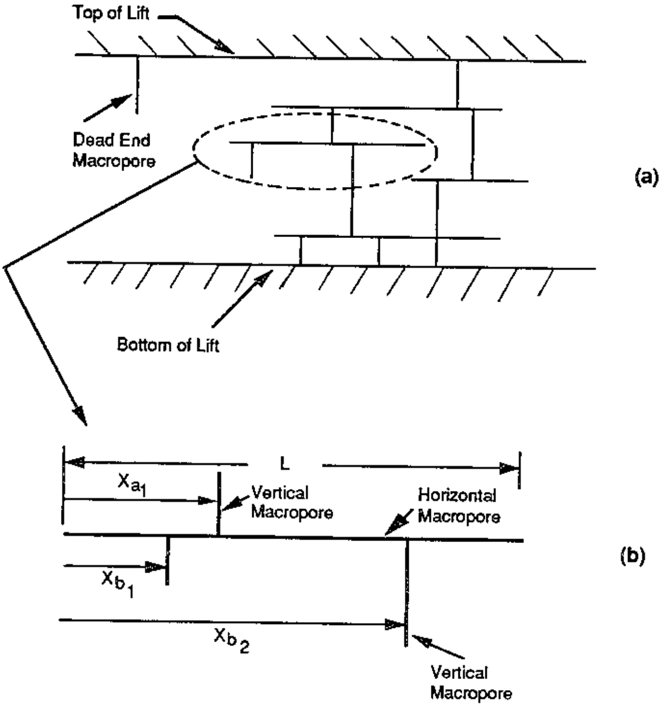

FIG. 9--Concept of flow in macropores (a) and definition of normalized location of intersections (b).

vertical macropores were evaluated and the frequency of vertical macropores stemming from horizontal macropores was determined. Locations of intersections of vertical macropores, for a given horizontal macropore, were measured relative to the length (i.e., X_a/L and X_b/L) of the horizontal macropore (Fig. 9b).

Fig. 10 shows histograms of the location of vertical macropores stemming from each horizontal macropore relative to the length of the horizontal macropore (X_a/L or X_b/L). The lack of shape present in the histograms suggests that the locations of the intersections (X_a's and X_b's) can be described by a uniform distribution. Vogel's probability plot correlation coefficient test for the uniform distribution (Vogel and Kroll, 1989) was used to test this hypothesis at a significance level of 0.05. The hypothesis was not rejected.

A similar analysis was conducted for the number of intersections of vertical and horizontal macropores (N_b). The number of vertical macropores stemming from each horizontal macropore was counted. Figure 11 is a histogram of N_b based on data collected from the macropore traces. The positive skew of N_b and the uniform distribution of the locations of the intersections suggests that a Poisson distribution can be used to describe N_b. To test this hypothesis, the chi-square test (Haan, 1977) was employed. At a significance level of 0.05, the hypothesis was not rejected.

Monte Carlo Simulation

A numerical model employing Monte Carlo simulation was developed to generate random networks of macropores. The Poisson distribution was used to generate the number of macropores and the log-normal distribution was used to specify their length. Locations of the intersections of horizontal and vertical macropores were generated from a uniform distribution.

After a network of macropores was generated, specimens of various size were "removed" from the network. Then, hydraulic heads corresponding to steady state flow throughout the network were computed and an equivalent hydraulic conductivity was determined as defined in Eq. 6. Heads were obtained by ensuring continuity at each intersection of the macropores. Details describing the simulation procedure and the method to compute heads and flow rates can be found in Benson and Hardianto (1992).

Networks of macropores were generated in a two-dimensional domain. The domain was 1 m wide and 0.15 m thick, representing one lift of compacted soil. Two different lifts were analyzed, each with different geometric properties for the macropores. Herein, the lifts are referred to as Lift 1 and Lift 2. Input data for the two lifts are summarized in Table 3. The writers admit that the input parameters were, in part, selected arbitrarily. Thus, using different parameters may yield different results.

Lift 1 was used to simulate macroscopic defects caused by poor construction practices (e.g., Site B). Statistics for the distributions used to describe macropores were obtained from the study by Elsbury et al. (1988). Eight starting points for vertical macropores were assigned on the top of Lift 1, with a spacing of 0.12 m between the starting points. Other inputs for Lift 1 included: mean number of vertical macropores (λ) of 1.31, log-mean and log-standard deviation of the length of horizontal macropores equal to μ=2.4 and σ=0.6, and log-mean and log-standard deviation for length of vertical macropores of μ=1.9 and σ=0.3. All lengths are in centimeters prior to logarithmic transformation. Each macropore was assigned a hydraulic conductivity of 1×10^{-4} m/sec.

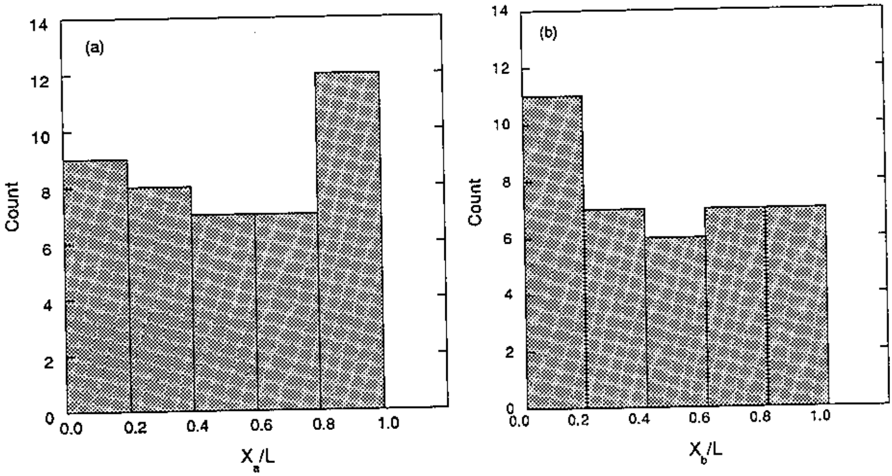

FIG. 10--Histograms of normalized locations.

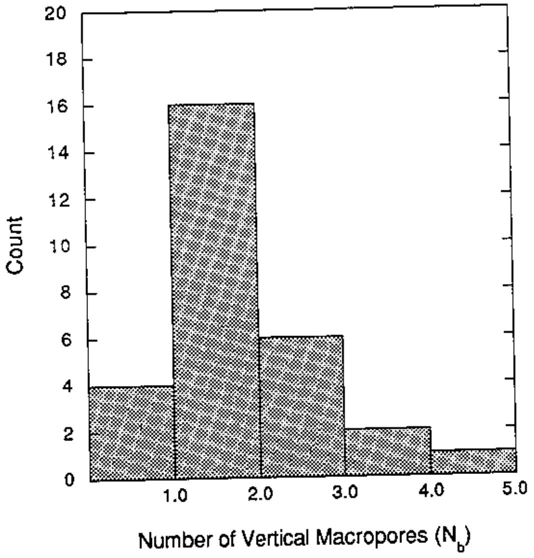

FIG. 11--Histogram of number of vertical macropores.

TABLE 3--Macropore input parameters for Lifts 1 and 2.

Parameter	Description	Lift 1	Lift 2
μ (horizontal)	log-mean length of horizontal macropores	2.4	1.2
σ (horizontal)	log-variance length of horizontal macropores	0.6	0.6
μ (vertical)	log-mean length of vertical macropores	1.9	0.95
σ (vertical)	log-variance length of vertical macropores	0.3	0.3
λ	mean of number of vertical macropores	1.31	1.31
No. starting points	number of vertical macropores at the top of the lift	8	16

Note: All units of length in centimeters prior to logarithmic conversion.

Lift 2 was used to simulate a lift with many macropores that are highly tortuous. These conditions are assumed to correspond to compaction of a pre-processed soil with heavy machinery, but slightly dry of the line of optimums (i.e., similar to conditions at Site A). Under this condition, the soil would contain numerous tortuous macropores (Benson and Daniel, 1990). The construction condition represented by Lift 2 is better than the condition represented by Lift 1, but still will result in scale-dependent hydraulic conductivity. Shorter horizontal and vertical macropores were used for Lift 2 and the number of starting points was doubled. Sixteen starting points were assigned to the top of the lift, with a 0.06 m-spacing. Log-means (μ's) of 1.2 and 0.95 were used for the length of horizontal and vertical macropores and their hydraulic conductivity was specified as 1×10^{-8} m/sec. Lower hydraulic conductivity was used to simulate greater tortuosity and smaller aperture width. The remaining parameters were the same as those used in Lift 1.

Moment sensitivity studies showed that stable estimates of the mean could be obtained with a minimum of 10 realizations (Hardianto, 1992). Because the mean hydraulic conductivity of each specimen size was the primary variable being considered, 12 realizations were used for each condition that was simulated. For each realization, a "specimen" was isolated from the simulated lift, with the center of the "specimen" always being located at the center of the lift. Each specimen had a different width; widths of 0.07, 0.15, 0.30, 0.45, 0.60, and 0.90 m were used.

Results and Discussion

Figure 12 shows results obtained with the model, experimental data obtained from Sites A and B, and data presented in Elsbury et al. (1988). Lines passing through the data points were fit by eye. For each specimen size, the geometric mean hydraulic conductivity (from test results or modeling) was computed and then normalized by dividing by the geometric mean hydraulic conductivity of the smallest specimens (diameter=0.07 m). For the modeling results, hydraulic conductivity of the matrix (K_w) was $1x10^{-10}$ m/sec for Sites A and B (Hardianto, 1992) and $1x10^{-11}$ m/sec for Elsbury et al. (1988).

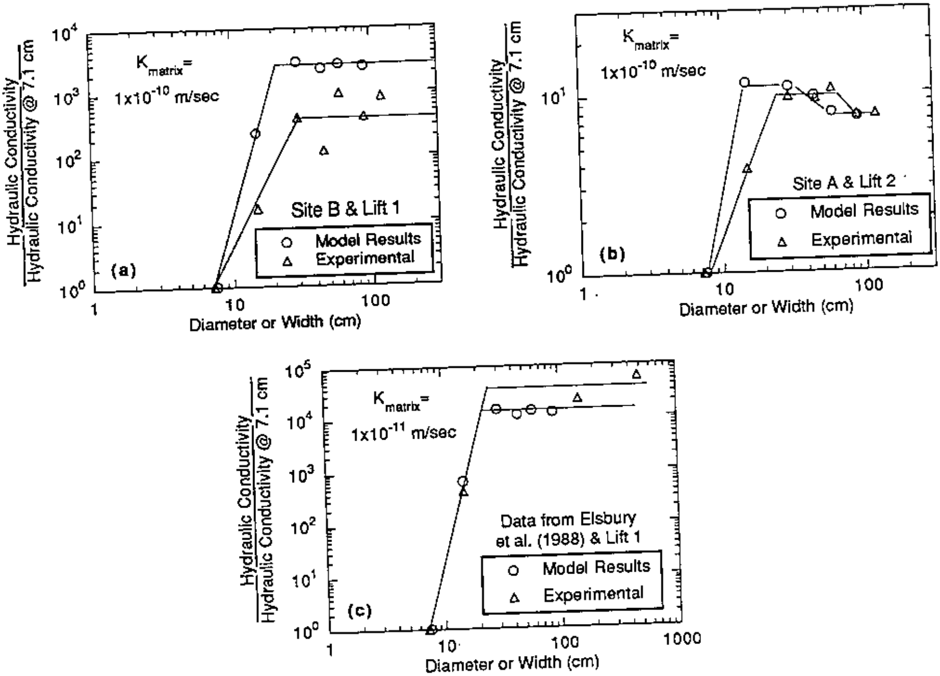

FIG. 12--Comparison of modeling results and field data:(a) Site B and Lift 1, (b) Site A and Lift 2, (c) Data from Elsbury et al., (1988) and Lift 1. Note: geometric mean hydraulic conductivities are shown.

Modeling results for Lift 1 are compared to the experimental results from the test pad at Site B in Fig. 12a. Lift 1 was selected for comparison with the experimental data because Site B had large widely spaced macropores. Figure 12a shows that trends exhibited by the experimental data and the modeling results are similar. The modeling results show a slightly larger increase in hydraulic conductivity and a slightly smaller representative specimen size than would be suggested by the experimental data. Nevertheless, both the model and the experimental data exhibit a similar trend and illustrate that hydraulic conductivity near field-scale can be measured using a specimen having a diameter greater than 0.30 m.

Fig. 12b is a comparison of experimental results obtained from Site A and modeling results for Lift 2. Results from Lift 2 were selected for comparison because macropores in the test pad at Site A were frequent and small relative to the thickness of the lifts. They also appeared highly tortuous. Thus, they were likely to have lower hydraulic conductivity than macropores for Site B.

The trends in the modeling results and experimental data shown in Fig. 12b are similar. Again, the modeling results indicate a slightly smaller specimen is required to achieve field-scale hydraulic conductivity than would be inferred from the experimental data. Nevertheless, the modeling results and the field data are similar. The modeling and experimental results in Fig. 12b also show a slight decrease in hydraulic conductivity that occurs as the specimen size is increased beyond 0.30 m. A similar decrease in hydraulic conductivity was observed in the test results for Site C.

Experimental data from Elsbury et al. (1988) and modeling results for Lift 1 are compared in Fig. 12c. The modeling results and experimental data are very similar, which is expected, because statistical data used in the model for Lift 1 was derived directly from the morphological study described in Elsbury et al. (1988). More importantly, however, the modeling results suggest that field-scale hydraulic conductivity may have been obtained if a specimen having diameter greater than 0.30 m had been tested. Unfortunately, Elsbury et al. did not perform tests on specimens of this size. Thus, this conclusion cannot be substantiated.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following conclusions and recommendations are made:

1. The size of a representative specimen for measurement of hydraulic conductivity of compacted soil liners depends on the method and quality of construction. If the soil is compacted poorly (e.g., dry of the line of optimums or with low compactive effort), the representative specimen size is large. However, when the soil is well compacted (wet of the line of optimums or with high compactive effort), the representative size is small. The key factor controlling the representative size is the size of the network of pores conducting flow and the ability to represent the network of pores in a test specimen.

2. The experimental results suggest that field-scale hydraulic conductivity can be measured on specimens with a diameter of at least 0.30 m and a thickness of 0.15 m for a wide variety of construction conditions. Block specimens of this size are recommended for use in hydraulic conductivity assessment of test pads but are not recommended for evaluation of constructed liners because of the large holes left in the liner after sampling.

3. The modeling results suggest that specimens with a diameter of 0.30 m are adequate to represent the presence of macropores and field-scale hydraulic conductivity. Trends observed in the modeling results and experimental data were similar.

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FINAL REPORT

CLEAN HARBORS ENVIRONMENTAL SERVICES

DEER TRAIL SECURE CELL NO. 3

TEST FILL REPORT

DEER TRAIL, COLORADO

Prepared for:

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June 6, 2006

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ACRONYMS

ASTM	American Society for Testing and Materials
CAT	Caterpillar
CCL	Compacted Clay Liner
CCR	Code of Colorado Regulations
CDPHE	Colorado Department of Public Health and Environment
CHDT	Clean Harbors Deer Trail
CQA	Construction Quality Assurance
CQAE	CQA Engineer
EPA	United States Environmental Protection Agency
Golder	Golder Associates Inc.
H:V	Horizontal:Vertical
MWH	Montgomery Watson Harza
OMC	Optimum Moisture Content
pcf	pounds per cubic foot
TSDF	Treatment, Storage and Disposal Facility
USCS	Unified Soil Classification System

1.0 INTRODUCTION

1.1 Overview and Site Location

This report, prepared by Golder Associates Inc. (Golder), of Lakewood, Colorado, documents construction activities and Construction Quality Assurance (CQA) monitoring and testing, performed during construction of the Compacted Clay Liner (CCL) Test Fill at the Clean Harbors Deer Trail (CHDT) Secure Cell No. 3 facility. Clean Harbors (Deer Trail), LLC operates a hazardous waste treatment, storage, and disposal facility (TSDF) in Adams County, Colorado under the United States Environmental Protection Agency (EPA) Identification No. COD991300484 and the Colorado Department of Public Health and Environment (CDPHE) Permit No. 086-001-002 (Permit).

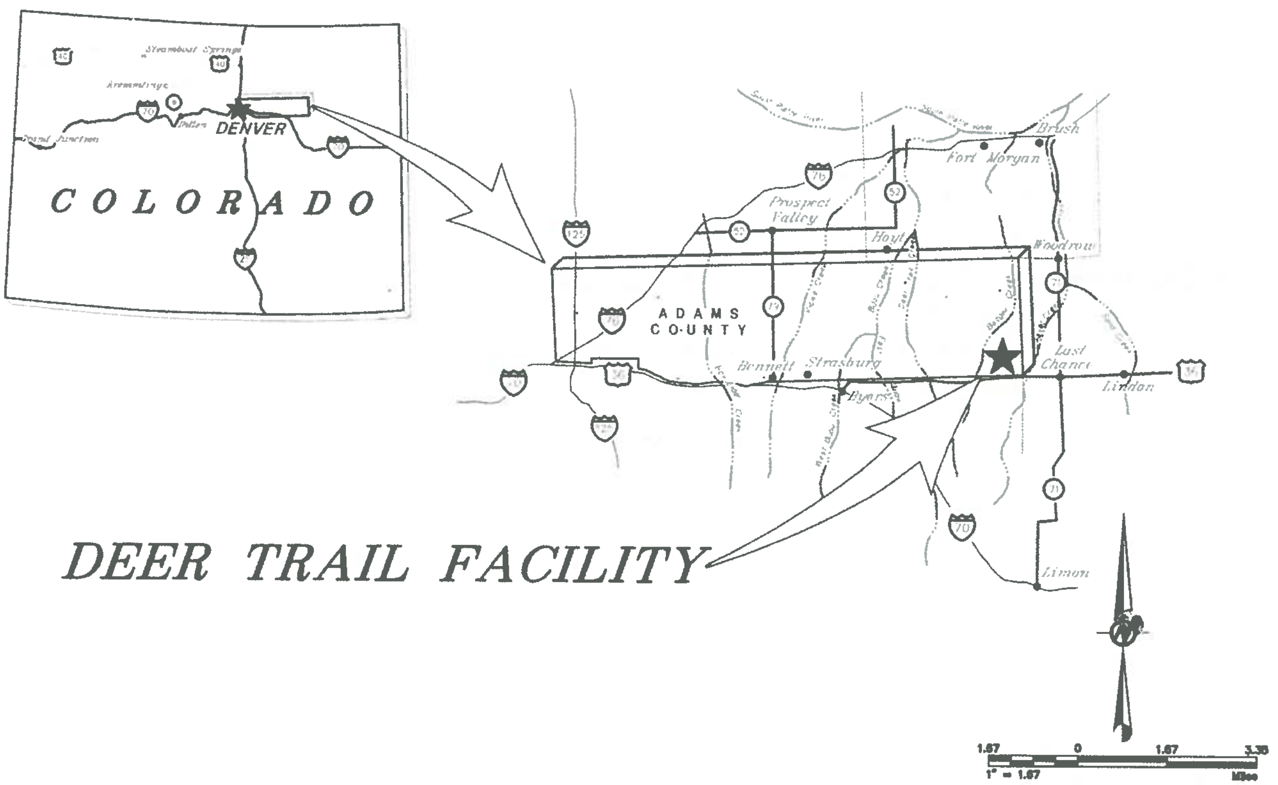
The project site is located along Colorado State Highway 36 between Byers and Last Chance, Colorado approximately 70 miles east of Denver as presented on Figure 1.1-1, Vicinity and Site Location Map. The location of the Test Fill is presented on Figure 1.1-2, Test Fill Location Map. A Plan view or schematic of the Test Fill is presented on Figure 1.1-3.

1.2 Test Fill Objectives

As stated in the Test Fill Work Plan (MWH 2006), the primary objective was to confirm the adequacy and suitability of the weathered Pierre Shale materials, equipment, and construction techniques for the installation of a CCL that meets the regulatory performance criterion requiring a vertical hydraulic conductivity less than or equal to 1 x 10-7 cm/sec for the Secondary CCL to be placed on the sideslopes of the landfill. Further discussion and relevance of Test Fill construction and methods is presented in the EPA guidance document (EPA 1993). The compaction window included in the specifications for all CCL materials, exclusive of the Clay Plug, was further evaluated by the Test Fill field and laboratory testing in order to provide a workable moisture-density range and develop a Final Compaction Window suitable for use during construction of the Secondary and Primary CCL materials regardless of location (e.g., floor or slope) in the landfill.

An additional objective of the Test Fill Work Plan was to confirm the adequacy for use of the same weathered Pierre Shale materials for areas where a Clay Plug is required as replacement of the sand lense present in the subgrade on the East and South slopes of the landfill. The Clay Plug requirements are such that 100 feet of 1 x 10^{-7} cm/sec clay are required or equivalent which was

SECURE CELL NO.3 TEST FILL
CLEAN HARBORS ENVIRONMENTAL SERVICES, INC
ADAMS COUNTY, COLORADO
MAY, 2006

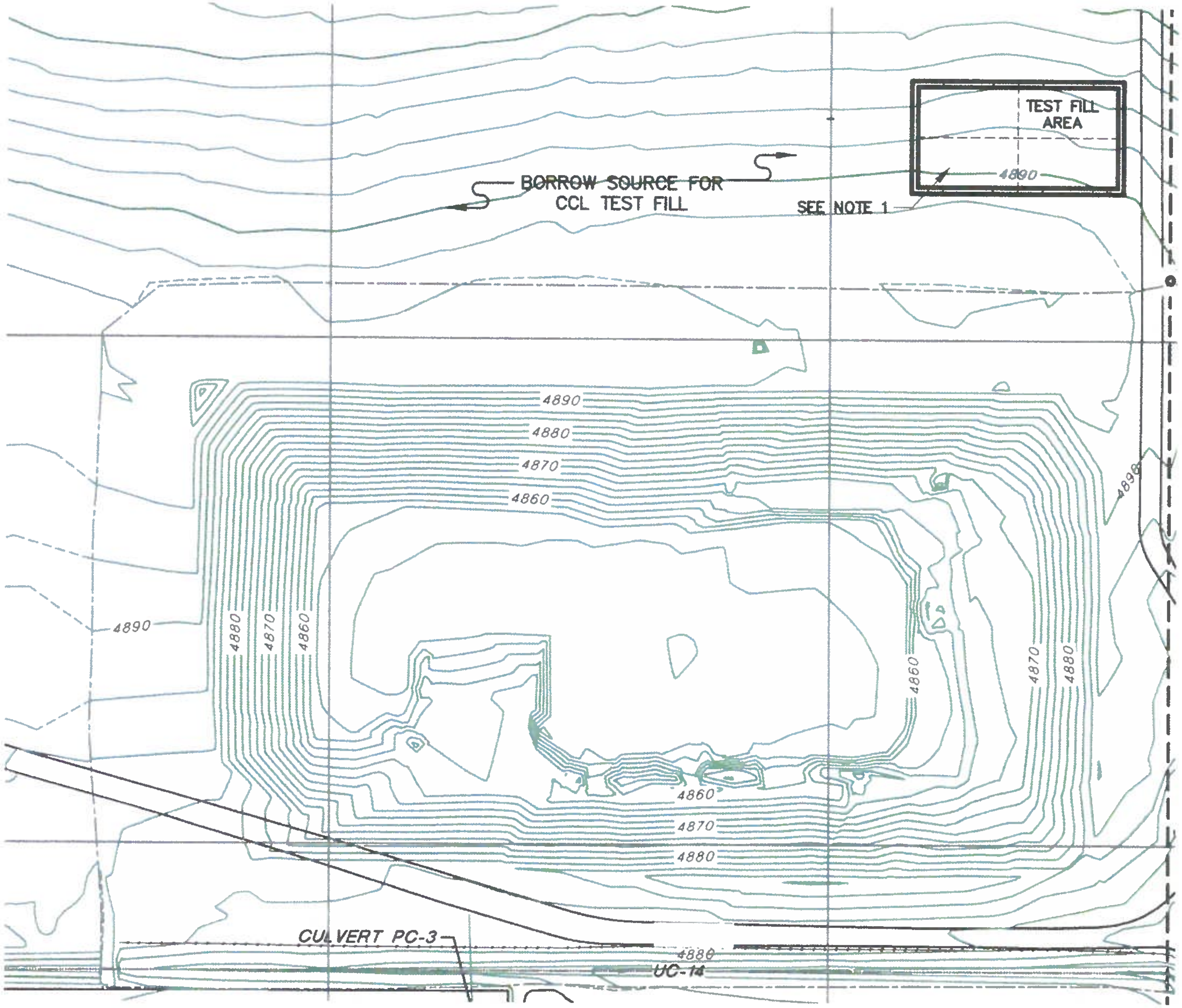


PROJECT
CLEAN HARBORS ENVIRONMENTAL INC.
SECURE CELL NO. 3 TEST FILL CQA
DEER TRAIL, ADAMS COUNTY, COLORADO

TITLE
VICINITY AND SITE LOCATION

Golder Associates
Denver, Colorado

PROJECT No.		063-2145	FILE No.	0632145A001
DESIGN			SCALE AS SHOWN	REV A
CADD	LAO	5/17/06		
CHECK	RD	5/22/06	FIG 1.1-1	
REVIEW	RCK	5/22/06		



LEGEND

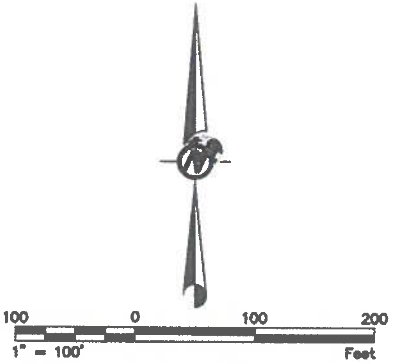
▨ EXISTING TOPOGRAPHY

NOTES

1. LOCATION APPROXIMATE

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY MWH.



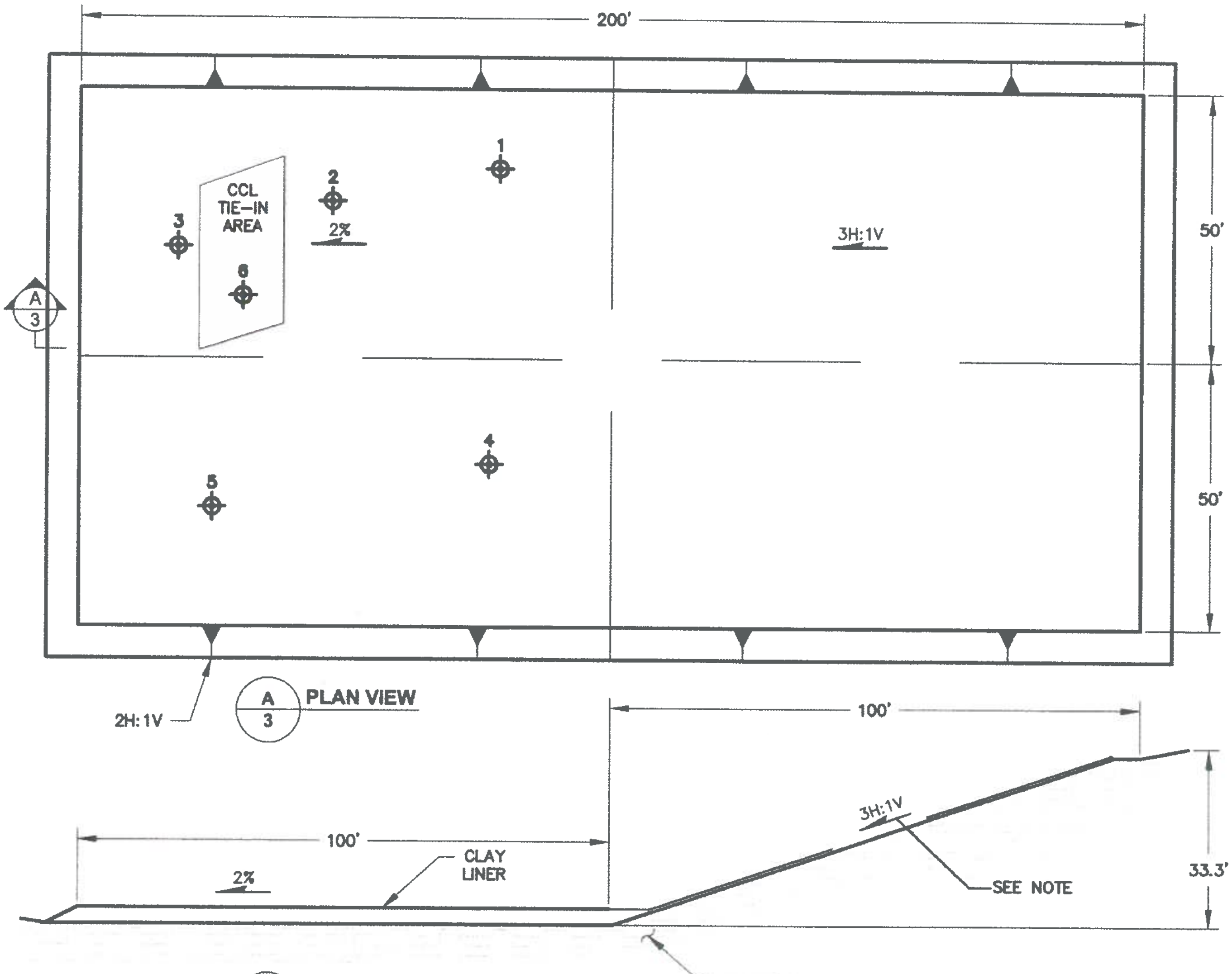
PROJECT
CLEAN HARBORS ENVIRONMENTAL INC.
SECURE CELL NO. 3 TEST FILL CQA
DEER TRAIL, ADAMS COUNTY, COLORADO

TITLE
TEST FILL LOCATION

Golder Associates
Denver, Colorado

PROJECT No.		083-2145	FILE No.	0832145A002
DESIGN			SCALE AS SHOWN	REV A
CADD	LAQ	3/17/08		
CHECK	RPD	3/22/08		
REVIEW	RCK	3/22/08		

FIG 1.1-2



A 3 **PLAN VIEW**

A 3 **CROSS SECTION A-A'**

NOTE:
3H:1V SLOPE SECTION NOT COMPLETED DUE TO PROBLEMS WITH COMPACTION EQUIPMENT

LEGEND

⌖ 1 SAMPLE LOCATION AND NUMBER

A 3 CROSS SECTION IDENTIFIER
SHEET WHERE SECTION IS LOCATED

SAMPLE LOCATION KEY

	SHELBY TUBE ID	SHELBY TUBE ID
1	07–P–01A	07–P–01A
2	07–P–02A	07–P–02A
3	07–P–03A	07–P–03A
4	08–P–01A	08–P–01A
5	08–P–02A	08–P–02A
6	07–P–T1–01A	N/A

NOTE:
Locations aproximate shelby tubes taken within 1 to 2 feet of block samples.

20 0 20 40
Feet

PROJECT
CLEAN HARBORS ENVIRONMENTAL INC.
SECURE CELL NO. 3 TEST FILL CQA
DEER TRAIL, ADAMS COUNTY, COLORADO

TITLE
TEST FILL PLAN VIEW
AND CROSS-SECTION

Golder Associates
Denver, Colorado

PROJECT No.		063–2145	FILE No.	0632145A003_REV
DESIGN			SCALE AS SHOWN	REV B
CADD	LAO	8/2/08	FIG 1.1-3	
CHECK	MRO	8/2/08		
REVIEW	RCK	8/3/08		

defined as 10 feet of 1 x 10^{-8} cm/sec material. The field and laboratory testing was also performed for the Clay Plug Test Fill to develop a similar Final Compaction Window for use during placement of the Clay Plug.

The proposed methods provided in the Work Plan were discussed in general terms during the pre-construction meeting as well as subsequent weekly progress meetings at the site between representatives of Clean Harbors, Golder, Fretco, Tri-County Health Department (TCHD) and CDPHE. Modifications to the Work Plan were determined necessary as the Test Fill construction progressed and are discussed in greater detail later in this report. This Report presents the following:

1. The results of the preconstruction testing performed;
2. The development of a preliminary compaction window used to begin construction of the Test Fill;
3. The methods used to construct the Test Fill as well as modifications made to the compaction window in the field;
4. The results of field and laboratory testing performed; and
5. The conclusions and revised specifications, or Final Compaction Window, developed as a result of the overall Test Fill effort.

2.0 PRECONSTRUCTION TESTING

Prior to Test Fill construction, in early April, samples TF-1 and TF-2 were collected as pre-construction samples in accordance with the CQA Plan requirements. The samples were collected from the Clay Stockpile after the material had been processed by the Caterpillar (CAT) RM350 Soil Processor and were transported to the Golder Soils Laboratory in Lakewood, Colorado, for Standard and Modified Proctor, Atterberg limits, grain-size analysis, and remolded hydraulic conductivity testing.

The test results indicated that the materials classified as a CH, or fat clay, according to American Society of Testing Materials (ASTM) D2487 and consisted of material with 98-99 percent passing the #200 sieve. Samples were remolded to moisture-density values at the margins of each of the preliminary compaction window lower limits to evaluate the ability of the materials to meet the required minimum hydraulic conductivity values. The testing indicated compliance with the specifications which requires the following:

- Classified as CL or CH according to the Unified Soil Classification System (USCS);
- A minimum liquid limit of 30, and a minimum plastic index of 11;
- No more than 15 percent (dry weight) retained on the No. 4 sieve; and
- Clod size particles no larger than 2-inches after processing and compaction for weathered Pierre Shale.

The pre-construction testing was performed in general compliance with the Work Plan. The following provides a listing of and rationale for several deviations from the Work Plan which occurred:

- Water content using the microwave oven (ASTM D4643) was not performed. Our experience has been that the microwave oven yields results which have a greater standard deviation than tests using conventional forced-air convection ovens.
- The Reduced Proctor method was not performed. Standard and Modified Proctors were performed on 2 samples and Specific Gravity testing performed in order to evaluate the compaction window using the "degree of saturation" method. Additional discussion is provided on this approach in Section 3.

- Moisture content testing was not recorded on Pre-Construction tests in the stockpiles other than for determination of the "as-received" moisture content for the two samples tested for Index Properties and Moisture-Density Relationships. Moisture content testing was performed to assist the contractor during mixing and processing, but was not recorded since moisture content of loosely compacted soils tends to give lower moisture values and was provided to the contractor for information only. The moisture content tests reported below were performed on the compacted clay materials in order to evaluate any differences between the nuclear gauge and oven methods.

Table 2.0-1 presents an overview of the testing performed versus required testing. Table 2.0-2 presents the test results in summary form. Individual test results are provided in Appendix A.

TABLE 2.0-1
Laboratory Soils Index Testing Frequencies for
Test Fill Pre-Construction Testing
Material Placed (Approx. 1,300 cy)

Property	**Method**	**CQAE Testing Frequency**		
		No. of Tests	**Specified**	**Actual**
Soil Classification	ASTM D 2487	2	1 per 1,000 cy	1 per 650 cy
Grain Size	ASTM D 422/D1140	2	1 per 1,000 cy	1 per 650 cy
Atterberg Limits	ASTM D 4318	2	1 per 1,000 cy	1 per 650 cy
Moisture Content	ASTM D2216	14	1 per 200 cy	1 per 93 cy
Specific Gravity	ASTM D854	2	Not Specified	1 per 650 cy
Standard Proctor	ASTM D 698	2	1 per 1,000 cy	1 per 650 cy
Reduced Proctor	ASTM D698-R	None	1 per 1,000 cy	None
Modified Proctor	ASTM D 1557	2	1 per 1,000 cy	1 per 650 cy
Recompacted Hydraulic Conductivity	ASTM D 5083	9 Tests	NA (6 to 8)	9 Tests

TABLE 2.0-2
Laboratory Soils Index Test Results Summary for
Test Fill Pre-Construction Testing

Property	**Requirement**	**Range**	**Average Value (Arithmetic)**
Liquid Limit, %	30	55-56	55.5
Plastic Limit, %	NA	16	16
Plasticity Index, %	11	39-40	39.5
Percent Retained on the #4 Sieve	≤ 15	0	0
Maximum Particle Size (After Processing)	2-inch	100	100
Soil Classification	CL, CH	CH	NA

3.0 DEVELOPMENT OF THE PRELIMINARY COMPACTION WINDOW

3.1 Existing Specifications

The existing specifications provided details for placement and compaction of the Secondary and Primary CCL on the slopes, but required further evaluation through the Test Fill program for placement of the Secondary CCL on the 3H:1V sideslopes with compaction equipment traveling parallel to the slope. Preliminary Compaction Windows were developed based on a review of the historic data (Geosyntec, 1991) and a review of the preconstruction test results and in general compliance with the procedures outlined in the Work Plan with the following exception. The Work Plan provided recommended procedures for development of an acceptable compaction window and included reference of the procedures developed by Daniels and Benson which is commonly referred to as the "line of optimums" method. The preliminary testing included tests for Modified and Standard Proctors for evaluation of moisture-density relationships, but did not include the Reduced Proctor tests. Based on the author's experience and other research (Othman and Luettich) defining the dry limits of placement using a degree of saturation approach can be more reliable as it does not rely on the Proctor moisture-density testing which have been proven to have some variability.

Our methodology in developing the preliminary compaction window involved plotting all of the previous hydraulic conductivity test data from the prior Test Fill performed on the weathered Pierre Shale at the site and evaluation of additional data from a series of remolded hydraulic conductivity tests compacted to moisture-density values intended to represent the dry limits of placement along a given degree of saturation line. The optimum moisture content from each of the two samples for the Standard Proctor and Modified Proctor were evaluated to determine an appropriate range of moisture content with the lower boundary typically one percent above the Modified Proctor Optimum Moisture Content (OMC) and an upper range typically no greater than 4 or 5 percent above the Standard Proctor OMC.

The following sections provide an overview of the development of the Preliminary Compaction Windows for three cases: 1) Secondary CCL material placed on the 3H:1V slopes; 2) Secondary CCL and Primary CCL material placed on the landfill base; and 3) Clay Plug material placed along the east and south slope to replace the sand lense.

3.2 Secondary CCL

The existing basis and specifications for the secondary CCL placed and compacted within the Cell 3 footprint are listed below:

- On the cell floor, CCL is compacted with a minimum of 6 passes of the CAT 825 or approved equivalent.
- On the sideslopes, CCL is compacted with a CAT 825 or approved equivalent making a number of passesthat will be determined from the Test Fill program.
- The compacted secondary CCL is 3.0 foot thick across the cell floor, and 4.5 feet up the side slopes.
- CCL will have a hydraulic conductivity not more than 1×10^{-7} cm/s after compaction to at least 95 percent of the maximum dry density at a moisture content between the optimum moisture content (OMC) and 3.0 percent wet of OMC on the cell floor and 1.5 to 4.0 percent above OMC on the sideslopes.

The Preliminary Compaction Window for the Secondary CCL material to be placed on the slopes, established by Golder, is shown on Figure 3.2-1. All of the historic data and pre-construction testing indicated hydraulic conductivity values lower than 1×10^{-7} cm/sec when compacted above 70 percent degree of saturation. Our experience, however, has been that weathered Pierre Shale materials in the Denver area compacted above 80 percent degree of saturation will consistently yield results much lower results than the required values and will result in a superior CCL for the site. Additionally, at the upper end of the compaction window, samples compacted above the Modified OMC may also provide suitable results. Based on this rationale the following limits or boundaries were established: 1) a lower limit bounded by the 80% degree of saturation line, 2) moisture content limits of 18.0 to 26.0 % moisture content, and 3) a lower density limit of 94.0 pounds per cubic foot (pcf) or the average value for 95% of the Standard Proctor Maximum Dry Density.

It was also determined that this compaction window could also be applied to the Secondary CCL and Primary CCL to be placed on the floor, in effect allowing for an expansion of the existing compaction window.

FIGURE 3.2-1

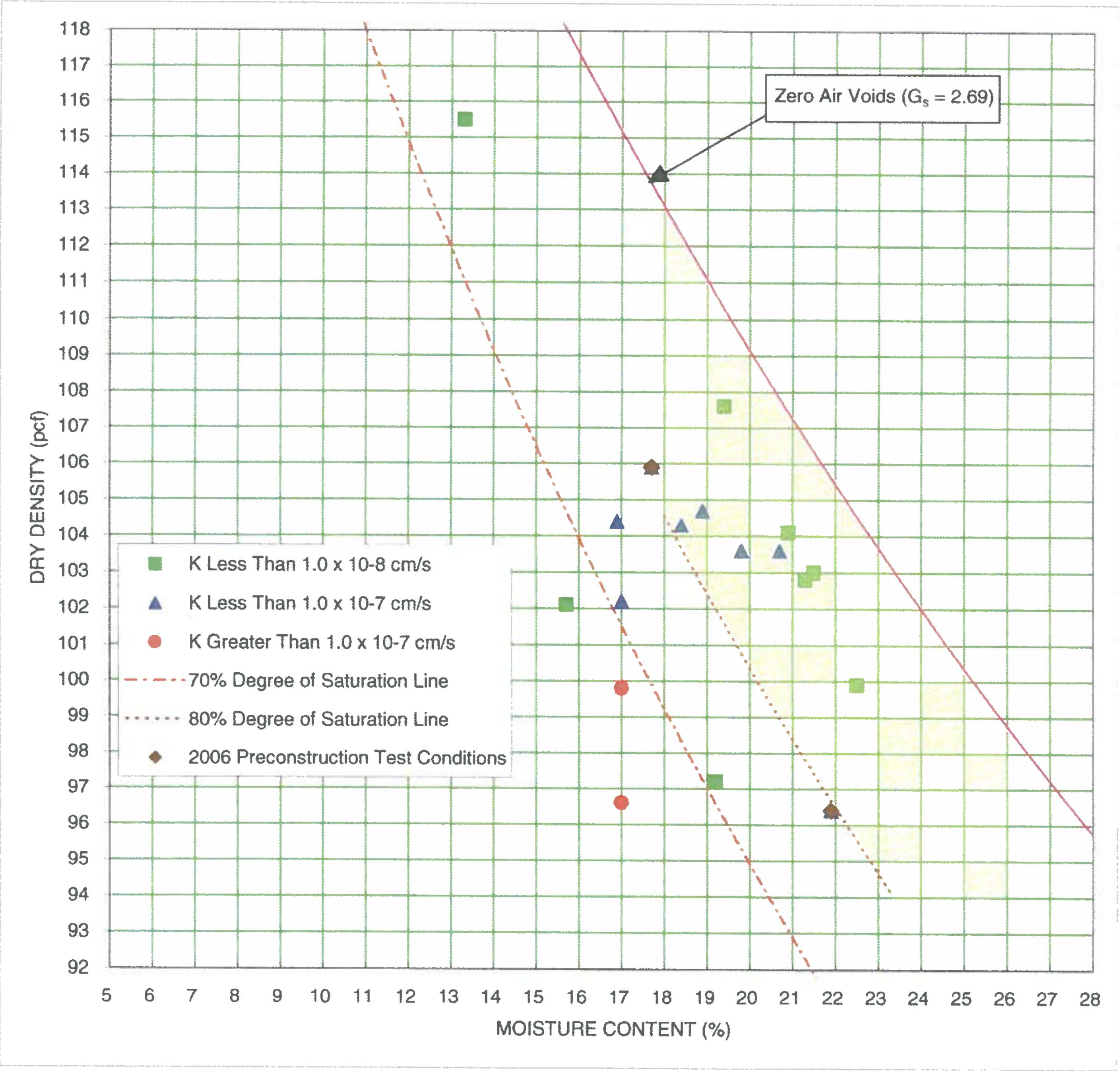
Preliminary Compaction Window for Compacted Clay Liner (K ≤ 1.0 x 10^{-7} cm/s)

Summary of Previous Laboratory Data
Weathered Pierre Shale (Geosyntec 1991)

Test ID	Dry Density (pcf)	Moisture Content (%)	Hydraulic Conductivity (cm/s)
WPS-2	104.1	20.9	4.0E-09
WPS-3	99.9	22.5	5.0E-09
ST-231	102.8	21.3	6.9E-09
WPS-5	102.1	15.7	7.0E-09
WPS-4	115.5	13.3	8.0E-09
WPS-6	97.2	19.2	9.0E-09
ST-232	103.0	21.5	9.0E-09
ST-263-3	107.6	19.4	9.1E-09
ST-214	103.6	19.8	1.8E-08
WPS-1	104.3	18.4	2.0E-08
ST-212	104.7	18.9	2.1E-08
ST-252	103.6	20.7	2.2E-08
ST-222	104.4	16.9	6.5E-08
ST-242	102.2	17.0	6.6E-08
ST-241	99.8	17.0	1.3E-07
ST-221	96.6	17.0	4.1E-07

Pre-Construction Testing (2006)

Test ID	Dry Density (pcf)	Moisture Content (%)	Hydraulic Conductivity (cm/s)
TF-1-1	96.4	21.9	4.7E-08
TF-1-2	105.9	17.7	8.6E-08



3.3 Clay Plug

The specifications and basis for the Clay Plug placed and compacted within the zone of influence of the existing sand layer on the east and south inboard slope of the Cell 3 footprint are listed below:

- Compacted in horizontal lifts, with a minimum of 6 passes of the CAT 825 or approved equivalent;
- The minimum number of passes may have to be increased to satisfy the lower overall hydraulic conductivity criteria as stated below;
- The clay plug material is placed a minimum of one foot above and one foot below the maximum and minimum elevation of the sand seam;
- The intent of the Clay Plug is to provide a barrier of a given thickness and hydraulic conductivity that will result in travel time equal to clay 100 feet thick with a hydraulic conductivity of 1×10^{-7} cm/s, or 10 feet thick with a hydraulic conductivity of 1×10^{-8} cm/s, or an equivalent combination thereof; and
- The Clay Plug will have a hydraulic conductivity not more than 1×10^{-8} cm/s after compaction of at least 95 percent of the maximum dry density and between OMC and 3.0 percent wet of OMC.

The Preliminary Compaction Window for the Clay Plug is shown on Figure 3.3-1. The following limits or boundaries were established: 1) a lower limit bounded by the 89% degree of saturation line, 2) moisture content limits of 19.0 to 25.0 % moisture content, and 3) a lower density limit of 100.0 pcf.

The basis for establishment of the Preliminary Compaction Window for the Clay Plug was based on a review of the historic data. The pre-construction remolded testing, however, indicated that there may be some difficulty in achieving consistent values at or below 1 x 10-8 cm/sec. This may be in part due to the difficulty in duplicating field efforts using remolded test samples. It was recognized that some modification to this Compaction Window might be needed during initial evaluation of the Clay Plug Test Fill. This was in fact the case and is discussed in Section 4 of this report in more detail.

FIGURE 3.3-1
Preliminary Compaction Window for Clay Plug $(K \leq 1.0 \times 10^{-8}$ cm/s)

Summary of Previous Laboratory Data
Weathered Pierre Shale (Geosyntec 1991)

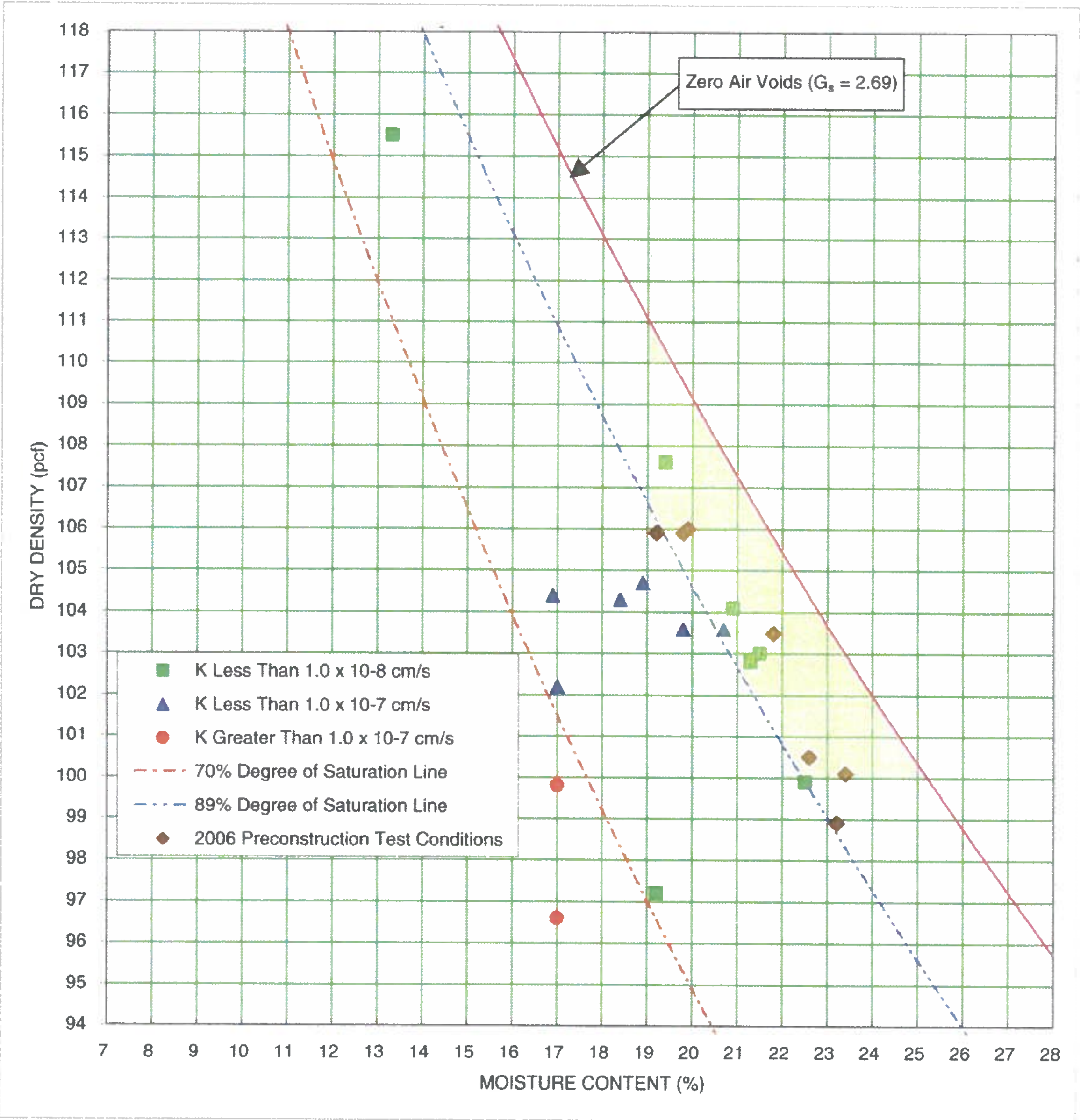
Test ID	Dry Density (pcf)	Moisture Content (%)	Hydraulic Conductivity (cm/s)
WPS-2	104.1	20.9	4.0E-09
WPS-3	99.9	22.5	5.0E-09
ST-231	102.8	21.3	6.9E-09
WPS-5	102.1	15.7	7.0E-09
WPS-4	115.5	13.3	8.0E-09
WPS-6	97.2	19.2	9.0E-09
ST-232	103.0	21.5	9.0E-09
ST-263-3	107.6	19.4	9.1E-09
ST-214	103.6	19.8	1.8E-08
WPS-1	104.3	18.4	2.0E-08
ST-212	104.7	18.9	2.1E-08
ST-252	103.6	20.7	2.2E-08
ST-222	104.4	16.9	6.5E-08
ST-242	102.2	17.0	6.6E-08
ST-241	99.8	17.0	1.3E-07
ST-221	96.6	17.0	4.1E-07

Pre-Construction Testing (2006)

Test ID	Dry Density (pcf)	Moisture Content (%)	Hydraulic Conductivity (cm/s @ 5psi)
TF-1-3	98.9	23.2	2.1E-08
TF-1-4	105.9	19.2	4.4E-08
TF-1-5	105.9	19.8	6.6E-08
TF-1-6	100.5	22.6	3.4E-08
TF-2-1	106.0	19.9	5.5E-08
TF-2-2	100.1	23.4	4.8E-08
TF-2-3	103.5	21.8	3.5E-08

Pre-Construction Testing (2006)

Test ID	Dry Density (pcf)	Moisture Content (%)	Hydraulic Conductivity (cm/s @ 12psi)
TF-2-1	106.0	19.9	1.7E-08
TF-2-2	100.1	23.4	9.0E-09



4.0 SUMMARY OF CONSTRUCTION AND FIELD TESTING

Test Fill construction began on May 3, 2006 and was completed by May 9, 2006. Golder provided full time observation of the Test Fill construction over this entire period and provided testing in accordance with the Work Plan. An approximate 100-foot by 200-foot area was staked with half of the area prepared along a 3H:1V (horizontal:vertical) sideslope of an existing stockpile with the remainder graded to meet a 2 percent slope immediately adjacent to the stockpile (See Figure 1.1-3). The surface within this area was stripped using a CAT D7R dozer to allow preparation of a competent base. The Test Fill was sub-divided into half, where the north half (slope section) would consist of the Secondary CCL Test Fill ($k < 1 \times 10^{-7}$ cm/s) and the south half (floor section) would consist of the Clay Plug Test Fill ($k < 1 \times 10^{-8}$ cm/s). Each of the Test Fill sections was further subdivided into two 50-foot lanes, one each for the CAT 815 and CAT 825 sheepsfoot compactor. The subgrade was first compacted, and then tested with a Troxler model 3440 moisture-density gauge to verify satisfactory conditions prior to placement of the clay materials. The subgrade was scarified by using a CAT 815 sheepsfoot compactor, then moisture conditioned with a tandem-axel water truck. Clay materials were brought in by use of several CAT 627 scrapers and compacted with CAT 815 and 825 sheepsfoot compactors in their respective lanes, prior to placement of subsequent clay materials.

It became apparent with the compaction of the first lift on the slopes, that the CAT compactors were unable to efficiently and effectively work on the 3H:1V slopes in the crest to toe direction. The first 5 passes of the first lift of clay on the slopes was compacted in the downslope direction only with the compactors returning to the top of the slope by traversing along a shallower ramp adjacent to the Test Fill sections. After 5 passes, the 815 CAT was able to manage the 3H:1V slopes in both directions going in the reverse direction when traveling upslope. However, due to the difficulties in compacting loose materials during the first 5 passes, it was decided to try other methods in order to increase efficiency. A field modification to the Test Fill plan was implemented in order to address placement and compaction activities on the inboard slopes, whereby the fill would be hauled and placed horizontally in lifts from the floor of the Secure Cell No. 3 and constructed upwardly. Due to the increased thickness of the Secondary CCL to 4.5 feet, the respective horizontal distance from subgrade to the Secondary CCL slope intersection was calculated to be approximately 14.5 feet. This width will be sufficient to allow for placement of the clay materials in horizontal lifts and allow for adequate overlap of the sheepsfoot compactors while minimizing the amount of overbuilt clay liner at nominally 6 inches or less.

Continued construction of the Test Fill included placement of clay materials in the Test Fill area on the floor only using the CAT D7 dozer and a CAT 143H motor grader. The CAT 825 sheepsfoot had mechanical problems during the first day of Test Fill construction, so the work progressed using the CAT 815 which was perceived as a relative equivalent (albeit a lighter compactor), in terms of padfoot type and kneading action provided, and in the interest of time. The floor section of the Test Fill was then subdivided into two sections and the Test Fill process was restarted. The Test Fill was modified such that one lane would be constructed to evaluate for the Secondary and Primary CCL materials, and the second lane would be constructed to evaluate the Clay Plug materials.

A total of seven 6-inch (nominal compacted thickness) CCL lifts were placed and compacted within the Test Fill floor footprint for each lane. The material was obtained from the clay processing area of the proposed CCL stockpiles located east and south of Secure Cell No. 3. Clay was processed in the stockpiles using the RM350 soil processor, the water truck, and a John Deere Tractor with disk. For each consecutive lift, the soil was placed on the Test Fill using scrapers and compacted by the CAT 815. Scarification between lifts was performed by the CAT D7 dozer. Vertical control of the lifts was maintained using marked stakes placed around the perimeter of the Test Fill. The contractor made efforts at varying the placement moisture contents as specified by the Work Plan in order to place and evaluate material performance in the Upper, Middle, and Lower Zones of the respective Compaction Windows. Material was hauled from different locations in the clay processing area based on visual estimates of moisture content and in-place moisture content tests taken with the Troxler 3440 gauge. Golder personnel were on site to observe placement and compaction of all CCL lifts on the Test Fill area and to perform the field moisture-density testing required by the CQA Plan.

During placement and compaction of the first four lifts, the compactive effort versus in-place moisture-density was evaluated after varying number of passes as required by the Work Plan. The moisture-density test results recorded in the field were plotted on the respective Preliminary Compaction Windows, Figures 3.2-1 and 3.3-1, in order to determine the optimum number of passes required to successfully fall within each compaction window. Plots of this data are presented on Figures 4.0-1 for the CCL Test Fill lane and Figure 4.0-3 for the Clay Plug Test Fill lane. The data is also summarized on Table B-1 in Appendix B.

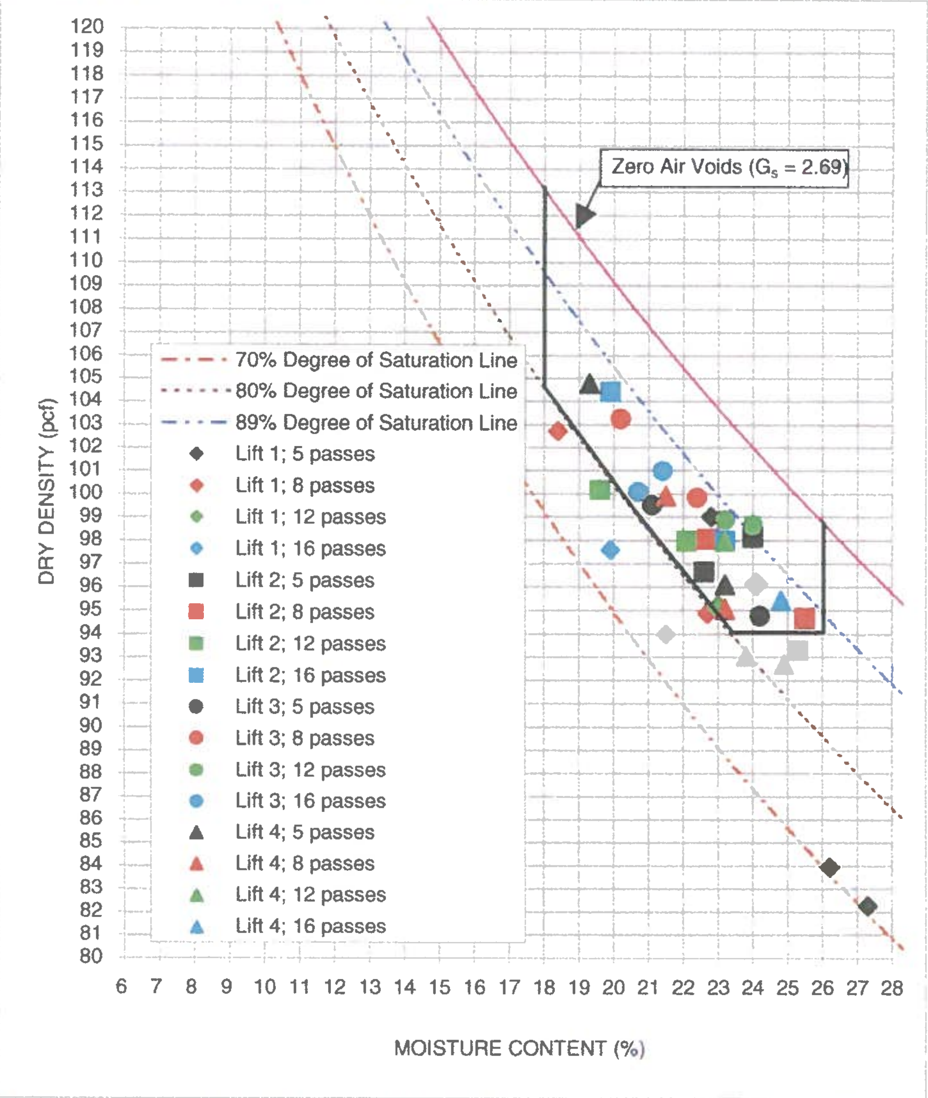
For the CCL Test Fill it was determined that 8 passes would be sufficient to reliably achieve results within the Preliminary Compaction Window therefore no changes were made recognizing that from time to time additional passes may still be required in order to fall within the Compaction Window.

For the Clay Plug Test Fill it was observed that the contractor could not consistently achieve moisture-density results within the established Preliminary Compaction Window even after 16 and 20 passes with the compaction equipment. The Preliminary Compaction Window for the Clay Plug was adjusted to revert back to the original specification of a minimum of 95 percent of Standard Proctor Maximum Dry Density at optimum to 3 percent over optimum moisture content with allowance for acceptance of tests that fell above the 89 percent degree of saturation line with moisture contents from 19 to 25 percent. The minimum compactive effort for the Clay Plug was established at 16 passes followed by at least one pass of a loaded CAT 627 scraper after each lift. At this level of effort a relative compaction of greater than 98 percent of the Standard Proctor Maximum Dry Density was achieved in all cases.

Lifts 5-7 were then placed and compacted for each of the Test Fill lanes following the procedures and number of passes established during the evaluation performed during lifts 1-4. The field moisture density tests from lifts 5-7 were plotted for review and analysis. Plots of this data are presented on Figure 4.0-2 for the CCL Test Fill lane and Figure 4.0-4 for the Clay Plug Test Fill lane. The data is also summarized on Table B-1 in Appendix B.

Golder performed additional field testing as required by the Work Plan including moisture content tests and comparison tests using the drive cylinder method. The results of these tests are also included in Appendix B on Table B-1. The results indicate that the nuclear gauge used is within 0.5 percent moisture content of the oven dry methods with a standard deviation of 1.4 percent. Based on this small variance, no moisture offsets are warranted on the project. The evaluation of the drive cylinder results also confirmed that the density values were consistent and reliable.

Photos taken during construction and sampling of the Test Fill are provided in Appendix C.



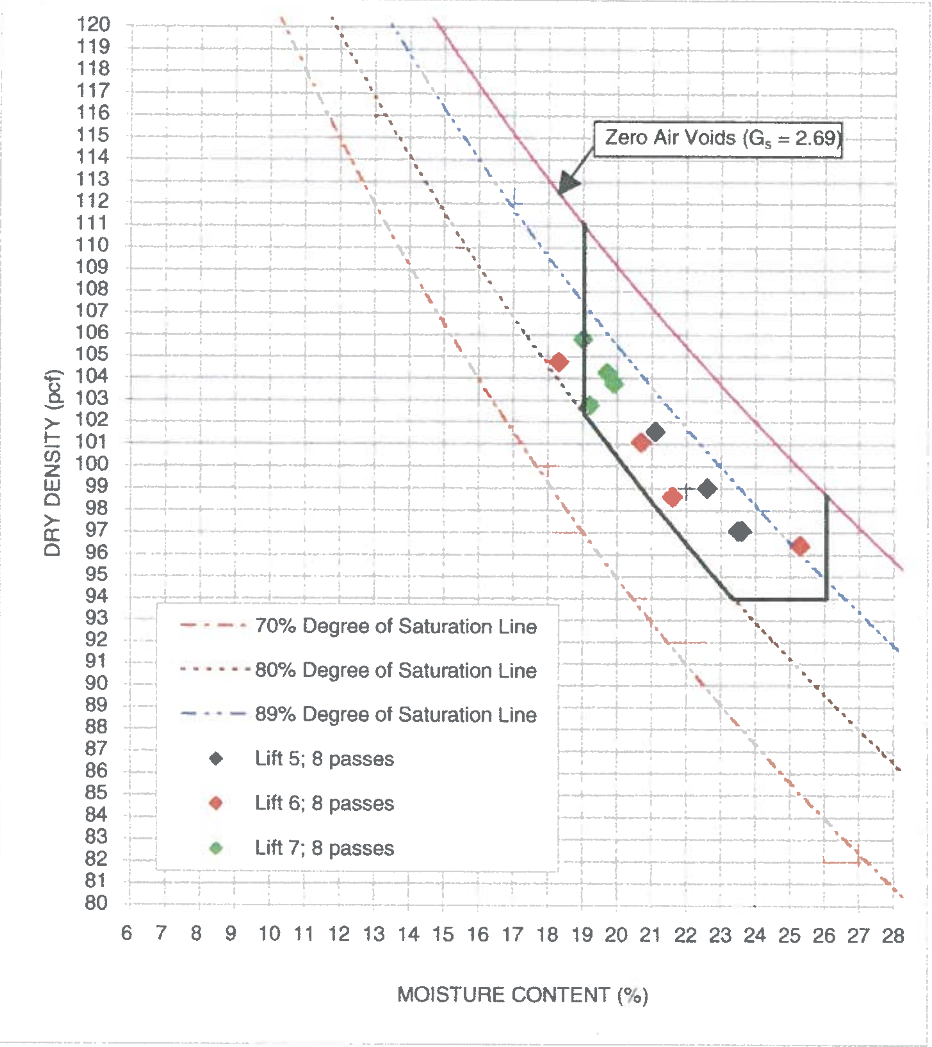
Test Number	Lift Number	Number of Passes	Dry Density (pcf)	Moisture Content (%)
07-F-815-01	Lift 1	5	82.2	27.3
07-F-815-02	Lift 1	5	83.9	26.2
07-F-815-03	Lift 1	5	99.0	22.8
07-F-815-04	Lift 1	8	102.7	18.4
07-F-815-05	Lift 1	8	94.9	22.7
07-F-815-06	Lift 1	12	96.1	24.1
07-F-815-07	Lift 1	12	95.1	23.0
07-F-815-08	Lift 1	16	97.6	19.9
07-F-815-09	Lift 1	16	94.0	21.5
07-F-815-10	Lift 2	5	98.1	24.0
07-F-815-11	Lift 2	5	96.7	22.6
07-F-815-12	Lift 2	8	94.7	25.5
07-F-815-13	Lift 2	8	98.0	22.7
07-F-815-14	Lift 2	12	100.2	19.6
07-F-815-15	Lift 2	12	93.3	25.3
07-F-815-16	Lift 2	12	98.0	22.1
07-F-815-17	Lift 2	16	104.4	19.9
07-F-815-18	Lift 2	16	98.0	23.2
07-F-815-19	Lift 3	5	99.5	21.1
07-F-815-20	Lift 3	5	94.8	24.2
07-F-815-21	Lift 3	8	99.8	22.4
07-F-815-22	Lift 3	8	103.2	20.2
07-F-815-23	Lift 3	12	98.6	24.0
07-F-815-24	Lift 3	12	98.9	23.2
07-F-815-25	Lift 3	16	101.0	21.4
07-F-815-26	Lift 3	16	100.1	20.7
07-F-815-27	Lift 4	5	104.8	19.3
07-F-815-28	Lift 4	5	96.1	23.2
07-F-815-29	Lift 4	8	95.0	23.2
07-F-815-30	Lift 4	8	99.9	21.5
07-F-815-31	Lift 4	12	98.0	23.2
07-F-815-32	Lift 4	12	92.7	24.9
07-F-815-33	Lift 4	16	93.1	23.8
07-F-815-34	Lift 4	16	95.4	24.8

Golder Associates
Denver, Colorado

TITLE
CCL Compaction Window and Moisture Density Tests, Lifts 1 through 4

CLIENT/PROJECT
Clean Harbors/Cell 3 Deer Trail CQA

DRAWN	RPD	DATE	6/1/2006	JOB NO.	063-2145
CHECKED	JEO	SCALE	N/A	DWG. NO.	N/A
REVIEWED	REK	FILE NO.	Figures 4.0-1 through 4.0-4.xls	FIGURE NO.	4.0-1



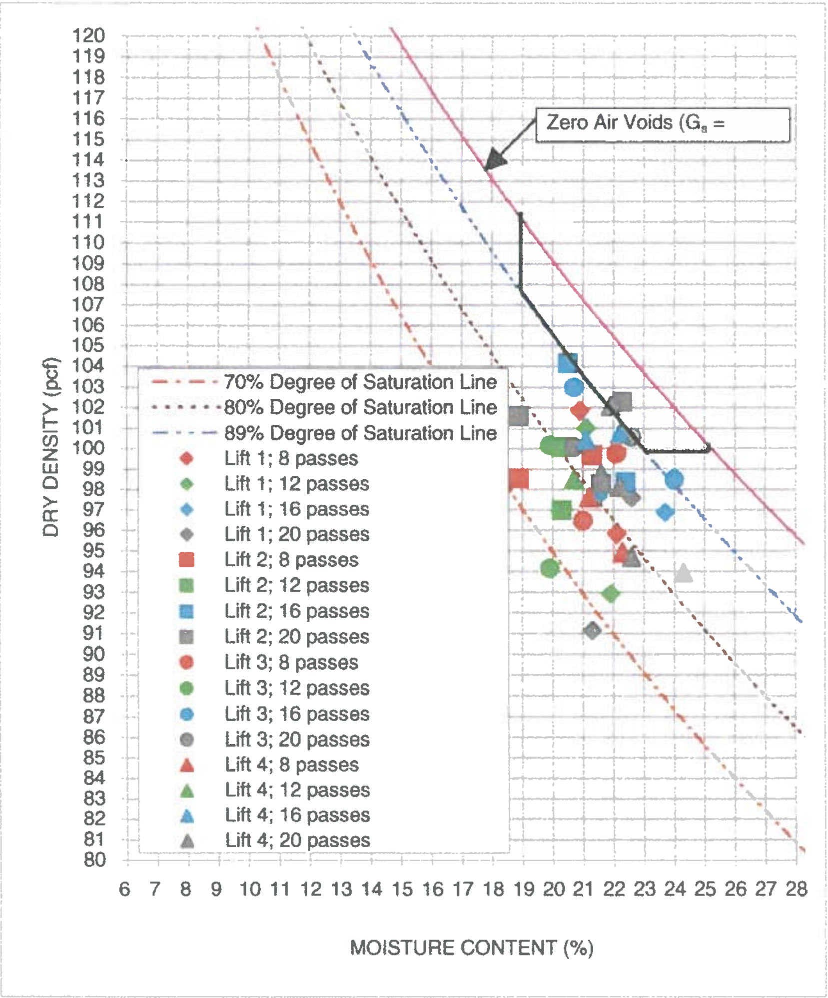
Test Number	Lift Number	Number of Passes	Dry Density (pcf)	Moisture Content (%)
07-F-815-35	Lift 5	8	101.6	21.1
07-F-815-36	Lift 5	8	97.1	23.5
07-F-815-37	Lift 5	8	99.0	22.6
07-F-815-38	Lift 6	8	98.6	21.6
07-F-815-39	Lift 6	8	96.4	25.3
07-F-815-40	Lift 6	8	101.1	20.7
07-F-815-41	Lift 7	8	102.8	19.2
07-F-815-42	Lift 7	8	105.8	19.0
07-F-815-43	Lift 7	8	104.3	19.7
F-815-07-P-01	Lift 7	8	103.8	19.9
F-815-07-P-02	Lift 6	8	104.7	18.3
F-815-07-P-03	Lift 5	8	97.1	23.6

Golder Associates
Denver, Colorado

TITLE
CCL Compaction Window and Moisture Density Tests, Lifts 5 through 7

CLIENT/PROJECT
Clean Harbors/Cell 3 Deer Trail CQA

DRAWN	RPD	DATE	6/1/2006	JOB NO.	063-2145
CHECKED	JEO	SCALE	N/A	DWG. NO.	N/A
REVIEWED	REK	FILE NO.	Figures 4.0-1 through 4.0-4.xls	FIGURE NO.	4.0-2



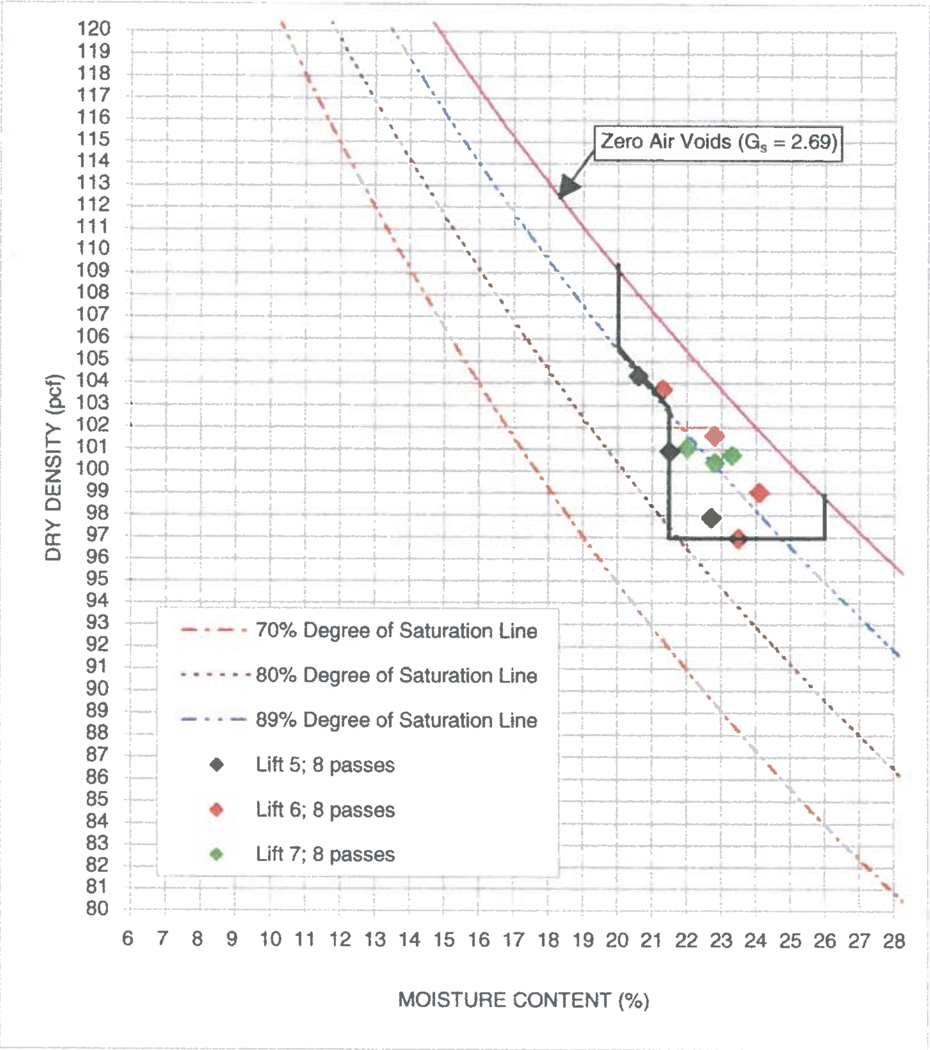
Test Number	Lift Number	Number of Passes	Dry Density (pcf)	Moisture Content (%)
F-815-01	Lift 1	8	101.8	20.9
F-815-02	Lift 1	8	95.8	22.1
F-815-03	Lift 1	12	101.0	21.1
F-815-04	Lift 1	12	92.9	21.9
F-815-05	Lift 1	16	97.7	21.5
F-815-06	Lift 1	16	96.9	23.7
F-815-07	Lift 1	20	97.6	22.6
F-815-08	Lift 1	20	91.1	21.3
F-815-09	Lift 2	8	98.5	18.9
F-815-10	Lift 2	8	99.7	21.3
F-815-11	Lift 2	12	100.1	20.3
F-815-12	Lift 2	12	97.0	20.3
F-815-13	Lift 1	Tested through L-2	101.6	20.0
F-815-14	Lift 1	Tested through L-2	105.1	17.7
F-815-15	Lift 2	16	104.1	20.5
F-815-16	Lift 2	16	98.4	22.4
F-815-17	Lift 2	20	98.3	21.6
F-815-18	Lift 2	20 (6" Test)	101.6	18.9
F-815-19	Lift 2	20 (4" Test)	102.3	22.3
F-815-20	Lift 3	8	99.8	22.1
F-815-21	Lift 3	8	96.4	21.0
F-815-22	Lift 3	12	100.2	19.9
F-815-23	Lift 3	12	94.2	19.9
F-815-24	Lift 3	16	103.0	20.7
F-815-25	Lift 3	16	98.5	24.0
F-815-26	Lift 3	20	100.6	22.6
F-815-27	Lift 3	20	100.1	20.7
F-815-28	Lift 4	8	94.9	22.3
F-815-29	Lift 4	8	97.6	21.2
F-815-30	Lift 4	12	94.0	24.3
F-815-31	Lift 4	12	98.5	20.7
F-815-32	Lift 4	16	100.4	21.1
F-815-33	Lift 4	16	100.7	22.2
F-815-34	Lift 4	20	94.7	22.6
F-815-35	Lift 4	20	102.1	21.9
F-815-36	Lift 4	20	98.1	22.2
F-815-37	Lift 4	20	98.8	21.6

Golder Associates
Denver, Colorado

TITLE
Clay Plug Compaction Window and Moisture Density Tests, Lifts 1 through 4

CLIENT/PROJECT
Clean Harbors/Cell 3 Deer Trail CQA

DRAWN	RPD	DATE	6/1/2006	JOB NO.	063-2145
CHECKED	JEO	SCALE	N/A	DWG. NO.	N/A
REVIEWED	REK	FILE NO.	Figures 4.0-1 thorugh 4.0-4.xls	FIGURE NO.	4.0-3



Test Number	Lift Number	Number of passes	Dry Density (pcf)	Moisture Content (%)
F-815-38	Lift 5	16	97.9	22.7
F-815-39	Lift 5	16	100.9	21.5
F-815-40	Lift 5	16	104.3	20.6
F-815-41	Lift 6	16	99.0	24.1
F-815-42	Lift 6	16	96.9	23.5
F-815-43	Lift 6	16	103.7	21.3
F-815-44	Lift 7	16	100.7	23.3
F-815-45	Lift 7	16	100.4	22.8
F-815-46	Lift 7	16	101.1	22.0
F-815-08-P-01	Lift 7	16	100.7	23.3
F-815-08-P-02	Lift 6	16	101.6	22.8

Golder Associates

Denver, Colorado

TITLE

Clay Plug Compaction Window and Moisture Density Tests, Lifts 5 through 7

CLIENT/PROJECT

Clean Harbors/Cell 3 Deer Trail CQA

DRAWN	RPD	DATE	6/1/2006	JOB NO.	063-2145
CHECKED	JEO	SCALE	N/A	DWG. NO.	N/A
REVIEWED	REK	FILE NO.	Figures 4.0-1 through 4.0-4.xls	FIGURE NO.	4.0-4

5.0 LABORATORY TESTING SUMMARY

Hydraulic conductivity testing was performed on Shelby tube and block samples collected in accordance with ASTM D5084. Golder collected Shelby tube samples as required by the Work Plan in each of the three upper lifts. Fretco staff assisted Golder in the collection of these samples and with collection of the large block samples. The block samples were collected in general compliance with the Work Plan with the following exception. Rather than field trim the entire block sample, then place the 13-inch diameter PVC-cylinder over the trimmed sample, the sample was collected by cutting to within 6-inches of the desired sample diameter, then the PVC-cylinder was hydraulically pushed using constant force from the blade of the motor grader in a vertical position (See photographs in Appendix C). A flat steel plate was placed over the top of the ring to provide a uniform surface. As the sample was pressed onto the soil cylinder, Golder personnel watched for any disturbance or excessive movement. This procedure resulted in providing a sample that fit snug within the PVC-cylinder. The samples were wrapped, taped and package for shipment to the University of Wisconsion at Madison's Geotechnical Engineering Laboratory. Golder personnel worked with Fretco staff in collecting these samples. In addition, five Shelby tube samples were collected adjacent to each of the block samples and one additional sample was collected for evaluation of a field repair technique as required by the Work Plan. The Shelby tubes were transported to Golder's Soils Laboratory in Lakewood, Colorado for laboratory hydraulic conductivity testing. The locations of the samples are shown on Figure 1.1-3.

Results of Golder's hydraulic conductivity testing from the Shelby tube samples are presented and summarized in Appendix D. Table 5.0-1 presents an overview of the test results showing the number of passes, field-moisture-density, percent saturation and hydraulic conductivity results for each of the Shelby Tube samples. Samples 07-P-01A through 07-P-03A represent samples taken from the CCL Test Fill and exhibited hydraulic conductivities ranging in value from 1.9×10^{-8} to 5.1×10^{-8} cm/s when tested at confining pressures of 5 psi. Sample 07 P-TI-01A represents a sample taken from the CCL Test Fill in an area that was evaluated for adequate bonding of lifts in a repair scenario. The sample exhibited a hydraulic conductivity of 4.8×10^{-8} cm/s when tested at a confining pressure of 5 psi. Samples 08-P-01A and 08-P-02A represent samples taken from the Clay Plug Test Fill and exhibited hydraulic conductivities ranging in value from 2.0×10^{-8} to 5.1×10^{-8} cm/s when tested at confining pressures of 5 psi and values ranging from 6.7×10^{-9} to 7.2×10^{-9} cm/s when tested at confining pressures of 12 psi.

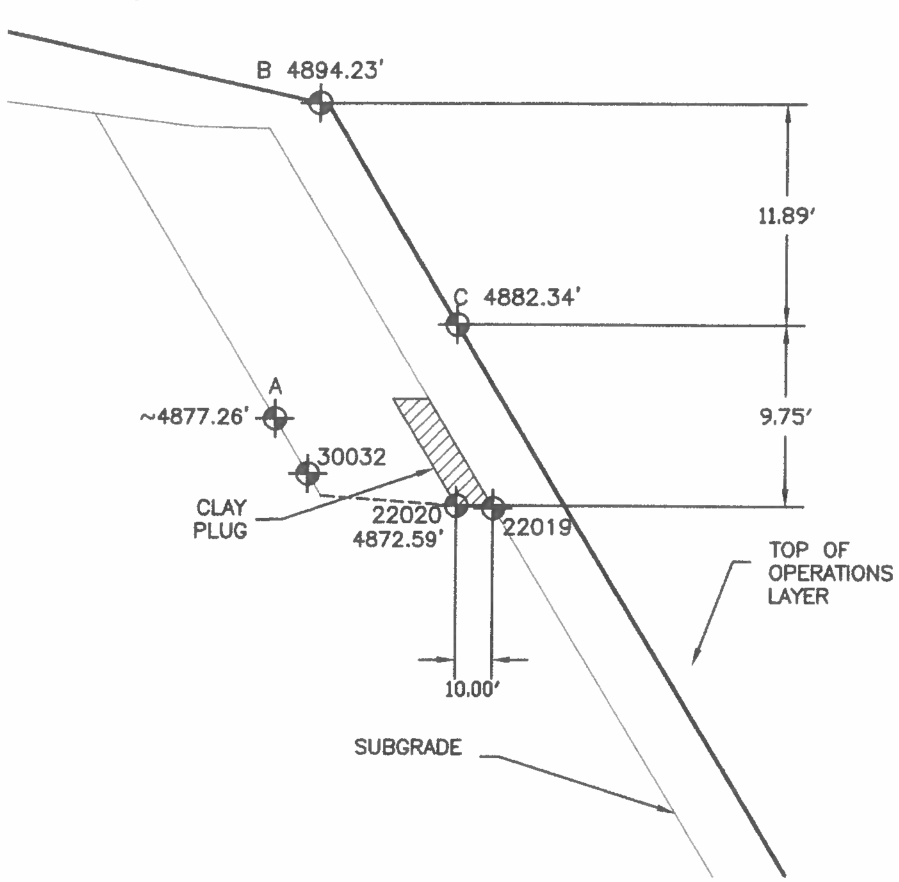
TABLE 5.0-1
Summary of Shelby Tube Testing
Hydraulic Conductivity Test Results

Sample Number	Lift Number	Number of Passes	Dry Density (pcf)	Moisture Content (%)	Degree of Saturation (%)	Hydraulic Conductivity (cm/sec @ 5psi)
07-P-01A	Lift 7	8	105.6	19.2	87.6	1.9 X 10^{-8}
07-P-02A	Lift 6	8	100.4	23.3	93.3	5.1 X 10^{-8}
07-P-03A	Lift 5	8	100.1	22.8	90.6	4.6 X 10^{-8}
07-P-TI-01A	Tie-in	8	107.1	19.7	93.4	4.8 X 10^{-8}
08-P-01A	Lift 7	16	101.0	23.3	94.7	5.1 X 10^{-8}
08-P-01A	Lift 7	16	101.0	23.3	94.7	7.2 X 10^{-9} @ 12 psi
08-P-02A	Lift 6	16	100.3	23.6	94.3	3.9 X 10^{-8}
08-P-02A	Lift 6	16	100.3	23.6	94.3	6.7 X 10^{-9} @ 12 psi

The samples from the Clay Plug Test Fill were tested at the higher confining stresses due to the location of the Clay Plug at approximate elevation 4,875 or more than 15 feet below the subgrade crest elevation. The effective stress at the base of the Clay Plug was selected at 12 psi based on loading conditions at this location. Figure 5.0-1 presents a schematic of the effective stress conditions for the Clay Plug. A total of five block samples were obtained in general accordance with the provisions suggested in the Work Plan. Three block samples were obtained from the CCL Test Fill from lifts 5, 6 and 7 and two samples were obtained from the Clay Plug Test Fill from lifts 6 and 7. The results of the hydraulic conductivity testing performed by the University of Wisconsin-Madison's geotechnical laboratory are presented and summarized in Appendix E. Table 5.0-2 presents an overview of the test results showing the number of passes, field-moisture-density, percent saturation and hydraulic conductivity results for each of the block samples. Reported ranges of hydraulic conductivity from the CCL Test Fill samples were 4.5 x 10^{-8} to 8.2 x 10^{-9} cm/sec, which exceed the requirements set forth in the specifications. Reported results of hydraulic conductivity from the Clay Plug Test Fill samples were 1.2 x 10^{-9} and 1.0 x 10^{-8} cm/s for tests at 5 psi confining pressures and 1.3 x 10^{-9} and 1.5 x 10^{-9} cm/s for tests at 12 psi.

TABLE 5.0-2
Summary of Block Sample Testing
Hydraulic Conductivity Test Results

Sample Number	Lift Number	Number of Passes	Dry Density (pcf)	Moisture Content (%)	Degree of Saturation (%)	Hydraulic Conductivity (cm/sec @ 5psi)
07-P-01A	Lift 7	8	102.3	19.2	80.7	3.2 X 10^{-8}
07-P-02A	Lift 6	8	103.6	21.0	91.0	4.5 X 10^{-8}
07-P-03A	Lift 5	8	99.2	24.5	95.3	8.2 X 10^{-9}
08-P-01A	Lift 7	16	99.8	26.0	100	1.2 X 10^{-9}
08-P-01A	Lift 7	16	99.8	26.0	100	1.3 X 10^{-9} @ 12 psi
08-P-02A	Lift 6	16	101.1	24.0	97.7	1.0 X 10^{-8}
08-P-02A	Lift 6	16	101.1	24.0	97.7	1.5 X 10^{-9} @ 12 psi



NOTES:

1. Confining pressure prior to waste placement = 8.3 psi at base of clay plug.
2. Confining pressure after waste placement to crest of slope = 16.5 psi at base of clay plug.
3. 5X vertical exaggeration.
4. Generalized cross section taken from 24150 survey line.
5. Survey points from KRW record survey for base of clay plug.

SURVEY DATA POINTS

A _ APPROXIMATE TOP OF SAND SEAM
B _ CREST OF SLOPE
C _ PROJECTION OF PT 22020 ONTO OPS. LAYER
22019 – TOP OVER–EX
22020 – OVER–EX SETBACK
30032 – SAND SEAM BTM

PROJECT
CLEAN HARBORS ENVIRONMENTAL INC.
SECURE CELL NO. 3 TEST FILL CQA
DEER TRAIL, ADAMS COUNTY, COLORADO

TITLE
CLAY PLUG EFFECTIVE STRESS AT
GENERALIZED CROSS SECTION 24150

Golder Associates
Denver, Colorado

PROJECT No.		063-2145	FILE No. 0632145A004		
DESIGN	MGC	06/05/06	SCALE AS SHOWN	REV. A	
CADD	MGC	06/05/06	5.0-1		
CHECK					
REVIEW					

6.0 CONCLUSIONS

Based on the field hydraulic conductivity data presented in this report, Golder concludes that the materials, equipment, and construction techniques used to construct the Test Fill for the CCL and Clay Plug are appropriate for installation of the clay liner and clay plug materials, respectively, and will meet the regulatory performance criterion requiring a vertical hydraulic conductivity of 1×10^{-7} cm/sec or less for the CCL and 1.0×10^{-8} cm/sec or less for the Clay Plug for a 10-foot wide section. Methods for the CCL placement will remain consistent with the original specifications and as modified by this report as follows:

Secondary and Primary CCL: Materials shall be placed and compacted in horizontal lifts as noted in the specifications with a minimum of 8 passes of a CAT 815 compactor. The Final Compaction Window for the CCL materials is presented on Figure 6.0-1 and is defined by: 1) a lower limit bounded by the 80% degree of saturation line, 2) moisture content limits of 19.0 to 26.0 % moisture content, and 3) a lower density limit of 94.0 pcf (average value for 95% of the Standard Proctor Maximum Dry Density).

Clay Plug materials: Materials shall be placed and compacted in horizontal lifts as noted in the specifications with a minimum of 16 passes of a CAT 815 compactor and 1 pass of a loaded scraper. The Final Compaction Window for the Clay Plug materials is presented on Figure 6.0-2 and is defined by: 1) a lower density limit of 97.0 pcf or 98% of Standard Proctor; 2) moisture content limits of optimum to nominally 4.5 percent above OMC (26% maximum) with allowances to accept moisture content from 19.0 to OMC when the degree of saturation is equal to or greater than 89 percent. This modification is based on our review of the in-situ moisture density values from lifts 5-7 and from the actual reported values noted on the block samples and Shelby tube samples.

Respectfully submitted,

GOLDER ASSOCIATES INC.

Rick Kiel

Rick Kiel, P.E.
Senior Consultant

Rick Kinsh

Rick Kinshella, P.E.
Senior Consultant

REK/RLK/kag

FIGURE 6.0-1

Final Compaction Window for Compacted Clay Liner (K ≤ 1.0 x 10^{-7} cm/s)

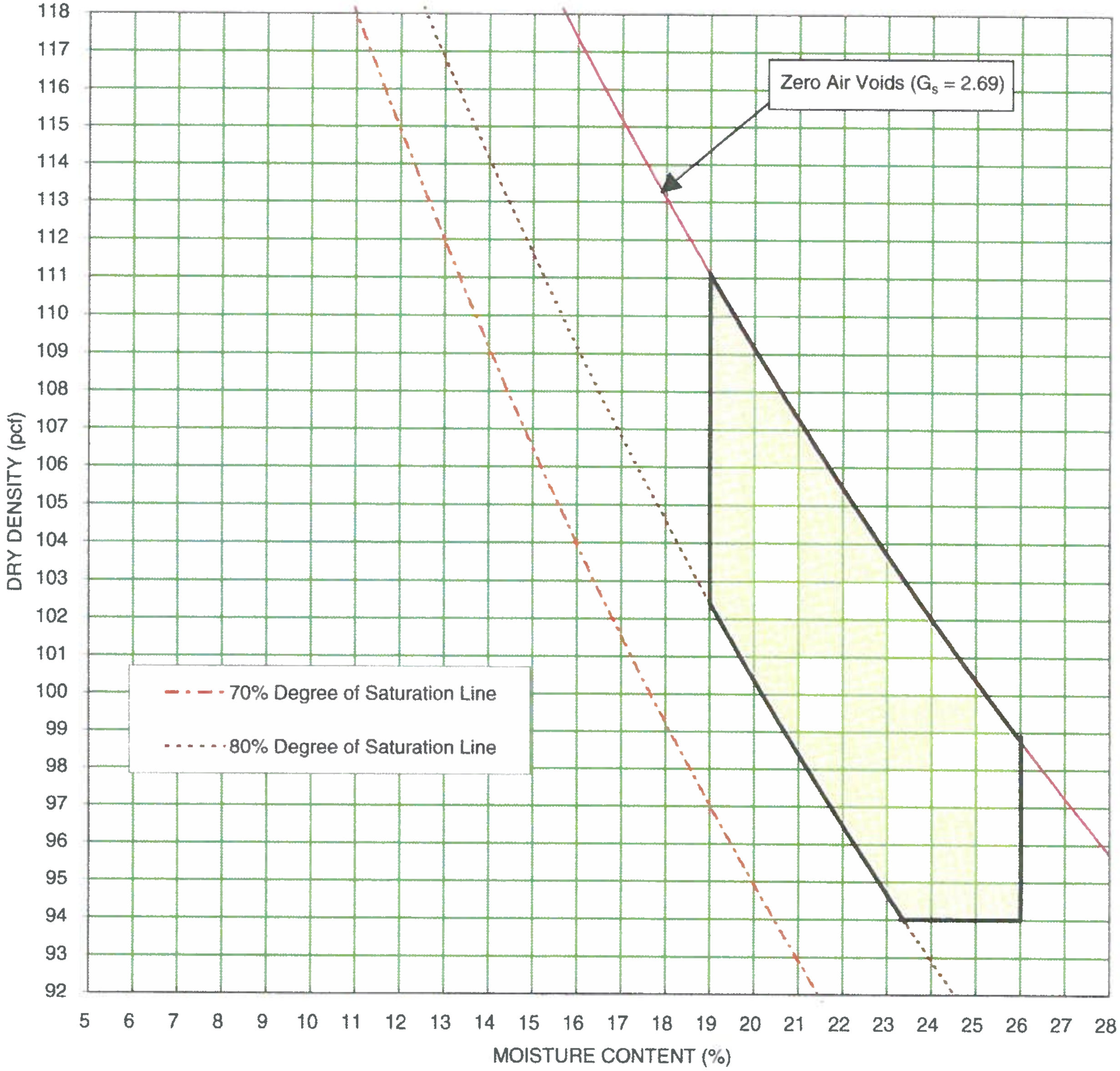
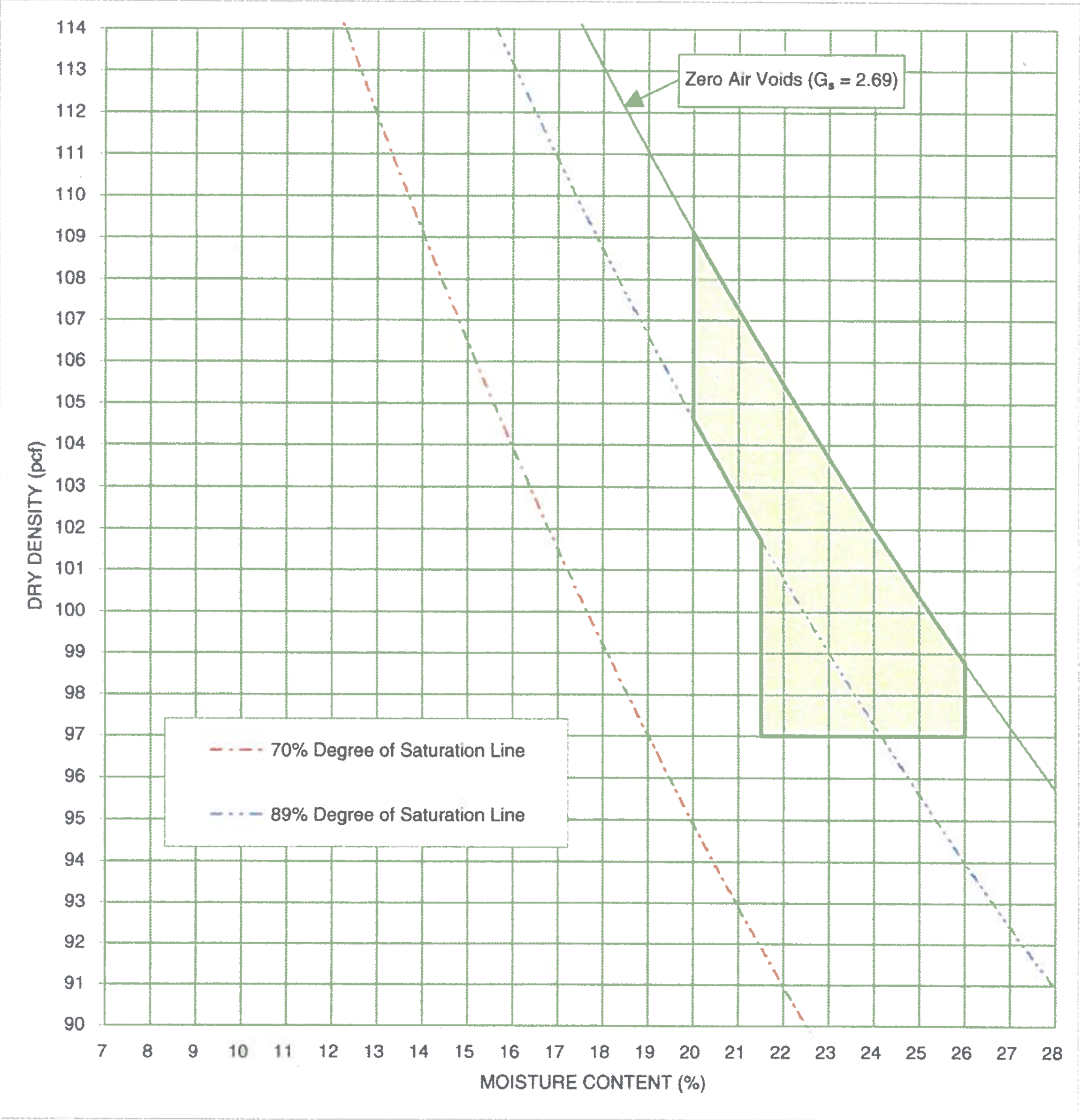


FIGURE 6.0-2

Final Compaction Window for Clay Plug (K ≤ 1.0 x 10^{-8} cm/s)



7.0 REFERENCES

EPA, 1993. "Quality Assurance and Quality Control Waste Containment Facilities," Technical Guidance Document EPA/600/R-93/182, prepared by the United States Environmental Protection Agency, dated September 1993.

Geosyntec, 1991. "Laboratory test results from a 1991 Test Fill at Clean Harbors Deer Trail – excerpts provided from Clean Harbor's project files, 1991.

MWH, 2006. "Revised Test Fill Work Plan for Secure Cells 3 Through 7," dated February, 2006.

Othman, Majdi A. and Scott M. Luettich. 1994. "Compaction Control Criteria for Clay Hydraulic Barriers," in Compaction of Difficult Soils and Resilient Modulus Testing, edited by Joseph M. Sussman (Transportation Research Record 1462), pp. 28-35.

APPENDIX A

PRECONSTRUCTION TESTING SUMMARY AND LABORATORY RESULTS

TABLE A-1
CLEAN HARBORS DEER TRAIL FACILITY/SECURE CELL NO. 3 CQA
SUMMARY OF TEST FILL PRE-CONSTRUCTION SOIL DATA

Sample Type	Sample/ Boring Number	Sample Depth (ft)	U.S.C.S. Soil Classi-fication	Delivered Moisture (%)	Atterberg Limits			Grain Size Distribution			Specific Gravity	Moist/Den Relationship Std/Mod Proctors		Additional Tests Comments (See Notes)
					LL	PL	PI	% Finer 3/4"	% Finer #4	% Finer #200		PCF (Dry)	Moist (%)	
Pail	TF-1	Stockpile	CH	18.2	55	16	39	100	100	98	2.66	98.9	21.6	ASTM D698
Pail	TF-1	Stockpile	--	--	--	--	--	--	--	--	--	113.8	14.8	ASTM D1557
Pail	TF-2	Stockpile	CH	--	56	16	40	100	100	99	2.71	98.7	21.9	ASTM D698
Pail	TF-2	Stockpile	--	--	--	--	--	--	--	--	--	111.5	16.5	ASTM D1557

NOTES:

LL = LIQUID LIMIT
PL = PLASTIC LIMIT
PI = PLASTIC INDEX
SL = SHRINKAGE LIMIT

T = TRIAXIAL TEST
U = UNCONFINED COMPRESSION TEST
C = CONSOLIDATION TEST
DS = DIRECT SHEAR TEST
PERM = PERMEABILITY

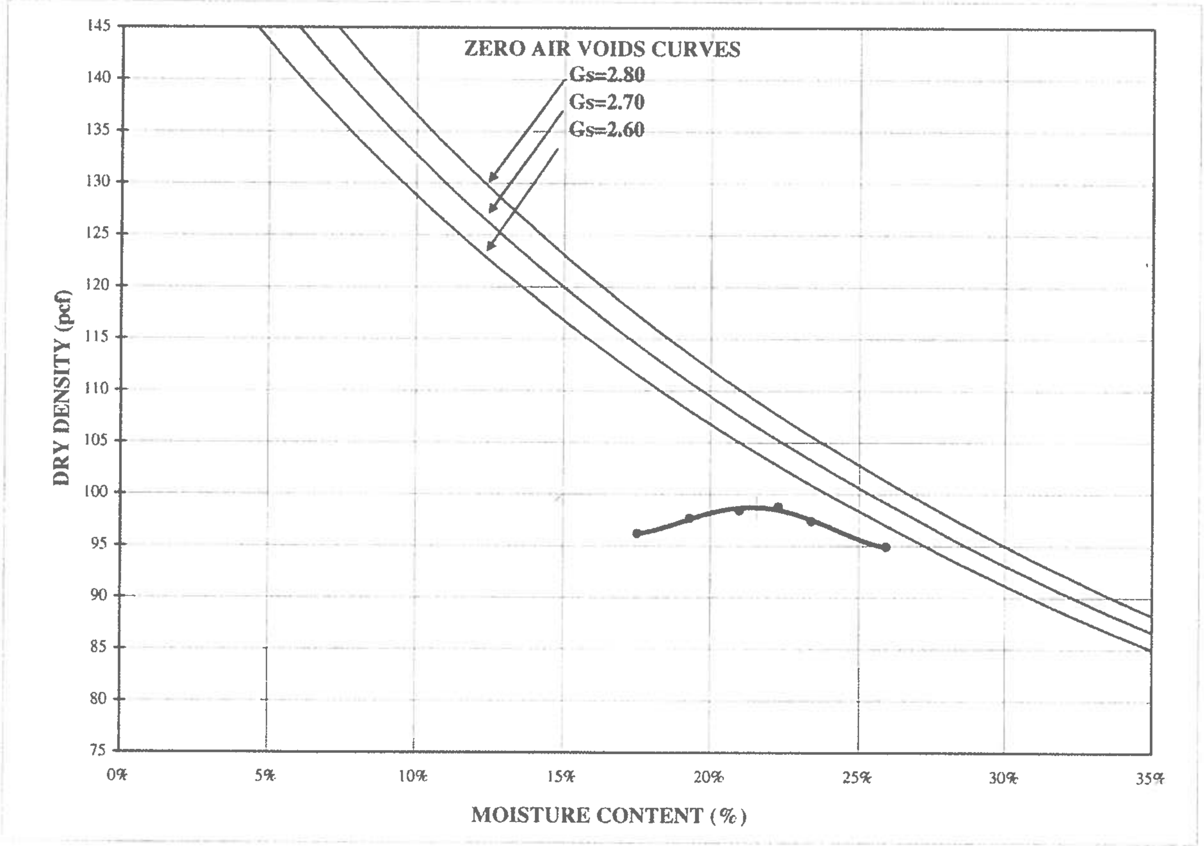
ASTM D698 - Standard Proctor
ASTM D1557 - Modified Proctor

April, 2006 **063-2145**

MOISTURE / DRY DENSITY CURVE
ASTM D 698 Method A

Mechanical	Standard	Wet Method

PROJECT NAME: **Clean Harbor/Cell No. 3 CQA Deer Trl/CO**
PROJECT NUMBER: **063-2145**
SAMPLE ID: **TF-1** DEPTH: **--** SAMPLE TYPE: **Pail**



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	96.2	17.5%
2	97.7	19.3%
3	98.4	21.0%
4	98.8	22.3%
5	97.4	23.4%
6	94.9	25.9%

Maximum Dry Density (pcf)	98.9
Optimum Moisture (%)	21.6
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	18.2%
% Passing #4 sieve	100.0
% Passing 3/8" sieve	100.0
% Passing 3/4" sieve	100.0

DESCRIPTION Very dark grayish brown fat clay

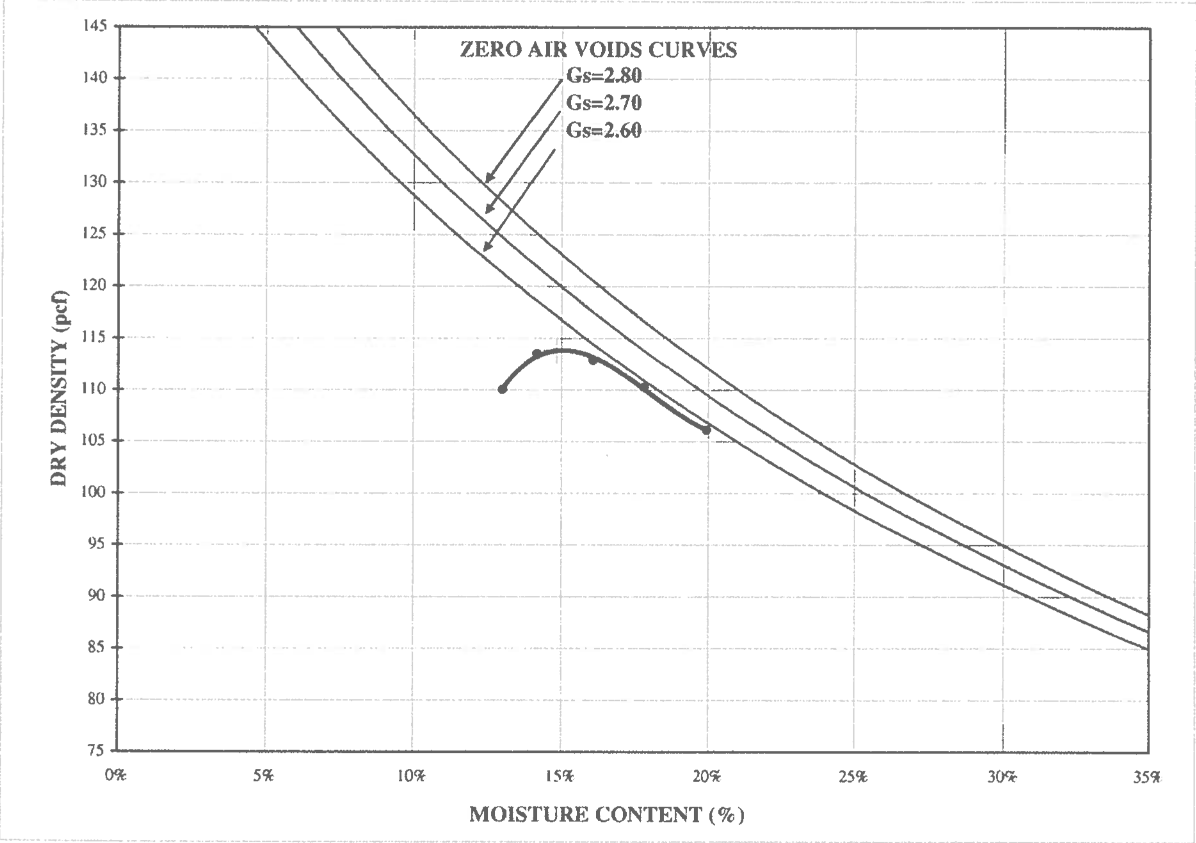
USCS CH

TECH	MB
DATE	4/17/06
REVIEW	RT

MOISTURE / DRY DENSITY CURVE
ASTM D 1557 Method A

Mechanical	Modified	Wet Method

PROJECT NAME: Clean Harbor/Cell No. 3 CQA Deer Trl/CO
PROJECT NUMBER: 063-2145
SAMPLE ID: TF-1 DEPTH: -- SAMPLE TYPE: Pail



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	110.1	13.0%
2	113.5	14.2%
3	112.9	16.1%
4	110.3	17.8%
5	106.1	19.9%

Maximum Dry Density (pcf)	113.8
Optimum Moisture (%)	14.8
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	18.2%
% Passing #4 sieve	100.0
% Passing 3/8" sieve	100.0
% Passing 3/4" sieve	100.0

DESCRIPTION Very dark grayish brown fat clay

USCS CH

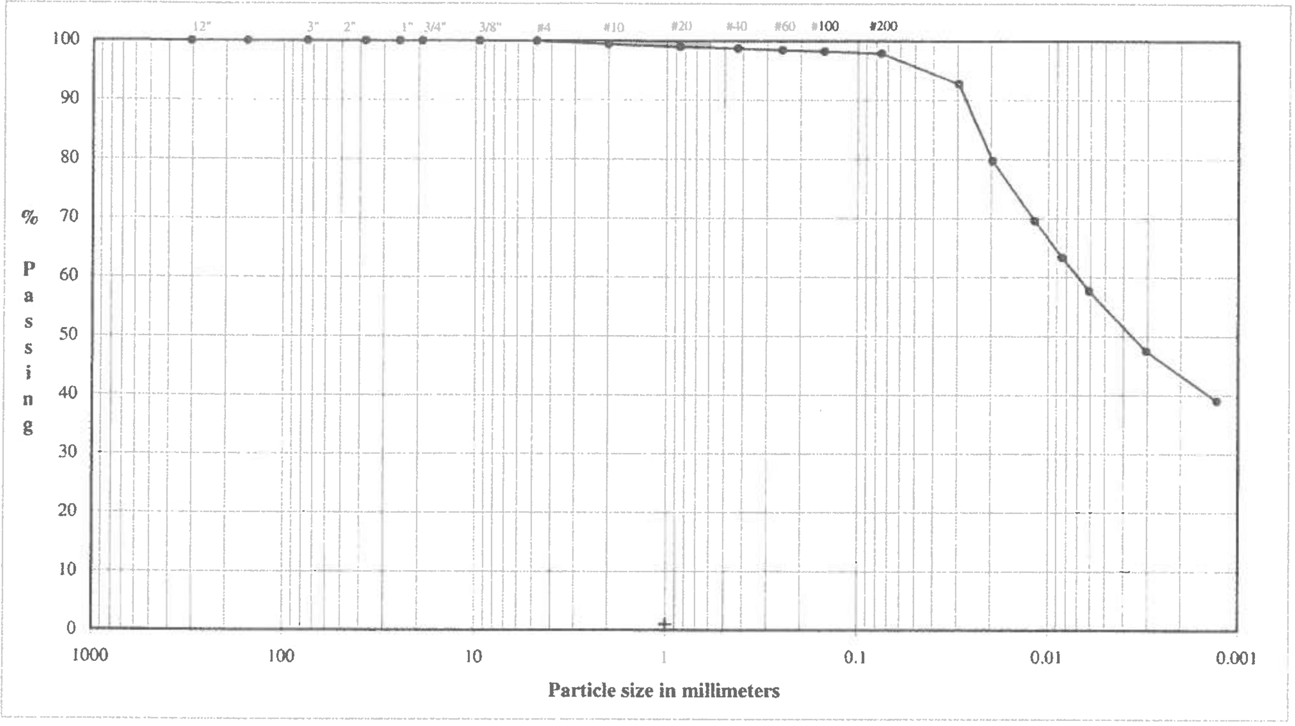
TECH	RT
DATE	4/17/06
REVIEW	MB

April-06 063-2145

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

PROJECT NAME:	**Clean Harbor/Cell No. 3 CQA Deer Trl/CO**		
SAMPLE ID:	**TF-1**	Depth (ft):	--
TYPE:	**Pail**		



COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

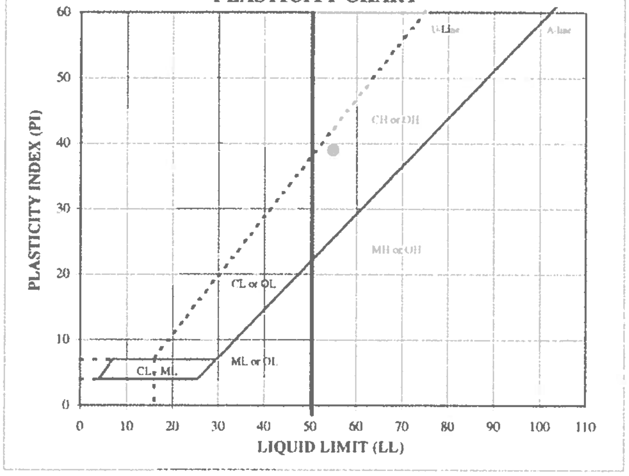
U.S. Standard Sieves Sizes and Numbers

	Particle Size (mm)	% Passing	Particle Size Classification	Percentage
12.0"	304.8	**100.0**		
12.0"	304.8	**100.0**	Cobbles	**0.00**
6.0"	154.2	**100.0**		
6.0"	154.2	**100.0**		
3.0"	75.0	**100.0**		
1.5"	37.5	**100.0**		
1.0"	25.0	**100.0**	Coarse Gravel	**0.00**
0.75"	19.0	**100.0**		
0.375"	9.5	**100.0**		
#4	4.8	**100.0**	Fine Gravel	**0.00**
#10	2.00	**99.4**	Coarse Sand	**0.59**
#20	0.85	**99.0**		
#40	0.43	**98.7**	Medium Sand	**0.68**
#60	0.25	**98.5**		
#100	0.15	**98.3**		
#200	0.075	**97.9**	Fine Sand	**0.81**

Hydrometer Analysis

(mm)	% Finer		
0.030	**92.8**		
0.020	**79.8**		
0.012	**69.6**	Fines	
0.008	**63.4**	Silt or Clay	**97.92**
0.006	**57.7**		
0.003	**47.5**		
0.001	**39.0**		

PLASTICITY CHART



ATTERBERG LIMITS

M_c	LL	PL	PI	SpG
18.2	55	16	39	2.66

DESCRIPTION: Very dark grayish brown fat clay

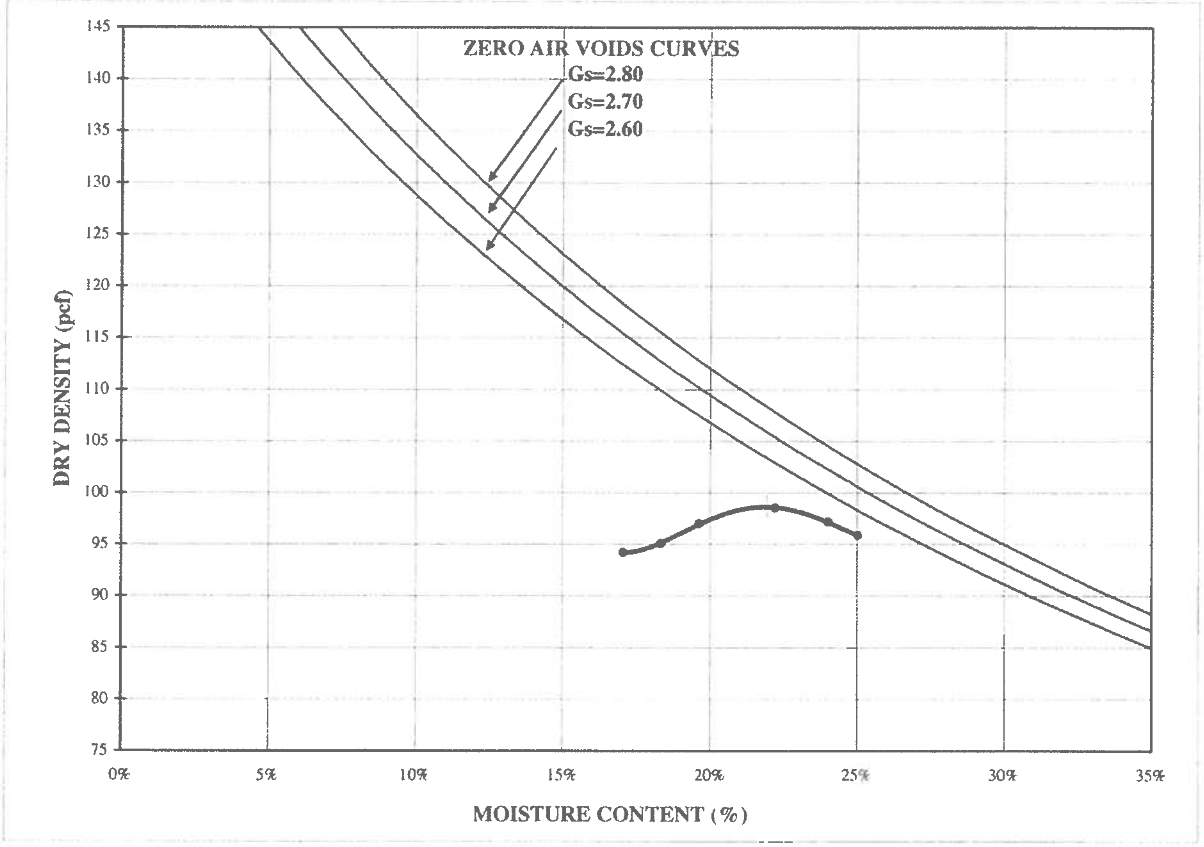
USCS: CH

TECH	DS
DATE	4/14/2006
REVIEW	MB

MOISTURE / DRY DENSITY CURVE
ASTM D 698 Method A

Mechanical	Standard	Wet Method

PROJECT NAME: **Clean Harbor/Cell No. 3 CQA Deer Trl/CO**
PROJECT NUMBER: **063-2145**
SAMPLE ID: **TF-2** DEPTH: -- SAMPLE TYPE: **Pail**



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	94.2	17.1%
2	95.1	18.3%
3	97.0	19.6%
4	98.5	22.2%
5	97.2	24.0%
6	95.9	25.0%

Maximum Dry Density (pcf)	98.7
Optimum Moisture (%)	21.9
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	--
% Passing #4 sieve	100.0
% Passing 3/8" sieve	100.0
% Passing 3/4" sieve	100.0

DESCRIPTION Very dark grayish brown fat clay

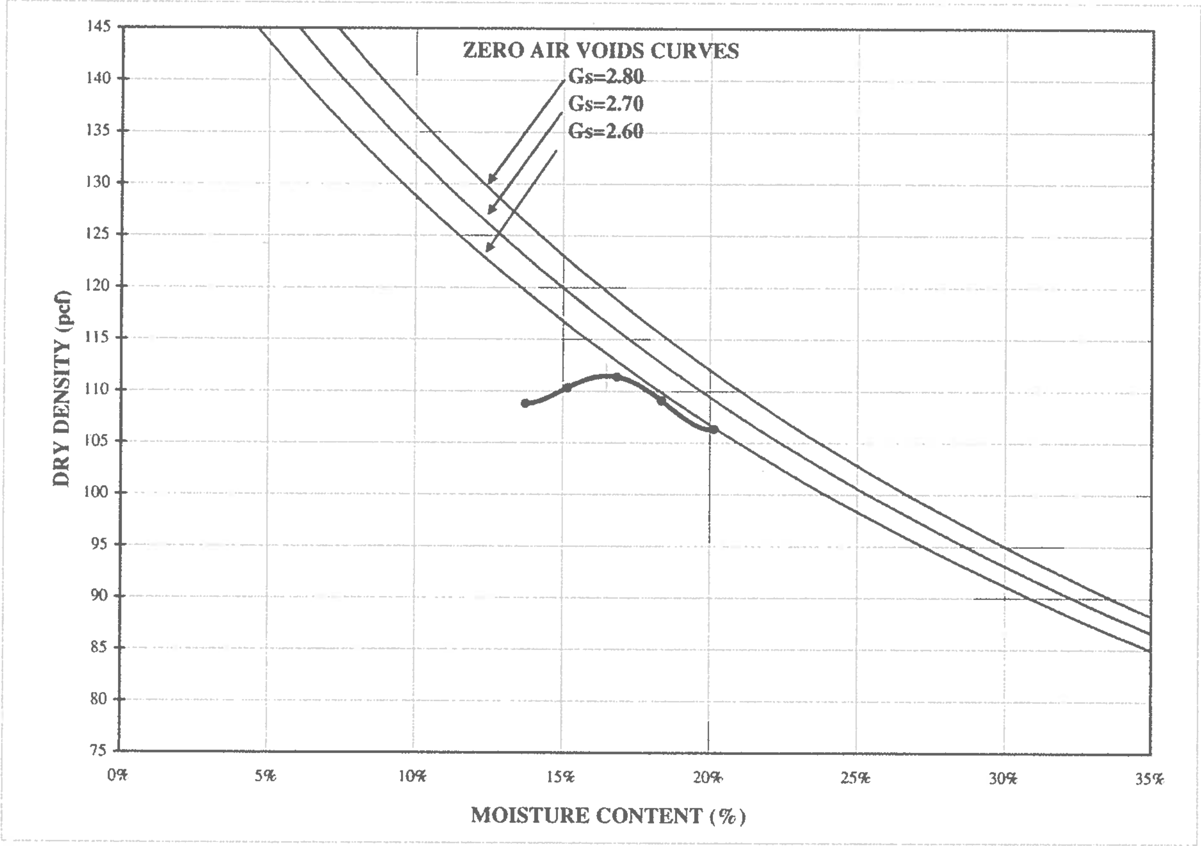
USCS CH

TECH	MS
DATE	4/27/06
REVIEW	MB

MOISTURE / DRY DENSITY CURVE
ASTM D 1557 Method A

Mechanical	Modified	Wet Method

PROJECT NAME: **Clean Harbor/Cell No. 3 CQA Deer Trl/CO**
PROJECT NUMBER: **063-2145**
SAMPLE ID: **TF-2** DEPTH: -- SAMPLE TYPE: **Pail**



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	108.8	13.7%
2	110.4	15.2%
3	111.4	16.8%
4	109.1	18.4%
5	106.3	20.2%

Maximum Dry Density (pcf)	111.5
Optimum Moisture (%)	16.5
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	--
% Passing #4 sieve	100.0
% Passing 3/8" sieve	100.0
% Passing 3/4" sieve	100.0

DESCRIPTION Very dark grayish brown fat clay

USCS CH

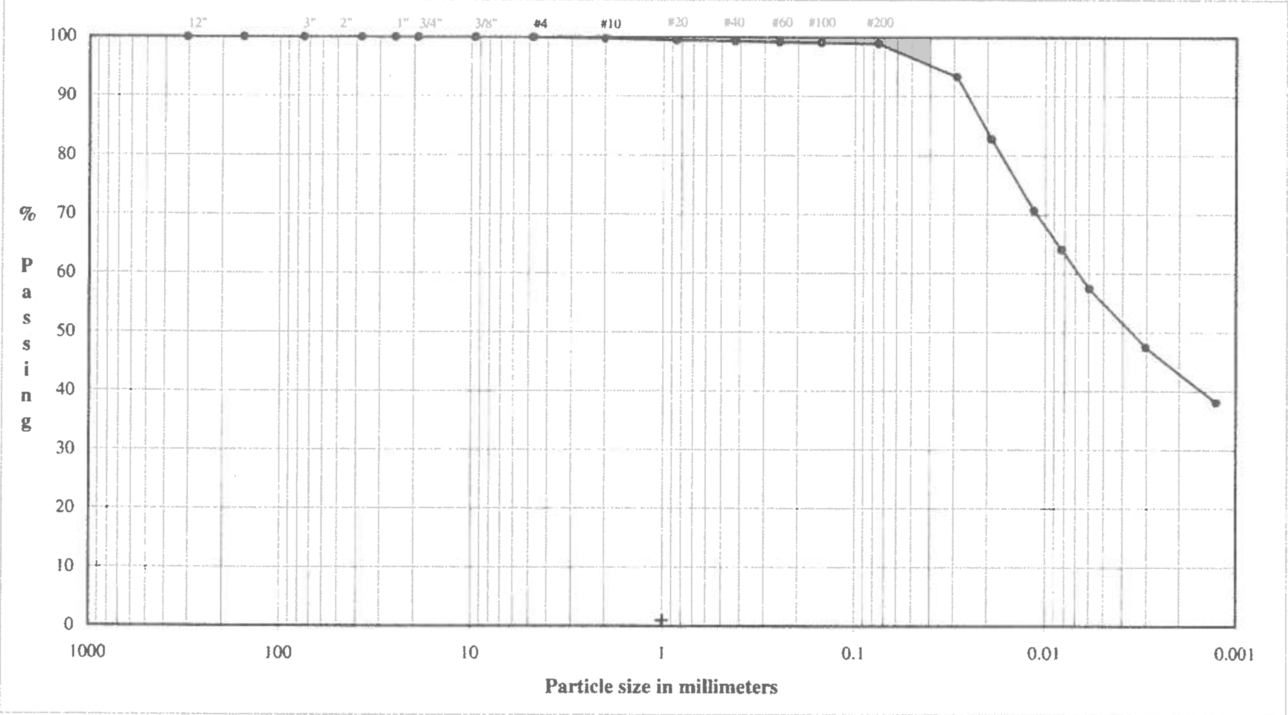
TECH	MS
DATE	4/27/06
REVIEW	MB

April-06 063-2145

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

PROJECT NAME: **Clean Harbor/Cell No. 3 CQA Deer Trl/CO**
SAMPLE ID: **TF-2** Depth (ft): --
TYPE: **Pail**



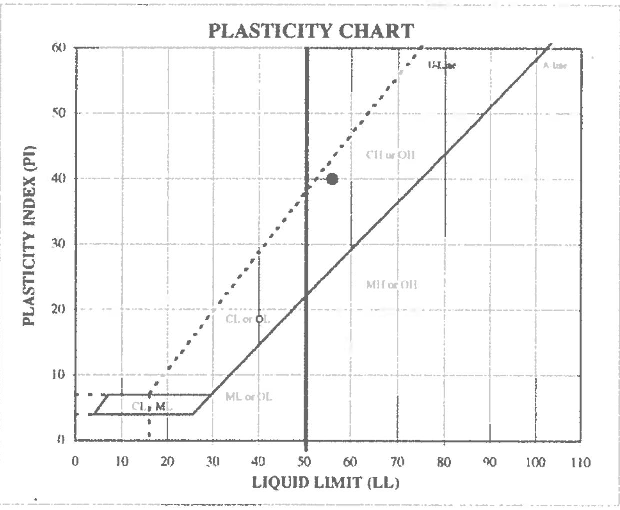
COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

U.S. Standard Sieves Sizes and Numbers

	Particle Size (mm)	% Passing	Particle Size Classification	Percentage
12.0"	304.8	**100.0**	Cobbles	**0.00**
12.0"	304.8	**100.0**		
6.0"	154.2	**100.0**	Coarse Gravel	**0.00**
6.0"	154.2	**100.0**		
3.0"	75.0	**100.0**		
1.5"	37.5	**100.0**		
1.0"	25.0	**100.0**		
0.75"	19.0	**100.0**	Fine Gravel	**0.00**
0.375"	9.5	**100.0**		
#4	4.8	**100.0**		
#10	2.00	**99.8**	Coarse Sand	**0.22**
#20	0.85	**99.6**	Medium Sand	**0.38**
#40	0.43	**99.4**		
#60	0.25	**99.2**	Fine Sand	**0.45**
#100	0.15	**99.1**		
#200	0.075	**99.0**		

Hydrometer Analysis

(mm)	% Finer		
0.029	**93.4**	Fines Silt or Clay	**98.95**
0.019	**82.9**		
0.011	**70.7**		
0.008	**64.1**		
0.006	**57.4**		
0.003	**47.5**		
0.001	**38.1**		


PLASTICITY CHART

ATTERBERG LIMITS

M_c	LL	PL	PI	SpG
--	56	16	40	2.71

DESCRIPTION: Very dark grayish brown fat clay

USCS: CH

TECH DS/MS
DATE 4/25/2006
REVIEW MB

TABLE A-2
CLEAN HARBORS DEER TRAIL FACILITY/SECURE CELL NO. 3 CQA
SUMMARY OF FLEXIBLE-WALL PERMEABILITY TEST RESULTS
REMOLDED SAMPLES

Sample Number	Sample Length (cm)	Sample Diameter (cm)	Sample Dry Density (pcf)	Initial Moisture (%)	Degree of Saturation (%)	Effective Stress (psi)	Back Pressure (psi)	Gradient	Average Permeability (cm/sec)
TF-1-1	9.47	7.30	96.4	21.9	80.7	5	95	14	4.7 X 10^{-8}
TF-1-2	9.55	7.27	105.8	17.8	83.2	5	95	8	8.6 X 10^{-8}
TF-1-3	9.47	7.30	98.9	23.2	91.0	5	95	16	2.1 X 10^{-8}
TF-1-4	9.45	7.30	106.2	19.2	90.7	5	95	15	4.4 X 10^{-8}
TF-1-5	9.52	7.27	105.9	19.8	92.8	5	95	16	6.6 X 10^{-8}
TF-1-6	9.45	7.30	100.5	22.6	92.3	5	95	19	3.4 X 10^{-8}
TF-2-1	9.50	7.27	106.1	19.9	90.8	5	95	12	5.5 X 10^{-8}
TF-2-1	9.50	7.27	106.1	19.9	90.8	12	88	19	1.7 X 10^{-8}
TF-2-2	9.54	7.27	100.1	23.4	92.0	5	95	14	4.8 X 10^{-8}
TF-2-2	9.54	7.27	100.1	23.4	92.0	12	88	15	9.0 X 10^{-9}
TF-2-3	9.53	7.27	103.3	21.8	92.7	5	95	20	3.5 X 10^{-8}

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co		
PROJECT NUMBER	063-2145		
SAMPLE ID	TF 1 - 1	-	-
SAMPLE TYPE	Remold		

BOARD #	5
CELL #	3
Flow Pump Speed	10
Technician	BDM

COMMENTS
1. The requested remold perameters were 97.0pcf and 21.8%MC
2. Water used as permeant
3. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.47	**B-Value, f**	95.00
Diameter, cm	7.30	**Cell Pres.**	100.0
Area, cm²	41.85	**Bot. Pres.**	95.0
Volume, cm^3	396.36	**Top Pres.**	95.0
Mass, g	746.30	**Tot. B.P.**	95.0
Moisture Content, %	21.9	**Head, max.**	151.00
Dry Density, pcf	96.4	**Head, min.**	135.00
Spec. Gravity	2.66	**Max. Grad.**	15.95
Volume Solids, cm^3	230.22	**Min. Grad.**	14.26
Volume Voids, cm^3	166.14		
Void Ratio	0.72		
Saturation, %	80.6%		

Flow Pump Rate 2.80E-05 cm^3/sec

Sample Data, Final

Height, cm	9.59
Diameter, cm	7.35
Area, cm²	42.43
Volume, cm^3	406.90
Mass, g	778.30
Moisture Content,%	27.3
Dry Density, pcf	93.7
Volume Solids, cm^3	229.77
Volume Voids, cm^3	177.13
Void Ratio	0.77
Saturation, %	94.3%

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	g	231.71	857.4
Wt Soil & Tare, f	g	196.03	690.37
Wt Tare	g	32.87	79.50
Wt Moisture Lost	g	35.68	167.03
Wt Dry Soil	g	163.16	610.87
Water Content	%	21.9%	27.3%

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient))	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
4/23/06	10:45											
4/23/06	11:00	15	20.7	10	1	151	9.47	41.85	15.95	2.8E-05	6.7E-07	4.2E-08
4/23/06	11:15	30	20.7	10	1	135	9.47	41.85	14.26	2.8E-05	6.7E-07	4.7E-08
4/23/06	11:30	45	20.7	10	1	135	9.47	41.85	14.26	2.8E-05	6.7E-07	4.7E-08
4/23/06	11:45	60	20.7	10	1	135	9.47	41.85	14.26	2.8E-05	6.7E-07	4.7E-08
4/23/06	12:00	75	20.7	10	1	136	9.47	41.85	14.36	2.8E-05	6.7E-07	4.7E-08
4/23/06	12:15	90	20.7	10	1	135	9.47	41.85	14.26	2.8E-05	6.7E-07	4.7E-08

PERMEABILITY REPORTED AS ** 4.7E-08 cm/sec **

DATE	4/23/2006
REVIEW	MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			**BOARD #**	4
PROJECT NUMBER	063-2145			**CELL #**	4
SAMPLE ID	TF 1 - 2	-	-	**Flow Pump Speed**	10
SAMPLE TYPE	Remold			**Technician**	BDM

COMMENTS
1. The requested remold perameters were 107.1pcf and 17%mc
2. Water used as permeant
3. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.55	**B-Value, f**	97.50
Diameter, cm	7.27	**Cell Pres.**	100.0
Area, cm²	41.51	**Bot. Pres.**	95.0
Volume, cm³	396.43	**Top Pres.**	95.0
Mass, g	791.80	**Tot. B.P.**	95.0
Moisture Content, %	17.8	**Head, max.**	81.00
Dry Density, pcf	105.8	**Head, min.**	75.00
Spec. Gravity	2.66	**Max. Grad.**	8.48
Volume Solids, cm³	252.79	**Min. Grad.**	7.85
Volume Voids, cm³	143.63		
Void Ratio	0.57		
Saturation, %	83.1%		

Sample Data, Final

Height, cm	9.92
Diameter, cm	7.44
Area, cm²	43.47
Volume, cm³	431.27
Mass, g	856.8
Moisture Content,%	25.2
Dry Density, pcf	99.0
Volume Solids, cm³	257.25
Volume Voids, cm³	174.02
Void Ratio	0.68
Saturation, %	99.1%

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	g	188.33	940.9
Wt Soil & Tare, f	g	164.80	768.60
Wt Tare	g	32.25	85.20
Wt Moisture Lost	g	23.53	172.30
Wt Dry Soil	g	132.55	683.40
Water Content	%	17.8%	25.2%

Flow Pump Rate 2.80E-05 cm³/sec

DATE/TIME		**dt (min)**	**TEMP (°C)**	**Speed (1-12)**	**Speed Coeff.**	**ΔH (cm)**	**L (cm)**	**A (cm²)**	**i (Gradient)**	**q (cm³/sec)**	**v (cm/sec)**	**Permeability (cm/sec)**
4/23/06	12:30											
4/23/06	12:45	15	20.7	10	1	81	9.55	41.51	8.48	2.8E-05	6.7E-07	8.0E-08
4/23/06	13:00	30	20.7	10	1	75	9.55	41.51	7.85	2.8E-05	6.7E-07	8.6E-08
4/23/06	14:00	90	20.7	10	1	75	9.55	41.51	7.85	2.8E-05	6.7E-07	8.6E-08
4/23/06	14:15	105	20.7	10	1	75	9.55	41.51	7.85	2.8E-05	6.7E-07	8.6E-08
4/23/06	14:30	120	20.7	10	1	75	9.55	41.51	7.85	2.8E-05	6.7E-07	8.6E-08
4/23/06	14:45	135	20.7	10	1	75	9.55	41.51	7.85	2.8E-05	6.7E-07	8.6E-08

PERMEABILITY REPORTED AS ** 8.6E-08 cm/sec **

DATE 4/23/2006
REVIEW MB

FLOW PUMP #2

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co		
PROJECT NUMBER	063-2145		
SAMPLE ID	TF 1 - 3	-	-
SAMPLE TYPE	Remold		

BOARD #	3
CELL #	5
Flow Pump Speed	11
Technician	BDM

COMMENTS
1. The requested remold perameters were 100.0pcf and 22.5%MC
2. Water used as permeant
3. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.47	B-Value, f	96.00
Diameter, cm	7.30	Cell Pres.	100.0
Area, cm²	41.85	Bot. Pres.	95.0
Volume, cm³	396.36	Top Pres.	95.0
Mass, g	773.90	Tot. B.P.	95.0
Moisture Content, %	23.2	Head, max.	170.00
Dry Density, pcf	98.9	Head, min.	149.00
Spec. Gravity	2.66	Max. Grad.	17.95
Volume Solids, cm³	236.14	Min. Grad.	15.73
Volume Voids, cm³	160.22		
Void Ratio	0.68		
Saturation, %	91.0%		

Sample Data, Final

Height, cm	9.54
Diameter, cm	7.35
Area, cm²	42.43
Volume, cm³	404.77
Mass, g	795.40
Moisture Content, %	25.1
Dry Density, pcf	98.0
Volume Solids, cm³	239.02
Volume Voids, cm³	165.75
Void Ratio	0.69
Saturation, %	96.3%

WATER CONTENTS		Trimmings Initial	Sample Final
Wt Soil & Tare, i	g	233.91	879.5
Wt Soil & Tare, f	g	195.91	719.90
Wt Tare	g	32.16	84.04
Wt Moisture Lost	g	38.00	159.62
Wt Dry Soil	g	163.75	635.86
Water Content	%	23.2%	25.1%

Flow Pump Rate 1.40E-05 cm³/sec

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm²)	i (Gradient)	q (cm³/sec)	v (cm/sec)	Permeability (cm/sec)
4/23/06	12:00											
4/23/06	12:30	30	20.7	10	1	170	9.47	41.85	17.95	2.8E-05	6.7E-07	3.7E-08
4/23/06	12:45	45	20.7	11	1	152	9.47	41.85	16.05	1.4E-05	3.3E-07	2.1E-08
4/23/06	13:00	60	20.7	11	1	150	9.47	41.85	15.84	1.4E-05	3.3E-07	2.1E-08
4/23/06	13:15	75	20.7	11	1	149	9.47	41.85	15.73	1.4E-05	3.3E-07	2.1E-08
4/23/06	13:30	90	20.7	11	1	150	9.47	41.85	15.84	1.4E-05	3.3E-07	2.1E-08

PERMEABILITY REPORTED AS ** 2.1E-08 cm/sec **

DATE	4/23/2006
REVIEW	MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			**BOARD #**	1
PROJECT NUMBER	063-2145			**CELL #**	AA
SAMPLE ID	TF 1 - 4	-	-	**Flow Pump Speed**	10
SAMPLE TYPE	Remold			**Technician**	BDM

COMMENTS
1. The requested remold perameters were 107.0pcf and 18.9%MC
2. Water used as permeant
3. Specific gravity is assumed

Sample Data, Initial			
Height, cm	9.45	B-Value, f	99.00
Diameter, cm	7.30	Cell Pres.	100.0
Area, cm²	41.85	Bot. Pres.	95.0
Volume, cm³	395.52	Top Pres.	95.0
Mass, g	802.9	Tot. B.P.	95.0
Moisture Content, %	19.2	Head, max.	156.00
Dry Density, pcf	106.2	Head, min.	143.00
Spec. Gravity	2.66	Max. Grad.	16.51
Volume Solids, cm³	253.14	Min. Grad.	15.13
Volume Voids, cm³	142.38		
Void Ratio	0.56		
Saturation, %	91.0%		

Flow Pump Rate 2.80E-05 cm³/sec

Sample Data, Final	
Height, cm	9.67
Diameter, cm	7.35
Area, cm²	42.43
Volume, cm³	410.29
Mass, g	840.0
Moisture Content,%	22.1
Dry Density, pcf	104.6
Volume Solids, cm³	258.64
Volume Voids, cm³	151.65
Void Ratio	0.59
Saturation, %	100.3%

WATER CONTENTS		Trimmings Initial	Sample Final
Wt Soil & Tare, i	g	220.87	923.9
Wt Soil & Tare, f	g	190.68	771.85
Wt Tare	g	33.76	83.87
Wt Moisture Lost	g	30.19	152.05
Wt Dry Soil	g	156.92	687.98
Water Content	%	19.2%	22.1%

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm²)	i (Gradient)	q (cm³/sec)	v (cm/sec)	Permeability (cm/sec)
4/23/06	8:30											
4/23/06	8:50	20	20.7	9	1	156	9.45	41.85	16.51	5.5E-05	1.3E-06	8.0E-08
4/23/06	9:15	45	20.7	10	1	143	9.45	41.85	15.13	2.8E-05	6.7E-07	4.4E-08
4/23/06	9:30	60	20.7	10	1	143	9.45	41.85	15.13	2.8E-05	6.7E-07	4.4E-08
4/23/06	9:45	75	20.7	10	1	143	9.45	41.85	15.13	2.8E-05	6.7E-07	4.4E-08
4/23/06	10:00	90	20.7	10	1	143	9.45	41.85	15.13	2.8E-05	6.7E-07	4.4E-08

PERMEABILITY REPORTED AS ** 4.4E-08 cm/sec **

DATE 4/23/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			**BOARD #**	8	
PROJECT NUMBER	063-2145			**CELL #**	5	
SAMPLE ID	TF 1 - 5	-	-	**Flow Pump Speed**	10	
SAMPLE TYPE	Remold			**Technician**	BDM	

COMMENTS
1. The requested remold perameters were 106pcf and 20%MC
2. Water used as permeant
3. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.52	**B-Value, f**	95.00
Diameter, cm	7.27	**Cell Pres.**	100.0
Area, cm²	41.51	**Bot. Pres.**	95.0
Volume, cm^3	395.18	**Top Pres.**	95.0
Mass, g	803.3	**Tot. B.P.**	95.0
Moisture Content, %	19.8	**Head, max.**	97.00
Dry Density, pcf	105.9	**Head, min.**	92.00
Spec. Gravity	2.66	**Max. Grad.**	10.19
Volume Solids, cm^3	252.08	**Min. Grad.**	9.66
Volume Voids, cm^3	143.10		
Void Ratio	0.57		
Saturation, %	92.8%		

Sample Data, Final

Height, cm	9.69
Diameter, cm	7.42
Area, cm²	43.24
Volume, cm^3	419.01
Mass, g	833.7
Moisture Content,%	20.6
Dry Density, pcf	103.0
Volume Solids, cm^3	259.97
Volume Voids, cm^3	159.04
Void Ratio	0.61
Saturation, %	89.4%

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	g	196.21	938.0
Wt Soil & Tare, f	g	169.31	795.87
Wt Tare	g	33.44	104.57
Wt Moisture Lost	g	26.90	142.13
Wt Dry Soil	g	135.87	691.30
Water Content	%	19.8%	20.6%

Flow Pump Rate 2.80E-05 cm^3/sec

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient)	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
4/30/06	10:00											
4/30/06	10:15	15	20.7	10	1	97	9.52	41.51	10.19	2.8E-05	6.7E-07	6.6E-08
4/30/06	10:30	30	20.7	10	1	92	9.52	41.51	9.66	2.8E-05	6.7E-07	7.0E-08
4/30/06	10:45	45	20.7	10	1	96	9.52	41.51	10.08	2.8E-05	6.7E-07	6.7E-08
4/30/06	11:00	60	20.7	10	1	97	9.52	41.51	10.19	2.8E-05	6.7E-07	6.6E-08
4/30/06	11:15	75	20.7	10	1	97	9.52	41.51	10.19	2.8E-05	6.7E-07	6.6E-08

PERMEABILITY REPORTED AS ** 6.6E-08 cm/sec **

DATE 4/30/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co		
PROJECT NUMBER	063-2145		
SAMPLE ID	TF 1 - 6	-	-
SAMPLE TYPE	Remold		

BOARD #	1
CELL #	AA
Flow Pump Speed	10
Technician	BDM

COMMENTS
1. The requested remold perameters were 100.5pcf and 23.0%MC
2. Water used as permeant
3. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.45	**B-Value, f**	100.00
Diameter, cm	7.30	**Cell Pres.**	100.0
Area, cm²	41.85	**Bot. Pres.**	95.0
Volume, cm^3	395.52	**Top Pres.**	95.0
Mass, g	781.30	**Tot. B.P.**	95.0
Moisture Content, %	22.6	**Head, max.**	188.00
Dry Density, pcf	100.5	**Head, min.**	184.00
Spec. Gravity	2.66	**Max. Grad.**	19.89
Volume Solids, cm^3	239.57	**Min. Grad.**	19.47
Volume Voids, cm^3	155.95		
Void Ratio	0.65		
Saturation, %	92.4%		

Flow Pump Rate 2.80E-05 cm^3/sec

Sample Data, Final

Height, cm	9.50
Diameter, cm	7.36
Area, cm²	42.54
Volume, cm^3	404.17
Mass, g	799.36
Moisture Content,%	22.8
Dry Density, pcf	100.5
Volume Solids, cm^3	244.68
Volume Voids, cm^3	159.49
Void Ratio	0.65
Saturation, %	93.1%

WATER CONTENTS		**Trimmings** **Initial**	**Sample** **Final**
Wt Soil & Tare, i	g	234.34	901.7
Wt Soil & Tare, f	g	197.32	753.13
Wt Tare	g	33.53	101.98
Wt Moisture Lost	g	37.02	148.57
Wt Dry Soil	g	163.79	651.15
Water Content	%	22.6%	22.8%

DATE/TIME		**dt (min)**	**TEMP (°C)**	**Speed (1-12)**	**Speed Coeff.**	**ΔH (cm)**	**L (cm)**	**A (cm^2)**	**i (Gradient)**	**q (cm^3/sec)**	**v (cm/sec)**	**Permeability (cm/sec)**
5/2/06	9:30											
5/2/06	9:45	15	20.7	10	1	184	9.45	41.85	19.47	2.8E-05	6.7E-07	3.4E-08
5/2/06	10:00	30	20.7	10	1	188	9.45	41.85	19.89	2.8E-05	6.7E-07	3.4E-08
5/2/06	10:15	45	20.7	10	1	184	9.45	41.85	19.47	2.8E-05	6.7E-07	3.4E-08
5/2/06	10:30	60	20.7	10	1	184	9.45	41.85	19.47	2.8E-05	6.7E-07	3.4E-08
5/2/06	10:45	75	20.7	10	1	184	9.45	41.85	19.47	2.8E-05	6.7E-07	3.4E-08

PERMEABILITY REPORTED AS ** 3.4E-08 cm/sec ******

DATE 5/2/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			
PROJECT NUMBER	063-2145			
SAMPLE ID	TF 2-1	-	-	
SAMPLE TYPE	Remold			

BOARD #	2
CELL #	7
Flow Pump Speed	10&11
Technician	BDM

COMMENTS
1. The requested remold perameters were 106cf and 20%MC
2. Water used as permeant

Sample Data, Initial

Height, cm	9.50	**B-Value, f**	97.50
Diameter, cm	7.27	**Cell Pres.**	100.0
Area, cm²	41.51	**Bot. Pres.**	95&88
Volume, cm^3	394.35	**Top Pres.**	95&88
Mass, g	803.50	**Tot. B.P.**	95&88
Moisture Content, %	19.9	**Head, max.**	185.00
Dry Density, pcf	106.1	**Head, min.**	116.00
Spec. Gravity	2.71	**Max. Grad.**	19.47
Volume Solids, cm^3	247.34	**Min. Grad.**	12.21
Volume Voids, cm^3	147.01		
Void Ratio	0.59		
Saturation, %	90.6%		

Sample Data, Final

Height, cm	9.65
Diameter, cm	7.35
Area, cm²	42.43
Volume, cm^3	409.44
Mass, g	826.70
Moisture Content, %	22.5
Dry Density, pcf	102.9
Volume Solids, cm^3	249.04
Volume Voids, cm^3	160.40
Void Ratio	0.64
Saturation, %	94.6%

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	**g**	153.45	911.1
Wt Soil & Tare, f	**g**	132.80	759.38
Wt Tare	**g**	28.90	84.80
Wt Moisture Lost	**g**	20.65	151.72
Wt Dry Soil	**g**	103.90	674.58
Water Content	**%**	19.9%	22.5%

Tested at 5 & 12psi effective stress.

Flow Pump Rate #N/A cm^3/sec

DATE/TIME		effective stress	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient)	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
5/10/06	15:00	5psi	20.7	10	1	116	9.50	41.51	12.21	2.8E-05	6.7E-07	5.5E-08
5/11/06	12:45	12psi	20.7	11	1	185	9.50	41.51	19.47	1.4E-05	3.4E-07	1.7E-08

PERMEABILITY REPORTED AS ** 1.7E-08 **cm/sec ****

DATE 5/11/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			
PROJECT NUMBER	063-2145			
SAMPLE ID	TF 2-2	-	-	
SAMPLE TYPE	Remold			

BOARD #	7
CELL #	CC
Flow Pump Speed	10&12
Technician	BDM

COMMENTS
1. The requested remold perameters were 100.5cf and 23.5%MC
2. Water used as permeant

Sample Data, Initial

Height, cm	9.54	**B-Value, f**	95.00
Diameter, cm	7.27	**Cell Pres.**	100.0
Area, cm²	41.51	**Bot. Pres.**	95&88
Volume, cm³	396.01	**Top Pres.**	95&88
Mass, g	783.70	**Tot. B.P.**	95&88
Moisture Content, %	23.4	**Head, max.**	140.00
Dry Density, pcf	100.1	**Head, min.**	134.00
Spec. Gravity	2.71	**Max. Grad.**	14.68
Volume Solids, cm³	234.30	**Min. Grad.**	14.05
Volume Voids, cm³	161.71		
Void Ratio	0.69		
Saturation, %	92.0%		

Sample Data, Final

Height, cm	9.55
Diameter, cm	7.32
Area, cm²	42.08
Volume, cm³	401.90
Mass, g	800.84
Moisture Content,%	25.5
Dry Density, pcf	99.1
Volume Solids, cm³	235.41
Volume Voids, cm³	166.49
Void Ratio	0.71
Saturation, %	97.8%

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	g	162.42	885.6
Wt Soil & Tare, f	g	138.00	722.79
Wt Tare	g	33.76	85.11
Wt Moisture Lost	g	24.42	162.81
Wt Dry Soil	g	104.24	637.68
Water Content	%	23.4%	25.5%

Tested at 5 & 12psi effective stress.

Flow Pump Rate #N/A cm³/sec

DATE/TIME		effective stress	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm²)	i (Gradient)	q (cm³/sec)	v (cm/sec)	Permeability (cm/sec)
5/10/06	11:00	5psi	20.7	10	1	134	9.54	41.51	14.05	2.8E-05	6.7E-07	4.8E-08
5/12/06	11:45	12psi	20.7	12	1	140	9.54	41.51	14.68	5.5E-06	1.3E-07	9.0E-09

PERMEABILITY REPORTED AS ** 9.0E-09 cm/sec **

DATE 5/12/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			**BOARD #**	9
PROJECT NUMBER	063-2145			**CELL #**	CC
SAMPLE ID	TF 2-3	-	-	**Flow Pump Speed**	10
SAMPLE TYPE	Remold			**Technician**	BDM

COMMENTS
1. The requested remold perameters were 103.5pcf and 22%MC
2. Water used as permeant

Sample Data, Initial

Height, cm	9.53	**B-Value, f**	95.00
Diameter, cm	7.27	**Cell Pres.**	100.0
Area, cm²	41.51	**Bot. Pres.**	95.0
Volume, cm³	395.60	**Top Pres.**	95.0
Mass, g	797.60	**Tot. B.P.**	95.0
Moisture Content, %	21.8	**Head, max.**	186.00
Dry Density, pcf	103.3	**Head, min.**	180.00
Spec. Gravity	2.71	**Max. Grad.**	19.52
Volume Solids, cm³	241.59	**Min. Grad.**	18.89
Volume Voids, cm³	154.00		
Void Ratio	0.64		
Saturation, %	92.8%		

Sample Data, Final

Height, cm	9.63
Diameter, cm	7.37
Area, cm²	42.66
Volume, cm³	410.82
Mass, g	818.50
Moisture Content,%	24.3
Dry Density, pcf	100.0
Volume Solids, cm³	242.99
Volume Voids, cm³	167.83
Void Ratio	0.69
Saturation, %	95.3%

WATER CONTENTS		**Trimmings** **Initial**	**Sample** **Final**
Wt Soil & Tare, i	g	144.62	901.6
Wt Soil & Tare, f	g	124.42	741.65
Wt Tare	g	31.86	83.30
Wt Moisture Lost	g	20.20	159.95
Wt Dry Soil	g	92.56	658.35
Water Content	%	21.8%	24.3%

Flow Pump Rate 2.80E-05 cm³/sec

DATE/TIME		**dt (min)**	**TEMP (°C)**	**Speed (1-12)**	**Speed Coeff.**	**ΔH (cm)**	**L (cm)**	**A (cm²)**	**i (Gradient)**	**q (cm³/sec)**	**v (cm/sec)**	**Permeability (cm/sec)**
5/11/06	11:45											
5/11/06	12:00	15	20.7	10	1	180	9.53	41.51	18.89	2.8E-05	6.7E-07	3.6E-08
5/11/06	12:15	30	20.7	10	1	184	9.53	41.51	19.31	2.8E-05	6.7E-07	3.5E-08
5/11/06	12:30	45	20.7	10	1	186	9.53	41.51	19.52	2.8E-05	6.7E-07	3.5E-08
5/11/06	12:45	60	20.7	10	1	186	9.53	41.51	19.52	2.8E-05	6.7E-07	3.5E-08
5/11/06	13:00	75	20.7	10	1	186	9.53	41.51	19.52	2.8E-05	6.7E-07	3.5E-08

PERMEABILITY REPORTED AS ** 3.5E-08 cm/sec **

DATE 5/11/2006
REVIEW MB

APPENDIX B

CONSTRUCTION TESTING – FIELD MOISTURE-DENSITY RESULTS

TABLE B-1
IN-SITU MOISTURE DENSITY SUMMARY
CLEAN HARBORS DEER TRAIL FACILITY / SECURE CELL NO. 3 TEST FILL

Test No.	Date	Test Reference	Reference Elevation or Depth (Lift)	Test Type		In-Situ Values				Number of Passes	Pass/ Fail
		Grid Location		DC/Perm/MC	Nuke	Wet Density (pcf)	Moisture Content (Nuclear)	Moisture Content (Oven)	Dry Density (pcf)		
Test Fill Subgrade Test Results											
TFSG-01	5/4/2006	SW QUAD	Subgrade	-	N	119.2	15.9%	-	102.8	-	Pass
TFSG-02	5/4/2006	SE QUAD	Subgrade	-	N	123.9	14.6%	-	108.1	-	Pass
TFSG-03	5/4/2006	NE QUAD	Subgrade	-	N	117.1	15.7%	-	101.2	-	Pass
TFSG-04	5/4/2006	NW QUAD	Subgrade	-	N	119.3	13.0%	-	105.6	-	Pass
1.0xE-8 cm/sec Clay Plug Test Fill (Cat 815 Compactor) - Lifts 1-4 Preliminary Evaluation										Results Plot Within Preliminary Compaction Window (Yes/No)	
F-815-01	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	122.7	20.5%	20.9%	101.8	8	No
F-815-02	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	114.7	19.7%	22.1%	95.8	8	No
F-815-03	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	121.5	20.3%	21.1%	101.0	12	No
F-815-04	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	114.2	22.9%	21.9%	92.9	12	No
F-815-05	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	118.8	21.6%	21.5%	97.7	16	No
F-815-06	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	118.2	22.0%	23.7%	96.9	16	No
F-815-07	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	117.9	20.8%	22.6%	97.6	20	No
F-815-08	5/4/2006	SE Test Fill (E-8)	Lift 1	MC	N	111.2	22.0%	21.3%	91.1	20	No
F-815-09	5/5/2006	SE Test Fill (E-8)	Lift 2	MC	N	121.3	23.1%	18.9%	98.5	8	No
F-815-10	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	120.9	21.3%	-	99.7	8	No
F-815-11	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	120.4	20.3%	-	100.1	12	No
F-815-12	5/5/2006	SE Test Fill (E-8)	Lift 2	MC	N	116.3	19.9%	20.3%	97.0	12	No
F-815-13	5/5/2006	SE Test Fill (E-8)	Lift 1	-	N	121.9	20.0%	-	101.6	Tested Through L-2	No
F-815-14	5/5/2006	SE Test Fill (E-8)	Lift 1	-	N	123.7	17.7%	-	105.1	Tested Through L-2	No
F-815-15	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	125.5	20.5%	-	104.1	16	Yes
F-815-16	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	120.4	22.4%	-	98.4	16	No
F-815-17	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	119.5	21.6%	-	98.3	20	No
F-815-18	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	120.8	18.9%	-	101.6	20 (6" TEST)	No
F-815-19	5/5/2006	SE Test Fill (E-8)	Lift 2	-	N	125.1	22.3%	-	102.3	20 (4" TEST)	Yes
F-815-20	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	121.8	22.1%	-	99.8	8	No
F-815-21	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	116.7	21.0%	-	96.4	8	No
F-815-22	5/5/2006	SE Test Fill (E-8)	Lift 3	TFDC-02	N	122.0	21.8%	19.9%	100.2	12	No
F-815-23	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	112.9	19.9%	-	94.2	12	No
F-815-24	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	124.3	20.7%	-	103.0	16	No

TABLE B-1
IN-SITU MOISTURE DENSITY SUMMARY
CLEAN HARBORS DEER TRAIL FACILITY / SECURE CELL NO. 3 TEST FILL

Test No.	Date	Test Reference	Reference Elevation or Depth (Lift)	Test Type		In-Situ Values				Number of Passes	Pass/ Fail
		Grid Location		DC/Perm/MC	Nuke	Wet Density (pcf)	Moisture Content (Nuclear)	Moisture Content (Oven)	Dry Density (pcf)		
F-815-25	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	122.1	24.0%	-	98.5	16	No
F-815-26	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	123.3	22.6%	-	100.6	20	Yes
F-815-27	5/5/2006	SE Test Fill (E-8)	Lift 3	-	N	120.8	20.7%	-	100.1	20	No
F-815-28	5/5/2006	SE Test Fill (E-8)	Lift 4	-	N	116.1	22.3%	-	94.9	8	No
F-815-29	5/5/2006	SE Test Fill (E-8)	Lift 4	-	N	118.3	21.2%	-	97.6	8	No
F-815-30	5/5/2006	SE Test Fill (E-8)	Lift 4	-	N	116.8	24.3%	-	94.0	12	No
F-815-31	5/5/2006	SE Test Fill (E-8)	Lift 4	-	N	118.9	20.7%	-	98.5	12	No
F-815-32	5/6/2006	SE Test Fill (E-8)	Lift 4	-	N	121.6	21.1%	-	100.4	16	No
F-815-33	5/6/2006	SE Test Fill (E-8)	Lift 4	-	N	123.1	22.2%	-	100.7	16	Yes
F-815-34	5/6/2006	SE Test Fill (E-8)	Lift 4	-	N	116.1	22.6%	-	94.7	20	No
F-815-35	5/6/2006	SE Test Fill (E-8)	Lift 4	-	N	124.4	21.9%	-	102.1	20	Yes
F-815-36	5/6/2006	SE Test Fill (E-8)	Lift 4	-	N	119.9	22.2%	-	98.1	20	No
F-815-37	5/6/2006	SE Test Fill (E-8)	Lift 4	-	N	120.1	21.6%	-	98.8	20	No
1.0xE-8 cm/sec Clay Plug Test Fill (Cat 815 Compactor) - Lifts 5-7 Final Evaluation										Results Plot Within Final Compaction Window (Yes/No)	
F-815-38	5/8/2006	SE Test Fill (E-8)	Lift 5	-	N	120.1	22.7%	-	97.9	16	Yes
F-815-39	5/8/2006	SE Test Fill (E-8)	Lift 5	-	N	122.6	21.5%	-	100.9	16	Yes
F-815-40	5/8/2006	SE Test Fill (E-8)	Lift 5	-	N	125.8	20.6%	-	104.3	16	Yes
F-815-41	5/9/2006	SE Test Fill (E-8)	Lift 6	-	N	122.9	24.1%	-	99.0	16	Yes
F-815-42	5/9/2006	SE Test Fill (E-8)	Lift 6	-	N	119.7	23.5%	-	96.9	16	Yes
F-815-43	5/9/2006	SE Test Fill (E-8)	Lift 6	-	N	125.8	21.3%	-	103.7	16	Yes
F-815-44	5/9/2006	SE Test Fill (E-8)	Lift 7	TFDC-05	N	124.2	23.3%	23.5%	100.7	16	Yes
F-815-45	5/9/2006	SE Test Fill (E-8)	Lift 7	-	N	123.3	22.8%	-	100.4	16	Yes
F-815-46	5/9/2006	SE Test Fill (E-8)	Lift 7	-	N	123.3	22.0%	-	101.1	16	Yes
F-815-08-P-01	5/9/2006	SE Test Fill (E-8)	Lift 7	08-P-01	N	124.2	23.3%	23.3%	100.7	16	Yes
F-815-08-P-02	5/9/2006	SE Test Fill (E-8)	Lift 6	08-P-02	N	124.8	22.8%	23.6%	101.6	16	Yes
1.0xE-7 cm/sec CCL Test Fill (Cat 815 Compactor) - Lifts 1-4 Preliminary Evaluation										Results Plot Within Preliminary Compaction Window (Yes/No)	
07-F-815-01	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	104.7	27.3%	-	82.2	5	No
07-F-815-02	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	105.9	26.2%	-	83.9	5	No
07-F-815-03	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	121.6	22.8%	-	99.0	5	Yes

TABLE B-1
IN-SITU MOISTURE DENSITY SUMMARY
CLEAN HARBORS DEER TRAIL FACILITY / SECURE CELL NO. 3 TEST FILL

Test No.	Date	Test Reference	Reference Elevation or Depth (Lift)	Test Type		In-Situ Values				Number of Passes	Pass/Fail
		Grid Location		DC/Perm/MC	Nuke	Wet Density (pcf)	Moisture Content (Nuclear)	Moisture Content (Oven)	Dry Density (pcf)		
07-F-815-04	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	121.6	18.4%	-	102.7	8	No
07-F-815-05	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	116.4	22.7%	-	94.9	8	No
07-F-815-06	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	119.3	24.1%	-	96.1	12	Yes
07-F-815-07	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	117.0	23.0%	-	95.1	12	Yes
07-F-815-08	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	117.0	19.9%	-	97.6	16	No
07-F-815-09	5/6/2006	SW Test Fill (E-7)	Lift 1	-	N	114.2	21.5%	-	94.0	16	No
07-F-815-10	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	121.7	24.0%	-	98.1	5	Yes
07-F-815-11	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	118.5	22.6%	-	96.7	5	Yes
07-F-815-12	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	118.8	25.5%	-	94.7	8	Yes
07-F-815-13	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	120.3	22.7%	-	98.0	8	Yes
07-F-815-14	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	119.8	19.6%	-	100.2	12	No
07-F-815-15	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	116.9	25.3%	-	93.3	12	No
07-F-815-16	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	119.6	22.1%	-	98.0	12	Yes
07-F-815-17	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	125.2	19.9%	-	104.4	16	Yes
07-F-815-18	5/6/2006	SW Test Fill (E-7)	Lift 2	-	N	120.7	23.2%	-	98.0	16	Yes
07-F-815-19	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	120.5	21.1%	-	99.5	5	Yes
07-F-815-20	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	117.7	24.2%	-	94.8	5	Yes
07-F-815-21	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	122.2	22.4%	-	99.8	8	Yes
07-F-815-22	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	124.1	20.2%	-	103.2	8	Yes
07-F-815-23	5/6/2006	SW Test Fill (E-7)	Lift 3	TFDC-03	N	122.3	24.0%	24.1%	98.6	12	Yes
07-F-815-24	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	121.8	23.2%	-	98.9	12	Yes
07-F-815-25	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	122.6	21.4%	-	101.0	16	Yes
07-F-815-26	5/6/2006	SW Test Fill (E-7)	Lift 3	-	N	120.8	20.7%	-	100.1	16	Yes
07-F-815-27	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	125.0	19.3%	-	104.8	5	Yes
07-F-815-28	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	118.4	23.2%	-	96.1	5	Yes
07-F-815-29	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	117.1	23.2%	-	95.0	8	Yes
07-F-815-30	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	121.4	21.5%	-	99.9	8	Yes
07-F-815-31	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	120.7	23.2%	-	98.0	12	Yes
07-F-815-32	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	115.8	24.9%	-	92.7	12	No
07-F-815-33	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	115.2	23.8%	-	93.1	16	No
07-F-815-34	5/6/2006	SW Test Fill (E-7)	Lift 4	-	N	119.1	24.8%	-	95.4	16	Yes

TABLE B-1
IN-SITU MOISTURE DENSITY SUMMARY
CLEAN HARBORS DEER TRAIL FACILITY / SECURE CELL NO. 3 TEST FILL

Test No.	Date	Test Reference	Reference Elevation or Depth (Lift)	Test Type		In-Situ Values				Number of Passes	Pass/ Fail
		Grid Location		DC/Perm/MC	Nuke	Wet Density (pcf)	Moisture Content (Nuclear)	Moisture Content (Oven)	Dry Density (pcf)		
1.0xE-7 cm/sec CCL Test Fill (Cat 815 Compactor) - Lifts 5-7 Final Evaluation										Results Plot Within Final Compaction Window (Yes/No)	
07-F-815-35	5/8/2006	SW Test Fill (E-7)	Lift 5	-	N	123.0	21.1%	-	101.6	8	Yes
07-F-815-36	5/8/2006	SW Test Fill (E-7)	Lift 5	-	N	119.9	23.5%	-	97.1	8	Yes
07-F-815-37	5/8/2006	SW Test Fill (E-7)	Lift 5	-	N	121.4	22.6%	-	99.0	8	Yes
07-F-815-38	5/8/2006	SW Test Fill (E-7)	Lift 6	-	N	119.9	21.6%	-	98.6	8	Yes
07-F-815-39	5/8/2006	SW Test Fill (E-7)	Lift 6	-	N	120.8	25.3%	-	96.4	8	Yes
07-F-815-40	5/8/2006	SW Test Fill (E-7)	Lift 6	TFDC-04	N	122.0	20.7%	21.0%	101.1	8	Yes
07-F-815-41	5/8/2006	SW Test Fill (E-7)	Lift 7	-	N	122.5	19.2%	-	102.8	8	Yes
07-F-815-42	5/8/2006	SW Test Fill (E-7)	Lift 7	-	N	125.9	19.0%	-	105.8	8	Yes
07-F-815-43	5/8/2006	SW Test Fill (E-7)	Lift 7	-	N	124.8	19.7%	-	104.3	8	Yes
F-815-07-P-01	5/9/2006	SW Test Fill (E-7)	Lift 7	07-P-01	N	124.4	19.9%	19.2%	103.8	8	Yes
F-815-07-P-02	5/9/2006	SW Test Fill (E-7)	Lift 6	07-P-02	N	123.9	18.3%	23.3%	104.7	8	Yes
F-815-07-P-03	5/9/2006	SW Test Fill (E-7)	Lift 5	07-P-03	N	120.0	23.6%	22.8%	97.1	8	Yes
Test Fill Tie-In Evaluation Test Results											
F-815-07-TI-01	5/9/2006	SW Test Fill (E-7)	Lift 7	07-TI-01	N	116.7	21.1%	NA	96.4	8	Bond Failed
F-815-07-TI-02	5/9/2006	SW Test Fill (E-7)	Lift 7	07-TI-02	N	133.6	18.9%	19.7%	112.4	8	Bond Passed

APPENDIX C

TEST FILL PHOTO LOG

1 - Grading south end of existing stockpile for test fill pad

2 - Grading and compacting Test Fill subgrade

Golder Associates
Denver, Colorado

TITLE

TEST FILL SITE PHOTOGRAPHS

CLIENT
CleanHarbors
DEER PARK, LP

CADD	RPD	DATE	051806	JOB NO.	063-2145
CHECK	KIEL	SCALE	AS SHOWN	DWG NO./REV. NO.	A
REVIEW	RPD	FILE NO.	0632145P004	PHOTO NO.	1

3 - Testing first lift on the east side of the Test Fill (Cat 815)

4 - Cat 815 (east side - left), Cat 825 (west side - right) compacting clay

Golder Associates

Denver, Colorado

TITLE

TEST FILL SITE PHOTOGRAPHS

CLIENT

CleanHarbors

CADD	RPD	DATE	051806	JOB NO.	063-2145
CHECK	KIEL	SCALE	AS SHOWN	DWG NO./REV. NO.	A
	RPD		0632145P004		

5 - Cat scraper compacting lift 6 on 1.0xE-8 (east side) Test Fill, Cat 815 compacting Lift 7 on 1.0E-7 (west side) Test Fill

6 - Cat scraper compacting lift 6 on 1.0xE-8 (east side) Test Fill, Cat 815 compacting Lift 7 on 1.0E-7 (west side) Test Fill

Golder Associates
Denver, Colorado

CLIENT
CleanHarbors

TITLE
TEST FILL SITE PHOTOGRAPHS

CADD	RPD	DATE	051806	JOB NO.	063-2145
CHECK	KIEL	SCALE	AS SHOWN	DWG NO./REV. NO.	A
	RPD		0632145P004		

7 - Cutting around 1.0E-7 (west side) large block sample with Cat motor grader

8 - Pressing large block sample ring with Cat motor grader on 1.0E-7 test fill

Golder Associates
Denver, Colorado

TITLE
TEST FILL SITE PHOTOGRAPHS

CLIENT
CleanHarbors

CADD	RPD	DATE	051806	JOB NO.	063–2145
CHECK	KIEL	SCALE	AS SHOWN	DWG NO /REV. NO.	A
	RPD		0632145P004		

9 - Pressing large block sample ring with Cat motor grader on 1.0E-7 test fill

10 - Large block sample number 07-P-01c after removal from the 1.0E-7 test fill

Golder Associates
Denver, Colorado

TITLE
TEST FILL SITE PHOTOGRAPHS

CLIENT	CleanHarbors	CADD	RPD	DATE	051806
		CHECK	KIEL	SCALE	AS SHOWN
			RPD		0632145P004

JOB NO.	063-2145
DWG NO./REV. NO.	A

APPENDIX D

LABORATORY TESTING – HYDRAULIC CONDUCTIVITY (SHELBY TUBE FLEXIBLE WALL HYDRAULIC CONDUCTIVITY RESULTS AND SUMMARY)

TABLE D-1
CLEAN HARBORS DEER TRAIL FACILITY/SECURE CELL NO. 3 CQA
SUMMARY OF FLEXIBLE-WALL PERMEABILITY TEST RESULTS
SHELBY TUBE SAMPLES - TEST FILL

Sample Number	Test Fill Lift No.	Number of Passes	Sample Dry Density (pcf)	Initial Moisture (%)	Degree of Saturation[1] (%)	Effective Stress (psi)	Back Pressure (psi)	Gradient	Average Permeability (cm/sec)
07-P-01A	Lift 7	8	105.6	19.2	87.6	5	95	18	1.9 X 10^{-8}
07-P-02A	Lift 6	8	100.4	23.3	93.3	5	95	13	5.1 X 10^{-8}
07-P-03A	Lift 5	8	100.1	22.8	90.6	5	95	15	4.6 X 10^{-8}
08-P-01A	Lift 7	16	101.0	23.3	94.7	5	95	13	5.1 X 10^{-8}
08-P-01A	Lift 7	16	101.0	23.3	94.7	12	88	19	7.2 X 10^{-9}
08-P-02A	Lift 6	16	100.3	23.6	94.3	5	95	17	3.9 X 10^{-8}
08-P-02A	Lift 6	16	100.3	23.6	94.3	12	88	20	6.7 X 10^{-9}
07-P-TI-01A	Tie-in		107.1	19.7	93.4	5	95	14	4.8 X 10^{-8}

Note 1 - Calculated using an Average Sp.G = 2.69 for Samples TF-1 and TF-2

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co		**BOARD #**	4
PROJECT NUMBER	063-2145		**CELL #**	4
SAMPLE ID	07-P-01A	-	-	**Flow Pump Speed** 11
SAMPLE TYPE	Shelby Tube		**Technician**	BDM

COMMENTS
1. Water used as permeant
2. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.28	B-Value, f	98.00
Diameter, cm	7.24	Cell Pres.	100.0
Area, cm²	41.17	Bot. Pres.	95.0
Volume, cm^3	382.05	Top Pres.	95.0
Mass, g	770.50	Tot. B.P.	95.0
Moisture Content, %	19.2	Head, max.	178.00
Dry Density, pcf	105.6	Head, min.	169.00
Spec. Gravity	2.66	Max. Grad.	19.18
Volume Solids, cm^3	242.98	Min. Grad.	18.21
Volume Voids, cm^3	139.07		
Void Ratio	0.57		
Saturation, %	89.3%		

Flow Pump Rate 1.40E-05 cm^3/sec

Sample Data, Final

Height, cm	9.22
Diameter, cm	7.27
Area, cm²	41.51
Volume, cm^3	382.73
Mass, g	787.2
Moisture Content,%	21.0
Dry Density, pcf	106.1
Volume Solids, cm^3	244.66
Volume Voids, cm^3	138.06
Void Ratio	0.56
Saturation, %	98.8%

WATER CONTENTS		Trimmings Initial	Sample Final
Wt Soil & Tare, i	g	222.19	890.9
Wt Soil & Tare, f	g	191.83	754.61
Wt Tare	g	33.82	104.11
Wt Moisture Lost	g	30.36	136.29
Wt Dry Soil	g	158.01	650.50
Water Content	%	19.2%	21.0%

Clay. dark olive gray.firm. moist. scattered gypsum crystals.

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient)	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
5/16/06	11:45											
5/16/06	13:00	75	20.7	10	1	178	9.28	41.17	19.18	2.8E-05	6.8E-07	3.5E-08
5/16/06	14:00	135	20.7	11	1	170	9.28	41.17	18.32	1.4E-05	3.4E-07	1.9E-08
5/16/06	14:15	150	20.7	11	1	171	9.28	41.17	18.43	1.4E-05	3.4E-07	1.8E-08
5/16/06	14:30	165	20.7	11	1	169	9.28	41.17	18.21	1.4E-05	3.4E-07	1.9E-08
5/16/06	14:45	180	20.7	11	1	169	9.28	41.17	18.21	1.4E-05	3.4E-07	1.9E-08
5/16/06	15:00	195	20.7	11	1	169	9.28	41.17	18.21	1.4E-05	3.4E-07	1.9E-08

PERMEABILITY REPORTED AS ** 1.9E-08 cm/sec **

DATE 5/16/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE Clean Harbor/Cell 3 CQA Deer Trail/Co
PROJECT NUMBER 063-2145
SAMPLE ID 07-P-02A - -
SAMPLE TYPE Shelby Tube

BOARD # 5
CELL # 3
Flow Pump Speed 10
Technician BDM

COMMENTS 1. Water used as permeant
2. Specific gravity is assumed

Sample Data, Initial

Height, cm	9.48	**B-Value, f**	95.00
Diameter, cm	7.23	**Cell Pres.**	100.0
Area, cm²	41.06	**Bot. Pres.**	95.0
Volume, cm^3	389.20	**Top Pres.**	95.0
Mass, g	772.25	**Tot. B.P.**	95.0
Moisture Content, %	23.3	**Head, max.**	129.00
Dry Density, pcf	100.4	**Head, min.**	126.00
Spec. Gravity	2.66	**Max. Grad.**	13.61
Volume Solids, cm^3	235.48	**Min. Grad.**	13.29
Volume Voids, cm^3	153.72		
Void Ratio	0.65		
Saturation, %	94.9%		

Sample Data, Final

Height, cm	9.52
Diameter, cm	7.36
Area, cm²	42.54
Volume, cm^3	405.03
Mass, g	791.5
Moisture Content, %	25.6
Dry Density, pcf	97.1
Volume Solids, cm^3	236.97
Volume Voids, cm^3	168.05
Void Ratio	0.71
Saturation, %	95.9%

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	g	251.20	876.0
Wt Soil & Tare, f	g	209.77	714.97
Wt Tare	g	31.88	85.11
Wt Moisture Lost	g	41.43	161.03
Wt Dry Soil	g	177.89	629.86
Water Content	%	23.3%	25.6%

Clay, dark gray, firm, moist, occasional gypsum crystals.

Flow Pump Rate 2.80E-05 cm^3/sec

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient)	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
5/18/06	14:00											
5/18/06	14:30	30	20.7	10	1	127	9.48	41.06	13.40	2.8E-05	6.8E-07	5.1E-08
5/18/06	14:45	45	20.7	10	1	127	9.48	41.06	13.40	2.8E-05	6.8E-07	5.1E-08
5/18/06	15:00	60	20.7	10	1	126	9.48	41.06	13.29	2.8E-05	6.8E-07	5.1E-08
5/18/06	15:15	75	20.7	10	1	129	9.48	41.06	13.61	2.8E-05	6.8E-07	5.0E-08
5/18/06	15:30	90	20.7	10	1	126	9.48	41.06	13.29	2.8E-05	6.8E-07	5.1E-08
5/18/06	16:00	120	20.7	10	1	127	9.48	41.06	13.40	2.8E-05	6.8E-07	5.1E-08

PERMEABILITY REPORTED AS ** 5.1E-08 cm/sec **

DATE 5/18/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co	**BOARD #**	7	**COMMENTS**	1. Water used as permeant
PROJECT NUMBER	063-2145	**CELL #**	1		2. Specific gravity is assumed
SAMPLE ID	07-P-03A - -	**Flow Pump Speed**	10		
SAMPLE TYPE	Shelby Tube	**Technician**	BDM		

Sample Data, Initial

Height, cm	10.38	B-Value, f	98.50
Diameter, cm	7.22	Cell Pres.	100.0
Area, cm²	40.94	Bot. Pres.	95.0
Volume, cm^3	424.97	Top Pres.	95.0
Mass, g	836.90	Tot. B.P.	95.0
Moisture Content, %	22.8	Head, max.	172.00
Dry Density, pcf	100.1	Head, min.	154.00
Spec. Gravity	2.66	Max. Grad.	16.57
Volume Solids, cm^3	256.28	Min. Grad.	14.84
Volume Voids, cm^3	168.69		
Void Ratio	0.66		
Saturation, %	92.0%		

Sample Data, Final

Height, cm	10.42
Diameter, cm	7.26
Area, cm²	41.40
Volume, cm^3	431.35
Mass, g	858.8
Moisture Content, %	24.6
Dry Density, pcf	99.7
Volume Solids, cm^3	259.17
Volume Voids, cm^3	172.18
Void Ratio	0.66
Saturation, %	98.4%

WATER CONTENTS		Trimmings Initial	Sample Final
Wt Soil & Tare, i	g	225.66	958.9
Wt Soil & Tare, f	g	189.89	789.56
Wt Tare	g	32.77	100.40
Wt Moisture Lost	g	35.77	169.34
Wt Dry Soil	g	157.12	689.16
Water Content	%	22.8%	24.6%

Clay, dark gray with yellow brown mottling, , firm, moist, occasional gypsum crystals.

Flow Pump Rate 2.80E-05 cm^3/sec

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient)	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
5/18/06	12:00											
5/18/06	12:30	30	20.7	9	1	172	10.38	40.94	16.57	5.5E-05	1.3E-06	8.1E-08
5/18/06	12:45	45	20.7	10	1	160	10.38	40.94	15.41	2.8E-05	6.8E-07	4.4E-08
5/18/06	13:00	60	20.7	10	1	156	10.38	40.94	15.03	2.8E-05	6.8E-07	4.6E-08
5/18/06	13:15	75	20.7	10	1	156	10.38	40.94	15.03	2.8E-05	6.8E-07	4.6E-08
5/18/06	13:30	90	20.7	10	1	154	10.38	40.94	14.84	2.8E-05	6.8E-07	4.6E-08
5/18/06	13:45	105	20.7	10	1	154	10.38	40.94	14.84	2.8E-05	6.8E-07	4.6E-08

PERMEABILITY REPORTED AS ** 4.6E-08 cm/sec **

DATE 5/18/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE Clean Harbor/Cell 3 CQA Deer Trail/Co
PROJECT NUMBER 063-2145
SAMPLE ID 08-P-01A | - | -
SAMPLE TYPE Shelby Tube

BOARD # 5
CELL # 3
Flow Pump Speed 10&12
Technician BDM

COMMENTS
1. Water used as permeant
2. Specific gravity is assumed

Sample Data, Initial

Height, cm	10.12	B-Value, f	95.50
Diameter, cm	7.23	Cell Pres.	100.0
Area, cm²	41.06	Bot. Pres.	95&88
Volume, cm^3	415.48	Top Pres.	95&88
Mass, g	828.90	Tot. B.P.	95&88
Moisture Content, %	23.3	Head, max.	188.00
Dry Density, pcf	101.0	Head, min.	136.00
Spec. Gravity	2.66	Max. Grad.	18.58
Volume Solids, cm^3	252.82	Min. Grad.	13.44
Volume Voids, cm^3	162.66		
Void Ratio	0.64		
Saturation, %	96.2%		

Sample Data, Final

Height, cm	10.12
Diameter, cm	7.26
Area, cm²	41.40
Volume, cm^3	418.93
Mass, g	839.20
Moisture Content,%	23.6
Dry Density, pcf	101.1
Volume Solids, cm^3	255.20
Volume Voids, cm^3	163.74
Void Ratio	0.64
Saturation, %	97.9%

WATER CONTENTS		Trimmings Initial	Sample Final
Wt Soil & Tare, i	g	242.13	943.0
Wt Soil & Tare, f	g	202.75	782.68
Wt Tare	g	33.43	104.10
Wt Moisture Lost	g	39.38	160.32
Wt Dry Soil	g	169.32	678.58
Water Content	%	23.3%	23.6%

Clay, dark gray with some yellow brown mottling, moist, firm, claystone fragments, and gypsum crystals.

Flow Pump Rate #N/A cm^3/sec

DATE/TIME		Effective Stress	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm^2)	i (Gradient)	q (cm^3/sec)	v (cm/sec)	Permeability (cm/sec)
5/18/06	13:45	5psi	20.7	10	1	136	10.12	41.06	13.44	2.8E-05	6.8E-07	5.1E-08
5/19/06	12:45	15psi	20.7	12	1	188	10.12	41.06	18.58	5.5E-06	1.3E-07	7.2E-09

PERMEABILITY REPORTED AS ** 7.2E-09 cm/sec **

DATE 5/18/2006
REVIEW MB

FLOW PUMP #1

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co	**BOARD #**	2	**COMMENTS**	1. Water used as permeant
PROJECT NUMBER	063-2145	**CELL #**	7		2. Specific gravity is assumed
SAMPLE ID	08-P-02A - -	**Flow Pump Speed**	10&12		
SAMPLE TYPE	Shelby Tube	**Technician**	BDM		

Sample Data, Initial				**Sample Data, Final**	
Height, cm	9.26	**B-Value, f**	99.00	**Height, cm**	9.14
Diameter, cm	7.24	**Cell Pres.**	100.0	**Diameter, cm**	7.28
Area, cm²	41.17	**Bot. Pres.**	95&88	**Area, cm²**	41.62
Volume, cm^3	381.22	**Top Pres.**	95&88	**Volume, cm^3**	380.45
Mass, g	757.22	**Tot. B.P.**	95&88	**Mass, g**	766.44
Moisture Content, %	23.6	**Head, max.**	186.00	**Moisture Content,%**	23.6
Dry Density, pcf	100.3	**Head, min.**	160.00	**Dry Density, pcf**	101.7
Spec. Gravity	2.66	**Max. Grad.**	20.09	**Volume Solids, cm^3**	233.07
Volume Solids, cm^3	230.27	**Min. Grad.**	17.28	**Volume Voids, cm^3**	147.38
Volume Voids, cm^3	150.96			**Void Ratio**	0.63
Void Ratio	0.66			**Saturation, %**	99.4%
Saturation, %	95.9%				

WATER CONTENTS		**Trimmings Initial**	**Sample Final**
Wt Soil & Tare, i	g	213.19	943.0
Wt Soil & Tare, f	g	178.91	782.68
Wt Tare	g	33.82	104.10
Wt Moisture Lost	g	34.28	160.32
Wt Dry Soil	g	145.09	678.58
Water Content	%	23.6%	23.6%

Clay, gray and gray brown , moist, firm, with gypsum crystals.

Flow Pump Rate #N/A cm^3/sec

DATE/TIME		**Effective Stress**	**TEMP (°C)**	**Speed (1-12)**	**Speed Coeff.**	**ΔH (cm)**	**L (cm)**	**A (cm^2)**	**i (Gradient)**	**q (cm^3/sec)**	**v (cm/sec)**	**Permeability (cm/sec)**
5/17/06	12:30	5psi	20.7	10	1	160	9.26	41.17	17.28	2.8E-05	6.8E-07	3.9E-08
5/18/06	10:30	15psi	20.7	12	1	186	9.26	41.17	20.09	5.5E-06	1.3E-07	6.7E-09

PERMEABILITY REPORTED AS ** 6.7E-09 cm/sec **

DATE 5/17/2006
REVIEW MB

FLOW PUMP #2

FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE	Clean Harbor/Cell 3 CQA Deer Trail/Co			**BOARD #**	9	
PROJECT NUMBER	063-2145			**CELL #**	cc	
SAMPLE ID	07-P-T1-01	-	-	**Flow Pump Speed**	10	
SAMPLE TYPE	Shelby Tube			**Technician**	BDM	

COMMENTS
1. Water used as permeant
2. Specific gravity is assumed

Sample Data, Initial			
Height, cm	9.25	B-Value, f	95.50
Diameter, cm	7.21	Cell Pres.	100.0
Area, cm²	40.83	Bot. Pres.	95.0
Volume, cm³	377.66	Top Pres.	95.0
Mass, g	776.00	Tot. B.P.	95.0
Moisture Content, %	19.7	Head, max.	181.00
Dry Density, pcf	107.1	Head, min.	131.00
Spec. Gravity	2.66	Max. Grad.	19.57
Volume Solids, cm³	243.71	Min. Grad.	14.16
Volume Voids, cm³	133.95		
Void Ratio	0.55		
Saturation, %	95.4%		

Sample Data, Final	
Height, cm	9.32
Diameter, cm	7.28
Area, cm²	41.62
Volume, cm³	387.94
Mass, g	796.7
Moisture Content,%	23.4
Dry Density, pcf	103.9
Volume Solids, cm³	242.76
Volume Voids, cm³	145.18
Void Ratio	0.60
Saturation, %	104.0%

WATER CONTENTS		Trimmings Initial	Sample Final
Wt Soil & Tare, i	g	213.01	880.2
Wt Soil & Tare, f	g	183.51	729.50
Wt Tare	g	33.78	84.85
Wt Moisture Lost	g	29.50	150.70
Wt Dry Soil	g	149.73	644.65
Water Content	%	19.7%	23.4%

Clay, dark gray, firm, slightly moist, claysyone fragments & gypsum crystals common

Flow Pump Rate 2.80E-05 cm³/sec

DATE/TIME		dt (min)	TEMP (°C)	Speed (1-12)	Speed Coeff.	ΔH (cm)	L (cm)	A (cm²)	i (Gradient)	q (cm³/sec)	v (cm/sec)	Permeability (cm/sec)
5/17/06	9:15											
5/17/06	9:30	15	20.7	8	1	181	9.25	40.83	19.57	1.4E-04	3.4E-06	1.8E-07
5/17/06	10:00	45	20.7	10	1	131	9.25	40.83	14.16	2.8E-05	6.9E-07	4.8E-08
5/17/06	10:15	60	20.7	10	1	131	9.25	40.83	14.16	2.8E-05	6.9E-07	4.8E-08
5/17/06	10:30	75	20.7	10	1	131	9.25	40.83	14.16	2.8E-05	6.9E-07	4.8E-08
5/17/06	10:45	90	20.7	10	1	131	9.25	40.83	14.16	2.8E-05	6.9E-07	4.8E-08
5/17/06	11:00	105	20.7	10	1	131	9.25	40.83	14.16	2.8E-05	6.9E-07	4.8E-08

PERMEABILITY REPORTED AS ** 4.8E-08 cm/sec **

DATE 5/17/2006
REVIEW MB

APPENDIX E

LABORATORY TESTING – HYDRAULIC CONDUCTIVITY (LARGE BLOCK SAMPLES – UNIVERSITY OF WISCONSIN AT MADISON REPORT)

SATURATED HYDRAULIC CONDUCTIVITY OF BLOCK SAMPLES FROM THE DEER TRAIL FACILITY

by

C.H. Benson and X. Wang

Geo Engineering Report No. 05-09

Geotechnics Laboratory

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May 28, 2006

1. SCOPE

Hydraulic conductivity tests were conducted on five block samples from the Deer Trail Facility. These samples have the following identification numbers: 07-P-01C, 07-P-02C, 07-P-03C, 08-P-01C, and 08-P-02C. All samples were tested at an effective confining pressure of 35 kPa (5 psi). Two samples were also tested at an effective confining pressure of 84 kPa (12 psi).

2. METHODS

Test specimens were prepared by trimming the block samples to a nominal diameter of 305 mm (12 in) and a nominal height of 150 mm (6 in). The test specimens were then placed in a flexible-wall permeameter, backpressure saturated at 280 kPa (40 psi), and consolidated following the procedures described in ASTM D 5084. The constant head-constant volume method (Method E) was used for the permeation phase using a hydraulic gradient of 16. All specimens were tested at an effective confining pressure of 35 kPa (5 psi). Two of the specimens (Sample Nos. 08-P-01C and 08-P-02C) were consolidated to 84 kPa (12 psi) after completing the test at 35 kPa (5 psi), and permeated again using the constant head-constant volume method (Method E).

3. RESULTS

A summary of the hydraulic conductivities is in Table 1. Data sheets summarizing the test results are included in the appendix.

Table 1. Summary of Hydraulic Conductivities.

Sample No.	Water Content (%)	Dry Density (Mg/m^3)	Hydraulic Conductivity (cm/s)	
			35 kPa (5 psi)	84 kPa (12 psi)
07-P-01C	19.2	1.64	3.2×10^{-8}	-
07-P-02C	21.0	1.66	4.5×10^{-8}	-
07-P-03C	24.5	1.59	8.2×10^{-9}	-
08-P-01C	26.0	1.60	1.2×10^{-9}	1.3×10^{-9}
08-P-02C	24.0	1.62	1.0×10^{-8}	1.5×10^{-9}

Note: 1 Mg/m^3 = 62.4 pcf

APPENDIX:

DATA SHEETS

HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **07-P-01C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

Test Date: 5/12/2006

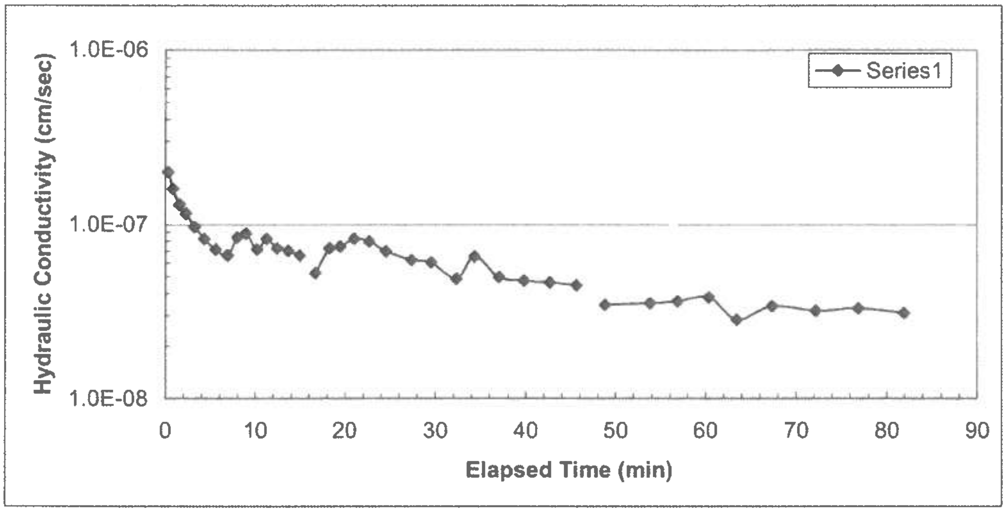
Constants:	a =	0.03016	cm^2
	G_{Hg} -G_w	12.5	
	Sample Thickness, L =	15.24	cm
	Sample Diameter, D =	30.48	cm
	Sample Area, A =	729.66	cm^2
	Head (H_g) =	19	cm
	Head (H_w) =	237.5	cm
	Hydraulic Gradient, i =	15.58	
	Cell Pressure =	46.70	psi
	Back Pressure =	40.00	psi
	Effective Stress =	5.01	psi

WT of Can	WT of Can Wet Soil	WT of Can Dry Soil	Water Content	Wet Density	Dry Density
(g)	(g)	(g)	(%) at 105 °C	(pcf)	(pcf)
51.07	**405.98**	**348.86**	**19.18**	121.98	**102.34**
Wet Weight	47.90	(lbs)			

Time	Reading	ΔT	Elapsed Time	Hydraulic Conductivity
(hh:mm)	(cm)	(sec)	(min)	(cm/sec)
0:00:00	34.5	0	0.000	
0:00:20	33	20	0.333	1.989E-07
0:00:53	31	33	0.883	1.607E-07
0:01:34	29	41	1.567	1.294E-07
0:02:20	27	46	2.333	1.153E-07
0:03:15	25	55	3.250	9.645E-08
0:04:19	23	64	4.317	8.289E-08
0:05:33	21	74	5.550	7.169E-08
0:06:53	19	80	6.883	6.631E-08
0:07:56	17	63	7.933	8.420E-08
0:08:56	15	60	8.933	8.841E-08
0:10:10	13	74	10.167	7.169E-08
0:11:14	11	64	11.233	8.289E-08
0:12:27	9	73	12.450	7.267E-08
0:13:42	7	75	13.700	7.073E-08
0:15:02	5	80	15.033	6.631E-08
0:00:00	45.5	0	15.033	
0:01:41	43.5	101	16.717	5.252E-08
0:03:12	41	91	18.233	7.287E-08
0:04:23	39	71	19.417	7.471E-08
0:05:59	36	96	21.017	8.289E-08
0:07:38	33	99	22.667	8.037E-08
0:09:31	30	113	24.550	7.042E-08
0:12:21	26	170	27.383	6.241E-08
0:14:33	23	132	29.583	6.028E-08
0:17:17	20	164	32.317	4.852E-08
0:19:19	17	122	34.350	6.522E-08
0:21:59	14	160	37.017	4.973E-08
0:24:46	11	167	39.800	4.765E-08

0:27:38	8	172	42.667	4.626E-08
0:30:36	5	178	45.633	4.470E-08
0:00:00	33		45.633	
0:03:12	30.5	192	48.833	3.454E-08
0:08:12	26.5	300	53.833	3.536E-08
0:11:16	24	184	56.900	3.604E-08
0:14:45	21	209	60.383	3.807E-08
0:17:51	19	186	63.483	2.852E-08
0:21:45	16	234	67.383	3.400E-08
0:26:35	12.5	290	72.217	3.201E-08
0:31:17	9	282	76.917	3.292E-08
0:36:17	5.5	300	81.917	3.094E-08

AVERAGE: 3.2E-08



HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **07-P-02C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

Test Date: 5/12/2006

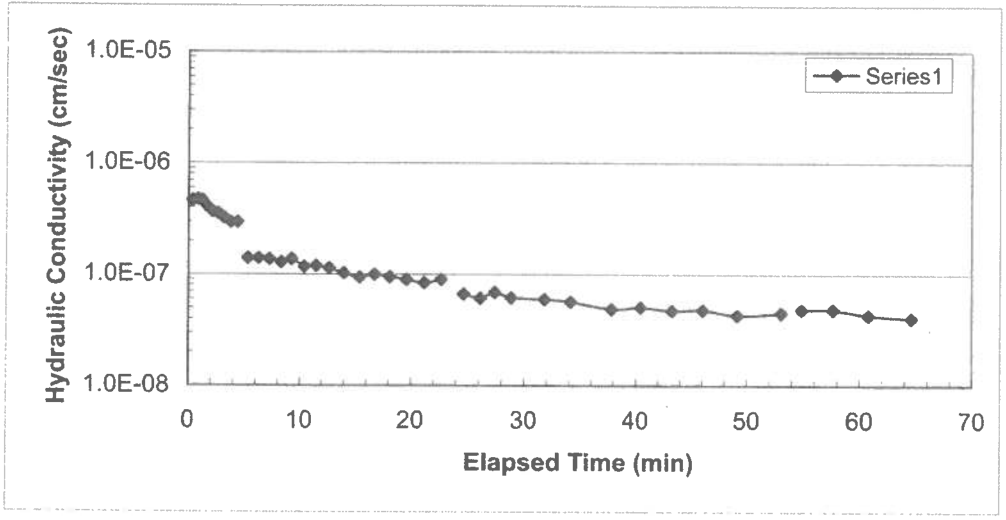
Constants:	a =	0.03016	cm^2
	G_{Hg} -G_w	12.5	
	Sample Thickness, L =	15.24	cm
	Sample Diameter, D =	30.48	cm
	Sample Area, A =	729.66	cm^2
	Head (H_g) =	19	cm
	Head (H_w) =	237.5	cm
	Hydraulic Gradient, i =	15.58	
	Cell Pressure =	46.70	psi
	Back Pressure =	40.00	psi
	Effective Stress =	5.01	psi

WT of Can (g)	WT of Can Wet Soil (g)	WT of Can Dry Soil (g)	Water Content (%) at 105 °C	Wet Density (pcf)	Dry Density (pcf)
50.97	**397.57**	**337.39**	**21.01**	125.54	**103.74**
Wet Weight	49.30	(lbs)			

Time (hh:mm:ss)	Reading (cm)	ΔT (sec)	Elapsed Time (min)	Hydraulic Conductivity (cm/sec)
0:00:00	41	0	0.000	
0:00:23	37	23	0.383	4.613E-07
0:00:51	32	28	0.850	4.736E-07
0:01:14	28	23	1.233	4.613E-07
0:01:40	24	26	1.667	4.081E-07
0:02:09	20	29	2.150	3.658E-07
0:02:39	16	30	2.650	3.536E-07
0:03:12	12	33	3.200	3.215E-07
0:03:48	8	36	3.800	2.947E-07
0:04:24	4	36	4.400	2.947E-07
0:00:00	49	0	4.400	
0:00:57	46	57	5.350	1.396E-07
0:01:54	43	57	6.300	1.396E-07
0:02:52	40	58	7.267	1.372E-07
0:03:54	37	62	8.300	1.283E-07
0:04:52	34	58	9.267	1.372E-07
0:06:00	31	68	10.400	1.170E-07
0:07:07	28	67	11.517	1.188E-07
0:08:17	25	70	12.683	1.137E-07
0:09:35	22	78	13.983	1.020E-07
0:11:00	19	85	15.400	9.361E-08
0:12:20	16	80	16.733	9.946E-08
0:13:44	13	84	18.133	9.473E-08
0:15:13	10	89	19.617	8.941E-08
0:16:48	7	95	21.200	8.376E-08
0:18:17	4	89	22.683	8.941E-08
0:03:51	41	0	22.683	
0:05:51	38	120	24.683	6.631E-08
0:07:18	36	87	26.133	6.097E-08
0:08:35	34	77	27.417	6.889E-08
0:10:01	32	86	28.850	6.168E-08

0:13:00	28	179	31.833	5.927E-08
0:15:21	25	141	34.183	5.643E-08
0:18:59	21	218	37.817	4.867E-08
0:21:37	18	158	40.450	5.036E-08
0:24:26	15	169	43.267	4.708E-08
0:27:13	12	167	46.050	4.765E-08
0:30:19	9	186	49.150	4.278E-08
0:34:15	5	236	53.083	4.496E-08
0:00:00	40		53.083	
0:01:50	38	110	54.917	4.822E-08
0:04:35	35	165	57.667	4.822E-08
0:07:40	32	185	60.750	4.301E-08
0:11:30	28.5	230	64.583	4.036E-08

AVERAGE: 4.5E-08



HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **07-P-03C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

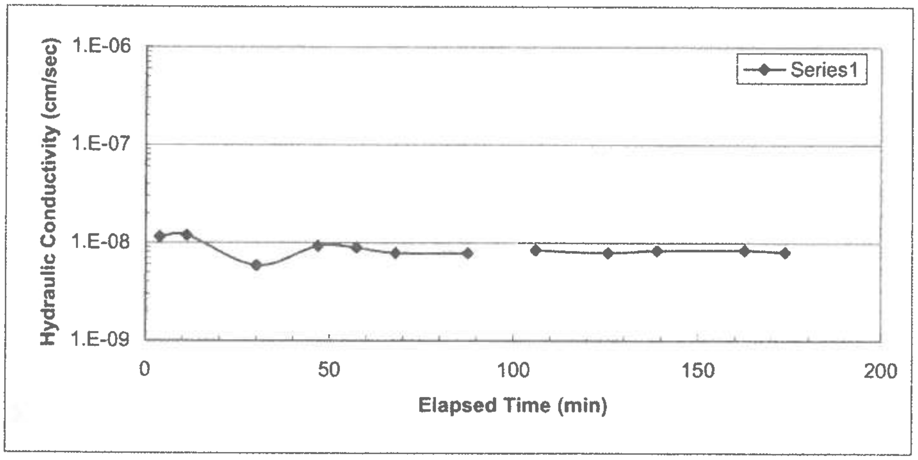
Test Date: 5/18/2006

Constants:	a =	0.03016	cm^2
	G_{Hg} - G_w	12.5	
	Sample Thickness, L =	15.24	cm
	Sample Diameter, D =	30.48	cm
	Sample Area, A =	729.66	cm^2
	Head (H_g) =	19	cm
	Head (H_w) =	237.5	cm
	Hydraulic Gradient, i =	15.58	
	Cell Pressure =	46.70	psi
	Back Pressure =	40.00	psi
	Effective Stress =	5.01	psi

WT of Can	WT of Can Wet Soil	WT of Can Dry Soil	Water Content	Wet Density	Dry Density
(g)	(g)	(g)	(%) at 105 °C	(pcf)	(pcf)
50.96	419.12	346.67	24.50	123.25	**98.99**
Wet Weight	48.40	(lbs)			

Time	Reading	ΔT	Elapsed Time	Hydraulic Conductivity	
(hh:mm:ss)	(cm)	(sec)	(min)	(cm/sec)	
0:00:00	23	0	0.000		
0:03:50	22	230	3.833	1.153E-08	
0:11:15	20	445	11.250	1.192E-08	
0:30:06	17.5	1131	30.100	5.863E-09	
0:46:49	14	1003	46.817	9.256E-09	
0:57:17	11.9	628	57.283	8.869E-09	
1:08:00	10	643	68.000	7.837E-09	
1:27:41	6.5	1181	87.683	7.861E-09	
0:00:00	30.5	0	87.683		Refill
0:18:23	27	1103	106.067	8.416E-09	
0:38:02	23.5	1179	125.717	7.874E-09	
0:51:18	21	796	138.983	8.330E-09	
1:14:56	16.5	1418	162.617	8.417E-09	
1:25:56	14.5	660	173.617	8.037E-09	

AVERAGE: 8.2E-09



HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **08-P-01C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

Test Date: 5/18/2006

Constants: a = 0.03016 cm^2

G_{Hg} -G_w 12.5

Sample Thickness, L = 15.24 cm

Sample Diameter, D = 30.48 cm

Sample Area, A = 729.66 cm^2

Head (H_g) = 19 cm

Head (H_w) = 237.5 cm

Hydraulic Gradient, i = 15.58

Cell Pressure = 46.70 psi

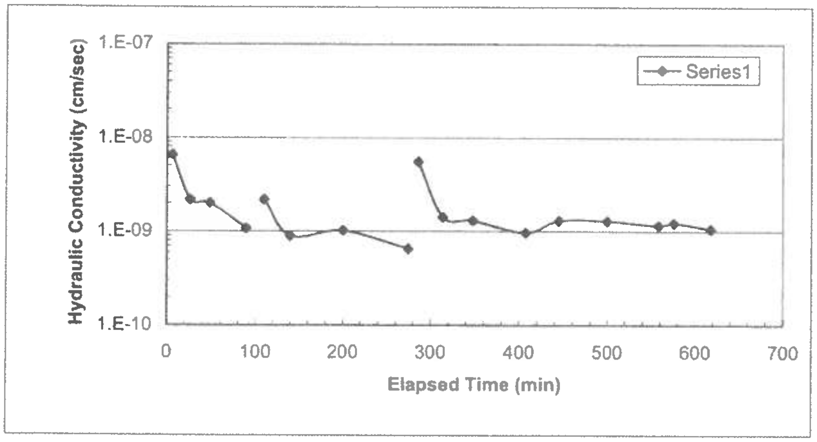
Back Pressure = 40.00 psi

Effective Stress = 5.01 psi

WT of Can	WT of Can Wet Soil	WT of Can Dry Soil	Water Content	Wet Density	Dry Density
(g)	(g)	(g)	(%) at 105 °C	(pcf)	(pcf)
51.06	415.98	342.97	**25.01**	125.03	**100.02**
Wet Weight	49.10	(lbs)			

Time	Reading	ΔT	Elapsed Time	Hydraulic Conductivity	
(hh:mm:ss)	(cm)	(sec)	(min)	(cm/sec)	
0:00:00	33.9	0	0.000		
0:06:04	33	364	6.067	6.558E-09	
0:26:32	32	1228	26.533	2.160E-09	
0:48:36	31	1324	48.600	2.003E-09	
1:29:28	30	2452	89.467	1.082E-09	
0:00:00	23.6	0	89.467		Refill
0:20:18	22.6	1218	109.767	2.178E-09	
0:50:03	22	1785	139.517	8.916E-10	
1:50:41	20.6	3638	200.150	1.021E-09	
3:05:26	19.5	4485	274.900	6.505E-10	
0:00:00	23.3	0	274.900		Refill
0:11:11	21.9	671	286.083	5.534E-09	
0:39:15	21	1684	314.150	1.418E-09	
1:13:10	20	2035	348.067	1.303E-09	
2:12:32	18.7	3562	407.433	9.680E-10	
2:50:05	17.6	2253	444.983	1.295E-09	
3:45:18	16	3313	500.200	1.281E-09	
4:43:06	14.5	3468	558.000	1.147E-09	
5:01:12	14	1086	576.100	1.221E-09	
5:43:03	13	2511	617.950	1.056E-09	

AVERAGE: 1.2E-09



HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **08-P-02C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

Test Date:

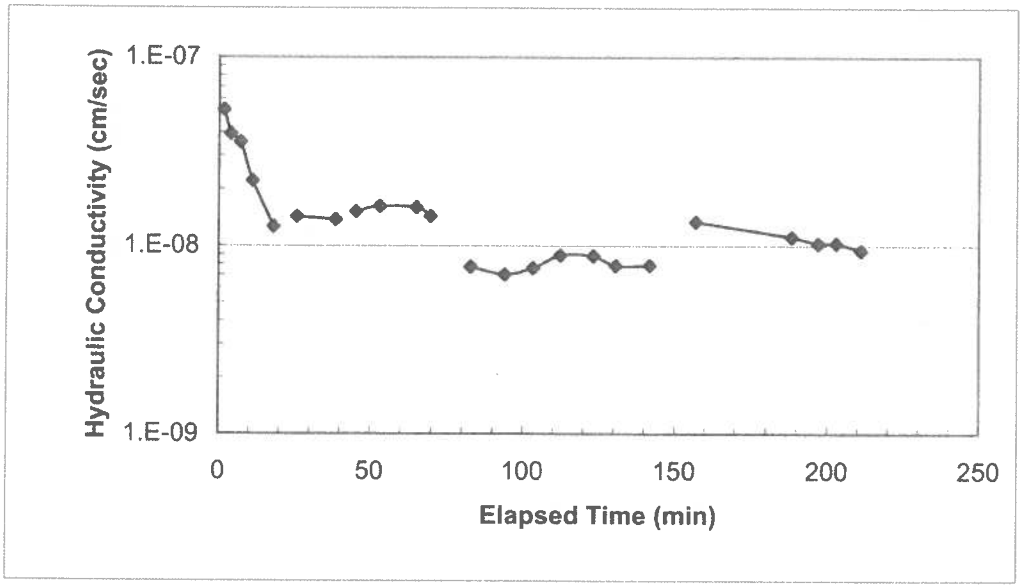
Constants:	a =	0.03016	cm^2
	G_{Hg} -G_w	12.5	
	Sample Thickness, L =	15.24	cm
	Sample Diameter, D =	30.48	cm
	Sample Area, A =	729.66	cm^2
	Head (H_g) =	19	cm
	Head (H_w) =	237.5	cm
	Hydraulic Gradient, i =	15.58	
	Cell Pressure =	46.70	psi
	Back Pressure =	40.00	psi
	Effective Stress =	5.01	psi

WT of Can	WT of Can Wet Soil	WT of Can Dry Soil	Water Content	Wet Density	Dry Density
(g)	(g)	(g)	(%) at 105 °C	(pcf)	(pcf)
50.10	425.35	352.63	**24.04**	125.29	**101.01**
Wet Weight	49.20	(lbs)			

Time	Reading	DT	Elapsed Time	Hydraulic Conductivity
(hh:mm:ss)	(cm)	(sec)	(min)	(cm/sec)
0:00:00	33.5	0	0.000	
0:01:41	31.5	101	1.683	5.252E-08
0:03:56	29.5	135	3.933	3.929E-08
0:07:03	27	187	7.050	3.546E-08
0:11:03	25	240	11.050	2.210E-08
0:18:03	23	420	18.050	1.263E-08
0:00:00	28	0	18.050	
0:07:43	25.5	463	25.767	1.432E-08
0:20:32	21.5	769	38.583	1.380E-08
0:00:00	34	0	38.583	
0:06:40	31.7	400	45.250	1.525E-08
0:14:33	28.8	473	53.133	1.626E-08
0:26:24	24.5	711	64.983	1.604E-08
0:31:01	23	277	69.600	1.436E-08
0:00:00	21	0	69.600	
0:13:11	18.7	791	82.783	7.712E-09
0:24:30	16.9	679	94.100	7.031E-09
0:33:47	15.3	557	103.383	7.619E-09
0:42:43	13.5	536	112.317	8.907E-09
0:53:43	11.3	660	123.317	8.841E-09
1:01:03	10	440	130.650	7.837E-09
1:12:17	8	674	141.883	7.871E-09

0:00:00	24	0	141.883	
0:15:09	19.4	909	157.033	1.342E-08
0:46:35	11.5	1886	188.467	1.111E-08
0:55:12	9.5	517	197.083	1.026E-08
1:01:12	8.1	360	203.083	1.031E-08
1:09:11	6.4	479	211.067	9.413E-09

Average: **1.0E-08**



HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **08-P-01C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

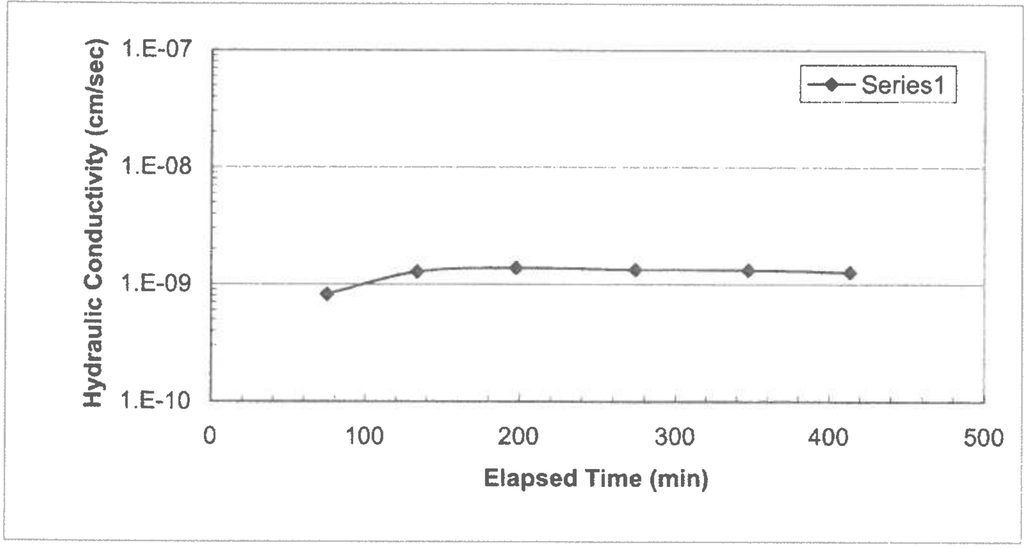
Test Date: 5/18/2006

Constants:	a =	0.03016	cm^2
	G_{Hg} - G_w	12.5	
	Sample Thickness, L =	15.24	cm
	Sample Diameter, D =	30.48	cm
	Sample Area, A =	729.66	cm^2
	Head (H_g) =	19	cm
	Head (H_w) =	237.5	cm
	Hydraulic Gradient, i =	15.58	
	Cell Pressure =	53.70	psi
	Back Pressure =	40.00	psi
	Effective Stress =	12.01	psi

WT of Can (g)	WT of Can Wet Soil (g)	WT of Can Dry Soil (g)	Water Content (%) at 105 °C	Wet Density (pcf)	Dry Density (pcf)
51.06	**415.98**	342.97	**25.01**	125.03	**100.02**
Wet Weight	49.10	(lbs)			

Time (hh:mm:ss)	Reading (cm)	DT (sec)	Elapsed Time (min)	Hydraulic Conductivity (cm/sec)	
0:00:00	24.8	0	0.0		
1:15:04	23.4	4504	75.1	8.244E-10	
2:13:49	21.7	3525	133.8	1.279E-09	
3:17:51	19.7	3842	197.9	1.381E-09	Refill
4:34:10	17.4	4579	274.2	1.332E-09	
5:47:36	15.2	4406	347.6	1.324E-09	
6:53:31	13.3	3955	413.5	1.274E-09	

Average: **1.3E-09**



HYDRAULIC CONDUCTIVITY TEST
ASTM D 5084 Method E

Sample ID : **08-P-02C**

Clean Harbors Deer Trail Facility, Lakewood, Colorado

Test Date:

Constants: a = 0.03016 cm^2

G_{Hg} -G_w 12.5

Sample Thickness, L = 15.24 cm

Sample Diameter, D = 30.48 cm

Sample Area, A = 729.66 cm^2

Head (H_g) = 19 cm

Head (H_w) = 237.5 cm

Hydraulic Gradient, i = 15.58

Cell Pressure = 53.70 psi

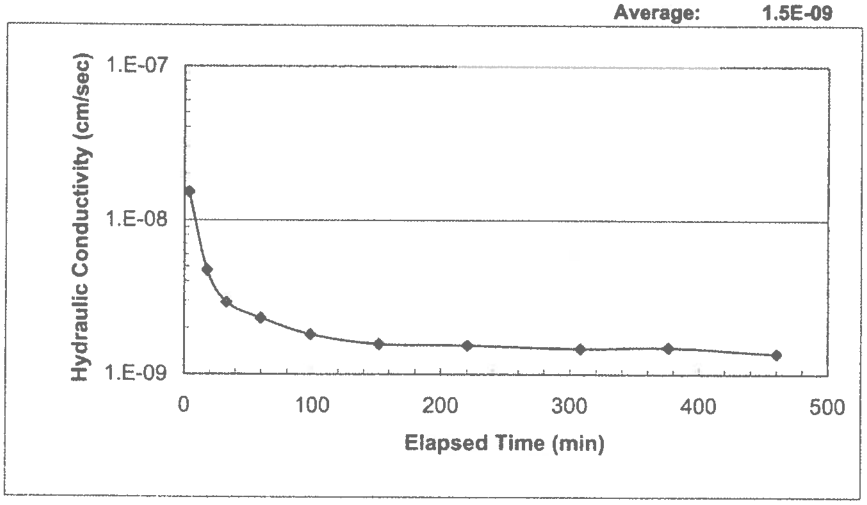
Back Pressure = 40.00 psi

Effective Stress = 12.01 psi

WT of Can	WT of Can Wet Soil	WT of Can Dry Soil	Water Content	Wet Density	Dry Density
(g)	(g)	(g)	(%) at 105 °C	(pcf)	(pcf)
50.10	**425.35**	352.63	**24.04**	125.29	**101.01**
Wet Weight	**49.20**	(lbs)			

Time	Reading	DT	Elapsed Time	Hydraulic Conductivity
(hh:mm:ss)	(cm)	(sec)	(min)	(cm/sec)
0:00:00	28.8	0	0.000	
0:03:47	27.5	227	3.783	1.519E-08
0:17:45	26	838	17.750	4.748E-09
0:32:51	25	906	32.850	2.928E-09
0:59:37	23.6	1606	59.617	2.312E-09
1:38:35	22	2338	98.583	1.815E-09
2:32:09	20.1	3214	152.150	1.568E-09
3:40:49	17.7	4120	220.817	1.545E-09
5:08:07	14.8	5238	308.117	1.468E-09
6:16:11	12.5	4084	376.183	1.494E-09
7:40:25	9.9	5054	460.417	1.364E-09

Average: **1.5E-09**



Technical Support For Rocky Mountain Arsenal

Final Test Fill Construction Program
Summary Report
Feasibility Study
Soils Support Program
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared for

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THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATIVE RECORD FOR THIS CERCLA OPERABLE UNIT.

December 31, 1997

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APPENDIXES

1.0 INTRODUCTION

This Test Fill Construction Program Summary Report (Summary Report) has been prepared in support of the Corrective Action Management Unit (CAMU) landfill design currently being prepared by the U.S. Army Corps of Engineers (USACE) as part of the remedy for cleanup of the Rocky Mountain Arsenal (RMA). This Summary Report describes the equipment and procedures used for the construction, testing, and evaluation of Test Fill 3 and presents the results and conclusions of the observations and testing performed for Test Fill 3. Test Fill 3 was constructed in the spring of 1997 and six large-scale (12-inch diameter) undisturbed hydraulic conductivity samples were obtained and tested from the test fill after construction. All six of these samples achieved a hydraulic conductivity of less than $1x10^{-7}$ centimeters per second (cm/s). A Site Plan showing the locations of Test Fill 3 and the borrow and process areas used to construct Test Fill 3 is included as Figure 1.

The Draft Final version of this Summary Report (dated June 6, 1997) contained recommended modifications to the full-scale compacted clay liner (CCL) construction specifications and Construction Quality Assurance (CQA) Plan. These recommended modifications were made based on the construction equipment, procedures, observations, and test results used or obtained as part of this Test Fill Program. As part of the 90 Percent Design Package submitted to the regulatory parties in September 1997, the USACE submitted a revised CQA Plan and revised Construction Specifications that had been modified based on: (1) the Draft Final Summary Report; (2) the regulatory comments (dated July 3, 1997 [Colorado Department of Public Health and Environment, CDPHE] and July 9, 1997 [U.S. Environmental Protection Agency, EPA]) on the Draft Final Summary Report; (3) the agreements made between the Army, CDPHE, and EPA at a meeting held July 29, 1997 to discuss the regulatory comments on the Draft Final Summary Report; and (4) the official Response to Comments submitted by the Army to the regulatory parties on September 23, 1997 (included in Appendix H).

EPA and CDPHE provided comments to the 90 Percent Design Package on October 9 and 21, 1997, respectively. The USACE is now incorporating these regulatory comments into the 100 Percent Design

Package. Because the results of the test fill have already been incorporated into the Construction Specifications and CQA Plan, the recommended modifications to the Construction Specifications (Section 7.3) and CQA Plan (Section 7.4) included in the draft final version have been deleted from the final version of this Summary Report. This was done to focus regulatory review comments on the Construction Specifications and CQA Plan to just those documents. Nevertheless, the contents of the September 23, 1997, Response to Comments (excluding comments on Sections 7.3 and 7.4) have been incorporated into this Summary Report as agreed in our July 29, 1997 meeting.

This Summary Report has been prepared by Harding Lawson Associates (HLA) as a contract deliverable under Delivery Order No. 0007 (Task 93-03, Feasibility Study Soil Support Program) of Contract DAAA05-92-D-0003 between HLA and the U.S. Department of the Army (Army). This document has been prepared at the direction of the Army for the sole use of the Army, the signatories of the Federal Facilities Agreement (FFA) of RMA, the State of Colorado (State), Adams County, and Tri-County Health Department, the only intended beneficiaries of this work. This document has been prepared to summarize the Test Fill 3 construction program at RMA and should not be used for any other purpose.

1.1 Background

Two CCL test fills (Test Fills 1 and 2) were constructed in the southeast portion of Section 25 during the summer of 1994 as part of the Feasibility Study Soils Support Program. The primary objective of this program was to demonstrate that a hydraulic conductivity of $1x10^{-7}$ cm/s or less can be achieved with the onsite clayey soils. These soils were obtained from borrow areas located within 2 miles of Section 25. The field-scale hydraulic conductivity of each of these two test fills was evaluated using a sealed double-ring infiltrometer (SDRI) and two-stage borehole permeameters (TSBP). The results of these field-scale tests indicated that a hydraulic conductivity of $1x10^{-7}$ cm/s or less was achieved. The results of Test Fills 1 and 2 are presented in the Final Landfill Site Feasibility Report for the Feasibility Study Soils Support Program, (Landfill FS Report) (HLA, 1995a) included as Appendix R of the CAMU Designation Document (CDD).

While the Test Fill 1 and 2 results indicated that the minimum hydraulic conductivity can be achieved with onsite soil, a letter dated August 30, 1995, to the Program Manager for Rocky Mountain Arsenal (PMRMA) from the CDPHE requested that:

- Compaction equipment, such as a Caterpillar 825, be evaluated to improve the efficiency of soil liner compaction.
- The full-scale landfill construction specifications reflect the equipment and methods used to condition soil moisture and reduce clod size and the lift thicknesses achieved in the field during the test fill construction.
- The test fill procedures include curing time for uniform absorption and hydration of soil particles when the moisture variance is increased by more than 3 percentage points. These procedures should be refined during completion of the Test Fill 3 program and carried forth into the full-scale construction specifications.
- The test fill procedures for reconditioning soil for moisture content be carried into the full-scale construction specifications.

Thus, Test Fill 3 was constructed to:

- Respond to the above listed requests made by CDPHE.
- Provide additional test fill data that will allow the landfill designer to finalize construction specifications and CQA procedures for CCLs based on the findings of the Test Fill 3 program.

1.2 Purpose and Scope

The purposes of the Test Fill 3 program are described below:

1. Provide data to the Army that will allow the USACE to develop CCL construction specifications which will achieve a hydraulic conductivity of $1x\ 10^{-7}$ cm/s or less using equipment and procedures for CCL moisture conditioning, placement, and compaction which will allow full-scale CCL construction to be performed in a productive and cost-effective manner.
2. Evaluate the similarity of geotechnical properties of two potential CCL material borrow areas at RMA. One of these areas (Site-Wide Implementation Plan [SWIP] Borrow Area 5) is identified as Borrow Area 1 in the Final Feasibility Soils Support Program Report (Borrow Study Report) (HLA, 1995b). The second area is the clayey soil within the CAMU Area identified in the CDD (HLA, 1996). This was done to identify whether the results of Test Fill 3 can be applied to the borrow area not used to construct Test Fill 3.
3. Identify any additional test fill data needs for future landfill design or construction that exist after the construction and testing of Test Fill 3.

The scope of the test fill program included the following activities:

1. Preparing, submitting, and obtaining approval of the Final Work Plan for the Test Fill Construction Program (Work Plan) (HLA, 1997). The Work Plan is attached as Appendix A.
2. Tabulating and analyzing the geotechnical index properties (i.e., percent fines [percent of sample passing a Number 200 sieve], liquid limit, plasticity index), submitting a proposed borrow area consistency assessment along with the supporting documentation as part of the Work Plan, and selecting which of the two potential borrow areas will be used for Test Fill 3 construction (addressed in the Work Plan and Section 2.0).
3. Performing preconstruction laboratory testing to obtain additional geotechnical index parameter data and to establish the relationship between moisture, density, and hydraulic conductivity of the Test Fill 3 borrow material (addressed in the Work Plan and Section 3.0).
4. Constructing the test fill using equipment, procedures, and specifications that will result in a hydraulic conductivity of $1x10^{-7}$ cm/s or less and that can be effectively implemented for full-scale construction (addressed in Section 4.0).
5. Performing CQA monitoring and testing during construction of Test Fill 3 (addressed in Section 5.0).
6. Performing post-test fill construction laboratory testing to verify that a hydraulic conductivity of $1x10^{-7}$ cm/s or less was achieved (addressed in Section 6.0).
7. Providing input to the USACE's full-scale CCL construction specifications and CQA Plan included in the 100 Percent Design Package based on the construction procedures and equipment used and the results of Test Fill 3 (addressed in Section 7.0).
8. Reviewing data from all test fills and identifying any additional future data needs (addressed in Section 7.0).
9. Preparing, submitting, and obtaining approval of this Summary Report.

Items 1, 2, and 3 of the scope of the test fill program were completed during preparation of the Work Plan. In a letter dated March 25, 1997, CDPHE issued a conditional approval of the Work Plan contingent upon incorporation of the comments included in the letter. The CDPHE approval letter is attached as Appendix B. Section 3.0 of the Work Plan presents the evaluation and comparison of the two borrow areas (Borrow Area 5 and the CAMU Area) and concludes that the geotechnical properties of both areas are sufficiently similar for the results of Test Fill 3 to be applied to construction specifications for projects utilizing CCL material obtained from either borrow source. Section 4.0 of the Work Plan discusses the preconstruction laboratory testing, evaluates the results, and presents the Acceptable Zone for Test Fill Construction (Preconstruction Acceptable Zone). The Preconstruction Acceptable Zone is included as Figure 2. Items 4 through 9 of the scope of the test fill program will be completed by submission and approval of this Summary Report.

Test Fill 3 was constructed by HLA's Construction Division. CQA was performed by HLA's Field Services Division under the direction of HLA's Remedial Design Center (RDC). The test fill was constructed on both a flat (2 percent) slope and a side (29 percent or 3.5 Horizontal: 1 Vertical) slope. The slopes used for the test fill are consistent with those selected for the design of the landfill cell floor and sideslopes. The test fill was constructed within the CAMU area (Sections 25 and 26) using the onsite clayey soils to be excavated from within the footprint of the double-lined landfill cell. Figure 1 shows the locations of Test Fill 3 and the Test Fill 3 borrow and process areas. Figure 3 shows a plan view and cross sections of Test Fill 3 along with the field moisture/density test locations, Shelby tube locations, and block sample locations.

The large-scale hydraulic conductivity of Test Fill 3 was evaluated by obtaining nine large diameter (approximately 14 inches) undisturbed soil liner samples and testing six of the samples in specially designed flexible wall permeameters in the same manner as small diameter (2.8 inches) Shelby tube samples and in general accordance with American Society for Testing and Materials (ASTM) D5084. The large diameter undisturbed samples are commonly referred to as "block" samples in published literature. Published comparisons between the hydraulic conductivity of large-scale block samples and the hydraulic conductivity of SDRIs have shown little variation in the test results (Benson, et al., 1993) except in cases where little or no CQA was performed.

1.3 Organization

The remainder of this Summary Report is divided into seven sections. Section 2.0 provides a background data on the low permeability soil. Section 3.0 describes the preconstruction laboratory testing activities and data interpretation methodology. Section 4.0 provides the construction chronology of the test fill. Section 5.0 discusses the CQA activities during construction of the test fill. Section 6.0 discusses the post-construction laboratory testing activities and presents the test results. Section 7.0 provides a summary of the field observations and laboratory test results and presents the conclusions of the Test Fill 3 construction program. Section 8.0 provides a list of acronyms, and Section 9.0 is a bibliography.

Appendix A is the Test Fill 3 Work Plan. Appendix B is CDPHE's conditional approval of the Work Plan. Appendixes C and D are the photographic log and daily field reports, respectively. Appendix E contains the field calibration and structural fill test results. Appendixes F and G contain the CCL field and laboratory test results, respectively. Appendix H presents the Army's response to the EPA and CDPHE comments on the draft final version of the Summary Report.

2.0 LOW PERMEABILITY SOIL BACKGROUND DATA

In addition to the Borrow Area Evaluation and Selection presented in Section 3.0 of the Work Plan, several other studies involving the evaluation of potential CCL borrow material sources have been conducted at RMA. This section provides a summary of the previous studies and discusses the borrow area evaluation performed during preparation of the Work Plan.

2.1 Previous Studies

The Borrow Study Report was published in January 1995. This report evaluated potential CCL material borrow areas at RMA and defined four areas that, based on geotechnical property data from each of the areas, contained potentially acceptable CCL material in substantial volumes. Because of U.S. Fish and Wildlife Service (FWS) concerns over disturbing three of these areas, only one of the four areas remains under consideration by the USACE as a CCL material source for landfill construction. To be consistent with the SWIP, this area, referred to as Borrow Area 1 in the Borrow Study Report and the CDD, is referred to as Borrow Area 5 in the Work Plan and this Summary Report. Borrow Area 5 is located immediately north of the landfill CAMU boundary in the southern portion of Section 24. In preparing the Borrow Study Report, numerous index (i.e., sieve analysis, Atterberg limits), remolded permeability, and other geotechnical tests were performed on 28 samples obtained from 9 subsurface borings drilled within Borrow Area 5 to a nominal 20-foot depth. All samples were classified in accordance with the Unified Soil Classification System (USCS). Tables 3.2 and 3.3 of the Borrow Study Report present results of the remolded permeability and index tests, respectively. These tables are also included in Appendix A of the Work Plan.

The Landfill FS Report was published in July 1995. This report identified the general location of the CAMU area as a feasible site for the landfill. As part of this work, 30 subsurface borings were drilled to a nominal 50-foot depth in or near the CAMU area. Numerous index and other geotechnical tests were performed on 360 samples obtained from the 30 subsurface borings. Table 4.5 of the Landfill FS Report presents index test and moisture content test results. Table 4.6 of the Landfill FS Report presents standard Proctor, permeability, shrink, and swell test results. Tables 4.5 and 4.6 of the Landfill FS Report are also included in the Work Plan as Appendix B.

During summer and fall of 1996, the USACE performed a subsurface investigation within both the Landfill CAMU area and Borrow Area 5. Results of this investigation are presented in the Final Geotechnical Report, Hazardous Waste Landfill, Rocky Mountain Arsenal (Subsurface Report) (USACE, 1996b). As part of the USACE subsurface investigation, a total of 29 borings and 22 test pits were completed within the Landfill CAMU area, and 27 test pits were excavated within Borrow Area 5. Numerous visual and laboratory (using index test results) USCS soil classifications were performed on samples obtained from these borings and test pits to evaluate suitability of the alluvial clays and weathered bedrock clays found in these areas. After completion of the soil classifications, Proctor compaction (standard and modified), and remolded permeability tests were performed on both alluvial and weathered bedrock clay samples collected from within the expected footprint of the double-lined cell. Results of these tests are presented in Appendix F of the Subsurface Report. Tables T-3 through T-6 of the Subsurface Report summarize the results of the laboratory testing and were included as Appendix C in the Work Plan.

Based on the results of the subsurface investigation, the USACE recommended that weathered bedrock clays not be used for CCL construction due to the variability of the material and difficulties encountered in processing this material. Therefore, Test Fill 3 used only alluvial soil.

2.2 Borrow Area Evaluation

To evaluate the suitability and similarity of the two borrow areas, Section 3.0 of the Work Plan was written to (1) evaluate and compare the alluvial soil within Borrow Area 5 and the CAMU area to assess the similarity of the two areas' permeability-related geotechnical index properties (i.e., percent fines, Atterberg limits, USCS classification), (2) identify the borrow area soil to be used for Test Fill 3 construction, and (3) identify which borrow area soil the results of Test Fill 3 will be applicable to.

The borrow area index properties were evaluated and compared in the Work Plan by statistically tabulating the number of data points for each index property, along with the maximum, minimum, average, and standard deviation values for each index property for all of the alluvial samples and also those meeting the minimum index property criteria given in the Work Plan. The minimum index property criteria used to screen the data were developed based on the findings of the previous studies, the requirements of the CDD, and Benson (1994). Table 1 presents the minimum index property criteria used to screen the raw borrow soil data.

A summary of the number of alluvial soil data points analyzed in each borrow area, the average index property values calculated for all of the data points, for those meeting the Table 1 criteria is provided in Section 3.0 of the Work Plan. Observations made from the evaluation of the two borrow areas follow:

- The two areas are located within 1,000 feet of each other and, according to U.S. Geological Survey (USGS) mapping, were deposited in the same eolian depositional environment.
- Approximately the upper 10 feet of Borrow Area 5 and the upper 20 to 25 feet of the CAMU Area both contain predominantly lean clays with some clayey sands and occasional sandy seams, gravel pockets, and fat clays.
- The average, maximum, minimum, and standard deviation of the index properties and the percentage of alluvial soil samples meeting the Table 1 criteria of both areas are similar. The average index property values for the two borrow areas did not vary by more than 10 percentage points.
- The amount of variation in the maximum, minimum, and standard deviation values between all samples in the two borrow areas is likely due to the fact that every sample and test performed does not represent the same volume of alluvial soil. That is, neither the boring and test pit locations, nor the number and depth of samples, nor number and type of index tests performed are evenly distributed (horizontally or vertically) over the volume of alluvial soil contained within each borrow area. This level of consistency was not an objective of any of the sampling and testing programs.
- No clear indication of differences in overall geotechnical properties between the two areas (i.e., the properties of one borrow area cannot be distinguished from the other borrow area) is apparent.
- The average properties (including samples failing the Table 1 criteria) indicate that a homogenized mixture of all the alluvial soil from one or both borrow areas would result in a lean clay soil meeting the Table 1 criteria.
- It is estimated that less than 40 percent of the total alluvial soil volume in both borrow areas will be unacceptable for CCL construction.

Based on these observations, Section 3.0 of the Work Plan concluded that: (1) the two borrow areas' index properties are sufficiently similar and both can be potentially processed to obtain the required minimum hydraulic conductivity of $1\text{x}10^{-7}$ cm/s; and (2) the results of Test Fill 3 can be applied to CCL material obtained from either borrow source. Section 3.0 of the Work Plan also identified the double-lined cell excavation area portion of the CAMU Area as the area for excavation of borrow soil for Test Fill 3.

3.0 PRECONSTRUCTION LABORATORY TESTING AND DATA INTERPRETATION

Prior to construction of Test Fill 3, a preconstruction laboratory testing program was performed using alluvial clay samples obtained from the anticipated footprint of the double-lined cell to evaluate the relationship between moisture content, dry density, and hydraulic conductivity for the Test Fill 3 compacted soil liner. This was done to establish the moisture content/dry density criteria for the Test Fill 3 CCL placement. The program followed the general methodology set forth initially by Daniel and Benson (1990) and is described in detail in Section 4.0 of the Work Plan. This section summarizes the preconstruction laboratory testing and data interpretation program.

Samples collected by the USACE during preparation of the Subsurface Report were used for the preconstruction laboratory testing. Index property; specific gravity; and modified, standard, and reduced Proctor compaction tests were performed on a composite of two samples collected by the USACE. The reduced Proctor test utilized the same procedure as the standard Proctor test with the exception that 15 blows per lift were used instead of the 25 blows per lift required by the standard Proctor test (ASTM D698). The two samples combined for the composite sample were carefully selected so that the resulting soil composite possessed index property values that reasonably represent the average clayey soil index properties for the borrow areas. The index values of the composite sample and the average index values of the two borrow areas are summarized below:

Index Property	Acceptable Zone Composite Sample Test Results	Average for CAMU Area		Average for Borrow Area 5	
		All Samples	Passing Samples	All Samples	Passing Samples
USCS Classification	CL	CL	CL	CL	CL
Percent Fines	62	52	63	57	66
Liquid Limit	38	39	40	38	39
Plasticity Index	24	22	23	21	22

After completion of these tests, the Preconstruction Acceptable Zone (AZ) for compacted soil liner placement during Test Fill 3 construction was developed. The three Proctor test results and the zero air voids (ZAV) curve (using the specific gravity test result) were plotted on a moisture content versus dry density graph. Then a "line of optimums" was drawn connecting the optimum moisture content of the three Proctors. The ZAV was used to define the right (wet) side of the AZ and the line of optimums was used to define the left (dry) side of the AZ.

The upper and lower boundaries of the AZ were selected by assuming a minimum density to define the lower boundary and assuming a minimum moisture content to define the upper boundary of the AZ. The AZ included in the Work Plan assumed a minimum density of 92 percent of standard Proctor maximum dry density for the lower boundary of the AZ. The lower boundary was later conservatively raised to 95 percent of standard Proctor maximum dry density during construction of Test Fill 3 to increase the minimum CCL shear strength to enhance the liner system's slope stability and bearing capacity. The upper boundary was defined as the modified Proctor optimum moisture content. To assist in evaluating the constructibility of CCLs at different moisture and density ranges, the AZ was further divided into the upper AZ and lower AZ. This was done by drawing a line perpendicular to the ZAV curve and intersecting the standard Proctor optimum moisture content and maximum dry density.

The accuracy of the AZ was then verified in the laboratory by performing 12 remolded hydraulic conductivity tests at a relatively evenly distributed range of moisture and density contents that plot just outside or inside the outer boundaries of the AZ. The 12 remolded samples exhibited hydraulic conductivities ranging from $6.0 \text{ x}10^{-8}$ cm/s to $1.6\text{x}10^{-9}$ cm/s.

The moisture content and dry density of the remolded hydraulic conductivity test samples along with each sample's test results were plotted on the moisture-density graph of the AZ. To account for potential variability in hydraulic conductivity between field compacted and laboratory compacted samples, the AZ for Test Fill 3 construction was not expanded to include the five sample points with passing test results that plotted outside of the AZ. Thus, the preliminary AZ was made the final AZ for

Test Fill 3 CCL construction. The AZ for Test Fill 3 construction, along with the moisture/density plots and hydraulic conductivity test results, is included as Figure 2.

4.0 CONSTRUCTION CHRONOLOGY

This section describes the chronology of the Test Fill 3 construction, including the construction equipment and procedures used. The CQA observations, test results, and documentation obtained during construction are described in Section 5.0 and are only referenced briefly in this section. The construction procedures and specifications adhered to during construction are given in Section 5.0 of the Work Plan. A complete list of the equipment used during construction is given in Table 2.

4.1 Site Preparation

Construction commenced on March 24, 1997, with mobilization of equipment and personnel to the job site. Flatirons Surveying of Boulder, Colorado, had previously set survey stakes to layout the borrow, processing, and test fill areas. The site preparation activities consisted of screening for unexploded ordnance (UXO); clearing and grubbing the borrow, process, and test fill areas (work areas); establishing haul roads between the three areas; and removing overburden from the borrow area. Figure 1 is a site plan showing the location of the haul roads and the borrow, process, and test fill areas. Appendix C is a photographic log of the test fill construction.

Prior to commencing site preparation activities, the location of the borrow area was moved approximately 100 feet north and 100 feet west from the area shown in the Work Plan. The borrow area location shown in the Work Plan was selected because the boring logs obtained in the southeast quarter of the double-lined cell footprint indicated lean clay (CL) material was present in the upper 10 feet of soil. Test pits excavated approximately 3 feet deep within the borrow area shown in the Work Plan indicated that a localized 6-inch-thick lens of fat clay (CH) material was present in three of the test pits overlying the CL material. The borrow area was moved to the northwest toward the location of the TP250011 to avoid the localized lens of CH material.

4.1.1 Ordnance Removal

HLA screened the work areas using a metal detector for the presence of UXO prior to disturbing any of the areas. No UXO was encountered. Although not required by RMA, this was done as an added health and safety measure. A macro-level screening of the general area had also been performed previously by PMRMA with no UXO encountered.

4.1.2 Clearing and Grubbing

Clearing and grubbing consisted primarily of removing and stockpiling topsoil from the work areas using a Caterpillar 140G motor grader (motor grader), a Caterpillar D7H dozer (dozer), and a Caterpillar 621B scraper (scraper). Dust control during clearing and grubbing was supplied by a GMC TC7 4,000-gallon water truck (water truck). From 6 to 12 inches of topsoil were removed from each of the three areas. Topsoil removed from the borrow area was stockpiled to the immediate west side of the borrow area. Topsoil removed from the process and test fill areas was stockpiled on the side of the process area closest to the test fill area. Minor drainage ditches and diversion berms were also constructed as necessary to divert run-on and runoff from the work areas. Also, an existing 1- to 2-foot-deep vee-shaped drainage channel, which was routed between the test fill, process, and borrow areas, was temporarily filled in. The vegetation removed consisted of small roots, grasses, and weeds. No trees or woody plants were encountered in the work areas. The Site Plan included as Figure 1 shows the record survey of the limits of the work areas disturbed.

4.1.3 Haul Road Preparation

Haul roads were constructed using the motor grader to provide a smooth surface for vehicles to travel between the work areas. The motor grader bladed the topsoil off the road surface and to the side of the road. Haul roads were constructed between the borrow and process areas, between the process area and the top of the test fill slope, and between the test fill and process areas. The approximate locations of the haul roads are also shown in Figure 1.

4.1.4 Borrow Area Overburden Removal

Overburden removal from the borrow area commenced after removal and stockpiling of the topsoil from the borrow area. The overburden was removed using the dozer and scraper and stockpiled to the immediate east side of the borrow area. Zones of caliche, sand, and cobbles were encountered in the upper 2 to 4 feet of material beneath the borrow area topsoil. Beneath the overburden, an approximate

6-inch-thick layer of CH material was encountered in the southeastern portion of the borrow area. CL material was encountered beneath the CH material. The overburden was removed until the lens of CH material was encountered. Minor amounts of the CH layer were also removed due to the presence of caliche and/or cobbles. CQA monitoring was performed throughout the overburden removal to verify that the unacceptable materials were removed. The CQA monitoring of the overburden removal is described in Section 5.0.

4.2 Test Fill Subgrade Preparation

On March 26, 1997, HLA began excavating the Test Fill 3 subgrade. Again, this work was performed using the dozer and scraper. Approximately 5,000 cubic yards (cy) of cut material were removed from above the test fill subgrade. The maximum depth of cut was approximately 11 feet at the toe of the 3.5:1 (horizontal to vertical) slope. In addition to the cut volume, a structural fill approximately 4 feet high was required at the top of the test fill slope to obtain a 30-foot 3.5:1 slope height. The cut material consisted primarily of noncohesive sands and cobbles. This material was stockpiled adjacent to the topsoil stockpile located between the process and test fill areas.

During the removal of overburden from above the test fill subgrade, numerous attempts were made to traverse the CAT 825C sheepsfoot compactor (compactor) up the 3.5:1 slope. Due to the noncohesive subgrade soils, the compactor was unable to obtain enough traction to traverse the slope. Based on this observation, it was decided to use the cohesive clay obtained from the borrow area to construct the 5-foot structural fill at the top of the slope and also to construct a 6- to 10-inch-thick "foundation" layer over the extent of the test fill subgrade (see Figure 3). The foundation layer was used as a base layer for the compactor to obtain enough traction to traverse the 3.5:1 slope. Approximately 500 cy of structural fill were placed at the top of the slope and as the foundation layer.

The structural fill and foundation layer were placed in accordance with the structural fill specifications in Section 5.0 of the Work Plan. The structural fill was placed in maximum 10-inch loose lifts and compacted to a minimum 95 percent of the standard Proctor maximum density (ASTM D698) at a moisture content ±3 percentage points of the optimum moisture content (see Section 5.0). The completed foundation layer surface was proof-rolled using the compactor and loaded scraper and graded using the motor grader.

At the completion of structural fill placement, Flatirons Surveying returned to the site to perform a record survey of the test fill subgrade surface (top of foundation layer) and to set stationing stakes to obtain testing and sampling locations. The record drawing of the test fill subgrade surface is included as Figure 4.

4.3 CCL Construction

The following paragraphs describe the equipment and procedures used to construct the Test Fill 3 CCL. Excavation and processing of CCL borrow material began on March 28, 1997. CCL placement and compaction began on April 3, 1997, and was completed on April 7, 1997.

4.3.1 Excavation and Processing

The material was excavated using the dozer and scraper and initially processed using a Caterpillar SS250 soil stabilizer (stabilizer). As stated in the Work Plan, experimentation was done using an International 7300DBP 4x4 tractor pulling 2-row by 8-foot-wide, 24-inch-diameter Rome disc to process the CCL material placed as Lift 6 for all of Lane 1 and the upper half of Lane 2. The surface of the process area material was sealed each night using the rubber tires of the scraper and motor grader to minimize the effects of precipitation and/or evaporation. On the last 2 days of CCL processing and placement (April 6 and 7, 1997), the overnight temperature fell below freezing. In these cases, the upper 1 to 2 inches of the processed material were removed using the motor grader prior to processing and placement.

Moisture was added as necessary using the water truck. The most effective method for adding moisture in the process area was achieved by:

- Traveling with the water truck ahead (approximately 5 to 10 feet) and to the side of the stabilizer
- Using the side fan spout of the water truck
- Spraying the water directly onto the material immediately prior to processing

This method minimized the amount of water lost to evaporation, increased the ability of rubber-tired vehicles to traverse over the processed material, and resulted in a relatively consistent moisture content.

At least two passes of the water truck and stabilizer were generally necessary to condition the CCL material to within the dryer moisture content range of the AZ (upper AZ or approximately 12 to 18 percent). As many as six passes of the equipment were necessary to condition the material to the wetter moisture content range (lower AZ or approximately 18 to 24 percent). The stabilizer processed the material to a clod size of approximately 1/2 inch. As required by the Work Plan, the CCL material was allowed to hydrate for a minimum of 24 hours whenever the moisture content of the processed material was raised by 3 percent or more.

Occasionally oversized rocks (1 to 8 inches in diameter) were observed in the borrow and process areas during the excavation and processing. The majority of these rocks was readily identified by CQA personnel and removed from the material. The percentage of oversized rock is estimated to be some fraction of 1 percent of the total soil volume based on an estimate of one oversized rock per scraper load (approximately 10 cy) of material. The very sporadic presence of the oversized rocks was not a significant concern to the integrity of the CCL because it was very unlikely that two of the rocks would be placed together in a manner resulting in a void space between the rocks. This is discussed further in Section 7.0.

4.3.2 Placement and Compaction

The processed CCL material was placed and spread into an 8-inch maximum loose lift using the scraper and dozer. The lifts were placed by the scraper entering the test fill area at the top of slope (westerly side), traveling down the slope while placing the material, and then exiting at the end of the base section (easterly end) of the test fill. Lift placement progressed in this manner by placing all of Lane 1, followed by all of Lane 2, and then all of Lane 3. Occasionally, oversized material (approximately one rock per lift) was observed in the placed material and removed.

After placing and spreading a complete lift over Lane 1, lift compaction was initiated. The compactor was used to compact each lift. In general, on each lift the compactor made four passes over Lane 1, six passes over Lane 2, and eight passes over Lane 3 prior to testing the underlying lift. A pass was defined as one complete coverage over a given area by both the front and rear drums of the compactor.

When the required number of compactor passes was made, CQA personnel tested the underlying lift in accordance with the Work Plan. When testing on a lift was completed, the compactor made an additional pass over areas of the lift surface that had been flattened by vehicular traffic. This was done to texturize the surface to promote layer bonding with the next (overlying) lift.

As with the process area, the test fill surface was sealed each night using the rubber-tired equipment. On the two occasions when overnight freezing temperatures occurred, the upper 1 to 2 inches of frozen material were removed using the grader, and the underlying surface was texturized using the compactor.

4.3.3 Surface Preparation and Protection

The CCL material fill placement and compaction progressed in the manner described above until Lift 7 was placed and compacted. Lift 6 was tested and Lift 7 was placed and compacted on April 7, 1997. The following morning had freezing temperatures and intermittent snow showers. As required by the Work Plan, a 3-foot thickness for the test fill was achieved by grading and removal of Lift 7. After removing the upper half of Lift 7 using the motor grader, it was decided to leave the lower 2 to 3 inches of Lift 7 as frost protection for the underlying Lift 6.

As required by the Work Plan, the graded test fill surface was rolled using a Caterpillar CP563 smooth drum roller (roller) in static mode. No field tests were performed on the rolled surface because the upper 1 inch of the freshly graded surface was freezing. The roller easily traversed the 3.5:1 slope. However, the freezing conditions impacted the ability of the motor grader to evenly grade the surface and thus the ability of the roller to provide a smooth surface. Block sampling (described in Section 5.0) was initiated after rolling the surface.

A record survey of the CCL surface was performed after rolling the surface and during block sampling. A record drawing showing the CCL surface topography is shown in Figure 5.

When the block sampling was completed, the resulting holes were backfilled using a Case 580 backhoe (backhoe), and the test fill surface was regraded using the motor grader. A 4-mil-thick layer of plastic sheeting was placed over the entire base section of the test fill and anchored with loads of dirt from the backhoe bucket. In a minor deviation from the Work Plan, no plastic sheeting was placed on the slope section of the test fill for slope stability reasons. Instead this area was covered with approximately 2 feet of soil within 24 hours of completing the block sampling.

4.4 Site Reclamation

Site reclamation activities began after completing the construction of Test Fill 3. These activities included placing an approximate 2-foot-thick soil layer over the test fill; filling and regrading the borrow area; and spreading topsoil over the borrow areas, process areas, and haul roads. Also, the site drainage channel filled in during the site preparation activities was re-established.

The soil layer placed over the test fill was required by the Work Plan to be a minimum of 4 inches thick. It was placed to a nominal 2-foot thickness to facilitate placement over the plastic sheeting on the base of the test fill and to provide additional protection to the slope section of the test fill. The dozer, scraper, and motor grader were used to place and grade the soil layer. Fill for the soil layer was obtained from the material stockpiled during excavation of the test fill subgrade.

The borrow area was backfilled and graded to drain to the north using the scraper, dozer, and motor grader. Backfill was obtained from the adjacent borrow area overburden stockpile and supplemented with additional material from the test fill subgrade overburden stockpile. Per the request of the FWS, no compaction of the borrow area backfill was performed. The maximum depth of fill was approximately 6 feet. After the backfilling was complete, the stockpiled topsoil was spread over the entire disturbed surface.

No backfilling of the process area or haul roads was required. These areas were regraded and topsoil placed over them. No topsoil was placed over the test fill soil layer to facilitate the collection of additional samples if necessary. A small portion of the test fill overburden stockpile (approximately 3 feet high) also remained.

After completion of the above activities, HLA met with a representative of the FWS at the site to verify the site had been sufficiently reclaimed. The FWS reported no problems with the site reclamation and is currently revegetating the disturbed areas.

5.0 CONSTRUCTION QUALITY ASSURANCE ACTIVITIES

This section describes the CQA activities associated with the construction activities described in Section 4.0. CQA activities included monitoring site preparation activities, screening borrow materials, performing Proctor and moisture content tests in a field laboratory, providing moisture control during processing, performing field moisture and density tests, verifying loose and compacted lift thicknesses, and obtaining Shelby tube and block samples. Photographs and videos were taken throughout the construction process to document the work (see Appendix C). CQA personnel also completed daily field reports during each day of construction. The daily reports are included as Appendix D.

5.1 Site Preparation

Upon arrival onsite during the first day of construction activities, HLA CQA personnel observed the surveyor's layout of the site, adjusted the borrow area location, and performed the UXO screening as described in Section 4.0. In addition, a field laboratory was set up to perform Proctor and moisture content tests, weigh sandcone test containers, and store the nuclear gauge. Sandcone and moisture content correlation tests were performed to verify the calibration of the nuclear gauge. The density of the sandcone sand was also calibrated. These calibration tests are included in Appendix E. The field laboratory was set up in Building 765 at RMA, more commonly known as the Hydrazine Building. When overburden removal of the borrow area had begun, the CQA personnel monitored the removal to verify that all unacceptable materials were removed.

5.2 Subgrade Preparation

The preparation of the test fill subgrade was also monitored, tested, and documented. The overburden removal was monitored to verify compliance with the design grades and dimensions. When the overburden removal was completed, the efforts of the compactor to climb the slope were observed and documented. The placement of structural fill was monitored, tested, and documented, and the results of the subgrade record survey were reviewed.

The excavated surface of the test fill was a clean sand with cobbles exhibiting no cohesion. During the subgrade excavation, it was observed that the compactor could not gain enough traction in this noncohesive soil to climb the 3.5:1 slope. Based on this observation, a 6- to 10-inch-thick foundation layer was constructed using the same structural fill material used at the top of the slope. Borrow material (CL) that had been processed to within 3 percent of the standard Proctor optimum moisture content was used as the structural fill. The foundation layer was placed in 8- to 10-inch loose lifts and compacted with the compactor to at least 95 percent of the standard Proctor maximum dry density. These ranges are all consistent with the Work Plan specifications.

A representative sample of the structural fill material was obtained, and a standard Proctor test and visual classification were performed (Sample No. 1). The material was visually classified as a lean clay with sand (CL). A total of six structural fill locations were tested to verify compliance with the Work Plan. A sandcone correlation test was performed at one of these locations. Three of these locations initially failed to meet the requirements and required reworking until the requirements were met. The structural fill field moisture and density test results and standard Proctor test result are included in Appendix E.

A record survey was performed at the completion of the structural fill placement (shown in Figure 4). The record survey verified that the slope between Station 1+18 and 2+16 was at a 3.5:1 incline and that the slope of the base section varied from 1 to 2 percent. The Work Plan stated the base section would be graded to a 2 percent slope. After consultation with CDPHE representatives, it was decided that no further grading of the base section would be necessary because this small degree of difference in slope would have no effect on the performance of the test fill.

5.3 Low Permeability Soil

CQA activities were ongoing throughout the excavation, processing, placement, and compaction of the Test Fill 3 CCL. The following paragraphs discuss the observations and test results.

5.3.1 Borrow and Process Area Monitoring

The borrow area excavation was monitored periodically throughout the removal of the borrow overburden and CCL material. After the overburden was removed, occasional thin seams (approximately 1 inch thick) of caliche (alluvial soil or bedrock cemented by calcium carbonate) were encountered and required the excavation activities to be directed elsewhere in the borrow area or removal of the caliche. Also, as stated in Section 4.0, occasional oversize materials (greater than 1 inch in diameter) were observed and removed from the borrow and process areas as they were observed. No caliche or organic material was observed within the CCL material placed over the process area. Therefore, no carbonate content or organic content tests were performed.

As stated in the Work Plan, the ability of the Rome disc to effectively condition CCL material to a moisture content range between the modified and the standard Proctor optimum moisture contents was assessed. This was done with material placed as part of Lift 6 (all of Lane 1 and the slope portion of Lane 2). The disc was unable to process the material to the maximum clod size of 2 inches required by the Work Plan but was, after approximately five passes, able to process the material to a relatively consistent moisture content at or near the standard Proctor optimum moisture content (16 to 17 percent). The discing action resulted in shavings of material that were generally about 1 to 2 inches thick and highly variable in height and length.

The stabilizer was able to consistently process the CCL material to a clod size of 1/2 inch or less in diameter. The stabilizer also effectively and productively processed the material up to a moisture content of approximately 4 to 5 percent wet of the standard Proctor optimum moisture content. The stabilizer was able to effectively process at wetter moisture content but its productivity decreased significantly. In general, a minimum of two passes of the stabilizer (with water truck spraying in front of it) was required to process the material to a moisture content within the AZ.

Moisture addition in the process area was regularly monitored during CCL conditioning. The in situ moisture content of the borrow material varied from approximately 6 to 14 percent. The nuclear gauge was used in backscatter mode to obtain quick moisture readings, and periodic microwave moisture contents were also performed. The data are included in Appendix F. A minimum hydration time of 24 hours was allowed whenever the moisture content was raised by 3 percent or more. Approximately 2,000 bank cy of CCL material were removed from the borrow area and placed in the process area.

5.3.2 Index and Proctor Testing

Ten days prior to beginning construction (March 14, 1997), HLA excavated four test pits (Sample Nos. TP-1 through TP-4) from the borrow area shown in the Work Plan. This was done as an attempt to obtain representative CCL samples for the direct shear testing program. The samples were shipped to GeoSyntec Consultants (GeoSyntec) in Atlanta, Georgia, for index testing on samples from each of the test pits. As discussed in Section 4.0, the samples obtained from three of the test pits indicated that a thin lens of CH material was present in this area. Therefore, the samples were not used for the direct shear testing program, and the borrow area was shifted approximately 100 feet to the west and north as described in Section 4.0 to minimize the amount of CH material used to construct the test fill.

When approximately 25 percent of the CCL material had been processed, but prior to beginning CCL placement, a representative composite sample was obtained from the surface of the process area (Sample 2). The sample was thoroughly mixed and three 4-point Proctors (modified, standard, and reduced) were performed at the field laboratory to compare against the line of optimums in the preconstruction AZ. A split of the sample was shipped to GeoSyntec for index and specific gravity tests.

The lines of optimums from the preconstruction AZ and from these three new samples were similar but varied slightly in slope. Therefore, these three new Proctor results were used to develop the construction-phase AZ included as Figure 6. The upper boundary of this new AZ was set at the modified Proctor optimum moisture content and the lower boundary was set at 95 percent of the standard Proctor maximum dry density. As with the preconstruction AZ, the construction-phase AZ was divided into the lower AZ and the upper AZ by drawing a line perpendicular to the ZAV curve and intersecting the standard Proctor optimum moisture content and maximum dry density. This was done to set target moisture and density ranges for the test fill in accordance with Table 6 of the Work Plan. The construction-phase AZ was used throughout the test fill CCL construction for acceptance of the in-place moisture content and dry density.

When approximately 40 percent of the CCL material had been processed, eight 5-gallon buckets of processed soil were obtained from over the surface of the process area and sent to GeoSyntec for use in the shear testing and chemical compatibility programs. Modified, standard, and reduced Proctors along with index tests were also performed on this sample. (Note: The site sample number is identified as "composite sample" on the laboratory report for this material.) Because the three Proctors were also performed on this material, an additional AZ can be developed from the sample to evaluate the sensitivity of the AZ development to minor variations in material properties and interlaboratory differences. Figure 7 is a graph comparing the three AZs (preconstruction AZ, construction-phase AZ, and this composite sample) developed from material obtained from within the double-lined cell footprint. Also, a standard Proctor test was performed in the field from material placed as Lift 6. The optimum moisture content and maximum dry density of this sample are also shown in Figure 7.

5.3.3 Placement and Compaction Monitoring

CCL placement and compaction commenced as described in Section 4.3.2 after a sufficient amount of CCL material had been processed, hydrated, and the construction-phase AZ developed. The maximum loose lift thickness of 8 inches was verified in the field by using the nuclear gauge's drive pin as a depth probe. Lift compaction began after the loose lift thickness had been verified. The number of passes made by the compactor over each lift was monitored to assess the relationship between number of passes and hydraulic conductivity. As stated in Section 4.0, a minimum of four passes was made by the compactor over Lane 1, six passes over Lane 2, and eight passes over Lane 3.

After the minimum number of passes was made, two test pads per lane (one on the slope section and one on the base section) were cut through the lift to the approximate surface of the underlying lift at random locations selected by CQA personnel. These locations were tested for in situ moisture content and dry density. In all cases except one (the slope section test location [Test No. 122] on Lane 2 of Lift 1), the in situ moisture content and dry density test result plotted within the construction-phase AZ after the minimum number of passes was made. Test No. 122 result did not plot within the AZ. Therefore, an additional two passes (for a total of eight passes) were applied to Lane 2 of Lift 2 to compact the material within the AZ.

Six locations were tested using nuclear methods for the field moisture content and dry density per lift. A three-digit numbering scheme was developed to number the test locations. The first digit in the test number is the lift number tested, the second number is the lane number tested, and the third number is either a 1 or a 2. A "l" in the last digit means the test location was on the base section. A "2" in the last digit means the test location was on the slope section. For example, Test No. 122 referenced above was taken on Lift 1 (first digit), Lane 2 (second digit), and the slope section (third digit). Figure 8 is a graph of the construction-phase AZ with the results of the in situ moisture content and dry density tests plotted on the graph.

At each nuclear test location, either a Shelby tube sample was obtained or a sandcone correlation test was performed. Except for Lift 3, five Shelby tubes and one sandcone correlation test were obtained on each lift. A sandcone correlation test was unable to be performed on Lift 3 because it began raining while testing of Lift 3 was ongoing. A Shelby tube sample was then obtained for each of the six Lift 3 test locations. Thirty-six locations were tested for the field moisture content and dry density. At these 36 locations, 31 Shelby tubes were obtained, and 5 sandcone correlation tests were performed. These locations are shown in Figure 3. The Shelby tubes were assigned the same sample number as the nuclear test number for that location and shipped to GeoSyntec for testing or archiving. Appendix F presents the results of the CCL testing performed in the field.

Either the dozer or compactor was used to cut the test pads for the field testing. In general, the test pads were cut 6 to 8 inches deep by 8 to 12 feet wide by 5 to 10 feet long. The same equipment was also used to fill and grade the test pad holes after testing was complete. Layer bonding and compacted lift thickness observations were also made in the test pads as the test pads were generally cut to the interface of the overlying and underlying lifts. This allowed rough measurements of compacted lift thickness to be obtained. In general, the compacted lift thickness was 5 to 6 inches. The degree of layer bonding was evaluated by the amount of peeling that occurred at the lift interface during cutting of the test pad. Generally, only a small degree of peeling at the lift interface was observed in the Test Pads meaning that layer bonding was acceptable. This was further verified in trenches excavated into the test fill during the block sampling. No delineation of layers was observed in vertical cuts made through the test fill.

During compaction of CCL lifts placed at lifts more than 3 percent wet of the standard Proctor optimum moisture content, it was observed that the compactor had increased difficulty climbing the slope section. The compactor speed slowed considerably, but no spinning of the compactor drums or tearing of the CCL material was observed. The field tests performed in these areas also were within the construction-phase AZ.

5.3.4 Block Sampling

Block sampling began on April 8, 1997, and was completed on April 9, 1997. Nine block samples were obtained from the test fill and shipped to GeoSyntec for testing or archiving. Each of these cylinder-shaped samples were 12 inches in height and 14 inches in diameter. The nine block sample locations were selected so that three of the samples were taken from the bottom foot of the test fill, three were taken from the middle foot, and three from the upper foot and also so that three samples were obtained from each of the three lanes.

Figure 3 also shows the locations of the nine block samples. A four-digit numbering scheme, similar to that used for the field moisture/density test numbers, was used for the block samples. As the block samples were 12 inches high, the first two digits represent the two lifts sampled (each lift is approximately 6 inches thick), the third digit represents the lane sampled, and the last digit represents the number of the sample in that lane (1, 2, or 3). For example, Block Sample Number 1212 was obtained from Lifts 1 and 2 (first two digits), in Lane 1 (third digit), and was the second sample (fourth digit) taken in Lane 1.

The block samples were obtained by excavating to the top of the sampling location and placing a sampling ring on top of the sample location. The sample rings were marked with the sample number and up direction. The sampling rings were fabricated from sections of Schedule 40 polyvinyl chloride (PVC) pipe, 12 inches high by 14 inches in diameter, with the inside edge of the bottom end of the pipe beveled at a 45 degree angle. When the sampling ring was in place, the backhoe excavated a 2- to 3-foot-deep trench around the sample. The inside wall of this trench was generally 1 to 2 feet from the outside of the sampling ring. When the trench was excavated, hand shovels were used to excavate within 1 to 2 inches from the outside of the sampling ring. Hand trowels and putty knives were then used to trim away the excess material. As this material was removed, the sampling ring was pushed over the sample using hand pressure. This methodology was followed until the entire ring was over the sample.

When the ring had been slid over the sample, the top of the sample was trimmed flush with the top of the ring, wrapped with shrink wrap (i.e., Saran Wrap), and taped. The bottom of the sample was extricated from the test fill by digging under the sample with a shovel and sliding the sample onto a steel plate. After extrication, the sample was carefully flipped upside down on top of a 16-inch by 16-inch by 1/2-inch sheet of plywood and the bottom trimmed, wrapped, and taped in the same manner as the top. A plywood sheet was then placed over this end, and the two sheets were tied together using nylon cord. At this point, the sample was transported from the test fill to the field laboratory. There, bubble wrap was wrapped around the samples and the samples placed in double-reinforced box (one box inside another) lined with plastic sheeting and additional bubble wrap. Wet paper towels were then placed within the box to provide a humid environment. The box was then sealed with shipping tape and shipped to GeoSyntec. Photographs of the block sampling and shipping procedures used are included in Appendix C.

5.3.5 Record Survey

A record survey was performed of the completed test fill prior to completing the block sampling. A record drawing showing the Test Fill 3 topography is included as Figure 5. As shown in Figure 5, the test fill surface, particularly the base section, was not graded evenly due to the weather conditions at the time of the survey. However, the record drawing does show that a minimum 3-foot thickness was generally maintained between Stations 0+20 and 2+10. This is a deviation from the 205-foot length included in the Work Plan but is not relevant to the evaluation of the test fill performance because only one test (No. 531) was performed outside these limits (see Figure 3).

6.0 POST-CONSTRUCTION LABORATORY TESTING

The post-construction laboratory testing consisted of performing hydraulic conductivity and index tests on the undisturbed Shelby and block samples. The laboratory test results are included in Appendix G. Of the 31 Shelby tubes obtained, 10 were tested to assess their hydraulic conductivity, and 1 was tested to obtain index property values. Of the 9 block samples obtained, 6 were tested to assess their hydraulic conductivity, and 3 were tested to obtain index property values.

As required by the Work Plan, essentially 2 hydraulic conductivity tests were performed on each sample tested; 1 at a 3 pounds per square inch (psi) effective stress (consolidation pressure) and 1 at a 10 psi effective stress. The consolidation pressure that will be applied to a full-scale CCL can be calculated by multiplying the average unit weight of overburden (protective soil, waste, etc.) by depth of the overburden. In general, as the consolidation pressure increases, the hydraulic conductivity decreases. The 3 psi consolidation pressure was selected to approximately represent the stress induced to a cover CCL (approximately 4 feet of overburden). The double-lined cell cover liner system does not include a CCL. Therefore, the 3 psi hydraulic conductivity test results are not applicable to the double-lined landfill cell. The 10 psi consolidation pressure was selected to conservatively represent the stress induced to a CCL placed as a bottom landfill liner (approximately 13 feet of overburden).

The results of the post-construction laboratory testing are summarized below:

Sample Type	Sample No.	Lift	Percent Fines	Liquid Limit	Plasticity Index	USCS Classi-fication	Dry Density (pcf)	Moisture Content (%)	Hyd. Conduc-tivity @ 3 psi (cm/s)	Hyd. Conduc-tivity @ 10 psi (cm/s)
Shelby	111	1					112.6	16.3	1.2E-8	5.3E-9
Shelby	112	1					109.3	17.7	4.7E-8	8.9E-9
Shelby	121	1					107.9	18.2	8.3E-9	2.8E-9
Shelby	122	1					113.8	15.1	1.9E-6	9.8E-7
Shelby	132	1					106.9	15.7	2.0E-5	2.1E-6
Shelby	231	2					111.1	17.8	2.0E-8	4.7E-9
Shelby	312	3					115.9	16.2	6.1E-9	1.7E-9
Shelby	412	4					111.2	18.4	6.0E-9	2.3E-9

Sample Type	Sample No.	Lift	Percent Fines	Liquid Limit	Plasticity Index	USCS Classification	Dry Density (pcf)	Moisture Content (%)	Hyd. Conductivity @ 3 psi (cm/s)	Hyd. Conductivity @ 10 psi (cm/s)
Shelby	511	5					109.4	19.1	1.2E-8	3.7E-9
Shelby	611	6	75	47	31	CL	104.8	22.0	6.4E-8	1.6E-8
Block	1211	1 & 2	73	42	27	CL	114.1	14.7	2.4E-8	3.6E-9
Block	1231	1 & 2					109.4	16.6	6.7E-8	7.2E-9
Block	3423	3 & 4					104.7	19.8	3.7E-8	3.7E-9
Block	3433	3 & 4	73	42	27	CL	104.8	20.9	6.9E-8	2.5E-9
Block	5613	5 & 6					106.4	19.5	7.0E-8	4.8E-9
Block	5621	5 & 6	74	43	27	CL	105.3	20.6	9.4E-8	3.7E-9

Except for Shelby Tube Sample Nos. 122 and 132, all of the undisturbed samples tested met the required hydraulic conductivity criteria at both 3 psi and 10 psi consolidation pressures. Sample No. 122 was obtained from Lane 2, which was compacted with eight passes of the compactor (six initially, plus two additional passes to attain a dry density with in the AZ). Sample No. 132 was taken from Lane 3, and was also compacted with eight passes of the compactor. Both of these failing samples were obtained from the slope section of Lift 1. However, Sample No. 112 was also obtained from the slope section of Lift 1 on Lane 1. This sample was compacted with only four passes of the compactor and easily met the required hydraulic conductivity. Additionally, the two block samples obtained and tested from the bottom foot of the test fill (Sample Nos. 1211 and 1231) easily achieved the required hydraulic conductivity as did two other Shelby tube samples (Sample Nos. 111 and 121) obtained from the base portion of the test fill's first lift. More discussion of the two failing samples is provided in Section 7.0.

Figure 9 is a graph showing the construction-phase AZ, the moisture content and dry density of the hydraulic conductivity samples tested, and their hydraulic conductivity values at a 3 psi consolidation pressure.

7.0 SUMMARY AND CONCLUSIONS

This section provides a summary of the information provided in the previous sections and presents the conclusions derived from the information.

7.1 Summary

Two CCL test fills (Test Fills 1 and 2) were constructed in 1994 as part of a feasibility study for an onsite landfill at RMA. The primary objective of these test fills was to verify that the use of onsite borrow soils is feasible for landfill CCL construction (i.e., could be moisturized and compacted to obtain a hydraulic conductivity of $1x10^{-7}$ cm/s or less). Though this primary objective was met, Test Fills 1 and 2 were not constructed using equipment and procedures that could be implemented productively for full-scale CCL construction as part of an onpost landfill. Thus, an additional test fill program (Test Fill 3) was implemented to verify that construction equipment and procedures conducive to full-scale construction could construct a CCL with a large-scale hydraulic conductivity of $1x10^{-7}$ cm/s or less and to provide information to the USACE to finalize the full-scale CCL construction specifications and CQA Plan currently being prepared as part of the landfill design.

As part of the Test Fill 3 program, an evaluation was performed of the hydraulic conductivity-related index properties of the two borrow areas currently being considered by the USACE as sources of CCL material for the full-scale construction. This evaluation was performed during preparation of (and presented in) the Work Plan. From the results of this evaluation, it was concluded that no significant differences in the index properties of both borrow areas exists and that the results of Test Fill 3 should be applicable to CCL material excavated from either borrow area.

Prior to Test Fill 3 construction, preconstruction laboratory testing was performed using a composite of two clay samples obtained from the future footprint of the RMA double-lined landfill cell. The methods and parameters used in the testing generally followed the methodology developed by Daniel and Benson (1990). Remolded hydraulic conductivity tests were performed on 12 sample points selected to cover the range of moistures and densities that may result in a hydraulic conductivity of less than

1×10^{-7} cm/s. All 12 samples tested resulted in a hydraulic conductivity of less than 1×10^{-7} cm/s. Based on this data, a preconstruction AZ was developed (Figure 2).

HLA began construction of Test Fill 3 on March 24, 1997. The CCL borrow material was obtained from the footprint of the double-lined landfill cell (Figure 1). The material was processed using a water truck and stabilizer. A Rome disc was also used to process part of the material placed as Lift 6. During the CCL material processing and prior to CCL placement, a composite sample was obtained from the process area, and Proctor and index tests were performed. The test results were then used to develop the construction-phase AZ (Figure 6) using the same criteria used to develop the preconstruction AZ.

The CCL material was placed in 8-inch maximum loose lifts and compacted to a 6-inch maximum compacted thickness. Six locations on each lift were field tested using a nuclear gauge to verify the material's in situ moisture content and dry density plotted within the construction-phase AZ (Figure 8). Either a Shelby tube or sandcone correlation test was obtained at each nuclear test location. Test Fill 3 was constructed to a 3-foot thickness by compacting seven 6-inch-thick (or less) lifts and then trimming off the majority of Lift 7.

The accuracy of the construction-phase AZ was verified during construction by performing another set of Proctors (modified, standard, and reduced) on a large composite sample obtained from the process area for use in the direct shear testing program. In addition, a check Proctor was performed in the field on a sample obtained from Lift 6.

Occasionally oversized rocks and cobbles (approximately one per scraper load) were observed in the CCL material. When observed, the oversized material was removed. The compactor also had some difficulty climbing the 3.5:1 slope at moisture contents greater than 3 percent wet of the standard Proctor optimum moisture content, but none of the test results indicated that this resulted in unacceptable hydraulic conductivity values.

Nine 12-inch-diameter block samples and thirty-one 2.8-inch diameter Shelby tubes were obtained from the test fill. Six block samples and ten Shelby tube samples were tested in the laboratory to obtain hydraulic conductivity values at both a 3 psi and a 10 psi consolidation pressure. All six block samples and eight of the ten Shelby tube samples tested resulted in a hydraulic conductivity of less than $1x10^{-7}$ cm/s. Index tests were also performed on four of these undisturbed samples. The index test results showed that the properties of all four samples were very similar (see Section 6.0) and classified the soil as a lean clay with sand (CL). These results also showed that the undisturbed samples were slightly finer and slightly more plastic than the borrow area averages.

7.2 Conclusions

Test Fill 3 was constructed in accordance with the objectives and intent of the Work Plan. The results of Test Fill 3 indicate that a hydraulic conductivity of less than $1x10^{-7}$ cm/s was obtained. Therefore, it can be concluded that the equipment and procedures used for the Test Fill 3 construction and described in this Summary Report can generally be incorporated into the full-scale CCL construction specifications and result in the required CCL hydraulic conductivity. Additional conclusions made during the test fill construction and evaluation are presented below:

- A cohesive subgrade or foundation layer may be required on the 3.5:1 slopes of the double-lined cell to allow enough traction for the compactor to travel up the slope without spinning its wheels. In areas of noncohesive soil where the compactor was able to traverse the slope, the compactor wheels spun and damaged the grade of the slope.
- Occasionally oversized rocks and cobbles were sporadically encountered in the CCL borrow material. Oversized rocks should be removed upon observation. However, these rocks are of limited concern to the performance of the CCLs due to the very small percentage (less than 1 percent) of the total CCL volume these rocks represent. This small percentage greatly minimizes the potential for two or more of these rocks to be placed adjacent to each other and thus create void spaces between the rocks that cannot be filled with finer material.
- A tractor pulling a Rome disc may possibly be used to process CCL material to a moisture range between the modified and the standard Proctor optimum moisture contents. However, it is recommended that the Rome disc only be used in addition to the stabilizer due to the Rome disc's inability to process the clay to a clod size of 2 inches or less. The Shelby tube (No. 611) and the block sample (No. 5613) tested from material processed with the Rome disc both achieved the required hydraulic conductivity.
- The highest degree of workability of CCL material placed within the AZ was observed at a moisture content between the modified Proctor optimum moisture content and approximately

2 percent above the standard Proctor optimum moisture content. The compactor performance was significantly reduced when compacting material wetter than approximately 2 percent of the standard Proctor optimum moisture content.

- The excavation, processing, placement, and compaction procedures used to construct Test Fill 3 resulted in a homogenous soil mixture. This is evidenced by a comparison of the Proctors performed during construction (Figure 7) and consistency of the 4 undisturbed sample and index test results. All of the Proctor results were within 3 percent and 5 pounds per cubic foot (pcf) of the other corresponding test method Proctor's optimum moisture content, and maximum dry density, respectively.

- The average percent fines, liquid limit, and plasticity index of the four undisturbed samples tested indicated these values are all within 11 points or less of the average values of the alluvial samples meeting the Table 1 criteria for both the CAMU Area and Borrow Area 5. This slight difference in index values can be attributed to effective visual screening of the Test Fill 3 borrow area excavation. Therefore, effective visual screening of the borrow excavation during full-scale construction will allow the results of Test Fill 3 to be applied to CCL material excavated from either borrow area and should result in CCL properties that classify the soil as CL material.

- The hydraulic conductivity test results of the eight passing Shelby tube samples correlated well with the results of the block samples. The volume of soil tested in the block samples was approximately 60 times greater than the volume of the Shelby tube samples. This indicates that no significant macro-scale defects were present in the block samples.

- The two Shelby tube samples (Nos. 122 and 132) that failed to attain the required hydraulic conductivity were both obtained from the slope section of Lift 1. The three other Lift 1 Shelby tube samples and the two block samples tested from the bottom foot of the test fill all easily attained the required hydraulic conductivity. The average hydraulic conductivity of the two failing Lift 1 Shelby tube samples (Sample Nos. 122 and 132) was 1×10^{-5} cm/s at a 3 psi confining pressure, whereas the average hydraulic conductivity of the three passing Lift 1 Shelby tube samples (Sample Nos. 111, 112, and 121) was 2×10^{-8} cm/s at a 3 psi confining pressure; a difference of three orders of magnitude. Additionally, the average of all 14 of the passing Shelby tube and block samples is 4×10^{-8} cm/s at a 3 psi confining pressure. It is likely that the two failing samples either accidentally contained part of the structural fill placed beneath Lane 1 or were disturbed at some point during sampling, shipping, or testing. Regardless of the exact reason why the two Shelby tubes failed, it is not believed that the failures were due to inadequate construction procedures. This conclusion is supported by: (1) the three orders of magnitude of difference between the average results of the passing and failing samples; (2) the comprehensive CQA effort implemented during the test fill construction; and (3) the Sample No. 112 hydraulic conductivity result of 5×10^{-8} cm/s at a 3 psi confining pressure achieved with a 50 percent less compactive effort than that given to the two failing sample locations (four passes for Sample No. 112 versus eight passes for Sample Nos. 122 and 132).

- Based on the information provided in this Summary Report, no additional test fill-related data needs are necessary for the CCL design or full-scale construction.

8.0 ACRONYMS

Army	U.S. Department of the Army
ASTM	American Society for Testing and Materials
AZ	Acceptable zone
backhoe	Case 580 backhoe
Borrow Study Report	Final Feasibility Study Soils Support Program Report
CAMU	Corrective Action Management Unit
CCL	Compacted clay liner
CDD	CAMU Design Document
CDPHE	Colorado Department of Public Health and Environment
CH	Fat clay
CL	Lean clay
cm/s	Centimeter per second
compactor	Caterpillar 825C Sheepsfoot Compactor
CQA	Construction Quality Assurance
cy	Cubic yard
dozer	Caterpillar D7H dozer
EPA	U.S. Environmental Protection Agency
FFA	Federal Facilities Agreement
FS	Feasibility Study
FWS	U.S. Fish and Wildlife Service
GeoSyntec	GeoSyntec Consultants
HLA	Harding Lawson Associates
Landfill FS Report	Final Landfill Site Feasibility Report for the Feasibility Study Soils Support Program
motor grader	Caterpillar 140G motor grader
pcf	Pounds per cubic foot
psi	Pounds per square inch

PVC	Polyvinyl chloride
PMRMA	Program Manager for Rocky Mountain Arsenal
RDC	Remedial Design Center
RMA	Rocky Mountain Arsenal
roller	Caterpillar CP563 Smooth Drum Roller
SC	Clayey sand
scraper	Caterpillar 62113 scraper
SDRI	Sealed double-ring infiltrometer
stabilizer	Caterpillar SS250 Soil Stabilizer
State	State of Colorado
Subsurface Report	Final Geotechnical Investigation Report, Hazardous Waste Landfill
Summary Report	Test Fill Construction Program Summary Report
SWIP	Sitewide Implementation Plan
TSBP	Two-stage borehole permeameters
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
UXO	Unexploded Ordnance
water truck	GMC TC7 4,000-gallon water truck
Work Plan	Find Work Plan for the Test Fill Construction Program
ZAV	Zero Air Voids

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Table 1: Raw Borrow Soil Index Property Criteria

Test	Low Permeability Soil Criteria	Test Method
Grain-size distribution	100 percent passing 1-inch sieve* ≥40 percent passing No. 200 sieve > 95 percent passing No. 4 sieve	ASTM D422
USCS classification	SC, CL, or CH	ASTM D2487
Organic content (by weight)	< 5 percent	ASTM D2974
Carbonate content (by weight)	< 5 percent	ASTM D4373

Processsed soil shall be ≥50 percent passing No. 200 sieve, shall classify as either CL or CH, and meet the other requirements above.

>	Greater than
≥	Greater than or equal to
<	Less than
ASTM	American Society for Testing and Materials
CH	Fat clay
CL	Lean clay
LL	Liquid limit
PI	Plasticity index
SC	
USCS	Unified Soil Classification

* Top lift shall be 100 percent passing the 1/2-inch sieve.

Table 2: Test Fill 3 Construction Equipment

Caterpillar D7H Dozer

Caterpillar 825C Sheepsfoot compactor

Caterpillar 621B Scraper

Caterpillar SS250 Soil Stabilizer

Caterpillar 140G Motor Grader

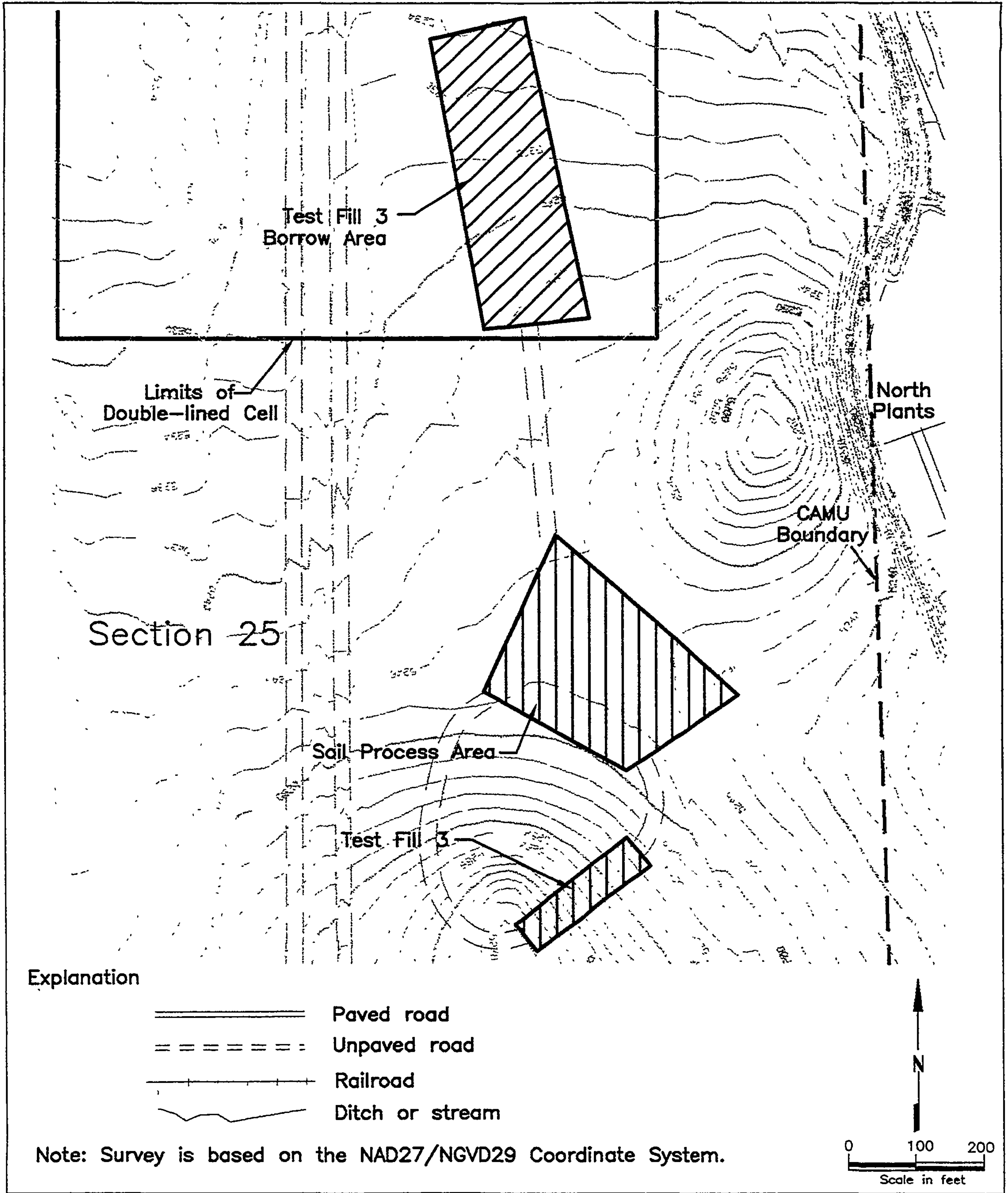
Caterpillar CD563 Smooth Drum Roller

Case 580E Backhoe

International 73000DBP 4-wheel drive tractor with 24-inch diameter Rome disc

GMC TC7 4,000-gallon water truck

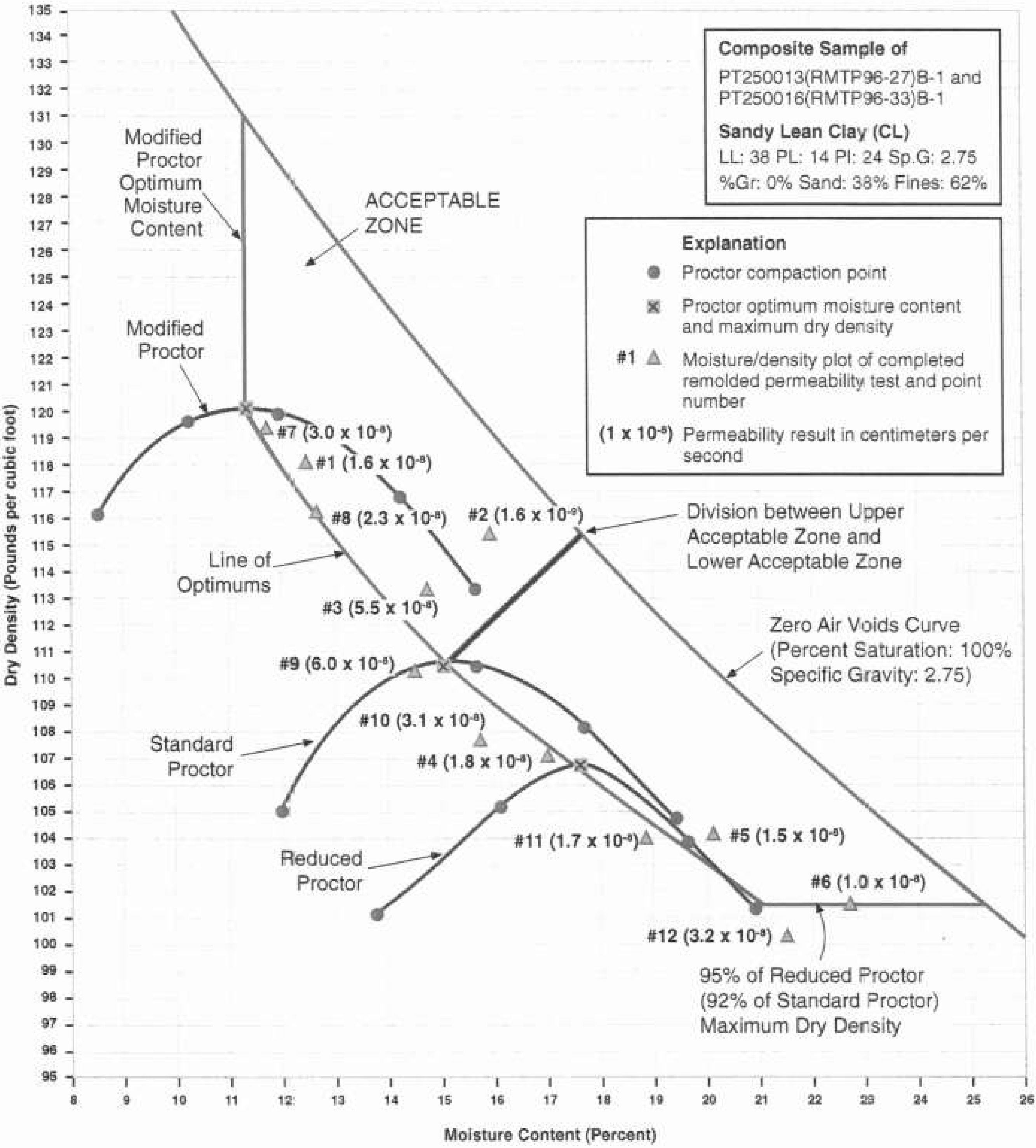
21907/CAD/DESIGN/TFLSBPAB 6/5/97 LDZ



Note: Survey is based on the NAD27/NGVD29 Coordinate System.

Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado Prepared by: Harding Lawson Associates	Figure 1 Site Plan Test Fill 3 Record Drawing

RMA 1276.2b 6/4/97 NLM



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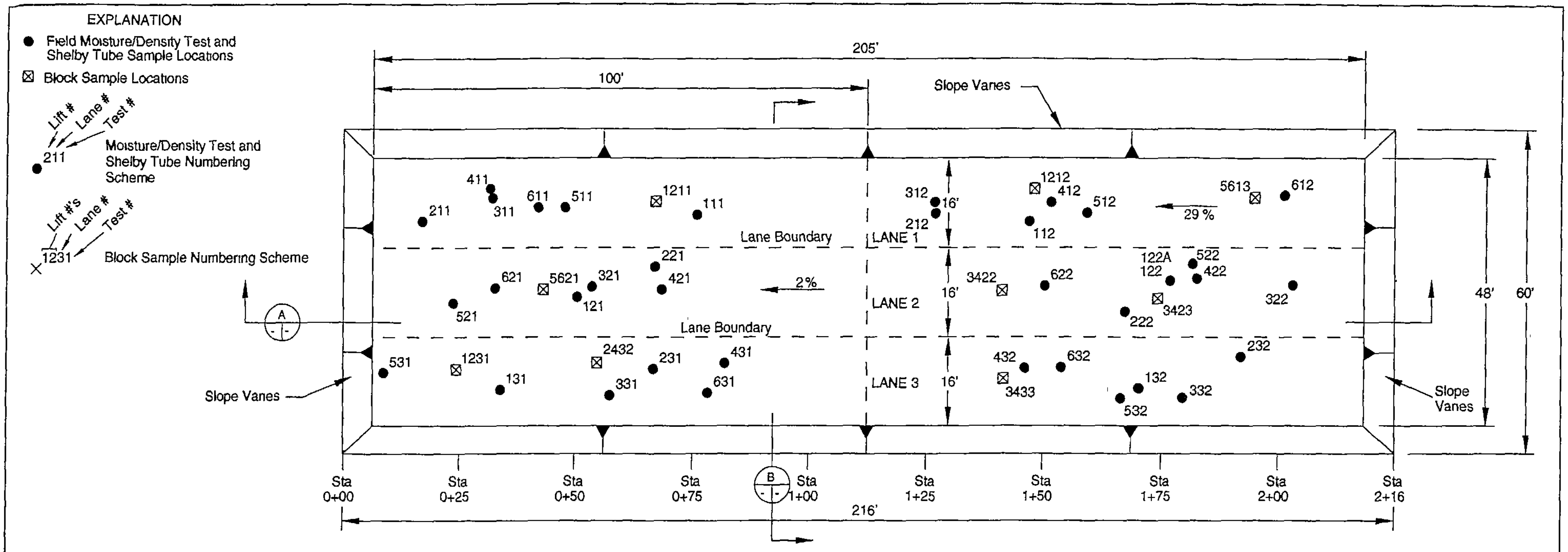
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
Harding Lawson Associates

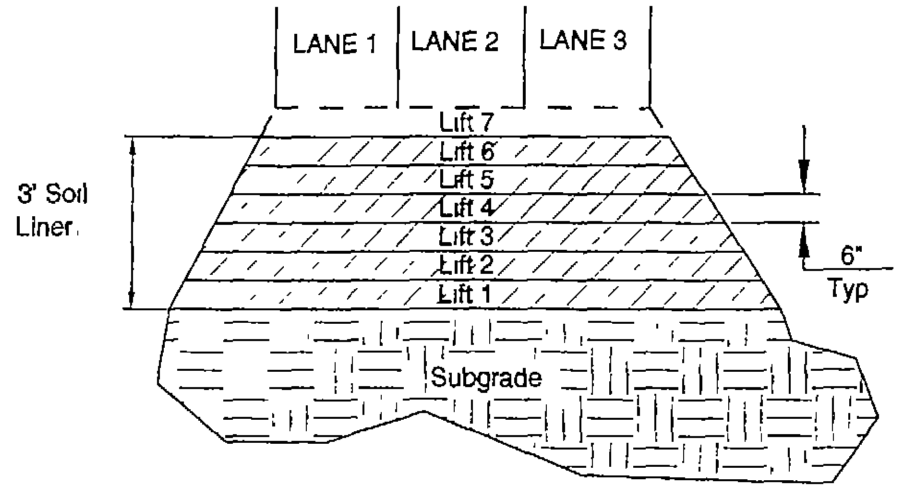
Figure 2

Pre-Construction Acceptable Zone
Test Fill 3 Construction Program



Test Fill 3 Plan View

Scale 1" = 20 Feet



B SECTION
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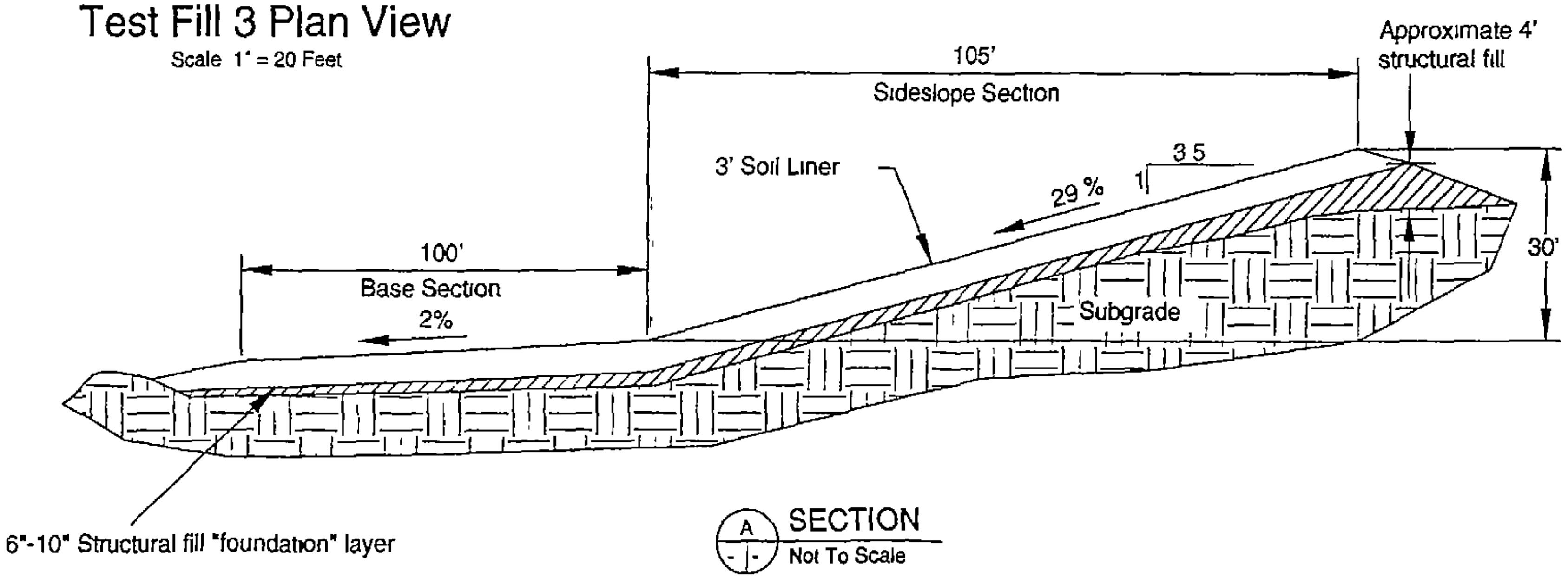

A SECTION
Not To Scale

Prepared for
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by.
Harding Lawson Associates

Figure 3
Test Fill 3 Plan View, Cross Sections, and Sampling and Test Locations

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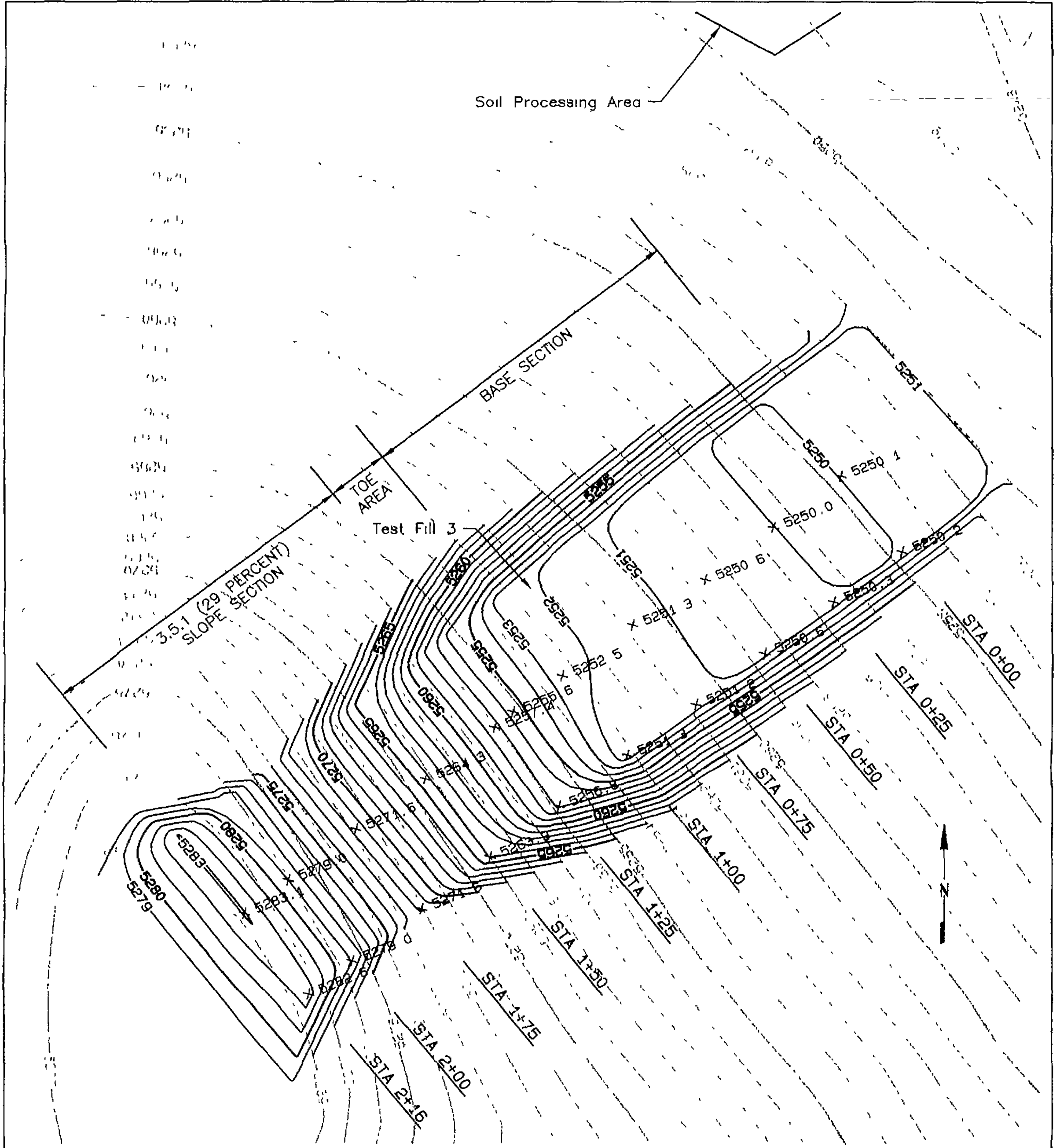

Explanation

— 5251 — **Prepared subgrade contour**

5250 **Existing grade contour**

Note: Survey is based on the NAD27/ NGVD29 Coordinate System.

0 15 30
Scale in feet

Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado Prepared by: Harding Lawson Associates	Figure 4 Subgrade Plan Test Fill 3 Record Drawing

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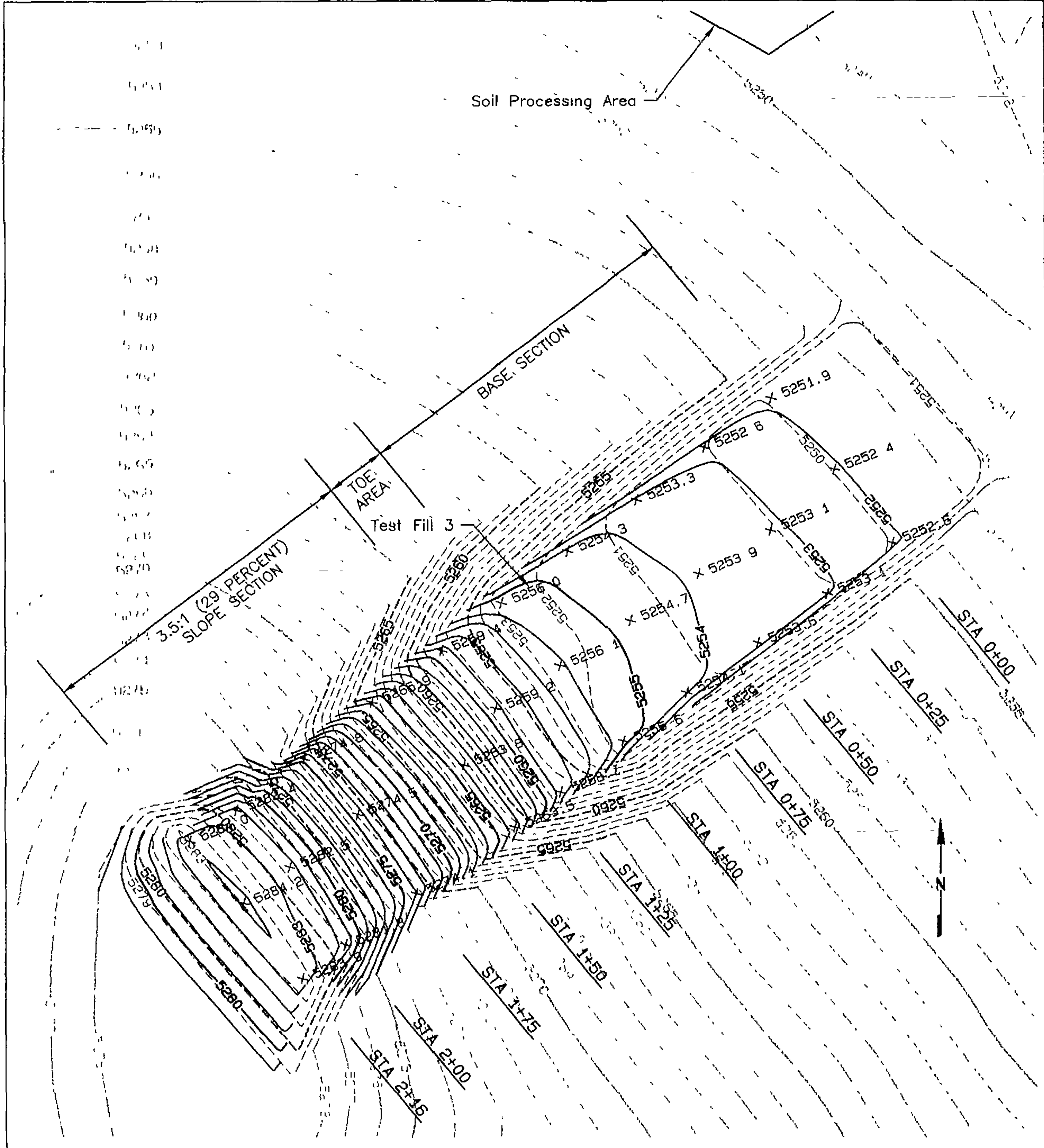

Explanation

—5250— **Clay grade contour**

--5250-- **Prepared subgrade contour**

5250 **Existing grade contour**

Block sample

Note: Survey is based on the NAD27/ NGVD29 Coordinate System.

0 15 30
Scale in feet

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Figure 5
Finish Grade Plan
Test Fill 3 Record Drawing

RMA 1276.2c 6/4/97 NLM

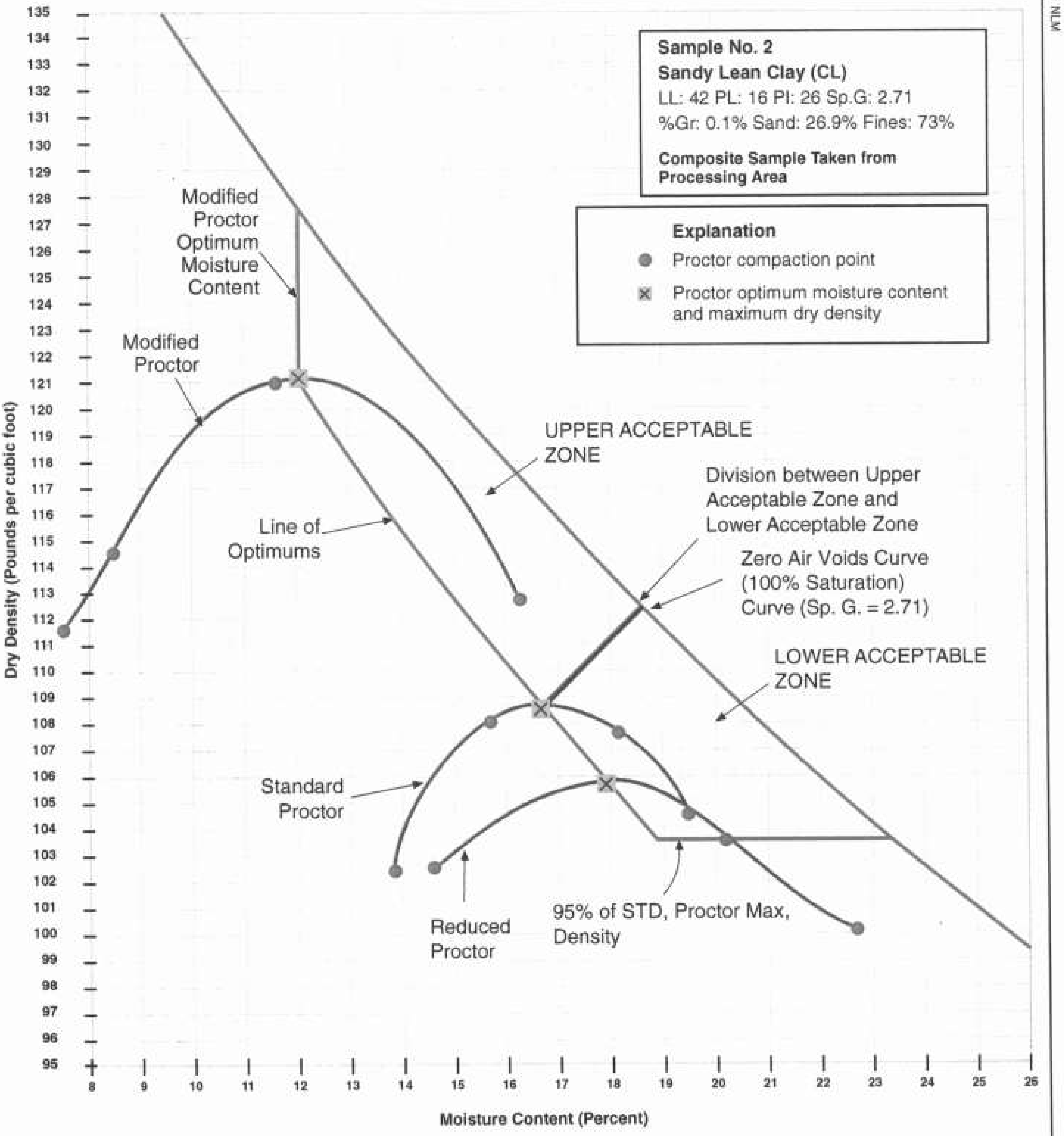

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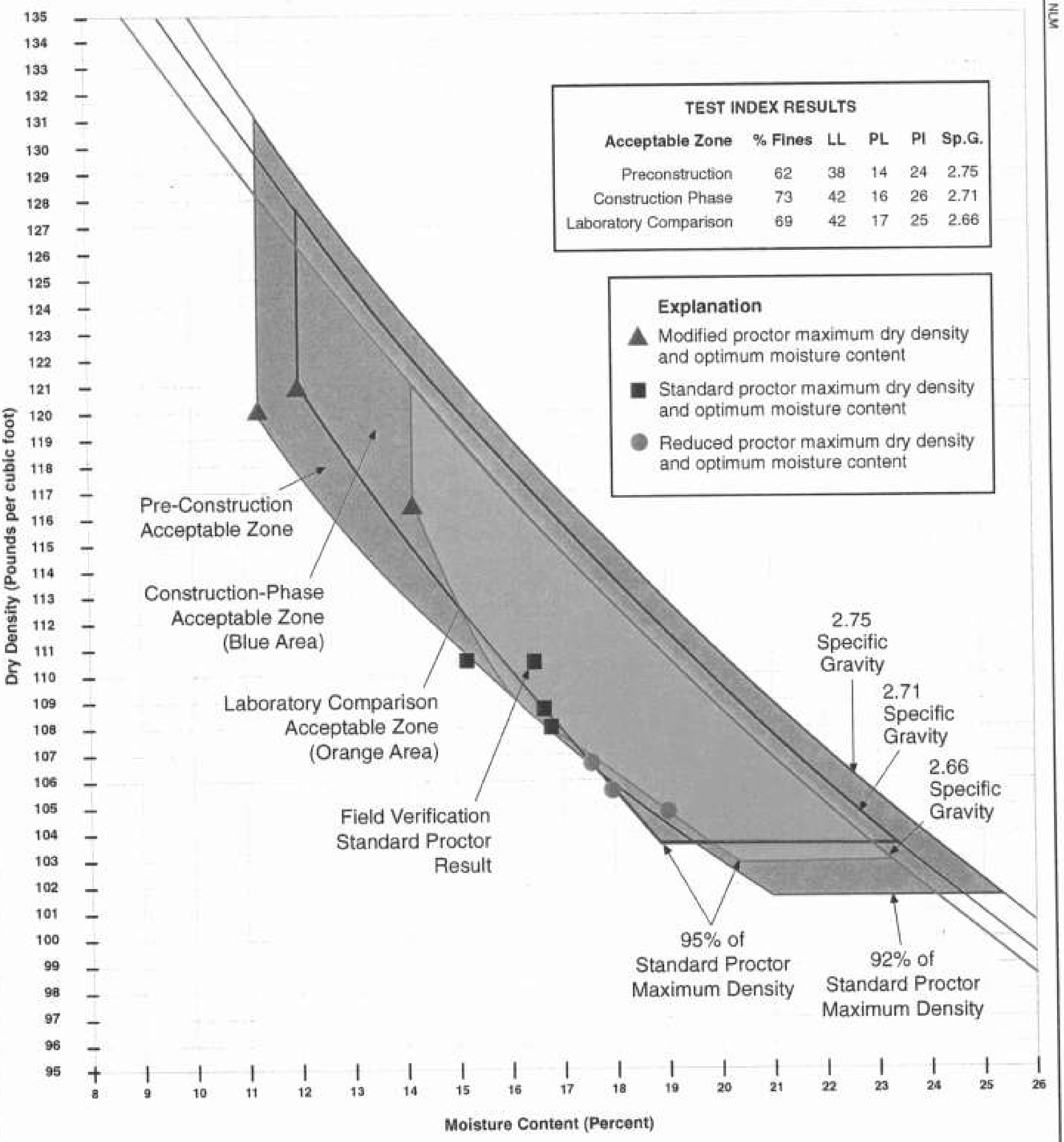
Figure 6

Construction-Phase Acceptable Zone
Test Fill 3 Construction Program

RMA 1276.2I 6/4/97 NLM



TEST INDEX RESULTS

Acceptable Zone	% Fines	LL	PL	PI	Sp.G.
Preconstruction	62	38	14	24	2.75
Construction Phase	73	42	16	26	2.71
Laboratory Comparison	69	42	17	25	2.66

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Figure 7

Proctor and Acceptable Zone Comparison
Test fill 3 Construction Program

RMA 1276.2d 6/4/97 NLM

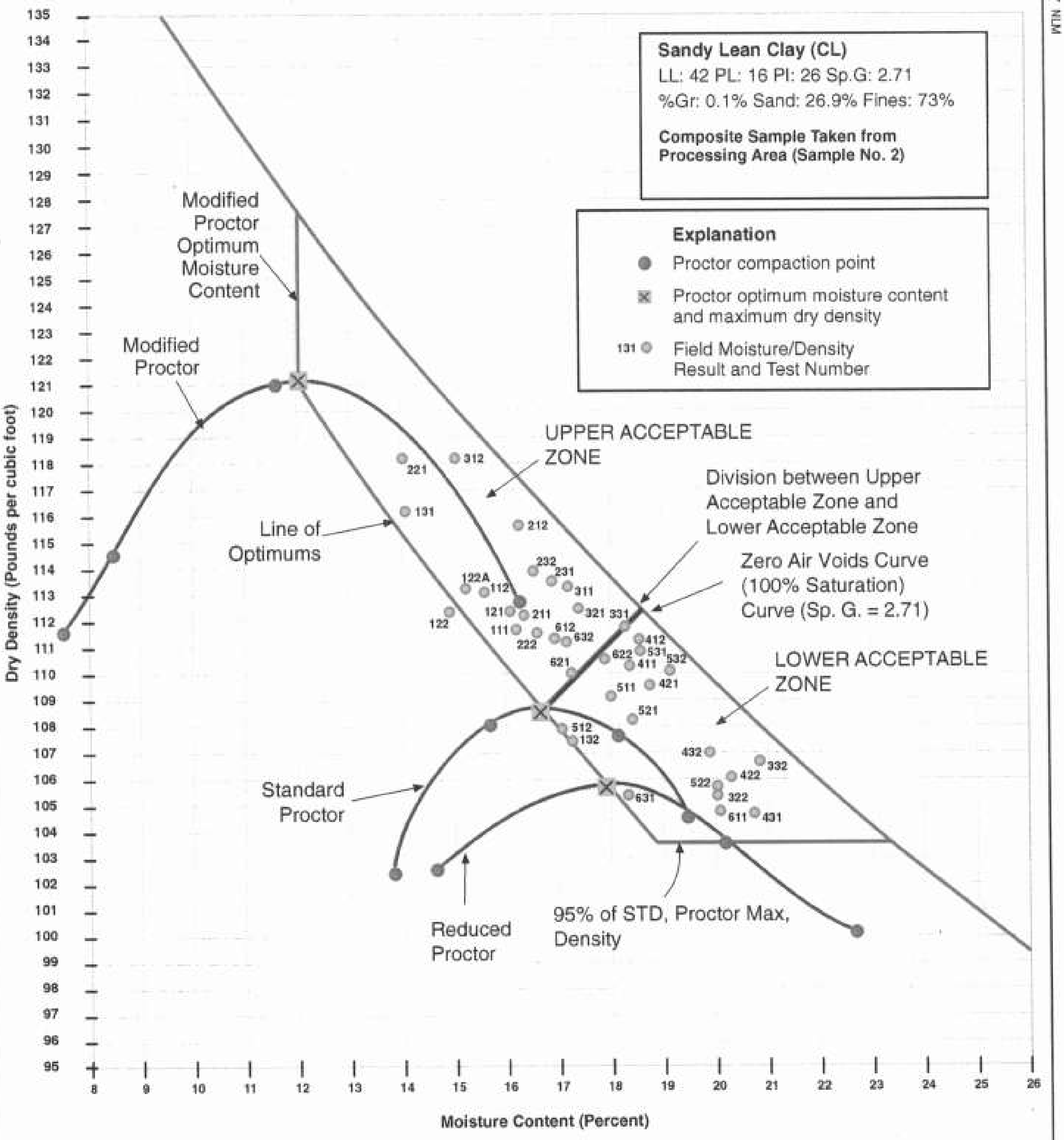

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Figure 8

Plot of Field Moisture/Density Test Results
Test Fill 3 Construction Program

RMA_2G 12/24/97 NLM

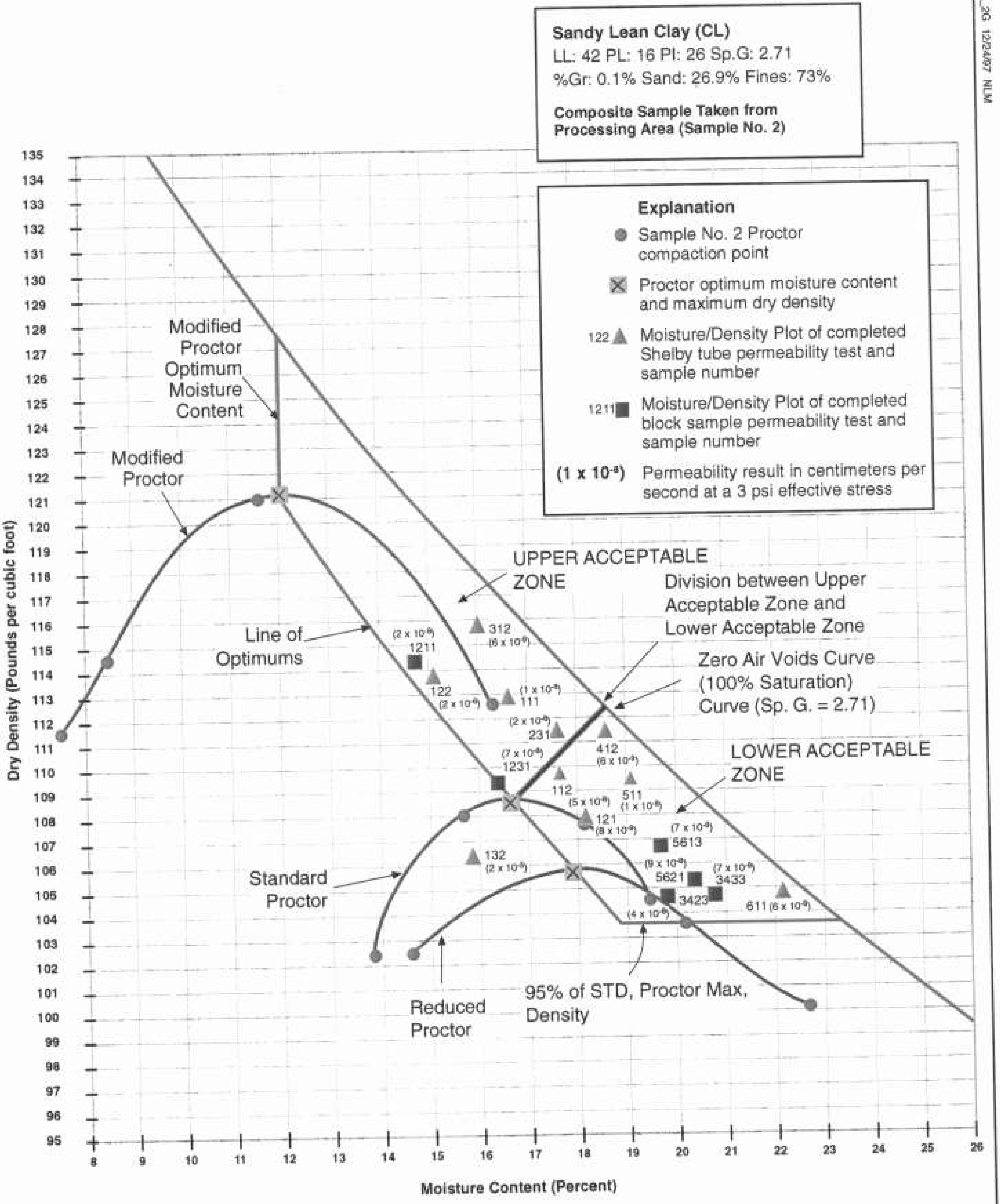

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Figure 9

Plot of Hydraulic Conductivity Test Results at a 3 psi Effective Stress Test fill 3 Construction Program

Appendix A

FINAL WORK PLAN FOR THE TEST FILL CONSTRUCTION

Technical Support For Rocky Mountain Arsenal

Final Work Plan for the
Test Fill Construction Program, Feasibility Study Soils Support Program Rocky Mountain Arsenal Commerce City, Colorado

Prepared for

Program Manager for Rocky Mountain Arsenal
Building 111, Rocky Mountain Arsenal
Commerce City, Colorado 80022-2180

HLA Project No. 21907 102010.6
Contract No. DAAA05-92-D-0003
Delivery Order No. 0007 (Task 93-03)

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATIVE RECORD FOR THIS CERCLA OPERABLE UNIT.

March 14, 1997

Harding Lawson Associates
Engineering and Environmental Services
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Denver, CO 80202 - (303) 292-5365

CONTENTS

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APPENDIXES

1.0 INTRODUCTION

This Test Fill Work Plan (Work Plan) has been prepared in support of the Corrective Action Management Unit (CAMU) design currently being prepared by the U.S. Army Corps of Engineers (USACE) as part of the remedy for cleanup of the Rocky Mountain Arsenal (RMA). This Work Plan sets forth the procedures for construction, testing, and evaluation of Test Fill 3. The results of Test Fill 3 will be incorporated into the construction specifications and construction quality assurance plans for full-scale landfill compacted clay liner (CCL) construction.

This Work Plan has been prepared by Harding Lawson Associates (HLA) as a contract deliverable under Delivery Order 0007 (Task 93-03, Feasibility Study Soil Support Program) of Contract No. DAAA05-92-D0003 between HLA and the U.S. Department of the Army (Army). This document has been prepared at the direction of the Army for the sole use of the Army, the signatories of the Federal Facilities Agreement (FFA) of RMA, the State of Colorado (State), Adams County, and the Tri-County Health Department, the only intended beneficiaries of this work. This document has been prepared for test fill construction at RMA and should not be used for any other purpose.

1.1 Background

Two CCL test fills (Test Fills 1 and 2) were constructed in the southeast portion of Section 25 during the summer of 1994. The primary objective of this program was to demonstrate that a hydraulic conductivity of 1 x 10^{-7} centimeters per second (cm/s) or less could be achieved with the onsite clayey soil. The secondary objective of this program was to use construction equipment and procedures to construct Test Fills 1 and 2 that are condusive to high-production construction of CCLs. However, due to the unavailability of equipment to do so, this objective was unable to be accomplished. The soil used for Test Fills 1 and 2 was obtained from borrow areas located within 2 miles of Section 25. The field-scale hydraulic conductivity of each of these two test fills was evaluated using a sealed double-ring infiltrometer (SDRI) and two-stage borehole permeameters (TSBP). The results of these field-scale tests indicated that a hydraulic conductivity of 1 x 10^{-7} cm/s or less was achieved. The results of Test Fills 1 and 2 are presented in the Final Landfill Site Feasibility Report for the Feasibility Study Soil Support

Program, (Landfill FS Report) (HLA, 1995a) included as Appendix R of the CAMU Designation Document (CDD).

While results for Test Fill 1 and 2 indicated that minimum hydraulic conductivity can be achieved with onsite soil, a letter dated August 30, 1995, to the Program Manager for Rocky Mountain Arsenal (PMRMA) from the Colorado Department of Public Health and Environment (CDPHE), requested that:

- Compaction equipment, such as a Caterpillar 825, be evaluated to improve the efficiency of soil liner compaction.
- The full-scale construction specifications reflect the lift thicknesses achieved in the field in constructing Test Fill 3.
- Test Fill 3 provide data to write specifications on equipment and methods used to condition soil moisture and reduce clod size.
- Test fill procedures include curing time for uniform absorption and hydration of soil particles when the moisture variance is increased by more than 3 percentage points. These procedures should be refined in the test fill program and carried forth into the full-scale construction specifications.
- The test fill procedures for reconditioning soils for moisture content should be carried into the full-scale construction specifications.

Thus, Test Fill 3 will be constructed to:

- Respond to the above listed requests made by CDPHE.
- Provide additional test fill data that will allow the landfill designer to finalize construction specifications and construction quality assurance (CQA) procedures for CCLs based on the findings of the Test Fill 3 program.

1.2 Purpose and Scope

The purposes of the test fill program outlined in this Work Plan are described below:

1. Provide data to the Army that will allow the USACE to develop CCL construction specifications that will achieve a hydraulic conductivity of $1x10^{-7}$ cm/s or less using equipment and procedures for CCL moisture conditioning, placement, and compaction that will allow full-scale CCL construction to be performed in a productive and cost-effective manner.
2. Evaluate the similarity of geotechnical properties of two potential CCL material borrow areas at RMA. One of these areas (Site-Wide Implementation Plan [SWIP] Borrow Area 5) is identified as Borrow Area 1 in the Final Feasibility Soil Support Program Report (Borrow Study Report) (HLA, 1995b). The second area is the clayey soil within the CAMU area identified in the

CAMU Designation Document (HLA, 1996). This evaluation will be performed to identify if results of Test Fill 3 can be applied to the borrow area not used to construct Test Fill 3.

3. Define any additional test fill data needs for future landfill construction that exist after construction and testing of Test Fill 3.

The scope of the test fill program described in this Work Plan includes the following activities:

- Preparing; submitting, and obtaining approval of this Work Plan.
- Tabulating and analyzing geotechnical index properties (i.e., percent fines [percent of sample passing a No. 200 sieve], liquid limit, plasticity index), submitting a proposed borrow area consistency assessment along with the supporting documentation to the regulatory agencies for approval, and selecting which of the two potential borrow areas will be used for Test Fill 3 construction (discussed in Section 3.0).
- Performing preconstruction testing and laboratory testing to obtain additional geotechnical index parameter data and establish the relationship between moisture, density, and hydraulic conductivity of Test Fill 3 borrow material (discussed in Section 4.0).
- Constructing the test fill using equipment, procedures, and specifications that will result in a hydraulic conductivity of 1 x 10^{-7} cm/s or less and that can be effectively implemented for full-scale construction (discussed in Section 5.0).
- Performing CQA monitoring and testing during construction of the test fill (discussed in Section 6.0).
- Regrading and revegetating the test fill borrow and process areas and covering the completed Test Fill 3 with a geomembrane and soil cover (discussed in Section 5.0).
- Performing post-test fill construction laboratory testing to verify that a hydraulic conductivity of 1 x 10^{-7} cm/s or less was achieved preparing CCL construction specification recommendations that incorporate the procedures and equipment used to construct Test Fill 3 (discussed in Section 7.0).
- Preparing, submitting, and obtaining approval of the Test Fill Program Summary Report (discussed in Section 7.0).
- Reviewing data from all test fills and identifying additional future data needs.

A CQA effort will be incorporated into construction of the test fill. The test fill will be constructed by an earthwork contractor (Contractor) experienced in low-permeability soil (clay) liner construction. CQA will be performed by a CQA Engineer (Engineer) who will direct the Contractor activities and perform tests and observations to evaluate the effectiveness of the construction procedures and equipment in achieving the required hydraulic conductivity at a workable moisture content range, and at an achievable dry density range. The Contractor will work as a subcontractor to the Engineer.

Draft full-scale CCL construction specifications and draft full-scale CCL CQA requirements are being prepared by the USACE and will be submitted to the regulatory agencies for review as part of the 30 percent CAMU design package. These documents have been prepared in conjunction with the CCL specifications given in Section 5.0 and the CCL CQA requirements given in Section 6.0. The equipment, procedures, and test results of Test Fill 3 will be used to finalize the full-scale CCL specification and CQA requirements.

Test Fill 3 will be constructed on both a flat (2 percent) slope and a side (29 percent or 3.5 Horizontal: 1 Vertical) slope in lifts placed parallel to the slopes. These slopes are consistent with those currently being considered for design of the landfill cell floor and sideslopes. If it is observed during construction of the test fill that CCL construction parallel to a 29 percent slope will not be feasible, the test fill side slope section may be flattened to a slope that is feasible for CCL construction parallel to the slope. Test Fill 3 will be constructed within the CAMU area (Sections 25 and 26) using onsite clayey soil to be excavated for construction of the double-lined landfill cell. Figure 1 shows the locations of Test Fills 1, 2, and 3 and the Test Fill 3 borrow and soil processing areas. Figure 2 shows a plan view and cross sections of Test Fill 3. Figure 3 shows the Test Fill 3 borrow area and excavation grading plans.

Large-scale hydraulic conductivity (i.e., hydraulic conductivity measured over a large enough area to include CCL macrostructures) will be evaluated by obtaining large diameter (typically 12 inches) undisturbed soil liner samples and testing them in specially designed flexible wall permeameters in the same manner as small diameter (2.8 inches) sleeve (Shelby tube) samples and in accordance with American Society for Testing and Materials (ASTM) D5084. The large diameter undisturbed samples are commonly referred to as "block" samples in published literature. Published comparisons between the hydraulic conductivity of large-scale block samples and the hydraulic conductivity of SDRIs have shown little variation in test results (Benson et al., 1993) except, in cases where little or no CQA was performed. A discussion of the hydraulic conductivity evaluation for Test Fill 3 is presented in Section 6.6.3.

1.3 Organization

The remainder of this Work Plan is divided into seven sections. Section 2.0 provides a discussion of recent U.S. Environmental Protection Agency (EPA) guidance and other reference documents applicable to test fill construction. Section 3.0 presents a comparison of geotechnical property data for the two potential Test Fill 3 borrow areas, provides technical rationale for why these two areas are sufficiently similar geotechnically, and identifies the double-lined cell excavation area as the specific area to be excavated for Test Fill 3 construction. Section 3.0 also provides an estimate of the CCL volumes needed for the double-lined landfill cell construction and a discussion of the volume of potential CCL material available within the double-lined cell excavation and Borrow Area 5. Section 4.0 describes the preconstruction laboratory testing activities and data interpretation methodology. Section 5.0 provides the procedures for construction of the test fill. Section 6.0 provides the CQA procedures for construction of the test fill. Section 7.0 provides requirements for the post-construction testing and the summary report to be generated at the conclusion of test fill construction and post-construction laboratory testing. Section 8.0 provides a list of acronyms, and Section 9.0 is the bibliography.

2.0 REFERENCED DOCUMENTS

Appendix I of the CDD, entitled “Conceptual Test Fill Work Plan,” was used as the primary reference in preparing this Work Plan. In addition, EPA guidance documents entitled "Quality Assurance and Quality Control for Waste Containment Facilities" (EPA, 1993) and "Requirements for Hazardous Waste Landfill Design, Construction, and Closure" (EPA, 1989) were also used to prepare this Work Plan. Other older EPA guidance documents discuss test fill construction and the contents of these documents were also considered in preparing this Work Plan. However, the two EPA documents referenced above, the published information referenced in these EPA documents, and other recently published documents were used as primary references in preparing this Work Plan. References used to compile this Work Plan are given in the bibliography in Section 9.0.

3.0 BORROW AREA EVALUATION AND SELECTION

Appendix I of the CDD states that the four borrow areas identified in the Borrow Study Report and clayey soil located within the CAMU area will be evaluated during the design phase of the landfill to: (1) identify borrow areas that contain clayey soil, which has sufficiently similar geotechnical properties and which can be processed to attain the required minimum strengths and permeabilities for the full-scale CCLs; (2) identify the borrow area soil to be used for Test Fill 3 construction; and (3) identify which borrow area soil the results of Test Fill 3 will be applicable to. Currently, the USACE is considering only the use of two of the five borrow areas identified in Appendix I of the CDD. This section provides an evaluation of the two borrow areas, presents a rationale of why the clayey soil within these two areas have sufficiently similar geotechnical properties, and identifies the clayey soil within the footprint of the double-lined cell as the specific portion of the CAMU area to be used for construction of Test Fill 3.

3.1 Previous Studies

The Borrow Study Report was published in January 1995. This report evaluated potential CCL material borrow areas at RMA and defined four areas that, based on geotechnical property data from each of the areas, contained potentially acceptable CCL material in substantial volumes. Because of U.S. Fish and Wildlife Service (FWS) concerns over disturbing three of these areas, only one of the four areas remains under consideration by USACE as a CCL material source for landfill construction. To be consistent with the Sitewide Implementation Plan, this area, referred to as Borrow Area 1 in the Borrow Study Report and the CDD, is hereinafter referred to as Borrow Area 5 in this Work Plan. Borrow Area 5 is located immediately north of the landfill CAMU boundary in the southern portion of Section 24. Numerous index (i.e., sieve analysis, Atterberg limits), remolded permeability, and other geotechnical tests were performed on 28 samples obtained from 9 subsurface borings drilled within Borrow Area 5 to a nominal 20-foot depth. All samples were classified in accordance with the Unified Soil Classification System (USCS). Tables 3.2 and 3.3 of the Borrow Study Report present results of the remolded permeability and index tests, respectively. These tables are included as Appendix A.

The Landfill Feasibility Study (FS) Report was published in July 1995. This report identified the general location of the CAMU area as a feasible site for the landfill. As part of this work, 30 subsurface borings were drilled to a nominal 50-foot depth in or near the CAMU area. Numerous index and other geotechnical tests were performed on 360 samples obtained from the 30 subsurface borings. Table 4.5 of the Landfill FS Report presents index test and moisture content test results. Table 4.6 of the Landfill FS Report presents standard Proctor, permeability, shrink, and swell test results. Tables 4.5 and 4.6 are included as Appendix B.

During summer and fall of 1996, the USACE performed a subsurface investigation within both the Landfill CAMU area and Borrow Area 5. Results of this investigation are presented in the Final Geotechnical Investigation Report, Hazardous Waste Landfill, Rocky Mountain Arsenal (Subsurface Report) (USACE, 1996). As part of the USACE subsurface investigation, a total of 29 borings and 22 test pits were completed within the Landfill CAMU area, and 27 test pits were excavated within Borrow Area 5. Numerous visual and laboratory (using index test results) USCS soil classifications were performed on samples obtained from these borings and test pits to evaluate suitability of the alluvial clays and weathered bedrock clays found in these areas. After completion of the soil classifications, Proctor compaction (standard and modified), and remolded permeability tests were performed on both alluvial and weathered bedrock clay samples collected from within the expected footprint of the double-lined cell. Results of these tests are presented in Appendix F of the Subsurface Report. Tables T-3 through T-6 of the Subsurface Report summarize the results of the laboratory testing and are attached as Appendix C.

Based on the results of the subsurface investigation, the USACE recommended that weathered bedrock clays not be used for CCL construction due to the variability of the material and difficulties encountered in processing this material. Therefore, Test Fill 3 will use only alluvial clay.

Figure 4 shows the locations of previous HLA borings in Borrow Area 5 (described in the Borrow Study Report), and the CAMU area (described in the Landfill FS Report), and also shows the locations of the USACE borings and test pits in both Borrow Area 5 and the CAMU area.

3.2 Borrow Area 5

As shown on Figure 3, the southern boundary of Borrow Area 5 is located approximately 1,000 feet north of the northern boundary of the Landfill CAMU area. Borrow Area 5 encompasses an area of approximately 140 acres and contains predominantly alluvial lean clays with lesser amounts of high plasticity (fat) clays, clayey sands, and silty sands in the upper 8 to 10 feet of the area's soil profile. According to the Subsurface Report, approximately 1.8 million cubic yards of potential CCL material are located within Borrow Area 5.

To evaluate the suitability and variability of the alluvial soil within Borrow Area 5, all of the geotechnical sample data from the Borrow Study Report and the Subsurface Report were combined to develop Table 2. The sample data in Table 2 were then screened using the index property (USCS classification, liquid limit, plasticity index, and percent fines) criteria presented in Table 1. (Table 1 is consistent with the minimum criteria given in Appendix I, Section 4.1 of the CDD with the exception of percent fines, which was conservatively raised from a minimum of 30 percent to a minimum of 40 percent.) The samples with any data points not meeting Table 1 criteria are identified in Table 2 by shading.

To statistically analyze the alluvial soil samples obtained from within Borrow Area 5, the number of data points for each index property, along with the maximum, minimum, average, and standard deviation for each index property were calculated for all of the alluvial samples and also just those meeting the Table 1 index property criteria. Moisture content and sample depth data were also included for informational purposes. These data are data is presented at the end of Table 2. As shown on Table 2, many more data points exist for the USCS classification (ASTM 2488) and moisture content than for other parameters. This is because these data were collected under two separate studies where the same tests were not performed on all samples. A number of samples obtained during compilation of the Subsurface Report had only visual USCS classifications (ASTM 2488) and moisture content tests performed. The average index property values of all of the Borrow Area 5 alluvial soil and the Borrow Area 5 alluvial soil samples that meet (pass) the Table 1 index property criteria are summarized below:

	Average		Maximum		Minimum		Std. Deviation		Number of Samples		
Index Property	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	Percent Meeting Table 1
USCS Classification	CL	CL	CH	CH	Sand	SC	N/A	N/A	188	166	88
Percent fines	57	66	85	85	5	42	20	13	62	44	71
Liquid Limit	38	39	77	55	21	30	10	6	61	45	74
Plasticity index	21	22	55	34	7	13	8	5	61	45	74

Note that the percentages reported in the far right column above only represent the percentage of the samples obtained from within Borrow Area 5, not the percentage of soil within Borrow Area 5. The soil sample locations were not evenly distributed to represent a consistent volume of soil per sample. As shown in Figure 4, many more samples were obtained in the eastern one-third of Borrow Area 5 than in the western two-thirds.

3.3 CAMU Area

The CAMU area extends over approximately 240 acres. It is located in the western half of Section 25 and extreme eastern portion of Section 26. Near-surface geology of the CAMU area consists of a few feet to 50 feet of alluvial soil overlying weathered bedrock. The alluvial soil, as with Borrow Area 5, consist primarily of lean clays with lesser amounts of clayey sands, silty sands, and occasional thin seams of fat clay. The weathered bedrock consists of weathered shale, claystone, and sandstone.

To evaluate the suitability and variability of the alluvial soil within the CAMU area, Table 3 was developed in the same manner as Table 2 for Borrow Area 5. That is, all of the index and moisture content test results, sample depths, and USCS classifications from each sample obtained as part of the work described in the Landfill FS Report and Subsurface Report were combined to develop Table 3.

The sample data in Table 3 were then screened using the Table 1 criteria and the samples with any data points that do not meet the Table 1 criteria were shaded.

The CAMU area alluvial soil was statistically analyzed in the same manner as Borrow Area 5. The average index property values of all of the CAMU area alluvial soil and the CAMU area alluvial soil samples meeting the Table 1 criteria are summarized below:

	Average		Maximum		Minimum		Std. Deviation		Number of Samples		
Index Property	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	Percent Meeting Table 1
USCS Classification	CL	CL	CH	CH	Sand	SC	N/A	N/A	384	300	78
Percent fines	52	63	95	95	2	40	21	12	197	135	69
Liquid Limit	39	40	63	60	17	30	8	7	182	141	77
Plasticity index	22	23	42	39	4	13	7	6	182	141	77

Again, the percentages reported in the far right column above only represent the percentages of the samples taken, not the percentages of the volume of alluvial soil in the CAMU area. As shown in Figure 4, many more samples were taken in the eastern half of the CAMU area than the western half.

3.4 Comparison of Borrow Areas

Borrow Area 5 and the CAMU area are located within 1,000 feet of each other and, according to U.S. Geological Survey (USGS) mapping, were deposited in the same eolian depositional environment (USGS, 1983). Approximately the upper 10 feet of Borrow Area 5 and the upper 20 to 25 feet of the CAMU area both contain predominantly lean clays with some clayey sands. Occasional sandy seams, gravel pockets, and fat clays are present in both areas. The average index properties of all of the alluvial soil sampled in both areas are nearly identical. The maximum, minimum, and standard deviation of the index properties and the percentage of alluvial soil samples meeting the Table 1 criteria of both areas are similar.

The amount of variation in the percentage of samples meeting Table 1 criteria and the maximum, minimum, and standard deviation values of the index tests are likely due to the fact that neither the boring and test pit locations, nor the number and depth of samples, nor number and type of index tests performed are evenly spaced over the volume of alluvial soil contained within each borrow area. That is, the boring/test pit locations were not evenly distributed over either borrow area, nor were the sample depths and frequencies the same for all borings and test pits, nor were the same tests performed on all samples. In other words, for the borrow area statistics cited above to be 100 percent valid, each sample shown in Tables 2 and 3 would have had to been strategically located horizontally and vertically so that every sample would be representative of the same volume of alluvial soil. This level of consistency was not an objective of any of the sampling programs.

However, the information presented above and in Tables 2 and 3, when reviewed in conjunction with boring/test pit logs, geologic profiles, and other information included in Subsurface Report, indicate that the alluvial soil within both borrow areas:

- Was deposited in the same geological environment.
- Possesses sufficiently similar geotechnical properties that give no clear indication of differences between the two areas (i.e., the properties of one borrow area cannot be prioritized over the other borrow area).
- Possesses average properties (including samples failing the Table 1 criteria) that indicate a homogenized mixture of all the alluvial soil from one or both borrow areas would result in a lean clay soil meeting the Table 1 criteria.

Based on the information presented above, it is the Army's opinion that clayey soil in the CAMU area and Borrow Area 5 meet the criteria given in Table 1 and have sufficiently similar geotechnical properties. Based on this conclusion and visual screening requirements of borrow area excavations presented in Section 6.3, the results of Test Fill 3 will be applicable to clayey soil meeting the Table 1 criteria excavated from both sources during full-scale construction of both the double-lined cell and the triple-lined cell. Also, after successful completion of Test Fill 3, the Program Management Contractor (PMC) and its subcontractors should have the option to use clayey soil that meet the criteria given in Table 1 from either area or a mixture of both areas to construct the CCLs for both the double- and triple-lined cells, provided construction specifications and CQA procedures developed as a result of Test Fill 3 are utilized for the full-scale CCL construction.

3.5 Test Fill 3 Borrow Source

The CAMU Area will be the borrow source for Test Fill 3. Specifically, clayey soil within the "footprint" of the area to be excavated for construction of the double-lined cell will be used to construct Test Fill 3. The double-lined cell will be constructed in the northeastern portion of the CAMU area as shown on Figure 1. Section 5.4 of the Subsurface Report states that (based on preliminary dimensions of the double-lined cell) approximately 480,000 cubic yards of clayey soil are present within the expected footprint of the double-lined cell, and approximately 300,000 cubic yards of CCL material will be required to construct the bottom liner portion (secondary and primary CCLs) of the double-lined cell. These quantities will likely change as the design is refined. Regardless, it is likely that enough clayey soil will be excavated from within the footprint of the double-lined cell to construct both secondary and primary CCLs of the double-lined cell.

Table 4 is a summary of all of the alluvial soil samples obtained from within the anticipated footprint of the double-lined cell. These data were derived from Table 3 using the boring and test pits located within the double-lined cell footprint (see Figure 1 or 4). As with Tables 2 and 3, the bottom of Table 4 shows the maximum, minimum, average, and standard deviation of index properties, moisture content, and sample depth of all samples obtained from within the cell footprint area and for just the samples meeting the Table 1 criteria. A summary of index property values for the double-lined cell approximate excavation area is given below:

	Average		Maximum		Minimum		Std. Deviation		Number of Samples		
Index Property	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples	Percent Meeting Table 1
USCS Classification	CL	CL	CH	CH	Sand	SC	N/A	N/A	45	40	89
Percent fines	61	67	95	95	13	43	23	15	17	15	88
Liquid Limit	38	38	50	50	30	30	6	6	15	15	100
Plasticity index	20	20	29	29	14	14	4	4	15	15	100

As is the case for Borrow Area 5 and all of the CAMU area, the percentages shown in the far right column above only represent the percentages of the samples taken, not the percentage of the cell excavation volume.

The Table 4 average results are nearly identical to the average results given in Table 2 (Borrow Area 5) and Table 3 (CAMU area). Table 5 presents a comparison of the average results of all alluvial soil samples obtained from within Borrow Area 5, the CAMU area, and the portion of the CAMU Area containing the double-lined cell excavation area. As can be seen on Table 5, clayey soil to be used for Test Fill 3 construction will be representative of clayey soil within both the CAMU area and Borrow Area 5.

4.0 PRECONSTRUCTION LABORATORY TESTING AND DATA INTERPRETATION

A preconstruction laboratory testing program has been performed using alluvial clay samples obtained from within the anticipated footprint of the double-lined cell. The laboratory testing program was performed to develop the moisture content-density criteria for the Test Fill 3 compacted soil liner. The program followed the general methodology set forth initially by Daniel and Benson (1990) and also in Appendix I of the CDD. Development of the moisture content-density criteria for Test Fill 3 followed the methodology described below:

- Performing specific gravity, and modified, standard, and reduced Proctor compaction tests on a representative sample of the borrow material.
- Plotting the three Proctor test results and the zero air voids curve (using the specific gravity test result) on a moisture content versus dry density graph, drawing a "line of optimums" connecting the optimum moisture content of the three Proctors, and defining the area on the graph between the zero air voids curve and the line of optimums as the preliminary Acceptable Zone (AZ) for compacted soil liner placement during Test Fill 3 construction.
- Assuming a minimum density to define the lower boundary of the AZ and assuming a minimum moisture content to define the upper boundary of the AZ.
- Verifying the accuracy of the AZ in the laboratory by performing 12 remolded hydraulic conductivity tests at a relatively evenly distributed range of moisture and density contents that plot near the outer boundaries of the AZ.
- Plotting the results of remolded hydraulic conductivity tests on the moisture-density graph of the AZ, modifying the AZ as necessary to include only the area where passing hydraulic conductivity values (less than or equal to 1×10^{-7} cm/s) were obtained, and defining this area as the final AZ for compacted soil liner placement during Test Fill 3 construction.

Figure 5 is a dry density versus moisture content graph showing the AZ and also the Proctor curves, line of optimums, zero air voids curves, and plots of the moisture and density of each of the 12 remolded hydraulic conductivity tests and each test result. The paragraphs below provide additional details of how the AZ for Test Fill 3 soil liner construction was developed.

4.1 Laboratory Index Property and Proctor Testing

Numerous bag samples of alluvial clayey soils within Borrow Area 5 and the footprint of the double-lined cell were obtained during the USACE geotechnical investigation. Based on the decision to use alluvial soil from within the expected footprint of the double-lined cell to construct Test Fill 3 and the results of the USACE laboratory testing on alluvial soil samples from that area, the preconstruction laboratory testing program was implemented using a composite of two of the bag samples collected from within the footprint of the double-lined cell. A composite sample was necessary to provide enough material for testing.

The bag samples chosen for compositing were selected to represent a reasonable index property average of the clayey soils anticipated to be used for Test Fill 3. One of the samples composited (Sample B-1 of Test Pit PT250013) was classified according to USCS as a sandy lean clay (CL) with 53 percent fines, a liquid limit of 37, and a plasticity index of 20. The other sample composited (Sample B-1 of Test Pit PT250016) was classified according to USCS as a lean clay with sand (CL) with 28 percent sand, 72 percent fines, a liquid limit of 36, and a plasticity index of 21. The test results for both of these samples are also shown in Table 4. Index test results on the composite of the two bag samples were a USCS classification as sandy lean clay (CL), 62 percent fines (37 percent silt size and 25 percent clay size), a liquid limit of 38, a plasticity index of 24, and a specific gravity of 2.75. The laboratory index test results for the composite sample are presented in Appendix D.

The composite sample index property test results indicate that the composite sample does reasonably represent the average clayey soil index properties for the borrow areas. These values are summarized below:

	Acceptable Zone Composite Sample Test Results	Average for Double-Lined Cell Foot Print		Average for CAMU Area		Average for Borrow Area 5	
Index Property		All Samples	Passing Samples	All Samples	Passing Samples	All Samples	Passing Samples
USCS Classification	CL	CL	CL	CL	CL	CL	CL
Percent Fines	62	61	67	52	63	57	66
Liquid Limit	38	38	38	39	40	38	39
Plasticity Index	24	20	20	22	23	21	22

After completion of the index testing on the composite sample, the relationship between moisture, density, and hydraulic conductivity of the soil was developed. Standard Proctor (ASTM D698), modified Proctor (ASTM D1557), and reduced Proctor tests were performed on the composite sample described above. The reduced Proctor test utilized the same procedure as the standard Proctor test with the exception that 15 blows per lift were used instead of the 25 blows per lift required by ASTM D698. The results of the standard, modified, and reduced Proctor tests are also presented in Appendix D.

4.2 Preliminary Acceptable Zone Development

The results of the three composite Proctor tests were plotted on a moisture content versus dry density graph along with the zero air voids (100 percent saturation) curve. The line of optimums was created by connecting the optimum moisture contents of each of the three Proctor tests. Benson's research has shown that a hydraulic conductivity of 1 x 10^{-7} cm/s or less will nearly always be achieved when samples are moisture conditioned and compacted such that a plot of moisture content and density will fall between the line of optimums and the zero air voids curve. This area defined the preliminary AZ.

The upper boundary of the preliminary AZ was set as a line beginning at the modified Proctor optimum moisture content and extending vertically until it intersects with the zero air voids curve. The lower boundary of the preliminary AZ was set as a horizontal line located at 95 percent of the reduced Proctor maximum dry density (92 percent of the standard Proctor maximum dry density).

4.3 Remolded Hydraulic Conductivity Testing

The preliminary AZ was verified in the laboratory as the final AZ by remolding hydraulic conductivity samples to a range of moisture contents and dry densities within or near the limits of the AZ. Twelve remolded hydraulic conductivity test points were tested to verify the AZ. The moisture content and dry density of the completed tests are shown on Figure 5 by filled triangles with the corresponding sample point number adjacent to the triangle. The hydraulic conductivity test result (in cm/s) is shown in parentheses next to the point number. The moisture content and dry density of the 12 tests were chosen to assess the hydraulic conductivity over the range of moistures and densities covered by the AZ. The moisture and density of 5 of these sample points plotted just outside of the limits of the AZ. All 12 of the sample points achieved a hydraulic conductivity of 6 x 10^{-8} cm/s or less. In addition to being shown on Figure 5, the laboratory test results of the 12 test points are presented in Appendix E and are summarized below:

Point No.	% Moisture	Dry Density (pcf)	Hydraulic Conductivity (cm/s)
1	12.4	118.1	1.6×10^{-8}
2	15.9	115.4	1.6×10^{-9}
3	14.7	113.5	5.5×10^{-8}
4	17.0	107.2	1.8×10^{-8}
5	20.1	104.1	1.5×10^{-8}
6	22.6	101.5	1.0×10^{-8}
7	11.7	119.6	3.1×10^{-8}
8	12.6	116.4	2.3×10^{-8}
9	14.4	110.3	6.0×10^{-8}
10	15.7	107.8	3.1×10^{-8}
11	18.8	104.0	1.7×10^{-8}
12	21.4	100.5	3.2×10^{-8}

4.4 Final Acceptable Zone Development

As shown in Figure 5, the AZ includes only the range of moisture contents and dry density that resulted in a passing remolded hydraulic conductivity. To account for potential variability between the hydraulic conductivity between field compacted and laboratory compacted samples, the AZ for Test Fill 3 construction was not expanded to include the passing test results of the five sample points which plotted outside of the AZ. The final AZ for Test Fill 3 construction, as shown in Figure 5, is therefore defined as the area on a dry density versus moisture content graph that lies between the zero air voids curve on the right (wet) side, the line of optimums on the left (dry) side, 92 percent of the maximum standard Proctor dry density on the bottom (low density) side, and the modified Proctor optimum moisture content on the top (high density) side.

The limits of the AZ may be further decreased depending on other factors required by the CAMU design, if known prior to Test Fill 3 construction. One such factor would be raising the lower boundary of the AZ based on the minimum required shear strength requirements for slope stability and bearing capacity. This may be necessary because a CCL compacted near the lower boundary of the AZ will have less shear strength (due to lower density and higher moisture content) and thus, less stability than a CCL compacted near the upper boundary of the AZ.

A shear strength testing program is currently ongoing to support the USACE landfill design. This program includes shear testing of CCL material at various moisture contents and densities. When completed, the test results will be used to evaluate stability. The results of the stability analyses (and the accompanying required shear strengths) will indicate the range of CCL moisture and density conditions that will be acceptable. This information will then be used to modify the AZ to only include the range of moisture and density conditions that will result in acceptable hydraulic conductivity and shear strength.

For construction of Test Fill 3, the AZ has been divided into two approximately equal zones: the Upper AZ (UAZ) and the Lower AZ (LAZ). The dividing line of the UAZ and LAZ is defined as a line drawn perpendicular to the zero air voids curve that intersects the standard Proctor optimum moisture content and maximum dry density. This line is also shown on Figure 5. The UAZ and LAZ will be used as target zones for the initial lifts of the test fill construction to evaluate the differences in constructibility (ease of moisture conditioning, placement, compaction, etc.) between compacted soil liner constructed placed within the upper (high density/low moisture) half and the lower (low density/high moisture) half of the AZ.

In addition to modifications of the AZ based on shear strength requirements, additional modifications to the AZ may be necessary based on variations in the CCL materials. To ensure that the Test Fill 3 borrow area is accurately defined by Figure 5 and to evaluate the sensitivity of the line of optimums to slight changes in material properties, an additional set of Proctors (modified, standard, and reduced) will be performed prior to the commencement of Test Fill construction on a composite sample obtained from the Test Fill 3 borrow area. This will define a new line of optimums that is anticipated to be within 1 to 2 percent of the Figure 5 line of optimums.

Index property tests and a specific gravity test will also be performed in the Test Fill 3 borrow area composite sample. This information, when compared to any change in the line of optimums, will be used to develop Proctor, specific gravity, and index testing frequency requirements for full-scale construction. Because of the research aspect of Test Fill construction, the line of optimums and specific gravity obtained for the composite sample will be used for the test fill construction. The upper and lower boundaries of the AZ will be kept at the new modified Proctor optimum moisture content and 92 percent of the new standard Proctor dry density, respectively.

As stated in Section 6.0, periodic one-point standard Proctor tests will be performed in the field during Test Fill construction. Higher gravel content and/or significant changes in plasticity or fines content will be indicators that one-point Proctor tests should be done to verify the AZ is still valid. The initial criteria used for evaluation of changes in the borrow source will be if the one-point Proctor varies less than ±3 percentage points and less than ±5 pcf (EPA, 1993). The results of the test fill program will be used to re-evaluate this criteria for full-scale construction.

5.0 TEST FILL CONSTRUCTION PROCEDURES

Test Fill 3 will be constructed to the dimensions shown in Figure 2. CQA procedures to be implemented by the Engineer are given in Section 6.0. Construction procedures and specifications to be adhered to by the Contractor are given below. The Engineer will be responsible for the Contractor's adherence to requirements given below. The Test Fill 3 Contractor will be working under the direction of the Engineer. The Engineer will be responsible for laying out the site, providing survey control during construction, and verifying that Test Fill 3 is constructed to the grades and dimensions shown on Figure 2.

The intent of this test fill program is to furnish data that will provide the technical basis to establish the detailed construction specifications for full-scale CCL construction. Specifications given below detail the minimum requirements for test fill construction, but allow flexibility for some experimentation with loose lift thickness and different clay processing procedures and equipment during construction of the lower three lifts. Specifications for full-scale CCL construction will be finalized after completion of the test fill program. Full-scale CCL construction specifications will incorporate the equipment and procedures used to construct Test Fill 3 and are anticipated to be consistent with test fill specifications given below. However, conditions encountered during Test Fill 3 construction and/or results of laboratory testing may necessitate changes in these specifications for full-scale CCL construction.

5.1 Site Preparation

The test fill will be constructed adjacent to an existing slope located near the double-lined cell excavation area as shown on Figures 1, 2, and 3. The footprint of the test fill, processing area, and borrow area will be cleared and grubbed of all vegetation, debris, or other deleterious material, as directed by the Engineer, and disposed of at a location designated by the Army.

5.2 Grading and Structural Fill Requirements

Structural fill will be placed as necessary to construct a smooth, uniform surface at grades shown in Figure 2. The sideslope section of the test fill subgrade will be graded to a 3.5 Horizontal: 1 Vertical

(29 percent) slope. The base section of the test fill subgrade will be graded to a 2 percent slope. Material for structural fill will be obtained from the cleared and grubbed surface of the borrow area or from cut areas of the test full subgrade. Structural fill will consist of soil classified according to USCS as SM, SC, CL, or CH. Structural fill will be free of vegetation and debris and will contain a maximum particle size of 4 inches. The material will be placed in maximum 10-inch loose lifts and compacted to 95 percent of the standard Proctor maximum density (ASTM D698) at a moisture content ±3 percentage points of the optimum moisture content. The Engineer will monitor, test, and document the structural fill placement.

After the subgrade is constructed to dimensions shown in Figure 2, the subgrade will be proof-rolled with a loaded piece of heavy equipment approved by the Engineer to achieve a uniform subgrade surface free of soft zones, irregularities, and loose earth. The Engineer will observe proof-rolling, and any unacceptable areas of the subgrade will be repaired to the satisfaction of the Engineer.

5.3 Soil Liner Material Requirements

Soil liner material will meet the requirements given in Table 1. The soil will contain no more than a negligible (less than 1 percent) amount of organic or other deleterious materials and will contain no more than 5 percent gypsum or caliche (calcium carbonate). Such concretions, nodules, or other deleterious material will be less than 1 inch in largest diameter. The soil will contain a maximum particle size of 1 inch for lower lifts and 0.5 inch for the top lift and a maximum of 10 percent gravel by weight. The Engineer will visually evaluate, sample, and test the soil liner material as described in Section 6.0 to document conformance to the specifications.

5.4 Soil Liner Conditioning

Soil to be used for test fill construction will be obtained as directed by the Engineer from the borrow area and placed in the processing area. During moisture conditioning above the standard Proctor optimum moisture content, the soil will be processed to a maximum clod size of 2 inches. Whenever the moisture content of the soil is adjusted upward by more than 3 percent, a minimum hydration time of 24 hours will be required prior to compaction. The Engineer will monitor, test, and document the conditioning as outlined in Section 6.0. A water truck equipped with a spray bar for even distribution of water over a given area will be used for adding moisture to the soil. The equipment listed below will be evaluated on their ability to evenly raise the moisture content to near the standard Proctor optimum moisture content:

- A tractor and Rome disc or equivalent
- A Caterpillar SS250 soil stabilizer (pulvamixer) or equivalent

Regardless of the evaluation cited above, a minimum two passes of a Caterpillar SS250 soil stabilizer (pulvamixer) or equivalent will be used for final moisture conditioning above the standard Proctor optimum moisture content.

5.5 Soil Liner Placement and Compaction

Soil liner material will be placed and compacted using the following procedures:

1. Processed soil liner material will be removed from the processing area using scrapers or other hauling equipment approved by the Engineer.
2. Processed soil liner material will be placed directly on the base section of the test fill and spread over the base and sideslope sections of the test fill to a nominal loose lift thickness of 8 inches. A bulldozer, approved by the Engineer, or the compactor will be used to spread the loose lift. In no case will the loose lift thickness exceed the length of the penetrating foot of the compactor.
3. The placed loose lift will be compacted by a Caterpillar 825c compactor. The compactor will make the minimum number of passes on each lift and in each lane as directed by the Engineer, and described in Section 6.6. A pass is defined as one coverage of a given area with both the front and rear drum of a duel drum compactor (i.e., Caterpillar 825c) or two coverages of a given area with a single drum compactor. Each compacted lift will be a nominal 6 inches or less. The loose lift thickness may be adjusted by the Engineer after placement of the second or third lift based on layer bonding observations and compacted thicknesses of the initial lift(s).
4. Prior to placement of subsequent lifts, the preceding lift will be texturized (roughened) using either a sheepsfoot compactor or other method approved by the Engineer.
5. A total of seven loose lifts of the soil liner will be placed to achieve six compacted lifts. After completion of Lift 7, the test fill surface will be graded to a minimum thickness of 3 feet.
6. The finish grade surface of test fill will be rolled smooth using a smooth-drum roller approved by the Engineer.

The Engineer will closely observe and evaluate the Caterpillar 825c compactor's ability to traverse and compact the soil liner material on the sideslope section as described in Section 6.0. If the compactor is unable to successfully traverse and compact the soil liner parallel to the sideslope, either:

- A different compactor, such as a Caterpillar CP563 sheepsfoot compactor, will be used to construct the sideslope section, or
- The sideslope section will be flattened to a slope where the compactor can successfully traverse and compact the soil liner parallel to the slope, or
- The sideslope section of the test fill will not be constructed.

If a different compactor is used, the maximum lift thickness will be adjusted so that it does not exceed the length of the compactor's penetrating feet. If the slope of the sideslope section is flattened, the landfill design will either be modified to incorporate the flattened slope or the full-scale CCL construction specifications will require that the CCL be constructed in horizontal lifts (as opposed to parallel to the slope) in the same manner as the base of the landfill. If the sideslope section is not constructed, full-scale CCL construction specifications for sideslopes will require that the CCL be constructed in horizontal lifts in the same manner as the base of the landfill.

Numerous testing and inspection activities will occur during and between lift placement. These activities are described in detail in Section 6.0. The Contractor will spray water on the test fill surface and surrounding areas as directed by the Engineer to prevent fugitive dust emissions and soil liner desiccation cracking.

5.6 Soil Liner Surface Protection

After the test fill construction and CQA sampling and testing activities are complete, the Contractor will immediately cover the test fill surface with a separator geomembrane (i.e., Visqueen) approved by the Engineer. The Contractor will then cover the separator geomembrane with a minimum soil thickness of 4 inches. This surface protection will remain in place until test fill results have been received and the test results approved by the regulatory agencies.

5.7 Drainage Control and Revegetation

The Contractor will regrade and revegetate all areas disturbed by the test fill construction if required by the Army and as directed by the Engineer. Areas to be regraded and revegetated include, but are not limited to, the borrow area, haul roads, and processing area. Regrading will consist of grading all areas to be relatively free-draining. All regrading will be done as directed by the Engineer. Revegetation will be done in accordance with the procedures given below:

- The topsoil will require grading, raking, and rolling with a roller weighing not more than 100 pounds per linear foot and not less than 25 pounds per linear foot.
- The seed will meet the requirements of the U.S. Fish and Wildlife Service.
- Seeds will be sown by dividing the seed equally and sowing at 90 degree angles to produce a uniform broadcast.
- The seed will require raking into the ground and rolling with a roller, or other technique approved by the Engineer.
- Seeding will not be allowed on rain compacted surfaces.
- Seeding will not be allowed when the wind velocity exceeds 6 miles per hour.
- No fertilizer will be applied.
- Mulch will be applied immediately after seeding.
- Mulch will be applied at a rate of 2 tons/acre.
- The mulch will be crimped immediately after application to prevent it from blowing away.
- The mulch must be placed loosely enough to allow some sunlight to penetrate and air to circulate, but thick enough to shade the ground, conserve soil moisture, and minimize erosion.

6.0 CONSTRUCTION QUALITY ASSURANCE PROCEDURES

CQA procedures to be implemented during construction of the test fill will be carried out by the Engineer. The Engineer will be responsible for the surveying, testing, observing, and documenting requirements set forth below. The Engineer will subcontract survey and laboratory testing activities as necessary to properly lay out and document the test fill construction.

This section presents the CQA requirements for the Test Fill 3 construction. After completion of the test fill program, detailed CQA requirements for full-scale CCL construction will be prepared based on the CQA procedures utilized, the observations made, and the test results obtained during completion of the test fill program.

6.1 Site Preparation

The Engineer will be responsible for layout of the borrow area, Test Fill 3, the processing area, and any associated haul roads. The Engineer will monitor, direct, and document the Contractor's site preparation activities set forth in Section 5.1 to verify compliance with this Work Plan.

6.2 Grading and Structural Fill Placement

The Engineer will direct the Contractor's removal of structural fill borrow soil. The Engineer will observe, test, and document placing, compacting, proof-rolling, and grading the structural fill to verify that the specifications given in Section 5.2 are met and that the test fill subgrade is shaped to the dimensions shown in Figure 2. The Engineer will survey the surface of the test fill subgrade to provide survey control and to document the subgrade dimensions and grades. A minimum of one sample of structural fill material will be tested to obtain index properties and standard Proctor values.

6.3 Soil Liner Excavation and Testing

The Engineer will lay out and direct the Contractor's excavation of the borrow area and will perform a minimum of two index tests on the soil liner material used to construct Test Fill 3. The index test results must meet the minimum requirements given in Table 1. A minimum of two in situ moisture content tests (ASTM D4643 and/or D2216) per day will be performed on material excavated from the borrow area. Index testing will consist of the following:

- Particle size analysis, including hydrometer testing (ASTM D422 and D1140)
- Atterberg limits (ASTM D4318)
- Soil classification (ASTM 2487)

A minimum of one set of the Proctor tests listed below will be performed to further verify consistency with the AZ:

- Modified Proctor (ASTM D1557)
- Standard Proctor (ASTM D698)
- Reduced Proctor (ASTM D698 with 15 blows per lift)

In addition, one-point Proctor compaction tests will be performed periodically to verify consistency with the Proctor test results.

The Engineer will observe and document the borrow area excavation to verify that only soil meeting the requirements of Table 1 is excavated and placed in the process areas. The Engineer will observe and document that calcareous lenses (caliche) and other deleterious materials within the clay zones are discarded and not used for test fill construction. At the conclusion of excavation activities, the Engineer will verify that the Contractor regrades the borrow area to be relatively free draining and also that the Contractor revegetates the borrow area in accordance with the specifications given in Section 5.6.

6.4 Soil Liner Conditioning

The Contractor will excavate the soil liner material from the borrow area and place it in the processing area for conditioning. The Engineer will direct and document the Contractor's conditioning of soil liner material to verify that the equipment and procedures set forth in Section 5.4 are utilized. The Engineer will observe and document the processing and moisture conditioning of the soil liner material to evaluate the following:

- The amount and distribution (evenness) of water applied by the water truck. The ability of the water truck to travel over the moisture conditioned clay will also be evaluated.
- The ability of heavy equipment to travel over and add moisture to clay within the process area at various moisture contents.
- The number of passes, range of moisture contents, the distribution (evenness) of moisture content, and the ranges of clod sizes that the Rome disc or equivalent can effectively condition prior to conditioning with the soil stabilizer. Experimentation with the Rome disc may be performed to evaluate whether this apparatus can be productively and effectively used for final moisture conditioning. The Engineer will observe, test, and document the initial and final moisture contents of the soil liner material and the amount of moisture that can be evenly and productively added to the soil liner material with the Rome disc.
- The number of passes, range of moisture contents, the distribution (evenness) of moisture content, and the range of clod sizes that the Caterpillar SS250 soil stabilizer or equivalent can effectively condition. Experimentation with the soil stabilizer may be performed to evaluate whether this apparatus can be productively and effectively used for initial moisture conditioning. The Engineer will observe, test, and document the initial and final moisture contents of the soil liner material and the amount of moisture that can be evenly and productively added to the soil liner material with the soil stabilizer.

6.5 Soil Liner Lift Placement

After conditioning, the Contractor will haul the soil liner material from the processing area and place it above the base section of the test fill. The soil liner will be spread over the base and sideslope section of the test fill using a bulldozer or the compactor. Lifts will be placed in nominal 8-inch loose lifts. The Engineer will observe and document the Contractor's placement of soil liner material to verify that the material is placed over the entire test fill area at the specified lift thickness.

Due to the heavily textured nature of lifts compacted with a sheepsfoot compactor, it will be difficult to physically measure the loose and compacted lift thickness. The Engineer will visually monitor the lift thickness and will take physical measurements where possible (discussed in Section 6.6.4). Experimentation may be done on Lifts 2 and 3 with various thicknesses to ascertain the optimum loose lift thickness that will result in effective layer bonding between lifts and a nominal 6-inch compacted thickness. The optimum loose lift thickness, if changed, will then be used on subsequent lifts to simulate full-scale CCL construction procedures.

6.6 Soil Liner Compaction and Testing

Soil liner compaction and testing activities will be performed in accordance with Table 6 and in the test fill lanes shown in Figure 2. Table 6 gives the target number of compactor passes for each lane and each lift of the test fill. Table 6 also gives the testing and sampling locations and frequencies for each lane and lift of the test fill. Due to the heavily textured nature of lifts compacted with a sheepsfoot compactor and the 8-inch nominal length of the compactor feet, it will be necessary to test each lift after placement and compaction of the overlying lift. The size of compactor and lift thickness were chosen so that the feet of the compactor will penetrate the underlying lift. Compaction in this manner will result in concurrent kneading action of the overlying (uppermost) lift and compaction of the underlying lift. It will also promote layer bonding between lifts.

6.6.1 Number of Compactor Passes

The Engineer will document the number of passes made over each lane of each lift (three lanes per lift). This will be done to establish a correlation between the number of passes and dry density at a specific moisture content range. The number of passes shown for each lane of each lift in Table 6 is only a preliminary estimate of the number of passes that will be required. It is likely that more passes will be required for the sideslope section than for the base section. The Engineer will test each lane of each lift after the minimum number of passes is made. If the test results indicate that the target area of the placement window (UAZ for Lifts 1 and 2, LAZ for Lift 3, or the entire AZ for Lifts 4, 5, 6, and 7) is met for that lift, no more passes will be made on that lift. If the target density area of the AZ is not met, additional passes will be made until the target area is met. If the target moisture content of the AZ is not met, the area will be repaired or replaced as discussed in Section 6.6.4.

When the minimum number of passes necessary to meet the target area of the AZ is defined for both the base and sideslope sections, additional passes, in increments of two to four, will be made in the next lanes to define the range of the target area that can be met. This will be done to allow the Engineer to evaluate whether soil liner material at various moisture contents can be compacted to the density range within the AZ. This will also allow hydraulic conductivity samples to be obtained at a range of moisture and density conditions within the AZ.

6.6.2 Moisture and Density Testing

The Engineer will perform nuclear moisture/density tests (ASTM D3017 and D2922) at a minimum frequency of six tests per lift. The nuclear tests will be taken at a minimum frequency of two test locations per lane, one on the base section and one on the sideslope section. One sand cone (ASTM D1556) or rubber balloon (ASTM D2167) correlation test will be performed on each lift. The Engineer will perform both oven (ASTM D2216) and microwave (ASTM 4643) moisture content tests in addition to the nuclear moisture test at the six test locations when testing both Lifts 1 and 2. This will be done to establish a correlation among nuclear, microwave, and oven-dried moisture contents. The Engineer may increase the testing frequencies based on previous test results.

6.6.3 Hydraulic Conductivity Sampling and Testing

Hydraulic conductivity sampling will be performed at the locations given in Table 6. Hydraulic conductivity sampling will consist of two types: Shelby tube (2.8-inch diameter) and block (12-inch diameter) sampling.

Shelby tube sampling will be performed at nuclear test locations after completion of the nuclear test. The samples will be obtained by pressing the tube into the test location using a hydraulic jack and back pressure from a piece of heavy equipment (i.e., the blade of a bulldozer or compactor). The samples will be extracted by digging the soil liner away from the sides of the tube. Upon removal, the samples will be sealed immediately to prevent moisture loss. After sealing, the samples will be labeled and prepared for archiving or shipment to the laboratory for hydraulic conductivity testing. A minimum of six of the Shelby tube samples will be tested.

Nine block samples will be excavated from the test fill after construction is completed. A minimum of six of these samples will be tested. The paragraphs below describe the rationale for performing block sampling and testing in lieu of other large-scale tests such as SDRIs.

Section 2.5.1 of "Quality Assurance and Quality Control for Waste Containment Facilities" (EPA, 1993) states that one of the objectives of a test fill is, "To verify that the materials and methods of construction will produce a compacted soil liner that meets the hydraulic conductivity objectives defined for a project, hydraulic conductivity should be measured with techniques that will characterize the large-scale hydraulic conductivity and identify any construction defects that cannot be observed with small-scale laboratory hydraulic conductivity tests."

The SDRI and TSBP field-scale test methods were developed to measure the large-scale hydraulic conductivity of low-permeability soil liners. Of these field-scale test methods, the SDRI has become the most widely used method primarily due to the large area tested (up to 25 square feet) compared to the TSBP method (approximately 10 inches). However, the calculated hydraulic conductivity obtained from an SDRI is only an approximation of the true hydraulic conductivity. Errors can be easily introduced into SDRI calculations due to the effects of soil (matric) suction, soil swell, and inaccurate wetting front measurements (Benson et al., 1994).

Another reason for using block testing instead of SDRI testing is that SDRIs (and TSBPs) cannot be practically performed on sideslopes when the soil liner is constructed in lifts parallel to the sideslope. A significant amount of research has been performed on block-scale testing, particularly the minimum block size (diameter) necessary to accurately reflect field-scale hydraulic conductivity. This research has indicated that a block sample diameter of approximately 12 inches can accurately reflect field-scale hydraulic conductivity (Benson et al., 1993).

Block test samples will be obtained by placing an approximately 12-inch-high by 14-inch-diameter sampling ring with a beveled cutting edge over the area to be sampled. A trench around the outside of the sampling ring will then be excavated to a depth of approximately 16 inches. The excess soil between the trench and the inside of the sampling ring will then be trimmed off using trowels and knives until the sampling ring can slide easily downward (concurrently with the trimming of the excess material) around the test sample. This process will continue until 2 or more inches of the test sample are above the top of the sampling ring.

The portion of the block test sample protruding from the top of the sampling ring will then be trimmed flush with the sampling ring. The top of the sample will then be sealed with plastic wrap (such as Visqueen) and duct tape to prevent moisture loss. The base of the sample will be freed from the test fill using a wire saw or flat-headed shovels. The sample will then be turned over carefully and the bottom trimmed and sealed in the same manner as the top. The sample will then be labeled, sealed an additional time, and placed on a shipping palette for transportation to the testing laboratory. After removal of the block sample, the Engineer will observe the resultant hole in the test fill and document the layer bonding between lifts.

Hydraulic conductivity testing for both the Shelby tube and the block samples will be performed in accordance with ASTM D5084. Samples selected for testing will encompass the range of moisture and density conditions within the AZ. The samples will be initially tested at a consolidation pressure (effective confining stress) of 3 pounds per square inch (psi) to obtain a hydraulic conductivity value that is representative of a cover CCL application. After completion of the initial test, the consolidation pressure will be raised to 10 psi to obtain a hydraulic conductivity value that is representative of a bottom liner CCL application. A minimum gradient of 30 will be used for both tests.

6.6.4 Other CQA Requirements

The Engineer will perform and document other CQA activities during the test fill construction. These activities will include evaluating the ability to repair nuclear, sand cone, and Shelby tube test holes, evaluating loose and compacted lift thickness, evaluating layer bonding between lifts, evaluating the effectiveness of repair or removal and replacement of soil liner areas failing to meet the placement specifications, evaluating the ability of the heavy equipment to travel over the process area and test fill, evaluating the ability of the heavy equipment to effectively and productively place and compact soil liner material on the sideslopes, and documenting all aspects of the test fill construction. Pass or fail assessments of these visual evaluations will be made based on the best professional judgment of the Engineer.

Nuclear probe holes will be repaired by compacting granular bentonite into the bottom half of the probe hole using the driving pin used to create the probe holes (or similar device) and then hydrating the bentonite. The upper half of the probe hole will be backfilled and hydrated in the same manner as the bottom half. Shelby tube and sand cone or rubber balloon test locations will be repaired by compacting processed clay and/or bentonite into the test locations using a sledge hammer or tamping rod. Sand used in sand cone tests will be removed prior to backfilling. Block samples will be obtained after the test fill construction is completed at the locations given in Table 6. These locations will be filled with loose soil and lightly compacted using available equipment. These activities will be documented by the Engineer.

As stated previously, the evaluation of loose and compacted lift thickness will be difficult to measure physically. The Engineer will visually monitor loose lift thickness and will obtain physical measurements where possible. Compacted lift thickness will be measured by using a survey rod and level and taking numerous measurements at designated locations over a cross-sectional area before a lift is placed and after that lift is compacted. The nominal compacted lift thickness will then be calculated by using the average vertical difference between the measurements. These activities will be documented by the Engineer.

Layer bonding will be evaluated when excavating nuclear and block test locations. A dozer or compactor blade will be used to trim each location selected by the Engineer for nuclear testing. The compacted soil will be trimmed to a depth corresponding to the bottom of the upper lift's sheepsfoot penetrations, which typically occurs at the interface between lifts. One indicator of less-than-desirable layer bonding is whether the top lift readily peels off when trimming the test locations. Should this occur, the loose lift of the next lift placed will be lessened until minimal peeling of the overlying areas is observed. Layer bonding may also be evaluated during or at the end of construction by trimming a vertical face along a portion or portions of the edge of the test fill. The vertical face will then be inspected for observable stratification between lifts. Effective layer bonding will be evident if no significant visual delineation can be observed between lifts. These observations will be documented by the Engineer.

The evaluation of repair or replacement of defective areas will be based on the Engineer's professional judgment. If it is determined that the soil is excessively wet or dry during initial lift placements, attempts will be made to repair the soil liner in place. If the soil is too wet, attempts will be made to dry it in place by mixing the soil using the disc and/or soil stabilizer and letting it air-dry. If this is found to be time consuming or ineffective, the lift will be removed and replaced. If the soil is too dry, attempts will be made to add moisture by adding water and mixing the soil in place using the disc and/or soil stabilizer. If this is found to be time consuming or too difficult, the lift will be removed and replaced. The Engineer will document these activities.

The Engineer will observe the ability of the heavy equipment used to construct the test fill to travel over the loose wet clay in the soil processing and test fill areas. Certain types of equipment may be more effective working within the processing area than others. The overall productivity of the equipment used in the process area will be evaluated and documented. The Engineer will also evaluate and document the ability of equipment to work on the sideslope section of the test fill and the efficiency of placing and compacting soil liner material on the sideslopes.

Comprehensive documentation will be performed on a daily basis by the Engineer. The documentation will be both written and photographic. Video tapes of various aspects of construction may also be made. The daily written documentation will consist of recording all testing and observation requirements given in this work plan including weather conditions, relevant observations, equipment in use, personnel onsite, and any pertinent conversations and observations. A photographic log of the test fill construction will be prepared and included as an appendix to the summary report.

7.0 POST-CONSTRUCTION TESTING AND SUMMARY REPORT

Post-construction testing will consist of completing the laboratory index and hydraulic conductivity testing on selected samples obtained during the test fill construction. A minimum six undisturbed block samples and six undisturbed Shelby tube samples will be tested for hydraulic conductivity. At least four of these undisturbed samples will be tested for index properties. The average of the minimum four index properties tests shall meet the USCS classification requirements for CL or CH material. When complete, the hydraulic conductivity results (both Shelby tube and block) will be plotted on a moisture/density graph showing the AZ derived during the preconstruction testing phase of the test fill program. The AZ will then be modified as necessary to reflect the field-scale AZ. Should conflicting or questionable results be obtained, additional laboratory testing will be performed as necessary to confirm the test fill results. Although additional sampling is not anticipated, additional samples may be obtained by removing a portion of the protective soil and separator geomembrane or geotextile and obtaining samples as needed.

The Engineer will prepare a summary report of the test fill construction and all laboratory testing. When data are assimilated and evaluated, recommended specifications and CQA procedures for full-scale construction of the CAMU soil liners will be given at the conclusion of the summary report. The summary report will include the following:

- A summary of the results of the borrow area evaluation and selection included in this Work Plan
- A discussion of the ability of the selected borrow area and areas that have material with similar properties to meet the total landfill borrow needs
- A summary of the preconstruction testing program described in this Work Plan, including all test results
- A summary of the test fill construction, including the materials, equipment, and procedures used; the construction schedule; personnel involved; and pertinent weather data
- A summary of the test fill CQA testing and observations, including all test results and daily field reports
- An assessment of the equipment and procedures used to construct the test fill and recommendations for full-scale construction equipment and procedures

- A summary of the post-construction testing, including test results
- Recommendations for technical specifications for full-scale soil liner construction
- Identification of any unresolved aspects relating to the test fill that may have to be addressed

8.0 ACRONYMS

Army	U.S. Department of the Army
ASTM	American Society for Testing and Materials
AZ	Acceptable zone
bgs	Below ground surface
Borrow Study Report	Final Feasibility Study Soils Support Program Report
CAMU	Corrective Action Management Unit
CCL	Compacted clay liner
CDD	CAMU Design Document
CDPHE	Colorado Department of Public Health and Environment
cm/s	Centimeter per second
Contractor	Earthwork contractor
CQA	Construction Quality Assurance
Engineer	CQA engineer
EPA	U.S. Environmental Protection Agency
FFA	Federal Facilities Agreement
FS	Feasibility Study
FWS	U.S. Fish and Wildlife Service
HLA	Harding Lawson Associates
Landfill FS Report	Final Landfill Site Feasibility Report for the Feasibility Study Soils Support Program
LAZ	Lower Acceptable Zone
pcf	Pounds per cubic foot
PMC	Program Management Contract
PMRMA	Program Manager for Rocky Mountain Arsenal
psi	Pounds per square inch
RMA	Rocky Mountain Arsenal
SDRI	Sealed double-ring infiltrometer

State	State of Colorado
Subsurface Report	Final Geotechnical Investigation Report, Hazardous Waste Landfill
SWIP	Sitewide Implementation Plan
TSBP	Two-stage borehole permeameters
USACE	U.S. Army Corps of Engineers
UAZ	Upper Acceptable Zone
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
Work Plan	Test Fill Work Plan

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Table 1: Low-permeability Borrow Soil Index Property Criteria

Test	Low-permeability Soil Criteria	Test Method
Atterberg Limits		ASTM D4318
Liquid limit (LL)	≥30 percent	
Plasticity index (PI)	≥11 percent	
Grain-size distribution		ASTM D422
	100 percent passing 1-inch sieve* ≥40 percent passing No. 200 sieve < 5 percent passing No. 4 sieve	
USCS classification	SC, CL, or CH	ASTM D2487
Organic content	< 5 percent	ASTM D2974
Carbonate content	< 5 percent	ASTM D4373

≥	Greater than or equal to
<	Less than
ASTM	American Society for Testing and Materials
USCS	Unified Soil Classification

* Top lift shall be 100 percent passing the 1/2-inch sieve.

Table 2: Borrow Area 5 Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
PT240001	240001	0.5 to 1	CH	FAT CLAY w/ sand	84	55	33	24
PT240001	240001	1.2 to 1.7	CL	LEAN CLAY w/ sand	85	37	18	16
PT240001	240001	2 to 2.5	SC	CLAYEY SAND	32	21	8	7
PT240001	240001	5 to 5 5	SC	CLAYEY SAND				8
PT240001	240001	7 to 7.5	SC	CLAYEY SAND				9
PT240001	240001	9.5 to 10	SC-SM	SILTY CLAYEY SAND	47	22	7	24
PT240002	240002	0.5 to 1	CH	FAT CLAY w/ sand				17
PT240002	240002	1.3 to 1.6	CL	SANDY LEAN CLAY	61	33	18	9
PT240002	240002	5.5 to 6	CL	LEAN CLAY w/ sand				9
PT240002	240002	7 5 to 8	SC	CLAYEY SAND				8
PT240002	240002	9.5 to 10	SC	CLAYEY SAND				6
PT240003	240003	0.5 to 1	CH	FAT CLAY w/ sand				17
PT240003	240003	1.2 to 1.6	CL	SANDY LEAN CLAY				6
PT240003	240003	3.2 to 3.6	CL	SANDY LEAN CLAY				4
[illegible]	[illegible]	5 to 5.5	SW-SM	SAND w/ silt	12			2
[illegible]	[illegible]	7.5 to 8	SW-SM	SAND w/ silt				2
[illegible]	[illegible]	[illegible]	SW-SM	SAND w/ silt				3
[illegible]	[illegible]	0.5 to 1	CL	SANDY LEAN CLAY	67	24	9	13
PT240004	240004	2 to 2.5	CL	LEAN CLAY w/ sand	83	40	20	13
PT240004	240004	5 to 5.5	CL	LEAN CLAY w/ sand				12
PT240004	240004	7.5 to 8	SC	CLAYEY SAND				11
PT240004	240004	9 5 to 10	CL	LEAN CLAY w/ sand				18
PT240005	240005	0.5 to 1	CL	SANDY LEAN CLAY				17
PT240005	240005	1.5 to 2	CL	LEAN CLAY w/ sand				13
PT240005	240005	2.5 to 3	SC	CLAYEY SAND	49	25	11	7
PT240005	240005	5 to 5.5	CL	SANDY LEAN CLAY	69	36	21	11
PT240005	240005	7.5 to 8	SC-SM	SILTY CLAYEY SAND				9
PT240005	240005	9.5 to 10	SC	CLAYEY SAND				7
PT240006	240006	0.5 to 1	CL	SANDY LEAN CLAY				16
PT240006	240006	1.5 to 2	CL	SANDY LEAN CLAY				7
PT240006	240006	4.5 to 5	SC	CLAYEY SAND				13
PT240006	240006	7.5 to 8	CL	SANDY LEAN CLAY				12
PT240006	240006	9.5 to 10	SC	CLAYEY SAND				16
PT240007	240007	0.5 to 1	CH	FAT CLAY w/ sand				13
PT240007	240007	2 to 2.5	CL	SANDY LEAN CLAY	63	35	21	9
PT240007	240007	5 to 5.5	SC	CLAYEY SAND				9
PT240007	240007	6.5 to 7	CL	SANDY LEAN CLAY				10
PT240007	240007	8 to 8.5	SC	CLAYEY SAND				9
PT240007	240007	9.5 to 10	CL	SANDY LEAN CLAY				15
PT240008	240008	0 5 to 1	CL	LEAN CLAY w/ sand	81	35	19	10
PT240008	240008	1.5 to 2	CL	SANDY LEAN CLAY	59	28	16	7
PT240008	240008	5 to 5.5	CL	LEAN CLAY w/ sand	76	36	20	9
PT240008	240008	7 to 7.5	CL	LEAN CLAY w/ sand				9
PT240008	240008	9.5 to 10	CL	SANDY LEAN CLAY				7
PT240009	240009	0.3 to 0.6	CL	LEAN CLAY w/ sand	74	33	19	19
PT240009	240009	2 to 2.5	CL	LEAN CLAY w/ sand				10
PT240009	240009	4 to 4.5	CL	LEAN CLAY w/ sand				11
PT240009	240009	5 to 5.5	CL	SANDY LEAN CLAY				12
PT240009	240009	7.5 to 8	CL	LEAN CLAY w/ sand				11
PT240009	240009	9.5 to 10	CL	LEAN CLAY w/ sand				12
PT240010	240010	0 5 to 1	CL	SANDY LEAN CLAY				10
PT240010	240010	1 5 to 2	CL	SANDY LEAN CLAY				6
PT240010	240010	5 to 5.5	SC	CLAYEY SAND				12
PT240010	240010	7 to 7.5	SC	CLAYEY SAND				11
PT240011	240011	0.5 to 1	CL	SANDY LEAN CLAY				13
PT240011	240011	1.5 to 2	CL	LEAN CLAY		37	18	11

Table 2: Borrow Area 5 Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)			USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
PT240011	240011	3	to	3.5	SC	CLAYEY SAND				8
PT240011	240011	7	to	7.5	CL	LEAN CLAY w/ sand				15
PT240011	240011	9.5	to	10	CL	LEAN CLAY w/ sand				9
PT240012	240012	0.5	to	1	CL	LEAN CLAY w/ sand				15
PT240012	240012	1.5	to	2	CL	LEAN CLAY w/ sand				12
PT240012	240012	2.5	to	3	CL	SANDY LEAN CLAY				10
PT240012	240012	5	to	5.5	CL	SANDY LEAN CLAY				14
PT240012	240012	7.5	to	8	CL	LEAN CLAY w/ sand				15
PT240012	240012	9.5	to	10	CL	SANDY LEAN CLAY				17
PT240013	240013	0.5	to	1	CL	LEAN CLAY w/ sand				15
PT240013	240013	1	to	1.5	CL	SANDY LEAN CLAY				9
PT240013	240013	3	to	3.5	CL	LEAN CLAY w/ sand				7
PT240013	240013	5	to	5.5	CL	LEAN CLAY w/ sand				10
PT240013	240013	7.5	to	8	CL	LEAN CLAY w/ sand				9
PT240013	240013	9.5	to	10	CL	SANDY LEAN CLAY				12
PT240014	240014	0.5	to	1	CL	LEAN CLAY w/ sand				11
PT240014	240014	2	to	2.5	CL	LEAN CLAY w/ sand				14
PT240014	240014	3.5	to	4	CL	SANDY LEAN CLAY				12
PT240014	240014	5	to	5.5	CL	LEAN CLAY w/ sand				11
PT240014	240014	7.5	to	8	CL	LEAN CLAY w/ sand				15
PT240014	240014	9.5	to	10	CL	SANDY LEAN CLAY				13
PT240015	240015	0 5	to	1	CL	LEAN CLAY w/ sand				14
PT240015	240015	1	to	1.5	CL	LEAN CLAY w/ sand				14
PT240015	240015	2	to	2.5	CL	SANDY LEAN CLAY				10
PT240015	240015	4	to	4.5	CL	LEAN CLAY w/ sand				14
PT240015	240015	5	to	5.5	CL	LEAN CLAY w/ sand				16
PT240015	240015	7	to	7.5	CL	SANDY LEAN CLAY	59	41	25	15
[illegible]	[illegible]	[illegible]	to	[illegible]	SC	CLAYEY SAND	44	29	14	[illegible]
PT240027	240027	0.5	to	1	CL	LEAN CLAY w/ sand				14
PT240027	240027	2.5	to	3	CL	SANDY LEAN CLAY				14
PT240027	240027	3.5	to	4	CL	LEAN CLAY w/ sand				10
[illegible]	[illegible]	[illegible]	to	[illegible]	CL	SANDY LEAN CLAY	[illegible]	[illegible]	[illegible]	14
PT240027	240027	9.5	to	10	CL	LEAN CLAY w/ sand	84	36	20	16
PT240016	240016	0.5	to	1	CL	SANDY LEAN CLAY	66	33	19	13
PT240016	240016	1.8	to	2.3	CL	LEAN CLAY w/ sand	81	35	22	9
PT240016	240016	3	to	3.5	SC	CLAYEY SAND	47	33	17	9
[illegible]	[illegible]	[illegible]	to	[illegible]	[illegible]	SANDY LEAN CLAY	[illegible]	[illegible]	[illegible]	[illegible]
PT240016	240016	5.6	to	5.9	CL	SANDY LEAN CLAY	55	39	18	13
PT240016	240016	7	to	7.5	CL	SANDY LEAN CLAY	57	30	16	7
PT240016	240016	9.5	to	10	CL	SANDY LEAN CLAY	70	39	26	10
PT240017	240017	0.4	to	0.5	CL	LEAN CLAY w/ sand				10
PT240017	240017	0.8	to	1 1	CL	LEAN CLAY w/ sand				12
PT240017	240017	2.4	to	2.8	CL	SANDY LEAN CLAY				10
PT240017	240017	3.5	to	3.8	CL	LEAN CLAY w/ sand				10
PT240017	240017	4 5	to	5	CL	SANDY LEAN CLAY				9
PT240017	240017	5.6	to	6	CL	SANDY LEAN CLAY	59	38	17	11
PT240017	240017	7.5	to	8	CL	SANDY LEAN CLAY				6
PT240017	240017	9.5	to	10	CL	SANDY LEAN CLAY				10
PT240018	240018	0.5	to	1	CL	SANDY LEAN CLAY				16
PT240018	240018	2.5	to	3	CL	LEAN CLAY w/ sand				5
PT240018	240018	5	to	5.5	CL	SANDY LEAN CLAY				9
PT240018	240018	7.5	to	8	CL	SANDY LEAN CLAY				10
PT240018	240018	9	to	9.5	CL	SANDY LEAN CLAY				11
PT240019	240019	0.5	to	1	CL	SANDY LEAN CLAY				
PT240019	240019	2	to	2.5	CL	LEAN CLAY w/ sand				8
PT240019	240019	3.5	to	4	CL	SANDY LEAN CLAY				6

Table 2: Borrow Area 5 Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
PT240019	240019	6 to 6.4	CL	SANDY LEAN CLAY				12
PT240019	240019	7.5 to 8	CL	SANDY LEAN CLAY				10
PT240019	240019	9.5 to 10	CL	SANDY LEAN CLAY				11
PT240020	240020	0.5 to 1	CL	SANDY LEAN CLAY				16
PT240020	240020	2 to 2.5	CL	LEAN CLAY w/ sand				9
PT240020	240020	2.5 to 3	SC	CLAYEY SAND				10
PT240020	240020	4 to 4.5	CL	SANDY LEAN CLAY				14
PT240020	240020	6.5 to 7	CL	LEAN CLAY w/ sand				7
PT240020	240020	9.5 to 10	CL	SANDY LEAN CLAY				5
PT240021	240021	0.5 to 1	CL	SANDY LEAN CLAY				11
PT240021	240021	1.5 to 2	CL	LEAN CLAY w/ sand				9
PT240021	240021	4 to 4.5	CL	SANDY LEAN CLAY				10
PT240021	240021	7 to 7.5	CL	SANDY LEAN CLAY				5
PT240021	240021	8 to 8.5	CL	SANDY LEAN CLAY				5
PT240021	240021	9.5 to 10	CL	SANDY LEAN CLAY				7
PT240022	240022	0.5 to 1	CL	SANDY LEAN CLAY				15
PT240022	240022	2.5 to 3	CL	SANDY LEAN CLAY	54	31	13	7
PT240022	240022	5.2 to 5.6	CL	SANDY LEAN CLAY				7
PT240022	240022	7 to 7.5	CL	SANDY LEAN CLAY				6
PT240022	240022	9.5 to 10	SM	SILTY SAND	21			4
PT240023	240023	0.5 to 1	CL	SANDY LEAN CLAY				16
PT240023	240023	2.5 to 3	SC	CLAYEY SAND				9
PT240023	240023	4.5 to 5	CL	SANDY LEAN CLAY	66	33	15	8
PT240023	240023	6 to 6.5	CL	SANDY LEAN CLAY				8
PT240023	240023	9.5 to 10	CL	SANDY LEAN CLAY				9
PT240024	240024	0.5 to 1	CL	SANDY LEAN CLAY				16
PT240024	240024	2 to 2.5	CL	LEAN CLAY w/ sand				10
PT240024	240024	4 to 4.5	CL	SANDY LEAN CLAY				9
PT240024	240024	5.5 to 6	CL	SANDY LEAN CLAY				19
PT240024	240024	7 to 7.5	CL	LEAN CLAY w/ sand				10
PT240024	240024	9.5 to 10	CL	SANDY LEAN CLAY				11
PT240025	240025	0.5 to 1	CL	SANDY LEAN CLAY				13
PT240025	240025	2.5 to 3	CL	LEAN CLAY w/ sand				11
PT240025	240025	3.5 to 4	CL	SANDY LEAN CLAY				7
PT240025	240025	4.5 to 5	CL	SANDY LEAN CLAY				6
PT240025	240025	5.5 to 6	SC	CLAYEY SAND	29	22	9	4
PT240025	240025	7.5 to 8	CL	SANDY LEAN CLAY				5
PT240025	240025	9.5 to 10	SM	SILTY SAND	[illegible]			3
PT240026	240026	0.5 to 0.8	CL	SANDY LEAN CLAY				21
PT240026	240026	1 3 to 1.6	CL	SANDY LEAN CLAY				7
PT240026	240026	2.3 to 2.7	CL	SANDY LEAN CLAY				8
PT240026	240026	3.4 to 3.8	SC	CLAYEY SAND				11
PT240026	240026	4 2 to 4.6	CL	SANDY LEAN CLAY				9
PT240026	240026	6.5 to 7	SC	CLAYEY SAND				8
PT240026	240026	9 5 to 10	CL	SANDY LEAN CLAY				9
NUB00893	8	0 to 2	CL	BROWN SANDY LEAN CLAY	66	33	17	9
NUB00893	8	2 to 4	CL	BROWN SANDY LEAN CLAY	68	33	17	11
NUB00893	8	9 to 11	SC	TAN CLAYEY SAND	42	41	27	7
NUB00993	9	0 to 2	CL	BROWN LEAN CLAY W/SAND	74	34	21	10
NUB00993	9	4 to 6	CL	BROWN SANDY LEAN CLAY	64	37	19	9
NUB00993	9	9 to 11	SC	BROWN CLAYEY SOIL	45	41	27	7
NUB01093	10	0 to 2	CL	BROWN LEAN CLAY WITH SAN	79	36	18	10
NUB01093	10	4 to 6	CL	BROWN LEAN CLAY W/SAND	81	36	20	12
NUB01093	10	9 to 11	SC	TAN CLAYEY SAND	44	39	26	14
NUB01193	11	0 to 2	CH	BROWN SANDY FAT CLAY	64	52	34	11
NUB01193	11	4 to 6	CL	BROWN LEAN CLALY WITH SA	65	39	18	9

Table 2: Borrow Area 5 Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
NUB01193	11	8 to 10	SC	BROWN CLAYEY SAND	42	36	20	11
NUB01293	12	0 to 2	CL	BROWN LEAN CLAY W/SAND	71	48	32	11
NUB01293	12	2 to 4	CL	BROWN LEAN CLAY	85	41	22	12
NUB01293	12	8.5 to 11.5	CL	TAN SANDY LEAN CLAYW/GRA	58	44	28	18
NUB07593	75	0 to 4	CL	LT.BRN LEAN CLAY W/SAND	79	46	28	16
NUB07593	75	4 to 8	CL	TAN LEAN CLAY W/SAND	79	45	24	13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WEB07193	71	0 to 4	CH	BROWN SANDY FAT CLAY	69	50	26	13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WEB07493	74	0 to 4	CL	BROWN SANDY LEAN CLAY	60	34	16	11
WEB07493	74	4 to 8	SC	RD/BRN CLAYEY SAND	48	40	25	9
[illegible]	[illegible]	[illegible]	SC	RD/BRN CLAYEY SAND	[illegible]	28	12	10
[illegible]	[illegible]	[illegible]	SW-SC	[illegible]	10	39	22	[illegible]
WEB07693	76	0 to 4	CL	LT.BRN LEAN CLAY	85	49	28	9
WEB07693	76	4 to 8	CL	BROWN SANDY LEAN CLAY	68	37	17	10
WEB07693	76	8 to 12	CL	TAN SANDY LEAN CLAY	51	49	28	9
WEB07693	76	12 to 16	SC	TAN CLAYEY SAND	44	43	26	10
ALL DATA POINTS								
Number of data points			**188**		**62**	**61**	**61**	**187**
Maximum		**12 to 16**	**CH**		**85**	**77**	**56**	**24**
Minimum		**0 to 0.5**	**Sand**		**5**	**21**	**7**	**2**
Standard deviation		**3.4 to 3.6**			**20**	**10**	**8**	**4**
Average		**4.6 to 5.5**	**CL**		**57**	**38**	**21**	**11**
DATA POINTS MEETING THE TABLE 1 CRITERIA								
Number of data points			**166**		**44**	**45**	**45**	**165**
Maximum		**12 to 16**	**CH**		**85**	**55**	**34**	**24**
Minimum		**0 to 0.5**	**SC**		**42**	**30**	**13**	**4**
Standard deviation		**3.2 to 3.3**			**13**	**6**	**5**	**3**
Average		**4.3 to 5.1**	**CL**		**66**	**39**	**22**	**11**

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bgs	Below ground surface
ID	Identification
USCS	Unified Soil Classification System

Shading indicates samples failing the Table 1 criteria

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
BR250023	250023	[illegible]	SC-SM	SILTY CLAYEY SAND	48	22	[illegible]	10
BR250023	250023	3 to 4	CL	LEAN CLAY		38	21	20
BR250023	250023	[illegible]	SC-SM	SILTY CLAYEY SAND	[illegible]	[illegible]	[illegible]	8
BR250023	250023	9.5 to 10	CL	SANDY LEAN CLAY	57	38	22	14
BR250023	250023	13 to 13.5	CH	SANDY FAT CLAY	64	57	34	18
BR250023	250023	14 to 14.5	CH	SANDY FAT CLAY				8
BR250023	250023	15.5 to 16	CL	SANDY LEAN CLAY	61	41	27	10
BR250023	250023	17.5 to 18	CH	SANDY FAT CLAY				17
BR250023	250023	20 to 21	CL	SANDY FAT CLAY				10
BR250023	250023	[illegible]	SC-SM	SILTY CLAYEY SAND	[illegible]	[illegible]	[illegible]	10
BR250023	250023	[illegible]	SC-SM	SILTY CLAYEY SAND	[illegible]	[illegible]	[illegible]	13
BR250024	250024	0.5 to 1	CL	LEAN CLAY		38	21	17
BR250024	250024	4 to 4.5	CL	LEAN CLAY		38	21	6
BR250024	250024	8.5 to 9	CH	SANDY FAT CLAY	64	57	34	6
BR250024	250024	11 to 11.5	CL	LEAN CLAY w/ sand	80	39	19	14
BR250024	250024	13 to 14	CL	SANDY LEAN CLAY	61	41	27	11
BR250024	250024	17 to 17 5	CL	SANDY LEAN CLAY	57	38	22	12
BR250025	250025	0.5 to 1	CL	SANDY LEAN CLAY	65	38	23	18
BR250025	250025	3.5 to 4	CL	LEAN CLAY				8
BR250025	250025	[illegible]	SC-SM	SILTY CLAYEY SAND	33	22	6	4
BR250025	250025	7.5 to 8	CL	SANDY LEAN CLAY				10
BR250025	250025	10 to 10.5	CL	LEAN CLAY w/ sand				10
BR250025	250025	14 to 14.5	CL	SANDY LEAN CLAY				14
BR250026	250026	0.5 to 1	CL	SANDY LEAN CLAY				16
BR250026	250026	4 to 5	CL	LEAN CLAY w/ sand	70	31	16	7
BR250026	250026	7.5 to 8	CL	SANDY LEAN CLAY				8
BR250026	250026	9 to 10	CL	LEAN CLAY w/ sand				8
BR250026	250026	10 to 10.5	CL	SANDY LEAN CLAY				8
BR250026	250026	11 to 12	CL	SANDY LEAN CLAY				8
BR250027	250027	0.5 to 1	CL	SANDY LEAN CLAY				13
[illegible]	[illegible]	[illegible]	SC	CLAYEY SAND w/ gravel	[illegible]	[illegible]	[illegible]	[illegible]
BR250028	250028	0.5 to 1	CL	LEAN CLAY w/ sand	70	40	18	22
[illegible]	[illegible]	[illegible]	CL	SANDY LEAN CLAY	55	26	12	[illegible]
BR250028	250028	6 to 6.5	CL	SANDY LEAN CLAY	57	42	24	11
BR250028	250028	11 to 12	CL	LEAN CLAY w/ sand	71	41	23	12
BR250029	250029	1.3 to 2	CL	SANDY LEAN CLAY	66	34	21	8
BR250029	250029	3 to 4	CL	LEAN CLAY	91	38	22	9
[illegible]	250029	[illegible]	CL	SANDY LEAN CLAY	57	29	16	[illegible]
BR250030	250030	0.3 to 0.8	CL	LEAN CLAY w/ sand				15
BR250030	250030	1 to 1.5	CL	LEAN CLAY w/ sand				15
BR250030	250030	3.5 to 4	CL	SANDY LEAN CLAY				5
BR250030	250030	[illegible]	SM	SILTY SAND	24	[illegible]	[illegible]	[illegible]
BR250030	250030	8.5 to 9	CL	SANDY LEAN CLAY				9
BR250030	250030	13.5 to 14	CL	LEAN CLAY w/ sand				9
BR250030	250030	18.5 to 19	CL	LEAN CLAY w/ sand				10
BR250030	250030	23 to 24	CL	LEAN CLAY w/ sand				7
BR250030	250030	25 to 26	CL	LEAN CLAY w/ sand				11
BR250031	250031	1 to 2	CL	SANDY LEAN CLAY	70	34	18	10
BR250031	250031	5 to 6.5	CL	SANDY LEAN CLAY	56	46	30	16
BR250031	250031	12.5 to 13.5	CL	SANDY LEAN CLAY	56	43	28	10
BR250031	250031	[illegible]	SP-SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BR250032	250032	0.5 to 1.3	CL	LEAN CLAY w/ sand				14
BR250032	250032	1.3 to 2	CL	SANDY LEAN CLAY w/ caliche				8
BR250032	250032	5 to 6.5	CL	SANDY LEAN CLAY w/ caliche				6

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)			USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
BR250032	250032	7	to	7.5	CL	LEAN CLAY w/ sand				7
BR250033	250033	1.2	to	1.7	CL	SANDY LEAN CLAY	72	36	21	9
BR250033	250033	[illegible]	to	[illegible]	CL	SANDY LEAN CLAY	51	30	10	11
BR250034	250034	0.5	to	1	CL	SANDY LEAN CLAY	70	37	22	15
BR250034	250034	2.5	to	3	CL	SANDY LEAN CLAY				10
BR250034	250034	5	to	6	SC	CLAYEY SAND	45	30	16	8
BR250035	250035	0.5	to	1.1	CL	SANDY LEAN CLAY	59	36	22	19
BR250035	250035	1.1	to	2	CL	SANDY LEAN CLAY				9
BR250035	250035	2.2	to	2.9	CL	SANDY LEAN CLAY				12
BR250036	250036	0.5	to	1	CH	SANDY FAT CLAY	65	57	39	20
BR250036	250036	1.5	to	2	CL	SANDY LEAN CLAY				9
BR250036	250036	4	to	4.5	CL	SANDY LEAN CLAY				15
BR250036	250036	5.5	to	6	CL	SANDY LEAN CLAY				10
BR250036	250036	7.5	to	8	CL	SANDY LEAN CLAY				12
BR250036	250036	10.5	to	11	CL	SANDY LEAN CLAY				13
BR250036	250036	12.5	to	13	CL	SANDY LEAN CLAY	70	45	28	15
BR250036	250036	13.5	to	14	CL	SANDY LEAN CLAY	60	42	26	16
BR250037	250037	1	to	1.6	CL	SANDY LEAN CLAY				19
[illegible]	250037	[illegible]	to	[illegible]	CL	SANDY LEAN CLAY	52	25	12	[illegible]
BR250037	250037	5	to	6.5	CL	SANDY LEAN CLAY	52	32	19	8
BR250037	250037	7	to	8	CL	SANDY LEAN CLAY	53	36	23	9
[illegible]	[illegible]	[illegible]	to	[illegible]	GC	CLAYEY GRAVEL w/ sand	13	30	17	[illegible]
BR250038	250038	0.5	to	0.9	CL	SANDY LEAN CLAY	66	34	19	21
BR250038	250038	0.9	to	2	CL	SANDY LEAN CLAY	75	36	23	9
BR250038	250038	5	to	6.5	CL	SANDY LEAN CLAY	50	34	21	8
BR250038	250038	8	to	9	SC	CLAYEY SAND	47	33	20	7
BR250038	250038	10	to	11.5	CL	SANDY LEAN CLAY				8
BR250038	250038	13.5	to	14	SC	CLAYEY SAND				5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SW-SM	SAND w/ silt [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SP	SAND [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	250038	[illegible]	[illegible]	[illegible]	SP	SAND	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SP-SM	SAND [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SP-SM	SAND w/ silt	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	250038	[illegible]	to	[illegible]	SW-SM	SAND w/ silt [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BR250039	250039	0.5	to	1	CL	SANDY LEAN CLAY				19
BR250039	250039	2	to	2.5	CL	LEAN CLAY		37	20	12
BR250039	250039	3.5	to	4	SC	CLAYEY SAND				7
BR250039	250039	9	to	10	SC	CLAYEY SAND				10
BR250039	250039	14	to	15	SC	CLAYEY SAND	46	34	20	11
[illegible]	[illegible]	[illegible]	to	[illegible]	SW-SM	SAND w/ silt and gravel	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	250039	[illegible]	to	[illegible]	SC-SM	SILTY CLAYEY SAND	18	[illegible]	[illegible]	[illegible]
BR250040	250040	0.5	to	1	CL	LEAN CLAY w/ sand	77	46	26	23
BR250040	250040	2	to	2.5	CH	FAT CLAY	95	50	29	12
BR250041	250041	1.5	to	2	CL	SANDY LEAN CLAY				7
BR250041	250041	4	to	4.5	CL	LEAN CLAY				11
BR250041	250041	5.5	to	6	SC	CLAYEY SAND	49	39	20	10
BR250041	250041	9	to	10	CL	SANDY LEAN CLAY				12
BR250041	250041	10	to	10.5	CL	SANDY LEAN CLAY				7
BR250042	250042	2	to	2.5	CH	SANDY FAT CLAY	74	60	39	17
BR250042	250042	3	to	3.5	CL	SANDY LEAN CLAY				15
BR250042	250042	8.5	to	9.5	SC	CLAYEY SAND				7
BR250042	250042	13	to	13.5	CL	SANDY LEAN CLAY	51	34	19	8
BR250043	250043	1.5	to	2	CL	SANDY LEAN CLAY				7
BR250043	250043	4	to	4.5	CL	SANDY LEAN CLAY				12

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)			USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
BR250043	250043	5.5	to	6	CL	SANDY LEAN CLAY				8
BR250044	250044	0.5	to	1	CL	SANDY LEAN CLAY				15
BR250044	250044	3	to	3.5	CL	SANDY LEAN CLAY				9
BR250044	250044	5.5	to	6	CL	SANDY LEAN CLAY				6
BR250045	250045	2	to	2.5	CL	SANDY LEAN CLAY				9
BR250045	250045	3.5	to	4	CL	SANDY CLAY	59	30	16	8
BR250045	250045	5.5	to	6	CL	SANDY CLAY				9
BR250046	250046	0.5	to	1	CL	SANDY LEAN CLAY				15
BR250046	250046	3	to	3.5	CL	SANDY LEAN CLAY				11
BR250046	250046	6	to	6.5	CL	SANDY LEAN CLAY				6
[illegible]	[illegible]	[illegible]	to	[illegible]	SC-SM	CLAYEY SAND w/ gravel	15	21	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SC-SM	SILTY, CLAYEY SAND	38	17	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SM	SILTY SAND	26	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SC-SM	SILTY, CLAYEY SAND	34	21	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SM	SILTY SAND	[illegible]	[illegible]	[illegible]	[illegible]
BR260134	260134	10.7	to	11.5	CL	LEAN CLAY	88	36	21	15
BR260134	260134	15	to	16.5	SC	SANDY LEAN CLAY	52	34	18	20
BR260134	260134	18.5	to	19.5	CL	CLAYEY SAND	50	35	22	12
[illegible]	260134	20	to	[illegible]	[illegible]	SANDY LEAN CLAY	58	41	23	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BR250047	250047	0.5	to	2	CL	LEAN CLAY w/ sand				12
BR250047	250047	3	to	4	CL	SANDY LEAN CLAY				5
BR250047	250047	5	to	6.5	CL	SANDY LEAN CLAY				9
BR250047	250047	10	to	11	CL	SANDY LEAN CLAY	54	36	23	12
BR250047	250047	11.4	to	12.3	CL	LEAN CLAY w/ sand				9
BR250047	250047	15	to	16	CL	LEAN CLAY w/ sand				15
BR250047	250047	20	to	21	CL	SANDY LEAN CLAY	58	40	23	13
BR250047	250047	23 2	to	24	CL	SANDY LEAN CLAY				18
BR250047	250047	25	to	26.8	CL	SANDY LEAN CLAY				18
[illegible]	250047	[illegible]	to	[illegible]	SC	CLAYEY SAND	23	37	18	10
BR250047	250047	30	to	31.3	SC	CLAYEY SAND				6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SC	CLAYEY SAND	50	27	12	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SC	CLAYEY SAND	[illegible]	29	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SC-SM	SILTY, CLAYEY SAND	[illegible]	21	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SC-SM	SILTY, CLAYEY SAND	[illegible]	[illegible]	[illegible]	[illegible]
BR260135	260135	10	to	11.5	CL	LEAN CLAY w/ sand	84	32	16	13
BR260135	260135	13	to	14	CL	LEAN CLAY	88	36	20	14
BR260135	260135	15	to	16.5	CL	SANDY CLAY	69	36	21	16
BR260135	260135	20	to	21.5	CL	SANDY CLAY	60	37	21	14
BR260135	260135	22.5	to	24	CL	SANDY CLAY				14
BR260135	260135	25	to	26.5	CL	SANDY CLAY				15
BR260135	260135	27.5	to	29	CL	LEAN CLAY w/ sand	70	47	28	23
[illegible]	260135	[illegible]	to	[illegible]	SC	CLAYEY SAND w/ gravel	[illegible]	[illegible]	[illegible]	[illegible]
BR260135	260135	32.5	to	34	SC	CLAYEY SAND w/ gravel				14
BR260135	260135	35	to	36.2	SC	CLAYEY SAND w/ gravel				20
BR260135	260135	38	to	39	SC	CLAYEY SAND w/ gravel				12
BR250048	250048	0	to	1.4	SC	CLAYEY SAND				12
BR250048	250048	1 4	to	2	CL	SANDY CLAY	63	33	19	8
BR250048	250048	5	to	6.5	CL	SANDY CLAY				9
BR250048	250048	10	to	10.4	CL	SANDY CLAY				9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CLAYEY SAND	[illegible]	30	15	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SAND	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SAND	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	250048	[illegible]	to	[illegible]	[illegible]	SAND w/ gravel	[illegible]	[illegible]	[illegible]	[illegible]

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
BR250048	250048	[illegible]	SP	SAND w/ gravel				[illegible]
BR250050	250050	2 to 4	CL	LEAN CLAY				8
BR250050	250050	6.7 to 7.8	CL	SANDY CLAY				5
BR250050	250050	12 to 14	CL	SANDY CLAY				9
BR250050	250050	17 3 to 19	CL	GRAVELLY SANDY CLAY				10
BR250051	250051	0.5 to 1.5	CL	SANDY CLAY				9
BR250051	250051	3 to 4.5	CL	SANDY CLAY				4
BR250051	250051	12 to 13	CL	SANDY CLAY				5
BR250051	250051	18 to 19	CL	SANDY CLAY				8
BR250051	250051	28.5 to 30	CL	SANDY CLAY				13
BR250051	250051	33 to 34	CL	SANDY CLAY				19
BR250051	250051	38.5 to 39.1	SC	CLAYEY SAND				8
BR250051	250051	39.1 to 40	SC	GRAVELLY CLAYEY SAND				7
BR250052	250052	[illegible]	GM	SILTY GRAVEL w/ sand				10
BR250052	250052	[illegible] to 20	[illegible]	GRAVEL w/ sand				[illegible]
BR250052	250052	[illegible]	[illegible]	GRAVEL w/ sand				[illegible]
BR250053	250053	1.4 to 2.7	CL-CH	LEAN CLAY				10
BR250053	250053	2.7 to 3.4	CL	SANDY LEAN CLAY				7
BR250053	250053	6.7 to 8	CL	SANDY LEAN CLAY				8
BR250054	250054	0 5 to 1.5	CL	SANDY LEAN CLAY				14
BR250054	250054	2.2 to 2.9	CL	SANDY LEAN CLAY				11
BR250054	250054	11 7 to 13	SC	CLAYEY SAND w/ gravel				5
BR260136	260136	0.5 to 2	CL	SANDY CLAY	62	31	18	14
BR260136	260136	3 to 4	SC	CLAYEY SAND				7
BR260136	260136	5 to 6.5	SC	CLAYEY SAND				10
BR260136	260136	8.5 to 9.5	CL	SANDY CLAY	64	40	22	19
BR260136	260136	10 to 11.5	CL	SANDY CLAY				16
BR260136	260136	15 to 16.5	CL	SANDY CLAY				15
BR260136	260136	20 to 21.5	CL	LEAN CLAY w/ sand				19
BR260136	260136	22 5 to 24	CL	LEAN CLAY w/ sand				21
BR260136	260136	25 to 26.5	SC	CLAYEY SAND w/ gravel				17
BR260136	260136	27 5 to 29	CL	LEAN CLAY w/ sand				23
BR260136	260136	30 to 31.5	CL	LEAN CLAY w/ sand				19
BR260136	260136	32 5 to 34	CH	FAT CLAY		59	36	31
BR260136	260136	35 to 36.5	CH	FAT CLAY				33
[illegible]	[illegible]	[illegible]	SM	SILTY SAND	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	SP-SM	SILTY SAND	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	SP-SM	SILTY SAND	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	SM	SILTY SAND	[illegible]	[illegible]	[illegible]	[illegible]
PT250001	250001	8 to 10	CL	LEAN CLAY		35	19	8
PT250001	250001	14 to 16	CL	SANDY LEAN CLAY	51	32	20	7
PT250001	250001	17.5 to 18.5	CL	SANDY LEAN CLAY	60	31	13	9
PT250001	250001	19.5 to 20	SM	SILTY SAND				[illegible]
PT250002	250002	5 to 6	CL	LEAN CLAY				7
PT250002	250002	[illegible]	SM	SILTY SAND	29			[illegible]
PT250002	250002	9 to 9 5	CL	SANDY LEAN CLAY				9
PT250002	250002	12.5 to 13	CH	FAT CLAY w/ sand	82	51	31	8
PT250002	250002	14.5 to 15	CH	FAT CLAY w/ sand	82	51	31	12
PT250002	250002	17 to 17.5	CH	FAT CLAY w/ sand	82	51	31	14
PT250003	250003	0 5 to 1	CL	SANDY LEAN CLAY	67	36	22	18
PT250003	250003	3 to 4	CH	FAT CLAY w/ sand	82	51	31	9
PT250003	250003	6 to 6.5	CH	FAT CLAY w/ sand	82	51	31	10
PT250003	250003	8 to 8.5	CL	SANDY LEAN CLAY				
PT250003	250003	10 to 10.5	CL	SANDY LEAN CLAY	60	36	22	9

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
PT250003	250003	11 to 11.5	CL	LEAN CLAY w/ sand	77	47	26	17
PT250004	250004	4 to 5	SM	SILTY SAND				[illegible]
PT250004	250004	11 to 12	CL	SANDY LEAN CLAY				7
PT250004	250004	14 to 15 5	CL	SANDY LEAN CLAY				9
PT250004	250004	16 to 17.5	CL	SANDY LEAN CLAY				7
PT250005	250005	3 to 4	CL	LEAN CLAY				8
PT250005	250005	6 to 6.5	CL	SANDY LEAN CLAY				9
PT250006	250006	2 to 3	CH	FAT CLAY w/ sand				14
PT250007	250007	0.5 to 1	CL	SANDY LEAN CLAY				20
PT250007	250007	1.2 to 1.5	CL	LEAN CLAY				7
PT250007	250007	5.6 to 6	CL	SANDY LEAN CLAY				7
PT250007	250007	10.5 to 11	CL	SANDY LEAN CLAY				8
PT250008	250008	3 to 3.5	CL	SANDY LEAN CLAY				8
PT250008	250008	5.5 to 6.5	CL	SANDY LEAN CLAY				15
PT250008	250008	8 to 9	CL	SANDY LEAN CLAY				10
PT250009	250009	3.5 to 4.5	CL	LEAN CLAY	87	44	25	11
PT250009	250009	5 to 6	CL	SANDY LEAN CLAY	70	34	15	8
PT250009	250009	7.5 to 8	CL	SANDY LEAN CLAY	65	38	17	10
PT250009	250009	14 to 15	CL	SANDY LEAN CLAY	65	36	19	9
PT250010	250010	4.5 to 5	CL	SANDY LEAN CLAY				7
PT250010	250010	7 to 8	CL	SANDY LEAN CLAY				15
PT250010	250010	[illegible] to 12	SC-SM	SILTY/CLAYEY SAND	23	22	[illegible]	[illegible]
PT250010	250010	[illegible] to 15	SC-SM	SILTY/CLAYEY SAND	16	22	5	[illegible]
PT250011	250011	2 to 3	CL	LEAN CLAY				11
PT250011	250011	7 to 8	CL	SANDY LEAN CLAY				8
PT250011	250011	10 to 11	CL	SANDY LEAN CLAY	59	36	21	10
PT250012	250012	0.2 to 0.5	CL	LEAN CLAY w/ sand	74	36	19	17
PT250012	250012	3 5 to 4	CL	SANDY LEAN CLAY				7
PT250012	250012	5.3 to 5.8	CL	SANDY LEAN CLAY				7
PT250012	250012	10 to 10.5	CL	LEAN CLAY	85	36	17	10
PT250012	250012	11.5 to 12	CL	LEAN CLAY	83	38	19	15
PT250013	250013	5 to 6	CL	SANDY LEAN CLAY	51	30	14	8
PT250013	250013	8 to 9	SC-SM	SILTY/CLAYEY SAND				15
PT250013	250013	11 to 12	CL	SANDY LEAN CLAY				8
PT250013	250013	13 to 14	CL	SANDY LEAN CLAY				13
PT250013	250013	15 to 16	CL	SANDY LEAN CLAY				11
PT250013	250013	19 to 20	SM	SILTY SAND w/ gravel	14			[illegible]
PT250013	250013	22 to 25	SM	SILTY SAND w/ gravel	[illegible]			10
PT250014	250014	4 to 4.5	CL	SANDY LEAN CLAY				6
PT250014	250014	11 to 11.5	CL	SANDY LEAN CLAY				7
PT250014	250014	12.5 to 13.5	SC	CLAYEY SAND	43	33	18	9
PT250014	250014	15 to 15 5	CL	SANDY LEAN CLAY				5
PT250014	250014	16.5 to 17	SM	SILTY SAND w/ gravel				3
PT250015	250015	3 to 5	CL	SANDY LEAN CLAY				8
PT250015	250015	6 5 to 7.5	CL	SANDY LEAN CLAY	61	32	16	6
PT250015	250015	10 to 10.5	CL	SANDY LEAN CLAY				6
PT250016	250016	0.5 to 1	CL	LEAN CLAY w/ sand				13
PT250016	250016	2 to 2.5	CL	SANDY LEAN CLAY				6
PT250016	250016	5 to 5.5	CL	SANDY LEAN CLAY				8
PT250017	250017	3 to 4	CL	SANDY LEAN CLAY				7
[illegible]	[illegible]	[illegible]	SM	SILTY SAND	13			[illegible]
[illegible]	[illegible]	[illegible]	SC	CLAYEY SAND	[illegible]	21	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	SC	CLAYEY SAND	[illegible]	25	[illegible]	[illegible]
PT250018	250018	5 to 5.5	SC	CLAYEY SAND	49	34	19	14

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)			USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
PT250018	250018	10	to	10.5	SC	CLAYEY SAND				10
PT250018	250018	12	to	12.5	CL	SANDY LEAN CLAY	65	38	24	13
PT250018	250018	13.5	to	14	CL	SANDY LEAN CLAY				14
PT260001	260001	0.5	to	1	SC	CLAYEY SAND				14
PT260001	260001	1.5	to	2	SC	CLAYEY SAND				5
PT260001	260001	3	to	3.5	SC	CLAYEY SAND				4
PT260001	260001	5	to	5.5	SC	CLAYEY SAND				14
PT260001	260001	10	to	10.5	SC	CLAYEY SAND				9
PT260001	260001	12	to	12.5	CL	SANDY LEAN CLAY				19
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
PT250019	250019	0.5	to	1	SC	CLAYEY SAND				9
PT250019	250019	2	to	2 5	SC	CLAYEY SAND				5
PT250019	250019	3	to	3.5	SC	CLAYEY SAND				5
PT250019	250019	5	to	5.5	SC	CLAYEY SAND				4
PT250019	250019	9.5	to	10	SC	CLAYEY SAND				9
PT250019	250019	11	to	11 5	CL	SANDY LEAN CLAY				7
PT250019	250019	15	to	15.5	CL	SANDY LEAN CLAY				8
PT250019	250019	17.5	to	18	GC	CLAYEY GRAVEL w/ sand				9
PT250019	250019	19	to	19.5	CL	SANDY LEAN CLAY	48	36	21	9
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
PT250020	250020	2.5	to	3	CL	LEAN CLAY w/ sand	84	35	21	9
PT250020	250020	5	to	5 2	SC	CLAYEY SAND				8
PT250020	250020	7	to	7.5	CL	SANDY LEAN CLAY				9
PT250020	250020	10 5	to	11	CL	SANDY LEAN CLAY				
PT250020	250020	12.5	to	13	SC	CLAYEY SAND				10
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
PT260002	260002	0.5	to	1	SC	CLAYEY SAND				13
PT260002	260002	2.5	to	3	CL	LEAN CLAY w/ sand				6
PT260002	260002	5	to	5.5	CL	LEAN CLAY w/ sand				8
PT260002	260002	8	to	8.5	CL	LEAN CLAY w/ sand				9
PT260002	260002	9.5	to	10	CL	SANDY LEAN CLAY				11
PT260002	260002	14	to	14 5	SC	CLAYEY SAND				3
ASB11594	115	4	to	8	CL	LT. BROWN SANDY CLAY	56	43	26	9
ASB11694	116	0	to	4	CL	BROWN SANDY LEAN CLAY	58	42	24	7
ASB11894	118	4	to	8	CL	BROWN SANDY LEAN CLAY	61	43	24	9
ASB11994	119	4	to	8	CL	BROWN SANDY LEAN CLAY	58	42	24	8
ASB12094	120	4	to	8	CL	BROWN SANDY LEAN CLAY	57	47	27	14
ASB12494	124	0	to	4	CL	BROWN SANDY LEAN CLAY	61	41	19	9
ASB12594	125	4	to	8	CL	BROWN SANDY LEAN CLAY	57	32	18	7
ASB12794	127	0	to	4	CL	BROWN SANDY LEAN CLAY	67	33	13	9
ASB12994	129	0	to	4	SC	BROWN CLAYEY SAND	49	34	16	8
BRB13094	130	20	to	24	CL	BROWN SANDY LEAN CLAY	53	42	27	11
BRB13594	135	8	to	12	CL	BROWN SANDY LEAN CLAY	51	35	16	7
WEB11494	114	8	to	12	CL	BROWN SANDY LEAN CLAY	51	31	13	9
SAB11794	117	8	to	12	CL	BROWN SANDY CLAY	47	36	20	11
SAB12194	121	4	to	8	CL	BROWN SANDY LEAN CLAY	56	39	24	8
SAB12294	122	16	to	20	CL	BROWN SANDY LEAN CLAY	53	44	28	9
SAB12394	123	4	to	8	CH	BROWN SANDY FAT CLAY	59	50	31	10
ASB12694	126	12	to	16	CL	BROWN SANDY LEAN CLAY	60	41	25	9
WEB11494	114	0	to	4	CL	BROWN SANDY CLAY	83	41	23	10
ASB12694	126	8	to	12	CL	BROWN SANDY LEAN CLAY	59	37	19	11
WEB11494	114	4	to	8	CL	BROWN SANDY LEAN CLAY	62	41	24	10
WEB11494	114	16	to	20	CL	BROWN SANDY LEAN CLAY	59	44	26	15

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)			USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
WEB11494	114	20	to	24	SC	BROWN CLAYEY SAND	36	40	24	11
ASB11594	115	0	to	4	CL	BROWN SANDY LEAN CLAY	69	40	22	11
SAB11794	117	16	to	20	SC	BROWN CLAYEY SAND W/GR	25	39	23	8
SAB11794	117	12	to	16	SC	BROWN CLAYEY SAND	36	38	23	8
SAB11794	117	4	to	8	SC	BROWN CLAYEY SAND	48	46	28	12
SAB11794	117	0	to	4	CH	BROWN SANDY FAT CLAY	56	57	37	10
ASB12594	125	0	to	4	CL	BROWN LEAN CLAY W/SAND	78	39	20	10
ASB12594	125	8	to	12	SC	BROWN CLAYEY SAND	44	35	21	7
ASB12594	125	12	to	16	CL	BROWN SANDY LEAN CLAY	54	38	21	7
ASB12794	127	4	to	8	CL	BROWN SANDY LEAN CLAY	51	33	14	9
ASB12094	120	0.5	to	4	ML	BROWN SANDY SILT	69	32	8	8
ASB12094	120	8	to	12	CL	BROWN SANDY LEAN CLAY	59	44	24	13
ASB12094	120	12	to	16	SC	BROWN CLAYEY SAND W/GR	17	47	29	[illegible]
ASB12094	120	16	to	20	SP-SM	BROWN SAND W/SILT AND G	11	[illegible]	[illegible]	[illegible]
ASB12094	120	20	to	24	SW-SM	BROWN SAND W/SILT AND G	8	[illegible]	[illegible]	12
SAB12294	122	0	to	4	CL	BROWN LEAN CLAY W/SAND	71	38	17	10
SAB12294	122	4	to	8	CL	BROWN SANDY LEAN CLAY	63	44	26	11
SAB12294	122	8	to	12	CL	BROWN SANDY LEAN CLAY	53	48	31	12
SAB12294	122	12	to	16	CL	BROWN SANDY LEAN CLAY	69	46	30	13
SAB12294	122	20	to	24	SC	BROWN CLAYEY SAND	29	37	20	[illegible]
SAB12294	122	24	to	28	SP-SC	BROWN SAND W/CLAY AND	12	63	42	[illegible]
SAB12394	123	0	to	4	CL	BROWN SANDY LEAN CLAY	55	39	15	10
SAB12394	123	8	to	12	CL	BROWN SANDY LEAN CLAY	67	49	35	13
SAB12394	123	12	to	16	SC	BROWN CLAYEY SAND	50	56	38	13
SAB12394	123	16	to	20	SW-SM	BROWN SAND W/SILT	7	[illegible]	[illegible]	[illegible]
ASB12694	126	0	to	4	SC	BROWN CLAYEY SAND	50	35	18	9
ASB12694	126	4	to	8	CL	BROWN SANDY LEAN CLAY	63	31	14	8
ASB12694	126	16	to	20	CL	BROWN LEAN CLAY W/SAND	71	44	27	11
ASB12694	126	20	to	24	CL	BROWN SANDY LEAN CLAY	52	43	29	11
ASB12694	126	24	to	28	CH	BROWN SANDY FAT CLAY	53	52	35	15
ASB12694	126	28	to	32	CL	BROWN SANDY LEAN CLAY	53	46	27	14
ASB12994	129	4	to	8	CL	BROWN SANDY LEAN CLAY	53	32	16	12
ASB12994	129	8	to	12	SC	BROWN CLAYEY SAND	38	51	30	13
ASB12994	129	12	to	16	SC	BROWN CLAYEY SAND	40	41	26	[illegible]
ASB12994	129	16	to	20	CL	BROWN SANDY LEAN CLAY	62	37	22	9
ASB12994	129	20	to	24	SC	BROWN CLAYEY SAND	47	44	20	10
BRB13094	130	0	to	4	SC-SM	BROWN SILTY CLAYEY SAND	28	26	5	[illegible]
BRB13094	130	4	to	8	CL	BROWN SANDY LEAN CLAY	59	33	14	7
BRB13094	130	8	to	12	SC	BROWN CLAYEY SAND	[illegible]	41	23	[illegible]
BRB13094	130	12	to	16	SC	BROWN CLAYEY SAND	44	48	25	11
BRB13094	130	16	to	20	SC	BROWN CLAYEY SAND	40	48	30	10
BRB13094	130	24	to	28	CH	BROWN FAT CLAY W/SAND	81	50	34	10
BRB13094	130	28	to	32	CH	BROWN SANDY FAT CLAY	62	50	33	12
BRB13594	135	0	to	4	SC	BROWN CLAYEY SAND	[illegible]	36	17	[illegible]
BRB13594	135	4	to	8	CL	BROWN SANDY LEAN CLAY	50	28	12	[illegible]
BRB13594	135	12	to	16	CL	BROWN SANDY LEAN CLAY	51	37	20	7
BRB13594	135	16	to	20	SC	BROWN CLAYEY SAND	48	43	25	8
BRB13594	135	20	to	24	CL	BROWN SANDY LEAN CLAY	54	48	31	9
BRB13594	135	24	to	28	CL	BROWN SANDY LEAN CLAY	60	39	20	8
BRB13594	135	28	to	32	CH	BROWN SANDY FAT CLAY	60	54	31	12
BRB13594	135	32	to	36	CH	BROWN SANDY FAT CLAY	61	54	34	
BRB13594	135	36	to	40	SC	BROWN CLAYEY SAND	20	46	24	[illegible]
BRB13594	135	40	to	42	SC	BROWN CLAYEY SAND	[illegible]	48	30	[illegible]
ASB11894	118	0	to	4	CL	BROWN LEAN CLAY W/SAND	83	44	23	10

Table 3: CAMU Area Alluvial Soil
Summary of Soil Parameters

Boring Number	Short ID	Sample Depth (feet bgs)	USCS Symbol	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
ASB11994	119	0 to 4	CL	BROWN SANDY LEAN CLAY	56	41	22	8
SAB12194	121	0 to 4	CL	BROWN LEAN CLAY W/SAND	74	39	19	10
ASB11594	115	8 to 10	SC	BROWN CLAYEY SAND	35	41	24	6
WEB11494	114	12 to 16	CL	BROWN SANDY LEAN CLAY	70	42	24	14
PT250016	250016	0.5 to 1	CL	LEAN CLAY w/sand	72	36	21	0
PT250013	250013	5 to 6	CL	SANDY LEAN CLAY	53	37	20	0
ALL DATA POINTS								
Number of Data Points			**384**		**197**	**182**	**182**	**381**
Maximum		**40 to 42**	**CH**		**95**	**63**	**42**	**53**
Minimum		**0 to 0.5**	**and/Gravel**		**2**	**17**	**4**	**0**
Standard Deviation		**8.6 to 8.9**			**21**	**8**	**7**	**5**
Average		**9.8 to 11.9**	**CL**		**52**	**39**	**22**	**10**
DATA POINTS MEETING TABLE 1 CRITERIA								
Number of Data Points			**300**		**135**	**141**	**141**	**297**
% of data points that meet Table 1 criteria			**78%**		**69%**	**77%**	**77%**	**N/A**
Maximum		**35 to 36.5**	**CH**		**95**	**60**	**39**	**33**
Minimum		**0 to 0.5**	**SC**		**43**	**30**	**13**	**0**
Standard Deviation		**7.2 to 7.6**			**12**	**7**	**6**	**4**
Average		**8.5 to 10.5**	**CL**		**63**	**40**	**23**	**11**

Shading indicates samples failing Table 1 criteria

Table 4: Double-lined Cell Excavation Area
Summary of Alluvial Soil Parameters

RMA ID/ Clay Thkns.	X-Section IDs	Sample Number	Sample Depth (feet bgs)	USCS Symbo	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
BR250040	E-W "I"	D-1	0.5-1.0	CL	LEAN CLAY w/ sand	77	46	26	23
0' - 3'	N-S "5"	D-2	2.0-2.5	CH	FAT CLAY	95	50	29	12
BR250041	E-W "I"	D-1	1.5-2.0	CL	SANDY LEAN CLAY				7
0' - 16'	N-S "6"	D-2	4.0-4.5	CL	LEAN CLAY				11
		D-3	5.5-6.0	SC	CLAYEY SAND	49	39	20	10
		D-4	9.0-10.0	CL	SANDY LEAN CLAY				12
		D-5	10.0-10.5	CL	SANDY LEAN CLAY				7
BR250044	E-W "K"	D-1	0.5-1.0	CL	SANDY LEAN CLAY				15
0' - 6'	N-S "6"	D-2	3.0-3.5	CL	SANDY LEAN CLAY				9
		D-3	5.5-6.0	CL	SANDY LEAN CLAY				6
BR250045	E-W "K"	D-1	2.0-2.5	CL	SANDY LEAN CLAY				9
0' - 12'	N-S "5"	D-2	3.5-4.0	CL	SANDY CLAY	59	30	16	8
		D-3	5.5-6.0	CL	SANDY CLAY				9
PT250011	E-W "H"	D-1	2.0-3.0	CL	LEAN CLAY				11
0' - 14'	N-S "6"	D-2	7.0-8.0	CL	SANDY LEAN CLAY				8
		D-3	10.0-11.0	CL	SANDY LEAN CLAY	59	36	21	10
PT250012	E-W "H"	D-1	0.2-0.5	CL	LEAN CLAY W/SAND	74	36	19	17
0' - 12'	N-S "5"	D-2	3.5-4.0	CL	SANDY LEAN CLAY				7
		D-3	5.3-5.8	CL	SANDY LEAN CLAY				7
		D-4	10.0-10.5	CL	LEAN CLAY	85	36	17	10
		D-5	11.5-12.0	CL	LEAN CLAY	83	38	19	15
PT250013	E-W "H"	D-1	5.0-6.0	CL	SANDY LEAN CLAY	51	30	14	8
0'-8'/11'-19'	N-S "4"	* B-1	5.0-6.0	CL	SANDY LEAN CLAY	53	37	20	
		D-2	[illegible]	SC-SM	SILTY CLAYEY SAND				14.5
		D-3	11.0-12.0	CL	SANDY LEAN CLAY				8
		D-4	13.0-14.0	CL	SANDY LEAN CLAY				13
		D-5	15.0-16.0	CL	SANDY LEAN CLAY				11
		[illegible]	[illegible]	SM	SILTY SAND W/GRAVEL				5
		[illegible]	[illegible]	SM	SILTY SAND W/GRAVEL				10
PT250014	E-W "I"	D-1	4.0-4.5	CL	SANDY LEAN CLAY				6
4' - 16'	N-S "6"	D-2	11 0-11 5	CL	SANDY LEAN CLAY				7
		D-3	12.5-13.5	SC	CLAYEY SAND	43	33	18	9
		D-4	15.0-15.5	CL	SANDY LEAN CLAY				5
		[illegible]	16.5-17.0	SM	SILTY SAND W/GRAVEL				3
PT250015	E-W "J"	D-1	3.0-5.0	CL	SANDY LEAN CLAY				8
0' - 16'	N-S "6"	D-2	6.5-7.5	CL	SANDY LEAN CLAY	61	32	16	6
		D-3	10.0-10.5	CL	SANDY LEAN CLAY				6
PT250016	E-W "J"	D-1	0.5-1.0	CL	LEAN CLAY w/ sand				13
0' - 10'	N-S "5"	* B-1	0.5-1.0	CL	LEAN CLAY w/ sand	72	36	21	
		D-2	2.0-2.5	CL	SANDY LEAN CLAY				6
		D-3	5.0-5.5	CL	SANDY LEAN CLAY				8
PT250017	E-W "J"	D-1	3.0-4 0	CL	SANDY LEAN CLAY				7
[illegible]	N-S "4"	D-2	[illegible]	SM	SILTY SAND				2
ASB11894	E-W "H"		0-4	CL	LEAN CLAY w/sand	83	44	23	10
0' - 8'	N-S "6"		4-8	CL	SANDY LEAN CLAY	61	43	24	9

Table 4: Double-lined Cell Excavation Area
Summary of Alluvial Soil Parameters

RMA ID/ Clay Thkns.	X-Section IDs	Sample Number	Sample Depth (feet bgs)	USCS Symbo	USCS Name	Percent Fines	Liquid Limit	Plasticity Index	Percent Moisture
ALL DATA POINTS						17	15	15	43
Number of Data Points				45					
Maximum				CH		95	50	29	23
Minimum				SC		13	30	14	2
Standard Deviation						23	6	4	4
Average				CL		61	38	20	9
DATA POINTS MEETING TABLE 1 CRITERIA									
Number of Data Points				40		15	15	15	38
Percentage of data points that meet Table 1 criteria				89%		89%	100%	100%	88%
Maximum				CH		95	50	29	23
Minimum				SC		43	30	14	5
Standard Deviation						15	6	4	4
Average				CL		67	38	20	10

Shading indicates samples failing Table 1 criteria.

bgs	Below ground surface
ID	Identification
RMA	Rocky Mountain Arsenal
USCS	Unified Soil Classification System

* Bag samples combined for composite sample used to develop the Acceptable Zone.

Table 5: Summary of All Alluvial Soil Borrow Area Index Properties

	Borrow Area 5	CAMU Area	Double-lined Cell Excavation Area*
Number of alluvial soil samples obtained	188	384	45
Average USCS Classification	CL	CL	CL
Average Percent Fines	57	52	61
Average Liquid Limit	38	39	38
Average Plasticity Index	21	22	20

Values given are for all alluvial soil in these areas, including samples that did not meet Table 1 criteria.

CAMU Corrective Action Management Unit

* Part of the CAMU Area.

Table 6: Compaction and Testing Criteria for Test Fill 3

Objectives	Lane 1	Lane 2	Lane 3
Place Lift 1 Target UAZ 10" loose lift	4 passes Check for subgrade contamination 1 moisture grab sample	6 passes Check for subgrade contamination 1 moisture grab sample	8 passes Check for subgrade contamination 1 moisture grab sample
Place Lift 2 Target UAZ Test Lift 1 8" loose lift	4 or more passes 2 nuclear tests and 2 Shelby tubes	6 or more passes 2 nuclear tests and 2 Shelby tubes	8 or more passes 2 nuclear tests and 2 Shelby tubes
Place Lift 3 Target LAZ Test Lift 2 8" loose lift	4 or more passes 2 nuclear tests and 2 Shelby tubes	6 or more passes 2 nuclear tests and 2 Shelby tubes	8 or more passes 2 nuclear tests and 2 Shelby tubes
Place Lift 4 Target LAZ Test Lift 3 8" loose lift	4 or more passes 2 nuclear tests and 2 Shelby tubes	6 or more passes 2 nuclear tests and 2 Shelby tubes	8 or more passes 2 nuclear tests and 2 Shelby tubes
Place Lift 5 Target AZ Test Lift 4 8" loose lift	4 or more passes 2 nuclear tests and 2 Shelby tubes	6 or more passes 2 nuclear tests and 2 Shelby tubes	8 or more passes 2 nuclear tests and 2 Shelby tubes
Place Lift 6 Target AZ Test Lift 5 8" loose lift	4 or more passes 2 nuclear tests and 2 Shelby tubes	6 or more passes 2 nuclear tests and 2 Shelby tubes	8 or more passes 2 nuclear tests and 2 Shelby tubes
Place Lift 7 Target AZ Test Lift 6 8" loose lift	4 or more passes 2 nuclear tests and 2 Shelby tubes	6 or more passes 2 nuclear tests and 2 Shelby tubes	8 or more passes 2 nuclear tests and 2 Shelby tubes
Grade to 3 feet minimum Smooth roll surface	2 nuclear tests and 2 Shelby tube samples	2 nuclear tests and 2 Shelby tube samples	2 nuclear tests and 2 Shelby tube samples
Obtain block samples	3 samples with 1 taken from the upper foot and 2 taken from the middle foot of the test fill	3 samples with 1 taken from the upper foot and 2 taken from the lower foot of the test fill	3 samples with 1 taken from the upper foot and 1 taken from the middle foot of the test fill

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AZ	Acceptable zone
LAZ	Lower acceptable zone
UAZ	Upper acceptable zone

1 Test and sample locations will be selected at random by Engineer in the areas specified. The locations within the areas specified will be varied for each lift.
2. Shelby and block samples will be taken perpendicular to the surface of the lift.
3 Not all Shelby tube and block samples will be tested. The Engineer will select a minimum of six each for initial testing. The remainder will be archived. Archived samples may be tested at a later date.
4. Shelby tube samples will be taken beneath the nuclear test location (adjacent to probe hole).
5. Block samples will be taken after completion of construction. Block samples located below surface level will be obtained by excavating through the overlying lifts to the required sample depths.
6. Microwave and oven moisture content tests will be performed on samples obtained at each nuclear test location when testing Lifts 1 and 2.
7. One sandcone or rubber balloon correlation test will be performed on each lift at one of the nuclear test locations.

Table 6 (continued)

8. A minimum of one nuclear test and one Shelby tube will be obtained from both the base section and the sideslope section of each lane of each lift.
9. Of the nine block samples obtained, five will be obtained from the slope section and four will be obtained from the base section.
10. Field Test Methods

Nuclear Moisture Content	ASTM D3017	Sandcone Density	ASTM D1556
Nuclear Density	ASTM D2922	Rubber Balloon Density	ASTM D2167
Microwave Moisture Content	ASTM D4643	Oven Moisture Content	ASTM D2216

Appendix A

Tables 3.2 and 3.3

Final Feasibility Study Soils Support Program Report (Borrow Study Report)

Table 3.2: Permeability Test Results

Boring Number	Sample Depth (feet)	Perm. at 90 Percent* (cm/s)	Perm. at 95 Percent* (cm/s)	Perm. at 100 Percent* (cm/s)	Borrow Area
NUB00193	12.0	---	$5.11\text{x}10^{-8}$	$4.12\text{x}10^{-8}$	OT
NUB00293	14.0	---	$4.97\text{x}10^{-8}$	$4.06\text{x}10^{-8}$	OT
WEB00493	4.0	---	$6.78\text{x}10^{-9}$	$3.91\text{x}10^{-9}$	OT
WEB00593	20.0	---	$9.04\text{x}10^{-9}$	$1.17\text{x}10^{-9}$	OT
NUB00893	4.0	---	$1.45\text{x}10^{-8}$	$6.79\text{x}10^{-9}$	OT
NUB00993	19.0	---	$3.88\text{x}10^{-9}$	$3.08\text{x}10^{-9}$	1
NUB01293	4.0	---	$1.34\text{x}10^{-8}$	$9.69\text{x}10^{-9}$	1
NUB01293	12.0	---	$1.17\text{x}10^{-8}$	$1.62\text{x}10^{-9}$	1
WEB01393	4.0	---	$8.24\text{x}10^{-8}$	$4.12\text{x}10^{-9}$	1
WEB01593	16.0	---	$9.26\text{x}10^{-9}$	$3.43\text{x}10^{-9}$	OT
WEB02393	12.0	---	$2.45\text{x}10^{-8}$	$7.77\text{x}10^{-9}$	2
BRB03393	8.0	---	$9.03\text{x}10^{-5}$	$7.50\text{x}10^{-5}$	5
WEB03493	4.0	---	$2.15\text{x}10^{-8}$	$1.36\text{x}10^{-8}$	OT
WEB03993	13.0	---	$5.49\text{x}10^{-9}$	$4.24\text{x}10^{-9}$	OT
BRB04193	4.0	---	$3.24\text{x}10^{-4}$	$1.89\text{x}10^{-4}$	5
BRB04793	9.0	---	$2.17\text{x}10^{-8}$	$1.14\text{x}10^{-8}$	5
WEB05193	8.0	$3.59\text{x}10^{-8}$	$1.98\text{x}10^{-8}$	---	4
WEB05593	12.0	$6.91\text{x}10^{-9}$	$3.02\text{x}10^{-9}$	---	4
WEB05893	8.0	$2.90\text{x}10^{-8}$	$1.83\text{x}10^{-8}$	---	3
WEB05993	8.0	$3.88\text{x}10^{-6}$	$3.93\text{x}10^{-6}$	---	OT
WEB06393	8.0	$1.39\text{x}10^{-7}$	$8.57\text{x}10^{-8}$	---	3
WEB06493	12.0	$9.96\text{x}10^{-9}$	$5.93\text{x}10^{-9}$	---	3
WEB06693	8.0	$2.04\text{x}10^{-8}$	$1.53\text{x}10^{-8}$	---	3
WEB07293	8.0	$1.67\text{x}10^{-5}$	$2.66\text{x}10^{-5}$	---	OT
NUB07593	8.0	$6.16\text{x}10^{-8}$	$4.87\text{x}10^{-8}$	---	1
WEB07693	8.0	$5.96\text{x}10^{-7}$	$5.33\text{x}10^{-7}$	---	OT
WEB08093	4.0	$4.63\text{x}10^{-6}$	$3.37\text{x}10^{-6}$	---	OT
WEB08193	4.0	$9.15\text{x}10^{-6}$	$4.92\text{x}10^{-6}$	---	OT
WEB08493	8.0	$7.80\text{x}10^{-8}$	$3.82\text{x}10^{-8}$	---	2
WEB08893	4.0	$5.02\text{x}10^{-7}$	$2.80\text{x}10^{-7}$	---	OT
WEB09593	20.0	$1.79\text{x}10^{-8}$	$1.21\text{x}10^{-8}$	---	4
WEB09893	8.0	$2.06\text{x}10^{-8}$	$1.68\text{x}10^{-8}$	---	4

---	Not applicable, analysis not performed
cm/s	Centimeters per second
OT	Boring located outside proposed borrow areas
Perm.	Permeability

* Percent of Standard Proctor (ASTM D698)

Table 3.3: Grain Size, Atterberg Limits, and Moisture Content Results

Boring Number	Target Soil Unit	Sample Depth (feet)	Percent Passing No. 200 Sieve	USCS Soil Classification	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Dry Density (pcf)	Moisture Content (%)
NUB00193	NUNN	12.0	68.4	CL	40	18	22	—	15.1
NUB00293	NUNN	2.0	81.0	CL	49	21	28	—	12.3
NUB00293	NUNN	14.0	56.5	CL	42	17	25	—	9.8
NUB00393	NUNN	2.0	62.5	CL	38	18	20	—	9.6
WEB00493	WELD	4.0	88.4	CL	42	20	22	—	13.9
WEB00593	WELD	2.0	78.8	CL	46	21	25	—	10.1
WEB00593	WBEDROCK	20.0	—	CL	—	—	—	—	—
WEB00693	WELD	2.0	72.2	CL	35	18	17	—	8.0
WEB00793	WELD	2.0	84.6	CL	42	21	21	—	10.0
NUB00893	NUNN	2.0	66.3	CL	33	16	17	—	9.1
NUB00893	NUNN	4.0	68.1	CL	33	16	17	—	10.5
NUB00893	NUNN	11.0	41.8	SC	41	14	27	—	7.3
NUB00993	NUNN	2.0	74.3	CL	34	13	21	—	9.6
NUB00993	NUNN	6.0	63.9	CL	37	18	19	—	8.7
NUB00993	NUNN	11.0	44.8	SC	41	14	27	—	7.4
NUB00993	WBEDROCK	19.0	78.9	CH	62	24	38	—	24.6
NUB01093	NUNN	2.0	79.0	CL	36	18	18	—	9.5
NUB01093	NUNN	6.0	80.5	CL	36	16	20	—	12.2
NUB01093	NUNN	11.0	43.8	SC	39	13	26	—	13.7
NUB01193	NUNN	2.0	63.8	CH	52	18	34	—	10.5
NUB01193	NUNN	6.0	65.3	CL	39	21	18	—	9.3
NUB01193	NUNN	10.0	41.6	SC	36	16	20	—	10.8
NUB01293	NUNN	2.0	71.4	CL	48	16	32	—	10.7
NUB01293	NUNN	4.0	85.3	CL	41	19	22	—	12.2
NUB01293	NUNN	11.5	57.6	CL	44	16	28	—	18.4
WEB01393	WELD	2.0	65.0	CL	38	18	20	—	9.1
WEB01393	WELD	4.0	85.8	CL	45	20	25	—	10.9
WEB01493	WELD	2.0	78.0	CL	38	19	19	—	9.2
WEB01593	WELD	16.0	54.8	CL	46	19	27	—	14.1
WEB01693	WELD	1.5	47.1	CL	31	16	15	—	13.4
WEB01793	WELD	2.0	46.5	CL	32	20	12	—	12.1
NUB01893	NUNN	2.0	78.3	CL	39	19	20	—	18.4
WEB01993	WELD	2.0	73.0	CL	49	17	32	—	8.7
WEB01993	WELD	11.0	43.9	SC	26	16	10	—	5.2
WEB02093	WELD	2.0	72.8	CH	53	19	34	—	12.0
WEB02093	WELD	11.0	43.8	SC	37	15	22	—	8.1
WEB02193	WELD	2.0	51.2	CL	34	13	21	—	6.6
WEB02193	WELD	6.0	54.2	CL	36	15	21	—	6.7
WEB02193	WELD	11.0	54.3	CL	32	13	19	—	10.8
NUB02293	NUNN	6.0	45.4	SC	32	17	15	—	7.2
WEB02393	WELD	2.0	58.7	CL	33	15	18	—	7.7
WEB02393	WELD	6.0	52.7	CL	37	16	21	—	6.4
WEB02393	WELD	12.0	66.4	CL	46	19	27	—	14.5
NUB02493	NUNN	2.0	58.8	CL	39	18	21	—	9.8
NUB02493	NUNN	6.0	56.7	CL	30	16	14	—	8.2
NUB02493	NUNN	12.0	63.2	CL	34	16	18	—	8.9
NUB02593	NUNN	2.0	57.2	CL	34	16	18	—	13.2
NUB02593	NUNN	6.0	50.7	CL	32	16	16	—	6.3
NUB02593	NUNN	16.0	53.3	CL	44	17	27	—	10.9
NUB02693	NUNN	2.0	71.4	CL	38	17	21	—	11.5
NUB02693	NUNN	6.0	63.7	CL	33	16	17	—	7.4
NUB02693	WBEDROCK	11.0	71.7	CL	44	18	26	—	13.7
NUB02693	WBEDROCK	15.0	28.2	SC	37	16	21	—	8.5
WEB02793	WELD	2.0	89.9	CL	48	20	28	—	13.1
WEB02793	WELD	6.0	53.5	CL	45	18	27	—	11.0
WEB02793	WELD	11.0	37.9	SC	50	15	35	—	9.1
WEB02793	WELD	16.0	45.6	SC	50	20	30	—	16.4
WEB02893	WELD	2.0	79.0	CL	39	19	20	—	10.9

Table 3.3 (continued)

Boring Number	Target Soil Unit	Sample Depth (feet)	Percent Passing No. 200 Sieve	USCS Soil Classification	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Dry Density (pcf)	Moisture Content (%)
WEB02893	WELD	6.0	61.1	CL	38	16	22	—	8.5
WEB02893	WELD	11.0	61.1	CL	37	14	23	—	9.3
WEB02893	WELD	16.0	55.4	CL	42	15	27	—	8.6
WEB02893	WBEDROCK	20.0	62.2	CL	42	19	23	—	9.6
WEB02993	WELD	2.0	76.8	CL	46	21	25	—	11.6
WEB02993	WELD	6.0	73.4	CL	37	16	21	—	9.1
WEB02993	WELD	11.0	50.5	CL	37	16	21	—	10.1
WEB02993	WBEDROCK	16.0	87.8	CL	48	26	22	—	20.3
WEB03093	WELD	2.0	56.7	CL	37	20	17	—	8.5
WEB03093	WELD	6.0	46.6	SC	49	18	31	—	8.4
WEB03093	WELD	11.0	29.5	SC	46	15	31	—	6.3
WEB03193	WELD	2.0	59.2	CL	49	21	28	—	9.3
WEB03193	WELD	6.0	47.3	SC	36	14	22	—	8.7
WEB03193	WELD	11.0	58.0	CH	52	17	35	—	11.7
WEB03293	WELD	2.0	75.9	CL	41	22	19	—	11.1
WEB03293	WELD	6.0	55.1	CL	47	22	25	—	12.9
WEB03293	WELD	11.0	53.8	CL	47	17	30	—	10.6
BRB03393	BRESSER	8.0	14.9	SC	30	15	15	—	3.1
WEB03493	WELD	4.0	81.8	CH	52	21	31	—	14.0
WEB03493	WBEDROCK	16.0	91.3	CH	65	24	41	—	23.2
BRB03593	BRESSER	6.0	24.5	CL	30	17	13	—	4.6
BRB03693	BRESSER	6.0	20.0	SC	25	17	8	—	3.8
BRB03793	BRESSER	6.0	45.7	SC	40	19	21	—	9.0
WEB03893	WELD	2.0	74.2	CL	38	20	18	—	10.3
WEB03893	WELD	6.0	51.0	CL	39	13	26	—	7.2
WEB03893	WBEDROCK	16.0	41.2	SC	36	21	15	—	9.6
WEB03993	WELD	2.0	82.1	CL	48	22	26	—	10.1
WEB03993	WBEDROCK	12.5	86.9	CH	59	23	36	—	16.3
BRB04093	BRESSER	11.0	46.5	SC	38	17	21	—	7.6
BRB04193	BRESSER	4.0	30.0	SC	34	18	16	—	6.3
BRB04293	BRESSER	2.0	27.6	SC	36	18	18	—	4.7
BRB04393	BRESSER	6.0	10.1	SC	31	15	16	—	2.5
BRB04493	BRESSER	6.0	29.6	SC	28	17	11	—	5.4
WEB04593	WELD	2.0	49.7	SC	24	15	9	—	6.8
BRB04693	BRESSER	11.0	13.1	SC	31	15	16	—	2.5
BRB04793	BRESSER	6.0	48.6	SC	24	19	5	—	6.7
BRB04793	WBEDROCK	9.0	—	SC	—	—	—	—	—
BRB04893	BRESSER	2.0	35.1	SC	34	17	17	—	5.3
WEB04993	WELD	4.0	84.7	CL	31	20	11	—	12.4
WEB04993	WELD	8.0	71.5	CL	41	19	22	91.0	10.2
WEB04993	WBEDROCK	12.0	45.9	SC	45	21	24	—	6.8
WEB04993	WBEDROCK	14.0	28.1	SC	47	18	29	—	5.1
WEB05093	WELD	4.0	76.7	CL	42	19	23	—	9.4
WEB05093	WELD	8.0	63.9	CL	40	22	18	—	8.2
WEB05093	WELD	12.0	57.2	CL	45	23	22	—	10.8
WEB05093	WELD	16.0	18.0	SC	38	20	18	—	3.0
WEB05193	WELD	4.0	85.2	CL	42	19	23	—	25.1
WEB05193	WELD	8.0	72.5	CL	41	17	24	105.0	9.1
WEB05193	WELD	12.0	59.8	CL	55	24	31	—	5.9
WEB05293	WELD	4.0	77.4	CL	32	20	12	—	11.7
WEB05293	WELD	8.0	71.7	CH	54	24	30	—	11.4
WEB05293	WELD	12.0	63.6	CL	45	20	25	—	11.9
WEB05293	WBEDROCK	14.0	31.1	SC	49	19	30	—	7.8
WEB05393	WELD	4.0	74.0	CL	46	24	22	—	9.8
WEB05393	WELD	8.0	71.1	CL	43	21	22	—	8.8
WEB05393	WELD	12.0	57.6	CL	46	20	26	—	10.6
WEB05393	WELD	16.0	27.2	SC	49	21	28	—	16.0
WEB05393	WBEDROCK	20.0	97.2	CH	69	26	43	—	24.9

Table 3.3 (continued)

Boring Number	Target Soil Unit	Sample Depth (feet)	Percent Passing No. 200 Sieve	USCS Soil Classification	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Dry Density (pcf)	Moisture Content (%)
WEB05493	WELD	4.0	84.1	CL	40	21	19	—	10.0
WEB05493	WELD	8.0	60.9	CL	41	21	20	—	9.2
WEB05493	WELD	12.0	68.4	CL	33	16	17	—	9.1
WEB05493	WELD	16.0	23.0	SC	49	23	26	—	7.0
WEB05593	WELD	4.0	80.1	CH	50	22	28	—	12.3
WEB05593	WELD	8.0	69.2	CH	51	27	24	—	11.6
WEB05593	WBEDROCK	12.0	84.7	CL	46	19	27	101.0	14.4
WEB05593	WBEDROCK	16.0	82.3	CH	88	37	51	—	24.6
WEB05593	WBEDROCK	20.0	92.1	CH	72	33	39	—	20.7
WEB05693	WELD	4.0	71.8	CL	39	19	20	—	15.3
WEB05693	WELD	8.0	53.7	CL	37	21	16	—	10.6
WEB05693	WELD	12.0	47.2	SC	36	20	16	—	12.3
WEB05693	WELD	16.0	30.6	SC	38	19	19	—	9.0
WEB05793	WELD	4.0	52.7	CL	39	23	16	—	11.6
WEB05793	WELD	8.0	59.7	CL	40	23	17	—	11.4
WEB05793	WELD	12.0	58.8	CL	49	20	29	—	10.4
WEB05893	WELD	4.0	74.7	CL	44	20	24	—	17.5
WEB05893	WBEDROCK	8.0	82.4	CH	53	21	32	100.0	15.1
WEB05893	WBEDROCK	12.0	96.9	CH	79	28	51	—	22.7
WEB05893	WBEDROCK	16.0	99.8	CH	71	27	44	—	21.0
WEB05993	WELD	4.0	63.1	CL	45	23	22	—	6.5
WEB05993	WELD	8.0	53.1	CL	43	17	26	105.0	10.6
WEB05993	WELD	12.0	40.7	SC	43	18	25	—	9.4
WEB05993	WBEDROCK	16.0	58.0	CL	43	20	23	—	11.2
WEB06093	WELD	4.0	75.3	CL	36	19	17	—	10.2
WEB06093	WELD	8.0	62.3	CL	36	19	17	—	9.5
WEB06093	WELD	12.0	42.7	SC	48	19	29	—	6.9
WEB06093	WBEDROCK	13.5	60.8	CH	55	20	35	—	12.6
WEB06193	WELD	4.0	84.3	CL	43	23	20	—	15.2
WEB06193	WELD	8.0	44.6	SC	49	19	30	—	6.2
WEB06193	WBEDROCK	10.5	61.2	ML	33	25	8	—	10.0
WEB06293	WELD	4.0	52.9	CL	34	19	15	—	7.0
WEB06293	WELD	8.0	66.8	CL	44	24	20	—	11.9
WEB06293	WELD	12.0	59.5	CL	45	24	21	—	8.9
WEB06293	WELD	16.0	11.6	SW-SM	30	23	7	—	2.5
WEB06393	WELD	4.0	61.4	CL	42	21	21	—	8.2
WEB06393	WELD	8.0	45.7	SC	43	20	23	107.0	10.5
WEB06393	WELD	12.0	22.5	SC	34	17	17	—	4.4
WEB06393	WELD	16.0	4.5	SP	57	26	31	—	2.1
WEB06493	WELD	4.0	59.8	CL	43	22	21	—	10.3
WEB06493	WBEDROCK	8.0	57.0	CH	50	21	29	—	12.3
WEB06493	WBEDROCK	12.0	87.5	CH	55	24	31	105.0	16.4
WEB06493	WBEDROCK	16.0	82.7	CL	39	21	18	—	15.2
WEB06493	WBEDROCK	19.0	84.3	CH	63	28	35	—	17.8
WEB06593	WELD	4.0	70.5	CL	46	24	22	—	8.2
WEB06593	WELD	8.0	27.3	SM	46	29	17	—	12.0
WEB06593	WELD	12.0	19.7	SC	48	27	21	—	6.0
WEB06593	WELD	16.0	76.7	CH	64	28	36	—	25.7
WEB06693	WELD	4.0	64.2	CL	47	25	22	—	8.6
WEB06693	WELD	8.0	54.6	CL	36	20	16	108.0	7.8
WEB06693	WELD	12.0	63.2	CL	40	21	19	—	9.3
WEB06693	WELD	16.0	42.3	SM	39	29	10	—	6.6
WEB06793	WELD	4.0	64.5	CL	41	20	21	—	21.2
WEB06793	WELD	8.0	57.5	CL	44	22	22	—	10.0
WEB06793	WELD	12.0	53.7	CL	43	25	18	—	8.9
WEB06793	WELD	16.0	57.7	ML	44	30	14	—	13.3
WEB06793	WELD	20.0	33.1	SM	44	34	10	—	9.6
WEB06893	WELD	4.0	84.0	CL	45	24	21	—	9.4

Table 3.3 (continued)

Boring Number	Target Soil Unit	Sample Depth (feet)	Percent Passing No. 200 Sieve	USCS Soil Classification	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Dry Density (pcf)	Moisture Content (%)
WEB06893	WELD	8.0	36.7	SC	42	17	25	---	8.2
WEB06893	WELD	12.0	30.4	SC	41	21	20	---	9.8
WEB06893	WELD	15.0	7.9	SP-SC	63	25	38	---	4.0
WEB06993	WELD	4.0	83.1	CH	53	17	36	---	14.2
WEB06993	WELD	8.0	54.5	CL	39	20	19	---	10.7
WEB06993	WELD	12.0	50.7	CH	54	24	30	---	14.7
WEB06993	WELD	16.0	53.2	CL	31	17	14	---	13.0
WEB06993	WELD	18.0	20.5	SC	46	23	23	---	5.3
WEB07093	WELD	4.0	90.6	CL	43	23	20	102.0	8.8
WEB07093	WELD	8.0	50.6	CL	37	20	17	---	10.6
WEB07093	WELD	12.0	50.1	CL	43	17	26	---	9.4
WEB07093	WELD	16.0	21.4	SC	45	20	25	---	6.8
WEB07193	WELD	4.0	68.8	CH	50	24	26	106.0	12.8
WEB07193	WELD	8.0	38.8	SC	54	21	33	---	6.3
WEB07193	WELD	12.0	32.2	SC	42	19	23	---	6.1
WEB07193	WELD	16.0	7.3	SP-SC	77	22	55	---	3.3
WEB07293	WELD	4.0	35.6	SC	45	16	29	---	5.7
WEB07293	WELD	8.0	34.2	SC	31	20	11	111.0	5.7
WEB07293	WELD	12.0	48.9	SC	36	19	17	---	18.6
WEB07293	WELD	16.0	30.5	SC	40	18	22	---	16.6
WEB07393	WELD	4.0	56.8	CL	39	19	20	---	8.4
WEB07394	WELD	8.0	84.0	CL	32	18	14	---	20.7
WEB07394	WELD	12.0	59.8	CL	35	22	13	---	24.9
WEB07493	WELD	4.0	60.3	CL	34	18	16	---	10.5
WEB07493	WELD	8.0	47.5	SC	40	15	25	---	8.8
WEB07493	WELD	12.0	38.6	SC	28	16	12	---	10.3
WEB07493	WELD	16.0	9.9	SW-SC	39	17	22	---	6.7
NUB07593	NUNN	4.0	79.3	CL	46	18	28	---	16.0
NUB07593	NUNN	8.0	78.6	CL	45	21	24	101.0	12.7
NUB07593	NUNN	12.0	34.8	SC	49	22	27	---	7.3
NUB07593	NUNN	16.0	5.4	SP-SC	62	18	44	---	2.5
WEB07693	WELD	4.0	85.2	CL	49	21	28	---	8.8
WEB07693	WELD	8.0	68.3	CL	37	20	17	101.0	9.5
WEB07693	WELD	12.0	51.3	CL	49	21	28	---	9.0
WEB07693	WELD	16.0	44.4	SC	43	17	26	---	9.9
WEB07793	WELD	4.0	54.8	CL	35	17	18	---	9.6
WEB07793	WELD	8.0	7.5	SP-SM	57	31	26	---	3.8
WEB07793	WELD	12.0	6.1	SP-SC	51	18	33	---	6.2
WEB07893	WELD	4.0	76.6	CL	41	19	22	106.0	22.1
WEB07893	WELD	6.0	34.5	SC	37	17	20	---	20.9
WEB07993	WELD	4.0	92.3	CL	43	24	19	---	15.5
WEB07993	WELD	8.0	78.7	CL	37	21	16	---	10.9
WEB07993	WELD	12.0	66.3	CL	42	21	21	---	11.7
WEB07993	WELD	16.0	62.4	CL	43	23	20	---	12.2
WEB08093	WELD	4.0	57.4	CL	43	20	23	112.0	16.5
WEB08093	WELD	8.0	37.5	SC	40	19	21	---	6.3
WEB08093	WELD	12.0	54.3	CL	41	19	22	---	8.2
WEB08093	WELD	16.0	51.6	CL	37	14	23	---	7.8
WEB08093	WELD	20.0	82.3	CH	79	23	56	---	7.4
WEB08193	WELD	4.0	71.6	CL	37	20	17	103.0	7.9
WEB08193	WELD	8.0	51.1	CL	31	16	15	---	6.5
WEB08193	WELD	12.0	6.5	SP-SC	46	16	30	---	8.3
WEB08193	WELD	16.0	47.8	SC	41	22	19	---	7.2
WEB08193	WELD	20.0	43.7	SC	56	20	36	---	7.6
WEB08293	WELD	4.0	55.3	CL	36	20	16	104.0	12.9
WEB08293	WELD	8.0	38.9	SC	43	15	28	---	5.3
WEB08293	WELD	12.0	43.6	SC	46	16	30	---	8.4
WEB08293	WELD	16.0	54.9	CL	48	22	26	---	14.1

Table 3.3 (continued)

Boring Number	Target Soil Unit	Sample Depth (feet)	Percent Passing No. 200 Sieve	USCS Soil Classification	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Dry Density (pcf)	Moisture Content (%)
WEB08293	WELD	20.0	48.5	SC	34	20	14	—	11.0
WEB08393	WELD	4.0	48.5	SC	49	22	27	—	8.1
WEB08393	WELD	8.0	52.3	CL	31	16	15	106.0	8.0
WEB08393	WELD	12.0	35.4	SC	35	18	17	—	11.5
WEB08393	WELD	16.0	53.8	CH	54	22	32	—	15.2
WEB08393	WELD	20.0	42.9	SC	50	24	26	—	13.7
WEB08493	WELD	4.0	71.2	CL	31	17	14	—	11.8
WEB08493	WELD	8.0	57.5	CL	37	20	17	102.0	8.1
WEB08493	WELD	12.0	44.8	SC	40	21	19	—	8.7
WEB08493	WELD	16.0	60.1	CL	34	20	14	—	14.8
WEB08493	WELD	20.0	42.8	SC	41	18	23	—	13.1
WEB08593	WELD	4.0	39.8	SC	30	19	11	—	10.1
WEB08593	WELD	8.0	63.5	CL	30	22	8	—	7.6
WEB08593	WELD	12.0	55.1	CL	30	18	12	—	7.1
WEB08593	WELD	16.0	34.4	SC	60	26	34	—	8.7
WEB08693	WELD	4.0	66.9	CL	48	20	28	—	8.2
WEB08693	WELD	8.0	69.1	CL	33	17	16	103.0	9.4
WEB08693	WELD	12.0	59.4	CL	42	19	23	—	9.0
WEB08793	WELD	4.0	54.3	CL	34	19	15	—	8.8
WEB08793	WELD	8.0	29.5	SC-SM	28	22	6	—	5.3
WEB08793	WELD	12.0	84.7	CH	51	23	28	—	12.5
WEB08793	WELD	15.0	79.7	CH	56	23	33	—	14.9
WEB08793	WELD	18.0	51.7	CH	54	16	38	—	10.9
WEB08893	WELD	4.0	40.7	SM	45	27	18	107.0	13.0
WEB08893	WELD	8.0	63.8	CL	45	23	22	—	9.9
WEB08893	WELD	12.0	72.7	CH	53	24	29	—	11.9
WEB08893	WELD	16.0	75.4	CH	51	21	30	—	18.7
WEB08893	WELD	20.0	26.8	SC	45	21	24	—	8.8
WEB08993	WELD	4.0	46.2	SC	36	20	16	—	6.1
WEB08993	WELD	8.0	44.0	SC	32	17	15	—	7.7
WEB08993	WELD	12.0	30.3	SC	42	20	22	—	6.0
WEB08993	WELD	16.0	36.3	SC	32	19	13	—	6.1
WEB09093	WELD	4.0	46.0	SC	41	20	21	—	6.0
WEB09093	WELD	8.0	55.7	CL	41	19	22	—	8.8
WEB09093	WELD	12.0	46.5	SC	38	22	16	—	13.3
WEB09093	WELD	16.0	22.0	SC	42	17	25	—	6.7
WEB09193	WELD	4.0	83.4	CL	49	25	24	—	11.3
WEB09193	WELD	8.0	74.1	CL	39	21	18	—	11.0
WEB09193	WELD	12.0	14.6	SC	35	20	15	—	3.9
WEB09193	WELD	14.0	8.8	SP	39	17	22	—	2.1
WEB09293	WELD	4.0	78.6	CL	35	17	18	—	8.5
WEB09293	WELD	8.0	61.7	CH	52	23	29	—	12.3
WEB09293	WELD	12.0	35.2	SC	42	19	23	—	7.2
WEB09293	WELD	16.0	47.5	SC	49	23	26	—	9.4
WEB09293	WELD	20.0	46.5	SC	50	20	30	—	11.6
WEB09393	WELD	4.0	59.2	CL	43	22	21	—	10.8
WEB09393	WELD	8.0	53.3	CL	31	19	12	105.0	9.2
WEB09393	WELD	12.0	43.8	SC	36	22	14	—	5.8
WEB09393	WELD	17.0	40.8	SC	39	19	20	—	7.8
WEB09493	WELD	4.0	83.6	CL	34	19	15	—	7.6
WEB09493	WELD	8.0	59.8	CL	31	15	16	—	7.2
WEB09493	WELD	12.0	36.0	SC	41	12	29	—	6.1
WEB09493	WELD	16.0	44.8	SC	31	16	15	—	7.0
WEB09593	WELD	4.0	45.3	SC	39	17	22	—	4.3
WEB09593	WELD	8.0	66.4	CL	33	18	15	—	9.2
WEB09593	WELD	12.0	47.8	SC	33	19	14	—	12.4
WEB09593	WELD	16.0	72.8	CL	47	22	25	—	17.5
WEB09593	WELD	20.0	65.8	CL	44	21	23	103.0	18.0

Table 3.3 (continued)

Boring Number	Target Soil Unit	Sample Depth (feet)	Percent Passing No. 200 Sieve	USCS Soil Classification	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Dry Density (pcf)	Moisture Content (%)
WEB09593	WELD	22.0	52.5	CL	48	20	28	---	19.4
WEB09693	WELD	4.0	72.7	CL	39	20	19	---	15.5
WEB09693	WELD	8.0	75.4	CL	40	22	18	---	9.9
WEB09693	WELD	12.0	81.0	CL	48	23	25	---	5.6
WEB09693	WELD	16.0	17.5	SC	39	21	18	---	7.0
WEB09793	WELD	4.0	76.3	CL	43	24	19	---	9.6
WEB09793	WELD	8.0	54.5	CL	38	21	17	---	8.4
WEB09793	WELD	12.0	83.1	CL	39	17	22	---	7.9
WEB09793	WELD	16.0	48.5	SC	56	28	28	---	19.9
WEB09793	WELD	20.0	39.8	SC	39	20	19	---	24.6
WEB09893	WELD	4.0	84.3	CL	37	20	17	---	10.8
WEB09893	WELD	8.0	79.3	CL	42	20	22	102.0	11.3
WEB09893	WELD	12.0	76.2	CH	52	25	27	---	15.3
WEB09893	WELD	16.0	55.4	CL	46	18	28	---	15.4
TSY09993	BERM	1.0	61.8	CL	34	22	12	---	11.2
TSY10093	BERM	1.0	43.8	SC	46	22	24	---	13.7
TSY10193	BERM	1.0	48.2	SC	44	22	22	---	14.5
Average			**56.1**		**42**	**20**	**23**	**104.0**	**10.5**

---	Not applicable, analysis not performed
%	Percent
BERM	Storage Area berm material
BRESSER	Bresser soil series
CH	Inorganic clays of high plasticity
CL	Inorganic clays of low to medium plasticity
ML	Inorganic silts with slight plasticity
NUNN	Nunn soil series
pcf	Pounds per cubic foot
SC	Clayey sand
SM	Silty sand
SP	Poorly graded sand
SW	Well graded sand
USCS	Unified Soil Classification System
WBEDROCK	Weathered bedrock
WELD	Weld soil series

Appendix B

Tables 4.5 and 4.6

Final Landfill Report for the Feasibility Study Soils Support Program (Landfill FS Report)

Table 4.5: Particle Size, Atterberg Limits, and Moisture Content Results

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
SAB11394	4.00	68.32	11.0	41	22	CL	Brown sandy lean clay
SAB11394	8.00	52.64	9.9	45	29	CL	Brown sandy lean clay
SAB11394	12.00	16.60	5.5	NA	NA	SM	Brown silty sand
SAB11394	16.00	17.41	5.6	NA	NA	SM	Brown silty sand
SAB11394	17.00	28.22	4.6	22	4	SC-SM	Brown silty clayey sand
WEB11494	4.00	18.02	10.0	41	23	CL	Brown sandy clay
WEB11494	8.00	62.32	10.1	41	24	CL	Brown sandy lean clay
WEB11494	12.00	50.90	8.9	31	13	CL	Brown sandy lean clay
WEB11494	16.00	69.50	14.1	42	24	CL	Brown sandy lean clay
WEB11494	20.00	59.46	14.5	44	26	CL	Brown sandy lean clay
WEB11494	24.00	35.92	10.7	40	24	SC	Brown clayey sand
WEB11494	28.00	23.23	10.0	39	23	SC	Brown clayey sand
WEB11494	29.60	27.65	7.4	58	36	SC	Brown clayey sand
WEB11494	30.50	80.17	13.8	66	41	CH	Brown fat clay with sand
WEB11494	31.00	98.11	21.7	72	47	CH	Brown fat clay
WEB11494	31.50	99.08	20.9	69	43	CH	Brown fat clay
WEB11494	32.50	92.87	21.9	75	50	CH	Brown fat clay
WEB11494	33.00	82.70	17.8	55	37	CH	Brown fat clay with sand
WEB11494	33.50	90.34	18.1	52	33	CH	Brown fat clay
WEB11494	33.70	79.82	19.1	56	37	CH	Brown fat clay with sand
ASB11594	4.00	69.20	11.3	40	22	CL	Brown sandy lean clay
ASB11594	8.00	55.90	9.0	43	26	CL	Light brown sandy clay
ASB11594	10.00	34.52	6.5	41	24	SC	Brown clayey sand
ASB11594	16.00	14.77	5.9	NA	NA	SM	Brown silty sand
ASB11594	20.00	18.44	4.8	28	9	SC	Brown clayey sand
ASB11594	24.00	31.65	3.8	28	10	SC	Brown clayey sand
ASB11594	27.00	16.96	4.5	30	11	SC	Brown clayey sand
ASB11694	4.00	58.39	7.3	42	24	CL	Brown sandy lean clay
ASB11694	8.00	22.63	3.8	40	17	SC	Brown clayey sand
ASB11694	12.00	14.20	3.6	NA	NA	SM	Brown silty sand
ASB11694	16.00	13.71	4.1	32	8	SM	Brown silty sand

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
ASB11694	20.00	18.31	4.9	34	16	SC	Brown clayey sand
ASB11694	24.00	17.87	4.9	31	11	SC	Brown clayey sand
ASB11694	28.00	52.45	16.0	54	36	CH	Brown sandy fat clay
ASB11694	32.00	82.71	30.5	69	39	CH	Brown fat clay with sand
ASB11694	36.00	68.37	17.5	56	39	CH	Brown sandy fat clay
ASB11694	40.00	70.18	19.6	41	20	CL	Brown lean clay with sand
SAB11794	4.00	56.15	10.3	57	37	CH	Brown sandy fat clay
SAB11794	8.00	47.65	12.3	46	28	SC	Brown clayey sand
SAB11794	12.00	47.30	10.8	36	20	SC	Brown clayey sand
SAB11794	16.00	36.17	7.6	38	23	SC	Brown clayey sand
SAB11794	20.00	25.11	8.0	39	23	SC	Brown clayey sand with gravel
SAB11794	24.00	11.66	5.6	45	27	SP-SC	Brown sand with clay
SAB11794	35.00	32.06	4.6	31	14	SC	Brown clayey sand
SAB11794	40.00	36.38	6.8	31	15	SC	Brown clayey sand
ASB11894	4.00	83.11	10.4	44	23	CL	Brown lean clay with sand
ASB11894	8.00	61.15	9.4	43	24	CL	Brown sandy lean clay
ASB11894	12.00	53.50	12.8	51	31	CH	Brown sandy fat clay
ASB11894	16.00	58.61	17.7	57	31	CH	Brown sandy fat clay
ASB11894	20.00	71.76	17.6	49	31	CL	Brown lean clay with sand
ASB11894	24.00	84.52	18.0	48	31	CL	Brown lean clay with sand
ASB11894	28.00	33.05	6.2	39	17	SC	Brown clayey sand
ASB11894	32.00	37.89	5.5	45	29	SC	Brown clayey sand
ASB11994	4.00	56.46	8.2	41	22	CL	Brown sandy lean clay
ASB11994	8.00	58.37	7.7	42	24	CL	Brown sandy lean clay
ASB11994	12.00	36.32	4.0	38	20	SC	Brown clayey sand
ASB11994	16.00	23.01	3.7	37	18	SC	Brown clayey sand
ASB11994	20.00	20.18	4.1	40	21	SC	Brown clayey sand
ASB11994	24.00	21.40	4.2	39	21	SC	Brown clayey sand
ASB11994	28.00	19.16	4.8	35	17	SC	Brown clayey sand
ASB11994	32.00	19.93	3.8	29	10	SC	Brown clayey sand
ASB11994	36.00	25.14	4.7	32	15	SC	Brown clayey sand

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
ASB11994	40.00	25.78	4.2	30	14	SC	Brown clayey sand
ASB11994	44.00	48.27	14.6	42	25	SC	Brown clayey sand
ASB11994	50.00	59.53	22.2	75	44	CH	Brown sandy fat clay
ASB12094	4.00	69.45	7.8	32	8	ML	Brown sandy silt
ASB12094	8.00	57.03	13.7	47	27	CL	Brown sandy lean clay
ASB12094	12.00	58.92	12.9	44	24	CL	Brown sandy lean clay
ASB12094	16.00	17.14	3.0	47	29	SC	Brown clayey sand with gravel
ASB12094	20.00	11.48	1.9	NA	NA	SP-SM	Brown sand with silt and gravel
ASB12094	24.00	8.25	1.6	NA	NA	SW-SM	Brown sand with silt and gravel
ASB12094	28.00	16.67	4.2	NA	NA	SM	Brown silty sand
ASB12094	32.00	28.67	4.2	39	20	SC	Brown clayey sand
ASB12094	36.00	26.48	4.2	41	24	SC	Brown clayey sand
ASB12094	40.00	23.15	4.0	42	24	SC	Brown clayey sand
ASB12094	44.00	22.04	4.3	37	17	SC	Brown clayey sand
ASB12094	48.00	26.23	5.3	40	22	SC	Brown clayey sand
SAB12194	4.00	74.40	10.4	39	19	CL	Brown lean clay with sand
SAB12194	8.00	56.05	7.8	39	24	CL	Brown sandy lean clay
SAB12194	16.00	44.92	6.9	27	10	SC	Brown clayey sand
SAB12194	20.00	67.65	9.5	44	27	CL	Brown sandy lean clay
SAB12194	24.00	88.86	14.0	53	35	CH	Brown fat clay
SAB12194	28.00	96.65	28.6	73	43	CH	Brown fat clay
SAB12194	32.00	88.64	24.9	75	52	CH	Brown fat clay
SAB12194	36.00	97.56	23.8	88	62	CH	Brown fat clay
SAB12194	40.00	90.00	16.3	66	48	CH	Brown fat clay
SAB12194	44.00	91.59	15.1	54	38	CH	Brown fat clay
SAB12194	48.00	49.15	9.0	46	28	SC	Brown clayey sand
SAB12294	4.00	71.08	10.0	38	17	CL	Brown lean clay with sand
SAB12294	8.00	63.47	11.2	44	26	CL	Brown sandy lean clay
SAB12294	12.00	52.59	11.6	48	31	CL	Brown sandy lean clay
SAB12294	16.00	69.08	12.7	46	30	CL	Brown sandy lean clay
SAB12294	20.00	53.15	8.6	44	28	CL	Brown sandy lean clay

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
SAB12294	24.00	29.36	4.0	37	20	SC	Brown clayey sand
SAB12294	28.00	11.75	2.5	63	42	SP-SC	Brown sand with clay and gravel
SAB12294	32.00	41.21	8.4	47	27	SC	Brown clayey sand with gravel
SAB12294	36.00	93.55	22.0	50	35	CH	Brown fat clay
SAB12294	40.00	93.88	20.7	75	49	CH	Brown fat clay
SAB12294	44.00	94.71	20.3	72	53	CH	Brown fat clay
SAB12294	48.00	83.87	16.0	56	43	CH	Brown fat clay with sand
SAB12394	4.00	54.76	9.6	39	15	CL	Brown sandy lean clay
SAB12394	8.00	59.21	10.2	50	31	CH	Brown sandy fat clay
SAB12394	12.00	66.78	12.8	49	35	CL	Brown sandy lean clay
SAB12394	16.00	49.68	12.6	56	38	SC	Brown clayey sand
SAB12394	20.00	7.13	1.5	NA	NA	SW-SM	Brown sand with silt
SAB12394	24.00	56.97	22.9	78	47	CH	Brown sandy fat clay
SAB12394	28.00	63.60	21.3	60	34	CH	Brown sandy fat clay
SAB12394	32.00	74.74	14.1	56	41	CH	Brown fat clay with sand
SAB12394	36.00	86.08	16.3	64	47	CH	Brown fat clay
SAB12394	40.00	70.00	13.6	49	33	CL	Brown sandy lean clay
ASB12494	4.00	61.09	9.3	41	19	CL	Brown sandy lean clay
ASB12494	8.00	41.94	5.3	32	14	SC	Brown clayey sand
ASB12494	12.00	19.84	4.1	NA	NA	SM	Brown silty sand
ASB12494	16.00	21.82	3.0	NA	NA	SM	Brown silty sand
ASB12494	20.00	18.93	3.2	27	9	SC	Brown clayey sand
ASB12494	28.00	19.09	3.5	28	7	SC-SM	Brown silty clayey sand
ASB12494	32.00	19.55	3.2	36	18	SC	Brown clayey sand
ASB12494	36.00	17.65	3.4	51	25	SC	Brown clayey sand
ASB12494	40.00	19.92	3.4	40	21	SC	Brown clayey sand
ASB12494	44.00	81.52	17.7	61	43	CH	Brown fat clay with sand
ASB12494	48.00	91.64	17.4	65	46	CH	Brown fat clay
ASB12594	4.00	78.12	9.5	39	20	CL	Brown lean clay with sand
ASB12594	8.00	56.54	7.3	32	18	CL	Brown sandy lean clay
ASB12594	12.00	43.91	6.9	35	21	SC	Brown clayey sand

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
ASB12594	16.00	53.51	7.5	38	21	CL	Brown sandy lean clay
ASB12594	20.00	69.84	11.1	42	24	CL	Brown sandy lean clay
ASB12594	24.00	72.35	16.7	60	41	CH	Brown fat clay with sand
ASB12594	28.00	77.22	17.7	76	56	CH	Brown fat clay with sand
ASB12594	32.00	83.93	18.0	94	75	CH	Brown fat clay with sand
ASB12594	36.00	86.79	13.7	59	42	CH	Brown fat clay
ASB12594	40.00	87.87	17.6	78	58	CH	Brown fat clay
ASB12594	44.00	93.76	22.8	88	65	CH	Brown fat clay
ASB12594	48.00	75.31	25.0	79	56	CH	Brown fat clay with sand
SAB12694	4.00	49.63	8.8	35	18	SC	Brown clayey sand
SAB12694	8.00	63.10	8.4	31	14	CL	Brown sandy lean clay
SAB12694	12.00	59.06	10.6	37	19	CL	Brown sandy lean clay
SAB12694	16.00	60.24	9.0	41	25	CL	Brown sandy lean clay
SAB12694	20.00	71.31	11.2	44	27	CL	Brown lean clay with sand
SAB12694	24.00	51.81	11.2	43	29	CL	Brown sandy lean clay
SAB12694	28.00	53.27	14.5	52	35	CH	Brown sandy fat clay
SAB12694	32.00	52.85	13.8	46	27	CL	Brown sandy lean clay
SAB12694	36.00	53.16	14.5	55	36	CH	Brown sandy fat clay
SAB12694	40.00	87.16	15.2	56	39	CH	Brown fat clay
ASB12794	4.00	66.62	9.4	33	13	CL	Brown sandy lean clay
ASB12794	8.00	50.78	9.0	33	14	CL	Brown sandy lean clay
ASB12794	12.00	63.06	12.1	43	22	CL	Brown sandy lean clay
ASB12794	16.00	88.10	20.6	71	46	CH	Brown fat clay
ASB12794	20.00	56.38	9.4	35	18	CL	Brown sandy lean clay
ASB12794	24.00	59.73	8.8	30	14	CL	Brown sandy lean clay
ASB12794	28.00	81.03	9.2	36	18	CL	Brown lean clay with sand
ASB12794	32.00	72.05	12.1	48	31	CL	Brown lean clay with sand
ASB12794	36.00	97.67	19.6	77	51	CH	Brown fat clay
ASB12794	40.00	88.65	11.3	48	31	CL	Brown lean clay
ASB12794	44.00	86.93	12.2	57	39	CH	Brown fat clay
ASB12794	48.00	86.71	19.4	88	67	CH	Brown fat clay

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
SAB12894	4.00	54.39	7.5	31	14	CL	Brown sandy lean clay
SAB12894	8.00	56.11	6.8	34	18	CL	Brown sandy lean clay
SAB12894	12.00	44.80	9.2	33	17	SC	Brown clayey sand
SAB12894	16.00	42.14	9.6	37	23	SC	Brown clayey sand
SAB12894	20.00	57.44	12.0	37	22	CL	Brown sandy lean clay
SAB12894	24.00	51.40	11.9	36	20	CL	Brown sandy lean clay
SAB12894	28.00	51.35	12.4	35	19	CL	Brown sandy lean clay
SAB12894	32.00	64.28	14.7	39	25	CL	Brown sandy lean clay
SAB12894	36.50	89.41	20.8	50	31	CH	Brown fat clay
SAB12894	40.00	63.01	17.5	44	24	CL	Brown sandy lean clay
SAB12894	44.00	29.82	13.0	47	23	SC	Brown clayey sand
SAB12894	48.00	7.61	4.5	NA	NA	SP-SM	Brown sand with silt
BRB12994	4.00	49.45	8.3	34	16	SC	Brown clayey sand
BRB12994	8.00	52.67	11.5	32	16	CL	Brown sandy lean clay
BRB12994	12.00	37.67	13.0	51	30	SC	Brown clayey sand
BRB12994	16.00	39.73	9.1	41	26	SC	Brown clayey sand
BRB12994	20.00	62.02	9.2	37	22	CL	Brown sandy lean clay
BRB12994	24.00	47.16	10.0	44	20	SC	Brown clayey sand
BRB12994	28.00	24.88	5.6	41	24	SC	Brown clayey sand
BRB12994	32.00	32.03	4.2	27	9	SC	Brown clayey sand
BRB12994	36.00	50.76	10.3	45	31	CL	Brown sandy lean clay
BRB12994	40.00	77.48	18.7	46	25	CL	Brown lean clay with sand
BRB12994	44.00	49.90	19.5	28	8	SC	Brown clayey sand
BRB12994	48.00	54.29	26.3	48	30	CL	Brown sandy lean clay
BRB13094	4.00	28.19	5.6	26	5	SC-SM	Brown silty clayey sand
BRB13094	8.00	58.72	7.4	33	14	CL	Brown sandy lean clay
BRB13094	12.00	36.96	6.2	41	23	SC	Brown clayey sand
BRB13094	16.00	44.23	11.0	48	25	SC	Brown clayey sand
BRB13094	20.00	39.83	9.7	48	30	SC	Brown clayey sand
BRB13094	24.00	53.29	11.2	42	27	CL	Brown sandy lean clay
BRB13094	28.00	81.28	10.4	50	34	CH	Brown fat clay with sand

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
BRB13094	32.00	62.33	12.3	50	33	CH	Brown sandy fat clay
BRB13094	36.00	64.80	11.1	53	37	CH	Brown sandy fat clay
BRB13094	40.00	87.48	20.7	71	48	CH	Brown fat clay
BRB13094	44.00	88.09	11.9	55	38	CH	Brown fat clay
SAB13194	4.00	48.53	8.6	34	15	SC	Brown clayey sand
SAB13194	8.00	76.01	7.8	34	14	CL	Brown lean clay with sand
SAB13194	12.00	59.01	6.2	27	11	CL	Brown sandy lean clay
SAB13194	16.00	62.24	8.7	38	21	CL	Brown sandy lean clay
SAB13194	20.00	64.77	9.4	41	21	CL	Brown sandy lean clay
SAB13194	24.00	68.10	9.8	38	19	CL	Brown sandy lean clay
SAB13194	28.00	63.11	10.4	42	22	CL	Brown sandy lean clay
SAB13194	30.00	54.85	8.3	40	21	CL	Brown sandy lean clay
SAB13194	36.00	57.69	9.9	44	25	CL	Brown sandy lean clay
SAB13194	37.00	97.11	15.7	50	32	CH	Brown fat clay
SAB13194	40.00	77.73	16.5	68	46	CH	Brown fat clay with sand
SAB13194	44.00	84.72	17.6	77	56	CH	Brown fat clay with sand
SAB13194	48.00	85.98	14.2	64	47	CH	Brown fat clay
ASB13294	4.00	54.09	8.6	33	15	CL	Brown sandy lean clay
ASB13294	8.00	60.12	9.1	34	12	CL	Brown sandy lean clay
ASB13294	12.00	48.56	9.9	48	28	SC	Brown clayey sand
ASB13294	16.00	56.18	7.1	38	23	CL	Brown sandy lean clay
ASB13294	20.00	39.92	8.1	53	36	SC	Brown clayey sand with gravel
ASB13294	24.00	46.20	10.6	59	37	SC	Brown clayey sand with gravel
ASB13294	28.00	80.19	15.3	45	29	CL	Brown lean clay with sand
ASB13294	32.00	69.63	17.4	62	42	CH	Brown sandy fat clay
ASB13294	36.00	84.74	19.1	75	52	CH	Brown fat clay with sand
ASB13294	40.00	68.88	13.3	51	32	CH	Brown sandy fat clay
ASB13294	44.00	73.58	14.0	54	36	CH	Brown fat clay with sand
ASB13294	48.00	84.87	17.6	76	51	CH	Brown fat clay with sand
ASB13394	4.00	65.36	8.7	32	16	CL	Brown sandy lean clay
ASB13394	8.00	58.14	7.8	33	17	CL	Brown sandy lean clay

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
ASB13394	12.00	50.01	6.9	28	13	CL	Brown sandy lean clay
ASB13394	16.00	50.50	8.2	33	19	CL	Brown sandy lean clay
ASB13394	20.00	35.23	4.6	30	15	SC	Brown clayey sand with gravel
ASB13394	24.00	64.61	6.8	41	25	CL	Brown sandy lean clay
ASB13394	28.00	58.54	7.0	38	23	CL	Brown sandy lean clay
ASB13394	32.00	41.11	8.0	53	37	SC	Brown clayey sand
ASB13394	36.00	61.52	11.1	58	41	CH	Brown sandy fat clay
ASB13394	40.00	79.07	15.2	55	36	CH	Brown fat clay with sand
ASB13394	44.00	78.99	15.8	55	34	CH	Brown fat clay with sand
ASB13394	48.00	93.00	19.6	40	19	CL	Brown lean clay
BRB13494	4.00	63.11	6.7	30	9	CL	Brown sandy lean clay
BRB13494	8.00	61.48	6.9	31	12	CL	Brown sandy lean clay
BRB13494	12.00	37.61	6.3	34	17	SC	Brown clayey sand
BRB13494	16.00	31.31	5.8	33	17	SC	Brown clayey sand
BRB13494	20.00	39.79	9.3	32	14	SC	Brown clayey sand
BRB13494	24.00	51.87	11.8	34	15	CL	Brown sandy lean clay
BRB13494	28.00	41.86	11.0	32	14	SC	Brown clayey sand
BRB13494	32.00	38.17	10.4	35	17	SC	Brown clayey sand
BRB13494	36.00	46.35	13.8	30	10	SC	Brown clayey sand
BRB13494	40.00	52.76	14.6	38	20	CL	Brown sandy lean clay
BRB13494	44.00	83.25	19.8	49	29	CL	Brown lean clay with sand
BRB13494	48.00	80.72	22.2	49	28	CL	Brown lean clay with sand
BRB13494	50.00	68.87	26.2	47	26	CL	Brown sandy lean clay
BRB13594	4.00	34.83	6.0	36	17	SC	Brown clayey sand
BRB13594	8.00	50.01	5.8	28	12	CL	Brown sandy lean clay
BRB13594	12.00	50.95	7.3	35	16	CL	Brown sandy lean clay
BRB13594	16.00	51.14	7.4	37	20	CL	Brown sandy lean clay
BRB13594	20.00	48.06	8.1	43	25	SC	Brown clayey sand
BRB13594	24.00	54.00	9.4	48	31	CL	Brown sandy lean clay
BRB13594	28.00	59.96	8.3	39	20	CL	Brown sandy lean clay
BRB13594	32.00	59.79	12.1	54	31	CH	Brown sandy fat clay

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
BRB13594	36.00	61.48	NA	NA	NA	CH	Brown sandy fat clay
BRB13594	40.00	19.87	7.2	46	24	SC	Brown clayey sand
BRB13594	42.00	34.77	14.0	48	30	SC	Brown clayey sand
BRB13694	4.00	32.90	5.1	48	30	SC	Brown clayey sand
BRB13694	8.00	52.38	5.7	32	16	CL	Brown sandy lean clay
BRB13694	12.00	67.27	6.9	32	15	CL	Brown sandy lean clay
BRB13694	16.00	65.17	8.3	39	23	CL	Brown sandy lean clay
BRB13694	20.00	51.51	10.2	41	26	CL	Brown sandy lean clay
BRB13694	24.00	53.20	9.1	33	20	CL	Brown sandy lean clay
BRB13694	28.00	65.67	9.1	43	28	CL	Brown sandy lean clay
BRB13694	32.00	91.81	12.3	44	24	CL	Brown lean clay
BRB13694	36.00	86.98	16.9	58	37	CH	Brown fat clay
BRB13694	40.00	98.44	18.3	68	46	CH	Brown fat clay
BRB13694	44.00	96.86	19.6	69	47	CH	Brown fat clay
BRB13694	48.00	97.48	20.8	77	56	CH	Brown fat clay
BRB13794	4.00	41.85	6.8	30	11	SC	Brown clayey sand
BRB13794	8.00	51.82	5.3	31	15	CL	Brown sandy lean clay
BRB13794	12.00	51.90	6.7	30	14	CL	Brown sandy lean clay
BRB13794	16.00	47.29	9.2	39	22	SC	Brown clayey sand
BRB13794	20.00	49.33	8.9	40	20	SC	Brown clayey sand
BRB13794	24.00	63.14	12.6	48	28	CL	Brown sandy lean clay
BRB13794	28.00	96.02	20.7	82	55	CH	Brown fat clay
BRB13794	32.00	86.34	20.0	77	52	CH	Brown fat clay
BRB13794	36.00	94.42	15.3	61	41	CH	Brown fat clay
BRB13794	40.00	97.38	8.2	58	38	CH	Brown fat clay
BRB13794	44.00	95.12	13.7	59	42	CH	Brown fat clay
BRB13794	48.00	96.57	14.9	58	38	CH	Brown fat clay
BRB13894	4.00	52.81	8.7	34	15	CL	Brown sandy lean clay
BRB13894	8.00	66.23	6.9	31	11	CL	Brown sandy lean clay
BRB13894	12.00	40.29	7.0	33	16	SC	Brown clayey sand
BRB13894	16.00	44.22	6.9	36	18	SC	Brown clayey sand

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
BRB13894	20.00	46.64	7.4	30	11	SC	Brown clayey sand
BRB13894	24.00	39.71	7.2	33	16	SC	Brown clayey sand
BRB13894	28.00	53.46	11.2	37	21	CL	Brown sandy lean clay
BRB13894	32.00	52.54	10.9	41	26	CL	Brown sandy lean clay
BRB13894	36.00	93.72	21.6	53	31	CH	Brown fat clay
BRB13894	40.00	77.81	21.3	50	30	CH	Brown fat clay with sand
BRB13894	44.00	17.41	7.4	41	22	SC	Brown clayey sand
BRB13894	48.00	24.39	10.2	46	27	SC	Brown clayey sand
WEB13994	4.00	24.77	4.3	30	12	SC	Brown clayey sand
WEB13994	8.00	22.38	3.8	NA	NA	SM	Brown silty sand
WEB13994	12.00	40.83	4.8	25	8	SC	Brown clayey sand
WEB13994	16.00	49.93	10.2	38	20	SC	Brown clayey sand
WEB13994	20.00	58.84	10.9	36	17	CL	Brown sandy lean clay
WEB13994	24.00	63.51	12.6	39	22	CL	Brown sandy lean clay
WEB13994	28.00	64.98	15.2	37	20	CL	Brown sandy lean clay
WEB13994	32.00	36.79	12.0	40	19	SC	Brown clayey sand with gravel
WEB13994	36.00	89.95	15.9	50	28	CH	Brown fat clay
WEB13994	40.00	93.77	19.4	57	38	CH	Brown fat clay
WEB13994	44.00	96.96	17.8	57	39	CH	Brown fat clay
WEB13994	48.00	91.88	18.0	54	36	CH	Brown fat clay
BRB14094	4.00	27.95	5.7	33	17	SC	Brown clayey sand
BRB14094	8.00	23.17	4.0	29	14	SC	Brown clayey sand
BRB14094	12.00	40.84	9.8	35	15	SC	Brown clayey sand
BRB14094	16.00	32.10	5.6	29	20	SC	Brown clayey sand
BRB14094	20.00	60.96	30.1	69	29	MH	Brown sandy elas. silt
BRB14094	22.00	37.72	27.1	61	27	SM	Brown silty sand
BRB14094	24.00	78.66	29.5	82	53	CH	Brown fat clay with sand
BRB14094	28.00	86.52	31.9	95	61	CH	Brown fat clay
BRB14094	32.00	85.88	32.9	101	71	CH	Brown fat clay
BRB14094	36.00	81.14	31.7	100	69	CH	Brown fat clay with sand
BRB14094	40.00	81.05	21.1	77	55	CH	Brown fat clay with sand

Table 4.5 (continued)

Boring Number	Sample Depth (feet)	Percent Passed No. 200* (%)	Moisture Content# (%)	Liquid Limit# (%)	Plasticity Index# (%)	USCS*	USCS Description*
BRB14094	44.00	75.23	20.5	64	44	CH	Brown fat clay with sand
BRB14094	48.00	79.45	20.3	78	55	CH	Brown fat clay with sand
BRB14194	4.00	41.33	5.5	30	9	SC	Brown clayey sand
BRB14194	8.00	46.13	5.4	30	11	SC	Brown clayey sand
BRB14194	12.00	62.50	9.0	31	13	CL	Brown sandy lean clay
BRB14194	16.00	47.40	7.9	37	20	SC	Brown clayey sand
BRB14194	20.00	44.35	6.7	32	14	SC	Brown clayey sand
BRB14194	24.00	45.45	7.2	35	19	SC	Brown clayey sand
BRB14194	28.00	67.00	21.9	61	31	CH	Brown sandy fat clay
BRB14194	32.00	59.70	17.2	60	40	CH	Brown sandy fat clay
BRB14194	36.00	63.68	15.2	59	45	CH	Brown sandy fat clay
BRB14194	40.00	56.80	17.3	37	21	CL	Brown sandy lean clay
BRB14194	44.00	82.54	18.2	59	41	CH	Brown fat clay with sand
BRB14194	48.00	71.19	17.3	51	35	CH	Brown fat clay with sand
BRB14294	4.00	49.89	6.7	35	17	SC	Brown clayey sand
BRB14294	8.00	56.66	8.5	37	20	CL	Brown sandy lean clay
BRB14294	12.00	70.74	10.7	55	28	CH	Brown fat clay with sand
BRB14294	16.00	67.27	11.1	36	20	CL	Brown sandy lean clay
BRB14294	20.00	53.04	11.1	41	23	CL	Brown sandy lean clay
BRB14294	24.00	56.02	13.7	48	28	CL	Brown sandy lean clay
BRB14294	27.50	74.97	18.1	49	23	CL	Brown lean clay with sand
BRB14294	32.00	58.63	16.9	48	22	CL	Brown sandy lean clay
BRB14294	36.00	53.83	17.9	51	29	CH	Brown sandy fat clay
BRB14294	40.00	48.86	18.4	52	27	SC	Brown clayey sand
BRB14294	44.00	38.40	13.8	40	20	SC	Brown clayey sand
BRB14294	48.00	48.90	18.3	40	21	SC	Brown clayey sand
BRB14294	50.00	46.64	27.3	55	31	SC	Brown clayey sand

Table 4.5 (continued)

%	Percent
ASTM	American Society for Testing and Materials
NA	Not analyzed
USCS	Unified Soil Classification System

* ASTM D 422
\# ASTM D 4318

Table 4.6: Compaction, Permeability, Shrink, and Swell Results

Boring Number	Sample Depth (feet)	Optimum Moisture Content[a] (%)	Maximum Dry Density[b] (pcf)	Permeability at 90 percent[c] (cm/s)	Permeability at 95 percent[c] (cm/s)	Shrinkage[d] (%)	Swell Pressure[e] (psf)	Organic Content[f] (%)
WEB11494	4.00	18.4	102.2	1.31×10^{-6}	1.54×10^{-6}	14.4	35.3	3.4
ASB11594	8.00	15.0	109.7	2.14×10^{-7}	5.42×10^{-7}	42.0	67.5	2.2
ASB11694	4.00	17.1	105.8	5.11×10^{-7}	7.81×10^{-7}	13.6	35.8	3.3
SAB11794	12.00	12.5	117.4	1.66×10^{-7}	7.92×10^{-8}	42.1	117.4	1.3
ASB11894	8.00	14.0	112.4	6.29×10^{-8}	3.58×10^{-8}	12.9	26.2	2.5
ASB11994	8.00	15.2	109.6	7.20×10^{-8}	1.11×10^{-8}	16.3	41.2	1.6
ASB12094	8.00	15.1	111.3	2.54×10^{-8}	1.10×10^{-7}	12.8	40.6	1.8
SAB12194	8.00	15.3	111.8	8.37×10^{-8}	4.47×10^{-8}	13.2	43.1	1.9
SAB12294	20.00	17.0	110.2	5.28×10^{-7}	3.03×10^{-7}	11.6	88.1	1.6
SAB12394	8.00	18.7	104.0	1.76×10^{-6}	1.38×10^{-6}	14.2	79.4	2.0
ASB12494	4.00	17.8	105.9	2.80×10^{-8}	1.67×10^{-8}	14.5	50.2	2.2
ASB12594	8.00	14.4	114.7	1.08×10^{-7}	7.64×10^{-8}	14.8	113.8	1.9
SAB12694	16.00	15.3	113.9	6.77×10^{-6}	5.00×10^{-6}	13.7	136.2	1.7
ASB12794	4.00	15.5	111.8	3.70×10^{-8}	1.54×10^{-8}	14.8	27.8	2.9
SAB12894	16.00	14.1	115.1	5.47×10^{-8}	2.61×10^{-8}	13.0	30.7	1.6
BRB12994	4.00	13.5	115.8	6.09×10^{-6}	8.16×10^{-6}	14.2	50.5	1.9
BRB13094	24.00	16.4	113.2	1.70×10^{-7}	1.34×10^{-7}	41.8	23.1	1.8
SAB13194	12.00	14.2	114.7	1.98×10^{-5}	2.39×10^{-5}	13.2	38.3	1.3
ASB13294	8.00	15.8	110.5	3.89×10^{-7}	4.96×10^{-7}	14.6	161.6	1.5
ASB13394	4.00	15.3	110.2	7.18×10^{-8}	4.01×10^{-8}	18.4	27.8	2.2
BRB13494	4.00	17.2	103.9	3.66×10^{-8}	2.08×10^{-8}	23.3	35.7	4.5
BRB13594	12.00	14.2	114.9	1.43×10^{-7}	1.16×10^{-7}	16.6	63.5	1.4
BRB13694	16.00	15.1	111.0	4.74×10^{-8}	2.55×10^{-8}	12.4	56.2	1.9
BRB13794	8.00	12.3	117.6	8.05×10^{-8}	2.30×10^{-8}	15.1	46.7	1.3
BRB13894	12.00	14.6	112.7	8.24×10^{-8}	3.96×10^{-8}	17.1	29.3	1.5
WEB13994	20.00	16.0	110.7	5.46×10^{-8}	4.51×10^{-8}	13.5	312.1	1.9
BRB14094	16.00	13.2	115.7	1.17×10^{-7}	8.02×10^{-8}	13.0	27.8	1.3
BRB14194	4.00	13.8	114.2	4.42×10^{-8}	3.42×10^{-8}	15.2	58.8	8.8
BRB14294	20.00	17.6	106.1	2.73×10^{-8}	1.38×10^{-8}	15.8	20.8	2.0

Table 4.6 (continued)

%	Percent
ASTM	American Society for Testing and Materials
pcf	Pounds per cubic foot
cm/s	Centimeters per second
psf	Pounds per square foot

a.	ASTM D 2216
b.	ASTM D 698
c.	EM 1110-2-19096
d.	ASTM D 427
e.	ASTM D 4546
f.	ASTM D 2974

Appendix C

Tables T-3 Through T-6

Final Geotechnical Investigation Report
(Subsurface Report)

TABLE T-3
PROCTOR CURVE SUMMARY INFORMATION FOR POTENTIAL LOW PERMEABILITY SOIL TYPES

Test Pit Number	Sample Depth (feet)	USCS[1] Classification	Standard Proctor (ASTM D 698)		Modified Proctor (ASTM D 1557)	
			γd_{max}^{2} (pcf)	w_{opt}^{3} (%)	γd_{max}^{2} (pcf)	w_{opt}^{3} (%)
PT250009 and PT250011 Composite	2-4.5	Lean Clay with Sand (CL)	100.9	20.8	111.8	15.5
PT250012 and PT250016 Composite	2-4	Sandy Lean Clay (CL)	110.6	15.7	120.2	12.0
PT250011 Composite	13-15 19.5-21	Weathered Claystone with Shale (CH)	95.1	24.3	105.7	19.0
PT250008	18-19	Weathered Claystone/Shale (CL)	100.4	20.8	109.8	16.7
PT250008	19-20	Weathered Claystone with Sand (CL)	106.8	17.7	114.4	14.1

Notes:

1. Unified Soil Classification System
2. Maximum dry unit weight in pounds per cubic foot
3. Optimum moisture content in percent

TABLE T-4
ENGINEERING PROPERTIES OF POTENTIAL LOW PERMEABILITY SOIL TYPES

USCS[1]		Atterberg Limits[2]		Percent Passing No. 200 Sieve
Classification	Description	Liquid Limit	Plasticity Index	
CL	Lean Clay with Sand (Alluvial)	42	26	85
CL	Sandy Lean Clay (Alluvial)	32	18	58
CH	Weathered Claystone with Shale (Bedrock)	77	59	85
CL	Weathered Claystone/Shale mixture (Bedrock)	49	31	95
CL	Weathered Claystone with Sand (Bedrock)	39	22	76

Notes:

1. Unified Soil Classification System
2. Atterberg Limits expressed as percent moisture content.

TABLE T-5
HYDRAULIC CONDUCTIVITY TEST RESULTS OF POTENTIAL LOW PERMEABILITY SOIL TYPES

Test Pit Number	Sample Depth (feet)	USCS[1] Classification	Maximum Density[2]	Moisture Content relative to Optimum[3] (%)	Hydraulic Conductivity[4] (cm/s)
PT250009 and PT250011 Composite	2-4.5	Lean Clay with Sand (CL)	90 % of Standard	+1.3	3.70×10^{-7}
				+2.9	5.02×10^{-6}
				+6.1	8.56×10^{-8}
			90 % of Modified	+0.6	1.50×10^{-6}
				+0.7	6.30×10^{-7}
				+4.9	1.01×10^{-7}
PT250012 and PT250016 Composite	2-4	Sandy Lean Clay (CL)	90 % of Standard	+1.1	4.07×10^{-7}
				+0.4	8.13×10^{-7}
				+3.0	1.34×10^{-7}
				+5.1	3.16×10^{-8}
				+5.2	1.58×10^{-8}
			90 % of Modified	+0.5	2.52×10^{-6}
				+3.9	2.24×10^{-7}
				+5.3	5.70×10^{-8}
PT250011 Composite	13-21	Weathered Claystone with Shale (CH)	90 % of Standard	+1.3	7.91×10^{-8}
				+2.2	1.28×10^{-4}
				+2.5	2.08×10^{-5}
				+5.5	8.86×10^{-9}
				+6.2	2.26×10^{-8}
			90 % of Modified	-0.5	5.47×10^{-6}
				+3.0	1.63×10^{-7}

Notes:

1. Unified Soil Classification System
2. Standard and modified pertain to ASTM D 698 and ASTM D 1557 maximum laboratory density, respectively
3. A "plus" moisture content indicates wet of optimum. A "minus" moisture content indicates dry of optimum.
4. Hydraulic conductivity determined in accordance with ASTM D 5084.

TABLE T-6
COMPARISON OF ALLUVIAL CLAY SOILS

CAMU Area Soil Borings and Piezometers						
Exploration Number	Sample Number	Depth[1]	USCS[2] Classification	Atterberg Limits[3]		% Passing No. 200 Sieve
				Liquid Limit	Plasticity Index	
BR250023	D-2	3.0- 4.0	Lean Clay	38	21	
	D-3	9.5-10.0	Sandy Lean Clay	38	22	57
	D-7	15.5-16.0	Sandy Lean Clay	41	27	61
BR250024	D-1	0.5- 1.0	Lean Clay	38	21	
	D-2	4.0- 4.5	Lean Clay	38	21	
	D-4	11.0-11.5	Lean Clay w/ Sand	39	19	80
	D-5	13.0-14.0	Sandy Lean Clay	41	27	61
	D-6	17.0-17.5	Sandy Lean Clay	38	22	57
BR250025	D-1	0.5- 1.0	Sandy Lean Clay	38	23	65
BR250026	D-2	4.0- 5.0	Lean Clay w/ Sand	31	16	70
BR250028	D-1	0.5- 1.0	Lean Clay w/ Sand	40	18	70
	D-2	3.5- 4.0	Sandy Lean Clay	26	12	55
	D-3	6.0- 6.5	Sandy Lean Clay	42	24	57
	D-4	11.0-12.0	Lean Clay w/ Sand	41	23	71
BR250029	D-1	1.3- 2.0	Sandy Lean Clay	34	21	66
	D-2	3.0- 4.0	Lean Clay	38	22	91
	D-3	6.0- 7.0	Sandy Lean Clay	29	16	57
BR250031	D-1	1.0- 2.0	Sandy Lean Clay	34	18	70
	D-2	5.0- 6.5	Sandy Lean Clay	46	30	56
	D-3	12.5-13.5	Sandy Lean Clay	43	28	56
BR250033	D-1	1.2- 1.7	Sandy Lean Clay	36	21	72
	D-2	4.0- 4.5	Sandy Lean Clay	30	10	51
BR250034	D-2	0.5- 1.0	Sandy Lean Clay	37	22	70
BR250035	D-1	0.5- 1.1	Sandy Lean Clay	36	22	59
BR250036	D-3	12.5-13.0	Sandy Lean Clay	45	28	70
	D-4	13.5-14.0	Sandy Lean Clay	42	26	60
BR250037	D-1	3.0- 4.0	Sandy Lean Clay	25	12	52
	D-2	5.0- 6.5	Sandy Lean Clay	32	19	52
	D-3	7.5- 8.0	Sandy Lean Clay	36	23	53
BR250038	D-1	0.5- 0.9	Sandy Lean Clay	34	19	66
	D-2	0.9- 2.0	Lean Clay w/ Sand	36	23	75
	D-3	5.0- 6.5	Sandy Lean Clay	34	21	50
BR250039	D-2	2.0- 2.5	Lean Clay	37	20	
BR250040	D-1	0.5- 1.0	Lean Clay w/ Sand	46	26	77
BR250042	D-4	13.5-13.5	Sandy Lean Clay	34	19	51
BR250045	D-2	3.5- 4.0	Sandy Lean Clay	30	16	59
BR250047	D-4	10.0-11.0	Sandy Lean Clay	36	23	54
	D-7	20.0-21.0	Sandy Lean Clay	40	23	58
BR250048	D-2	1.4- 2.0	Sandy Lean Clay	33	19	63
BR260134	D-5	10.7-11.5	Lean Clay	36	21	88
	D-6	15.0-16.5	Sandy Lean Clay	34	18	52
	D-8	20.0-21.5	Sandy Lean Clay	41	23	58
BR260135	D-5	10.0-11.5	Lean Clay w/ Sand	32	16	84
	D-6	13.0-14.0	Lean Clay	36	20	88
	D-7	15.0-16.5	Sandy Lean Clay	36	21	69
	D-8	20.0-21.5	Sandy Lean Clay	37	21	60
	D-11	27.5-29.0	Lean Clay w/ Sand	47	28	70
BR260136	D-1	0.5- 2.0	Sandy Lean Clay	31	18	62
	D-4	8.5- 9.5	Sandy Lean Clay	40	22	64

Notes:

1. Depth measured in feet below ground surface.
2. Unified Soil Classification System
3. Atterberg Limits expressed as percent moisture content.

TABLE T-6 (continued)
COMPARISON OF ALLUVIAL CLAY SOILS

CAMU Area Test Pits						
Exploration Number	Sample Number	Depth[1]	USCS[2] Classification	Atterberg Limits[3]		% Passing No. 200 Sieve
				Liquid Limit	Plasticity Index	
PT250001	D-2	8.0-10.0	Lean Clay	35	19	
	D-3	14.0-16.0	Sandy Lean Clay	32	20	51
	D-4	17.5-18.5	Sandy Lean Clay	31	13	60
PT250003	D-1	0.5- 1.0	Sandy Lean Clay	36	22	67
	D-5	10.0-10.5	Sandy Lean Clay	36	22	60
	D-6	11.0-11.5	Lean Clay w/ Sand	47	26	77
PT250009	D-1	3.5- 4.5	Lean Clay	44	25	87
	D-2	5.0- 6.0	Sandy Lean Clay	34	15	70
	D-3	7.5- 8.0	Sandy Lean Clay	38	17	65
	D-4	14.0-15.0	Sandy Lean Clay	36	19	65
PT250011	D-3	10.0-11.0	Sandy Lean Clay	36	21	59
PT250012	D-1	0.2- 0.5	Lean Clay w/ Sand	36	19	74
	D-4	10.0-10.5	Lean Clay	36	17	85
	D-5	11.5-12.0	Lean Clay	38	19	83
PT250013	D-1	5.0- 6.0	Sandy Lean Clay	30	14	51
PT250015	D-2	6.5- 7.5	Sandy Lean Clay	32	16	61
	D-4	12.0-13.0	Sandy Lean Clay	32	19	
PT250016	D-4	6.0- 6.5	Sandy Lean Clay	41	18	

Notes:

1. Depth measured in feet below ground surface.
2. Unified Soil Classification System
3. Atterberg Limits expressed as percent moisture content.

TABLE T-6 (continued)
COMPARISON OF ALLUVIAL CLAY SOILS

Borrow Area 5 Test Pits						
Exploration Number	Sample Number	Depth[1]	USCS[2] Classification	Atterberg Limits[3]		% Passing No. 200 Sieve
				Liquid Limit	Plasticity Index	
PT240001	D-2	1.2- 1.7	Lean Clay w/ Sand	37	18	85
PT240002	D-2	1.3- 1.6	Sandy Lean Clay	33	18	61
PT240004	D-1	0.5- 1.0	Sandy Lean Clay	24	9	67
	D-2	2.0- 2.5	Lean Clay w/ Sand	40	20	83
PT240005	D-4	5.0- 5.5	Sandy Lean Clay	36	21	69
PT240007	D-2	2.0- 2.5	Sandy Lean Clay	35	21	63
PT240008	D-1	0.5- 1.0	Lean Clay w/ Sand	35	19	81
	D-2	1.5- 2.0	Sandy Lean Clay	28	15	59
	D-3	5.0- 5.5	Lean Clay w/ Sand	36	20	76
PT240009	D-1	0.3- 0.6	Lean Clay w/ Sand	33	19	74
PT240011	D-2	1.5- 2.0	Lean Clay	37	18	
PT240015	D-6	7.0- 7.5	Sandy Lean Clay	41	25	59
PT240016	D-1	0.5- 1.0	Sandy Lean Clay	33	19	66
	D-2	1.8- 2.3	Lean Clay w/ Sand	35	22	81
	D-4	5.0- 5.5	Sandy Lean Clay	27	12	59
	D-5	5.6- 5.9	Sandy Lean Clay	39	18	55
	D-6	7.0- 7.5	Sandy Lean Clay	30	16	57
	D-7	9.5-10.0	Sandy Lean Clay	39	26	70
PT240017	D-6	5.6- 6.0	Sandy Lean Clay	38	17	59
PT240022	D-2	2.5- 3.0	Sandy Lean Clay	31	13	54
PT240023	D-3	4.5- 5.0	Sandy Lean Clay	33	15	66
PT240027	D-4	7.0- 7.5	Sandy Lean Clay	27	14	55
	D-5	9.5-10.0	Lean Clay w/ Sand	36	20	84

Notes:

1. Depth measured in feet below ground surface.
2. Unified Soil Classification System
3. Atterberg Limits expressed as percent moisture content.

TABLE T-6 (continued)
COMPARISON OF ALLUVIAL CLAY SOILS

CAMU Area Statistical Values				
USCS[1] Classification	Statistic	Atterberg Limits[2]		% Passing No. 200 Sieve
		Liquid Limit	Plasticity Index	
Lean Clay	Maximum	44	25	91
	Minimum	35	17	83
	Average	37.6	20.5	87.0
	Standard Deviation	2.4	2.0	2.8
Lean Clay w/ Sand	Maximum	47	28	84
	Minimum	31	16	70
	Average	39.5	21.4	74.8
	Standard Deviation	5.6	4.2	4.5
Sandy Lean Clay	Maximum	45	30	70
	Minimum	25	10	50
	Average	35.7	20.3	59.8
	Standard Deviation	4.7	4.4	6.2
Borrow Area 5 Statistical Values				
Lean Clay w/ Sand	Maximum	40	22	85
	Minimum	33	18	74
	Average	36.1	19.5	80.6
	Standard Deviation	2.0	1.3	4.1
Sandy Lean Clay	Maximum	41	26	70
	Minimum	24	9	54
	Average	32.9	17.3	61.3
	Standard Deviation	5.1	4.7	5.3

Notes:

1. Unified Soil Classification System
2. Atterberg Limits expressed as percent moisture content.

Appendix D

Index and Proctor Test Results

Note: USACE Test Pit Numbers RMTP96-27 and RMTP96-33 Correspond to RMA Test Pit Numbers PT250013 and PT250016, respectively

M.R. LAB NO. 4024

DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

10 DEC 1996

Subject: Standard, Modified and Reduced Effort Compactions on Soil Report Series No. 25
Project: Rocky Mountain Arsenal; Hazardous Waste Landfill
Intended Use:
Source of Material: Borings RMTP96-27&33 Bags #1 Composite and RMTP96-33 Bag #1

Submitted by: Chief, CEMRO-ED-GA
Date Sampled: , **Date Received:** 6/28/96
Method of Test or Specification: EM 1110-2-1906, ASTM D-2487 ASTM D-698 and ASTM D-1557
References: Omaha District Request No. S-2634 (MIL) dated 8/29/96
Purchase Request No. LAB 66 dated 5/14/96

1. Subject testing has been performed in accordance with the above test method and reference. Test results are shown in Figures 1 through 5. All tests were performed on specimens obtained from bag samples. Preliminary results were sent on 29 October and 5 and 6 November 1996.

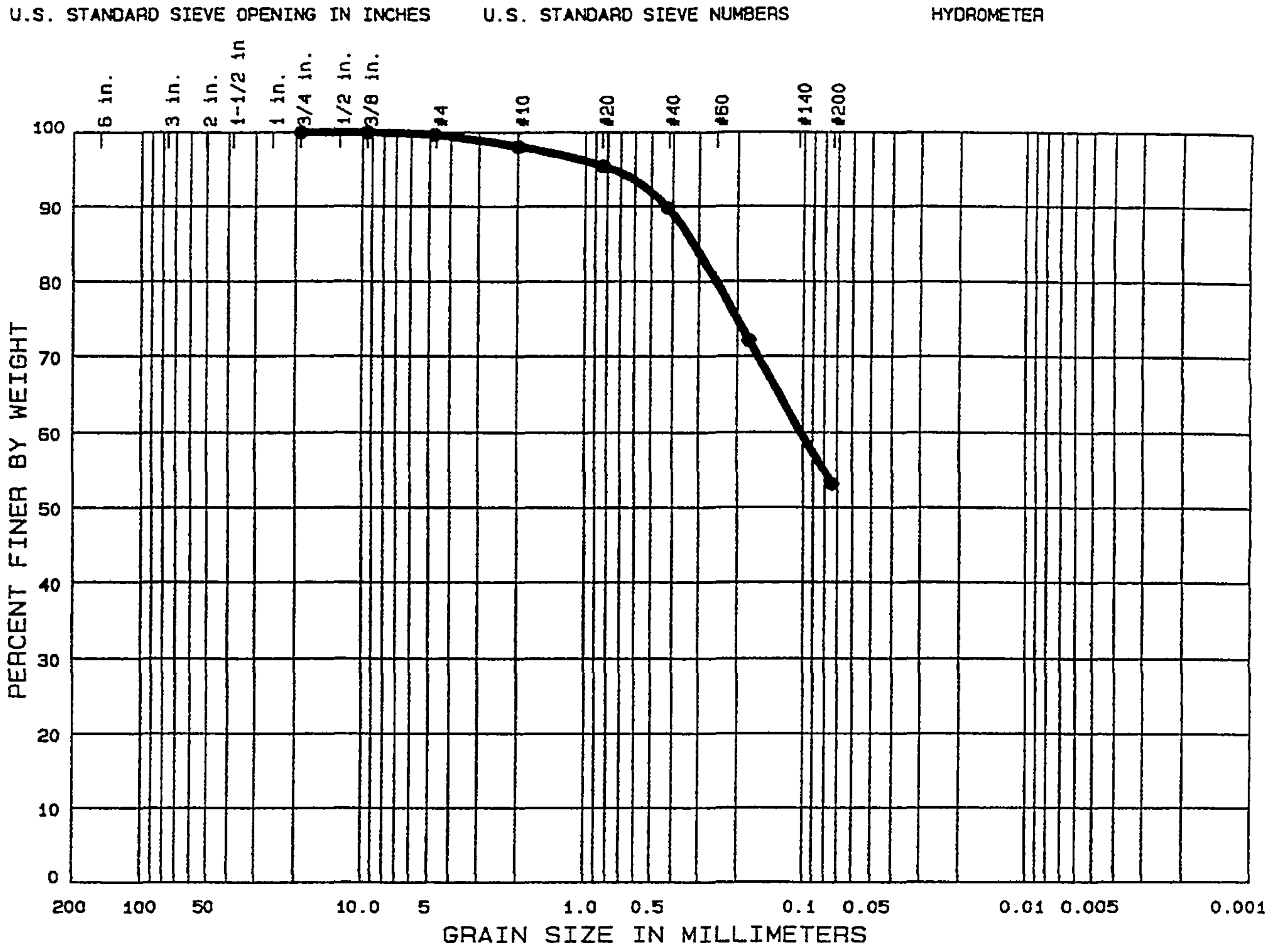
2. Unless otherwise notified, all remaining material will be disposed of 90 days after the date of this report.

Submitted by:

for DOUGLAS B. TAGGART
Director, M.R. Laboratory

Hankins/(402)444-4309

W.O. No. rma26-3
Req. No. S-2634 (MIL)
Contract No.



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	0.3	46.5	53.2

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	TP96-27 B-1	5.0'-6.0'		37	17	20		

CLASSIFICATION

● Sandy Lean Clay CL
Reddish Brown with White

Remarks:

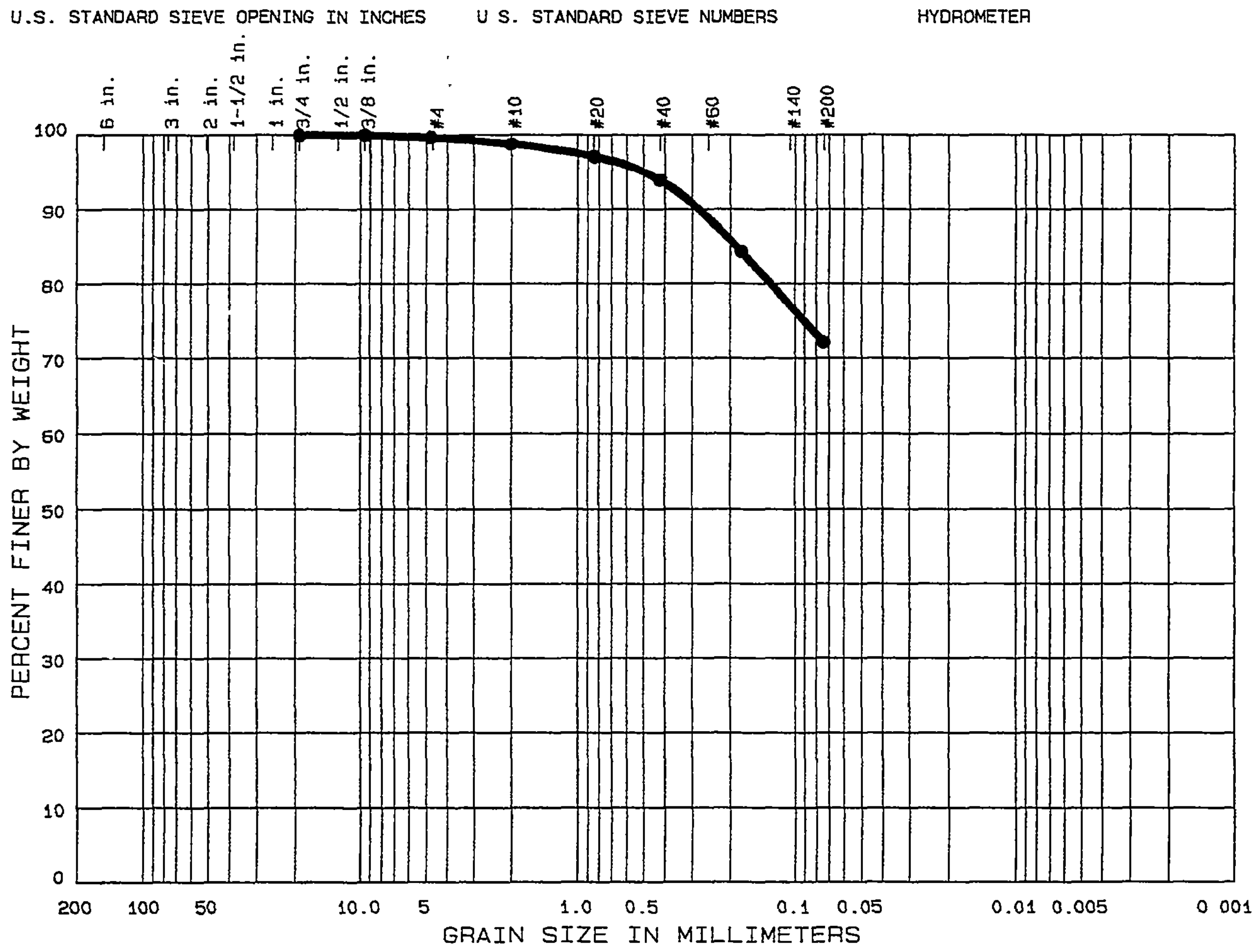
Project Rocky Mountain Arsenal
Hazardous Waste Landfill
Lab No. 4024
Area

Boring No. TP96-27 B-1 Date 9/16/96

GRADATION CURVES

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586

W.O. No. rmatp33-1
Req. No. S-2634
Contract No.



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	0.3	27.6	72.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	TP96-33 B-1	0.5'-1.0'		36	15	21		

CLASSIFICATION

● Lean Clay with sand, CL

Remarks:

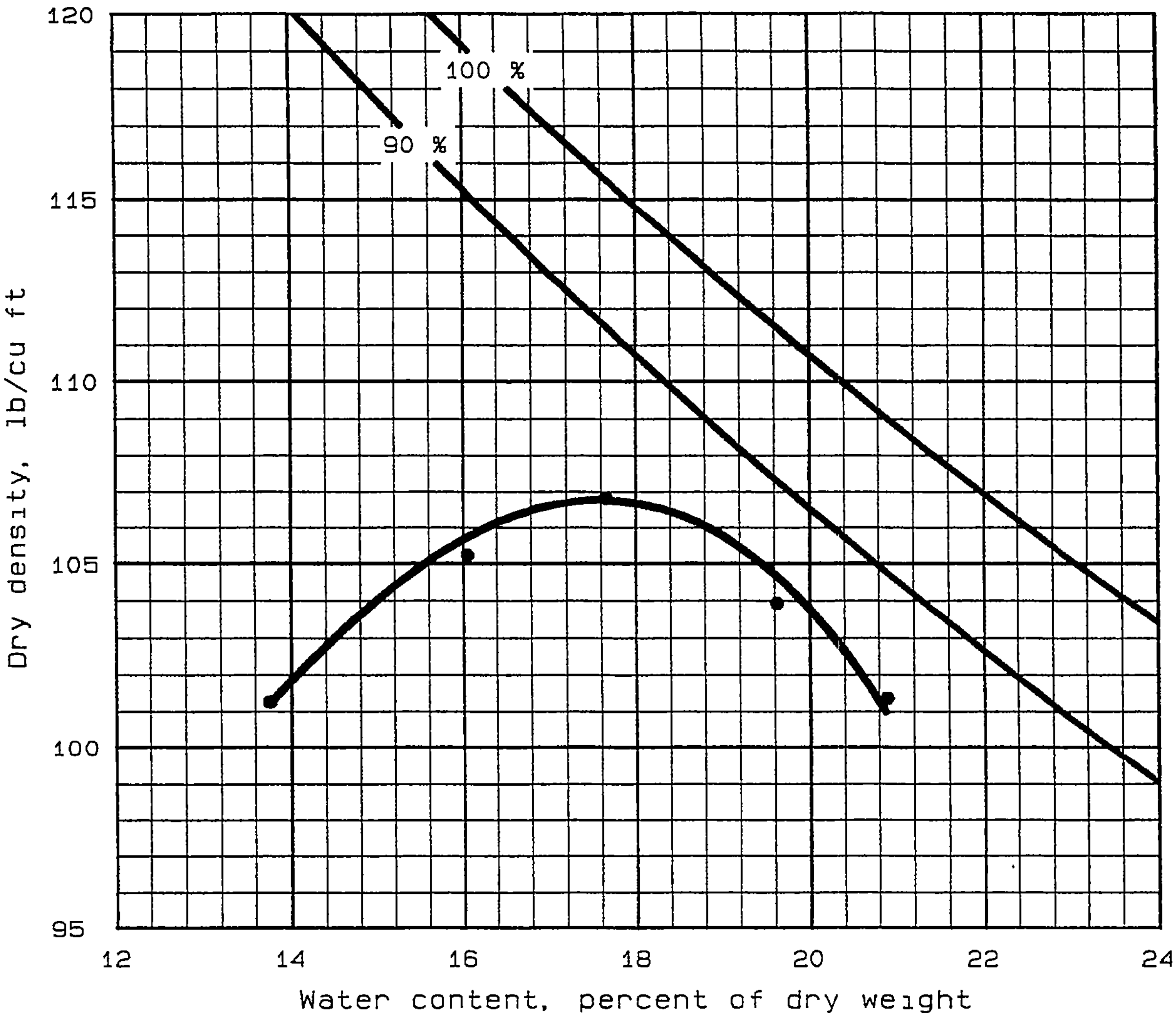
Project Rocky Mountain Arsenal
Hazardous Waste Landfill
Lab No. 4024
Area

Boring No. TP96-33 B-1 Date 10/29/96

GRADATION CURVES Figure 1

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586

WORK ORDER NO. rma27/33-1
Req. No. S-2634 MIL
Contract No.



Reduced compaction test EM-1110-2-1906
15 blows per each of 3 layers, with 5.00 lb sl. weight rammer
and 12.0 inch drop. 4.0 inch diameter mold

Sample No.	Elev/ Depth	Classification	G	LL	PL	% > No.4	% > 3/4 in.
27/33	.5'-6'	Sandy Lean Clay CL	2.75	38	14	0.0	0.0

Sample No.	27/33			
Water content, percent	2.0	air-dried		
Optimum water content, percent	17 6			
Max dry density, lb/cu ft	106.8			

Remarks:

Project: Rocky Mountain Arsenal
Hazardous Waste Landfill
Lab No.: 4024
Area:
Boring No.: TP27/33 B-1
Date: 11/5/96

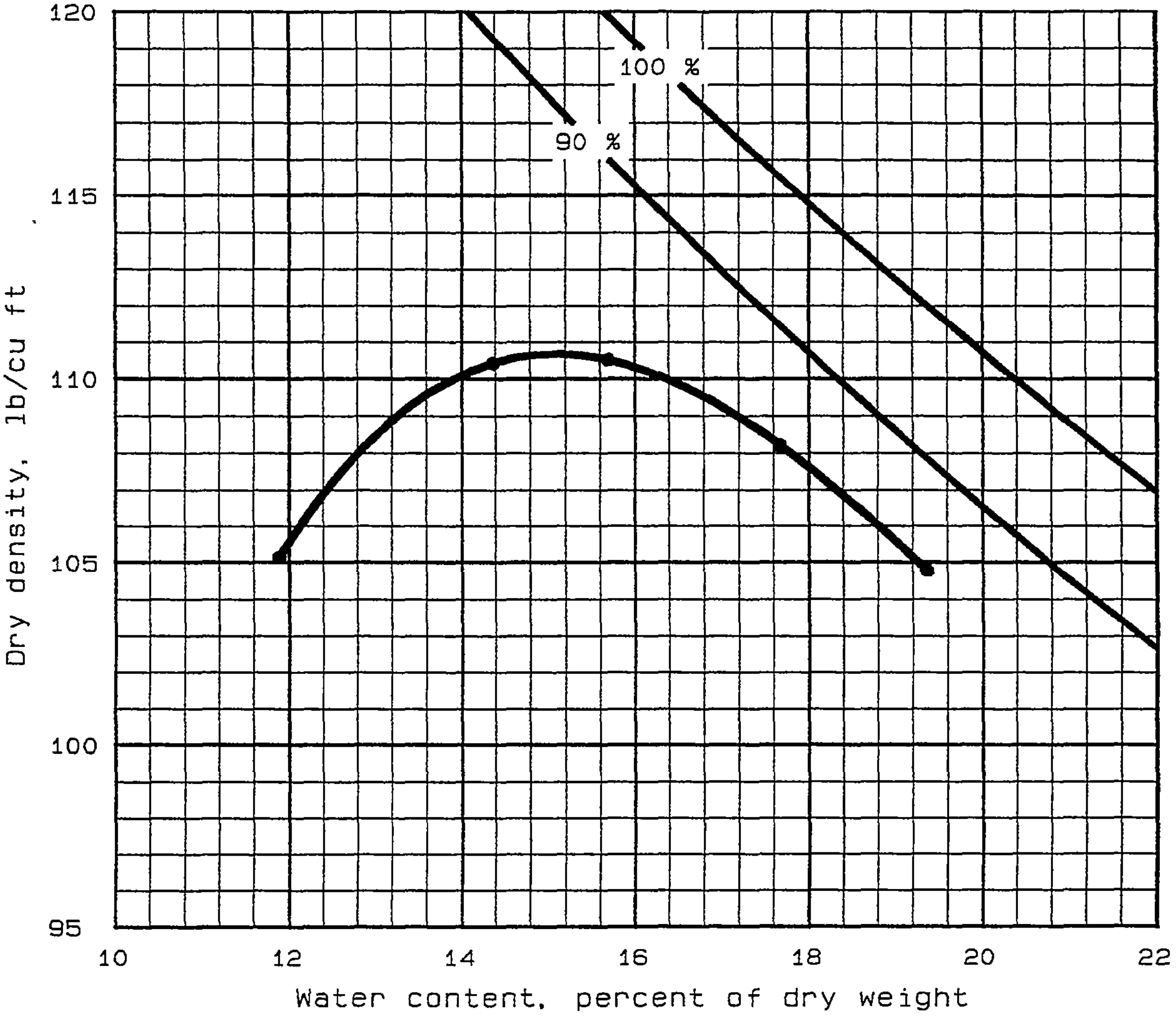
COMPACTION TEST REPORT

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586

Figure 2

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586

WORK ORDER NO. rma27/33-1
Req. No. S-2634 MIL
Contract No.



Standard compaction test ASTM D698 Method A
25 blows per each of 3 layers, with 5.50 lb. sleeve rammer
and 12.0 inch drop.   4.0 inch diameter mold

Sample No.	Elev/ Depth	Classification	G	LL	PL	% > No.4	% > 3/4 in.
27/33	.5'-6'	Sandy Lean Clay CL	2.75	38	14	0.0	0.0

Sample No.	27/33			
Water content, percent	2.0	air-dried		
Optimum water content, percent	15.1			
Max dry density, lb/cu ft	110.7			

Remarks:

Project: Rocky Mountain Arsenal
Hazardous Waste Landfill
Lab No.: 4024
Area:

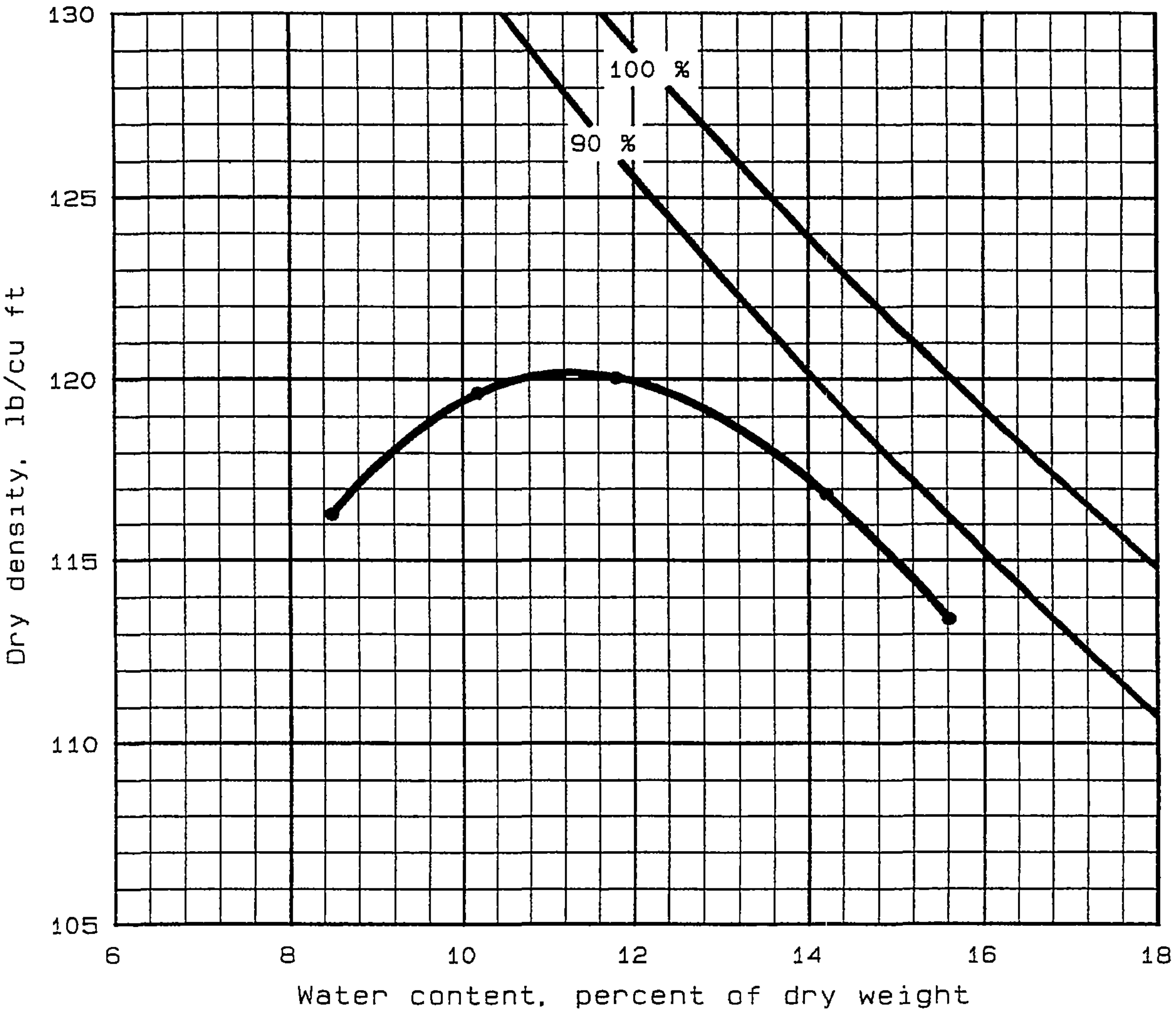
Boring No.: TP27/33 B-1 | Date: 11/5/96

COMPACTION TEST REPORT

Figure 3

WORK ORDER NO. rma27/33-1
Req. No. S-2634 MIL
Contract No.

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586



Modified compaction test EM-1110-2-1906
25 blows per each of 5 layers, with 10.00 lb. sl. weight rammer
and 18.0 inch drop.   4.0 inch diameter mold

Sample No.	Elev/ Depth	Classification	G	LL	PL	% > No.4	% > 3/4 in.
27/33	.5'-6'	Sandy Lean Clay CL	2.75	38	14	0.0	0.0

Sample No.	27/33			
Water content, percent	2.0	air-dried		
Optimum water content, percent	11.3			
Max dry density, lb/cu ft	120.2			

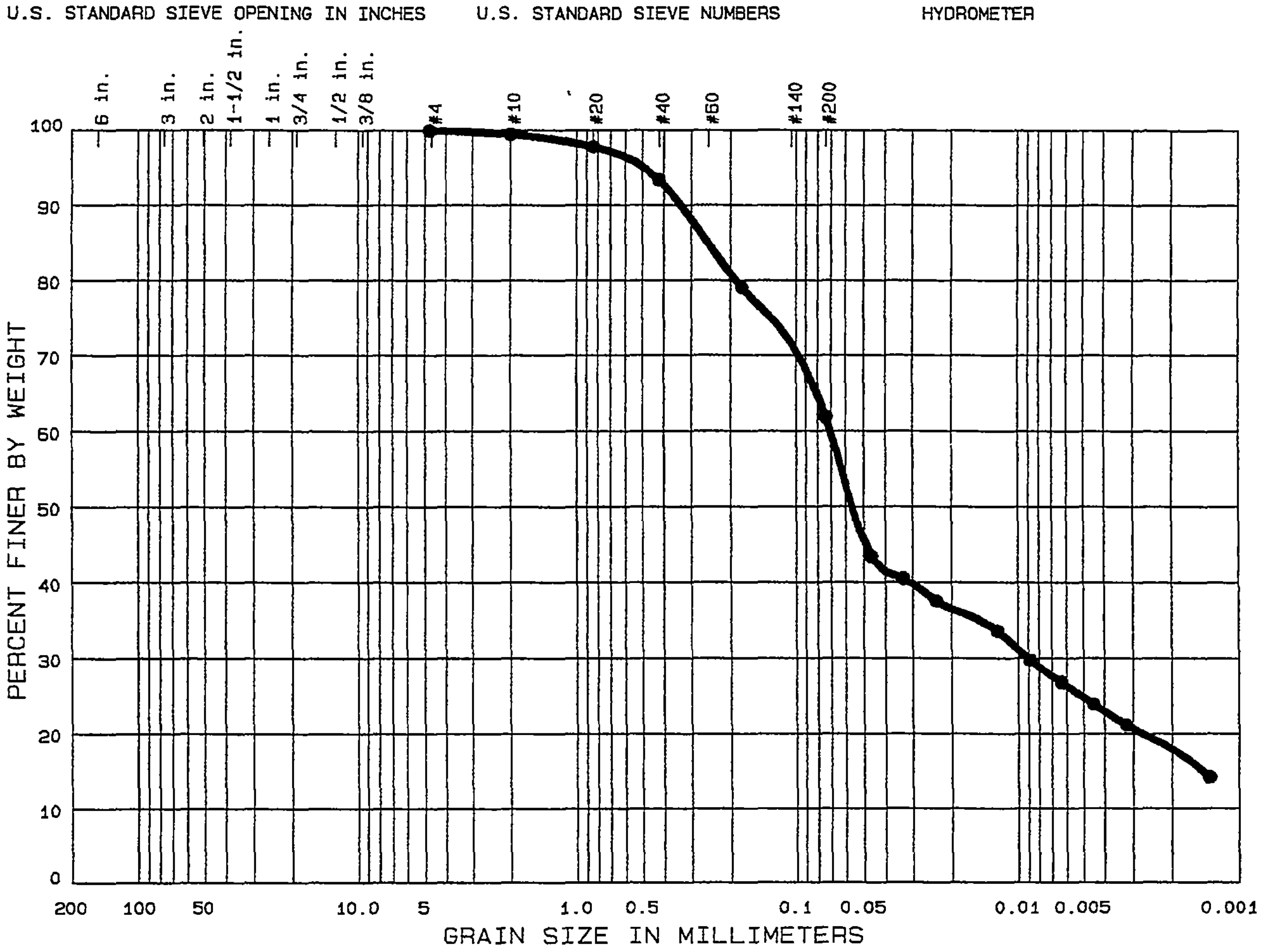
Remarks:

Project: Rocky Mountain Arsenal
Hazardous Waste Landfill
Lab No.: 4024
Area:
Boring No.: TP27/33 B-1 | Date: 11/5/96

COMPACTION TEST REPORT

Figure 4

W.O. No. rma27/33-1
Req. No. Lab-66
Contract No.



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY	
●	0.0	0.0	38.1	37.1	24.8

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	TP27/33 B-1	.5'-6'		38	14	24	1.14	71.0

CLASSIFICATION

● Sandy Lean Clay, CL
Specific Gravity = 2 75

Remarks:

Project Rocky Mountain Arsenal
Hazardous Waste Landfill
Lab No. 4024
Area

Boring No. TP27/33 B-1 Date 11/6/96

GRADATION CURVES Figure 5

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586

MR LAB NO. 4024

10 DEC 1996

DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Subject: Falling Head Rising Tailwater Permeability Tests
Report Series No. 26
Project: R.M.A.
Intended Use: Hazardous Waste landfill
Source of Material: Borings TP 96-27&33 Bag#1

Submitted by: Chief, CEMRO-ED-GA
Date Sampled:, **Date Received:** 06/28/96
Method of Test or Specification: ASTM D-5084-90

References: Omaha District Request No. S-2634 (MIL) dated 08/29/96
Purchase Request No. LAB-66 dated 05/14/96

1. Subject testing has been performed in accordance with the above test method and reference. Test results are shown in Figures 1 through 6 and Tables 1 through 6. All tests were performed on specimens from composite bag samples. Preliminary results were sent on 12/02/96.

2. Falling head permeability tests were performed on remolded specimens. Specimens were remolded at the following conditions:
Dry Density = 118.5 pcf @ Water Content = 12.3%
Dry Density = 116.5 pcf @ Water Content = 15.6%
Dry Density = 113.5 pcf @ Water Content = 14.4%
Dry Density = 108.5 pcf @ Water Content = 17.0%
Dry Density = 104.0 pcf @ Water Content = 19.3%
Dry Density = 102.5 pcf @ Water Content = 22.5%

3. Unless otherwise notified, all remaining material will be disposed of 90 days after the date of this report.

Submitted by:

for DOUGLAS B. TAGGART
Director, MR Laboratory

Bahwawsi/(402)444-4325

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 1

FALLING HEAD PERMEABILITY TEST DATA
RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	06-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density = 118.5 pcf @ Water Content = 12.3%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions

Moisture Content (%)	12.4
Height (in)	3.015
Diameter (in)	1.400
Wet weight (g)	161.85
Void Ratio	0.45
Saturation (%)	75.4
Dry Density (pcf)	118.1

Specimen Conditions After Consolidation

Moisture Content (%)	16.4	
Height Change (in)	-0.016	SWELL
Height (in)	3.031	
Diameter (in)	1.407	
Void Ratio	0.48	
Saturation (%)	94.8	
Dry Density (pcf)	116.3	

Test Pressures

Chamber (psi)	100.00
Inflow (psi)	98.00
Outflow (psi)	96.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

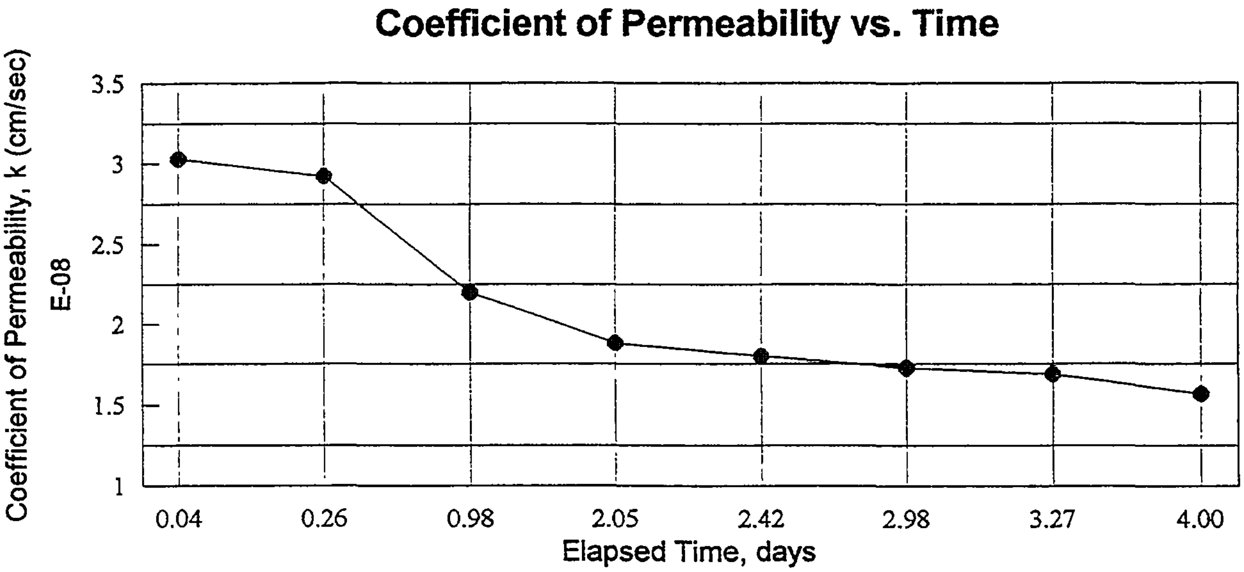
Permeability - Top to Bottom

Time (min)	5760.00
Initial Head (cm)	164.41
Final Head (cm)	157.09
k (cm/sec)	1.57E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/06/96	0.00	0.00	0.00	-
12/06/96	0.04	0.05	0.05	3.03E-08
12/06/96	0.26	0.30	0.30	2.92E-08
12/07/96	0.98	0.85	0.85	2.20E-08
12/08/96	2.05	1.50	1.55	1.88E-08
12/08/96	2.42	1.70	1.75	1.80E-08
12/09/96	2.98	2.00	2.00	1.73E-08
12/09/96	3.27	2.15	2.10	1.69E-08
12/10/96	4.00	2.45	2.40	1.57E-08



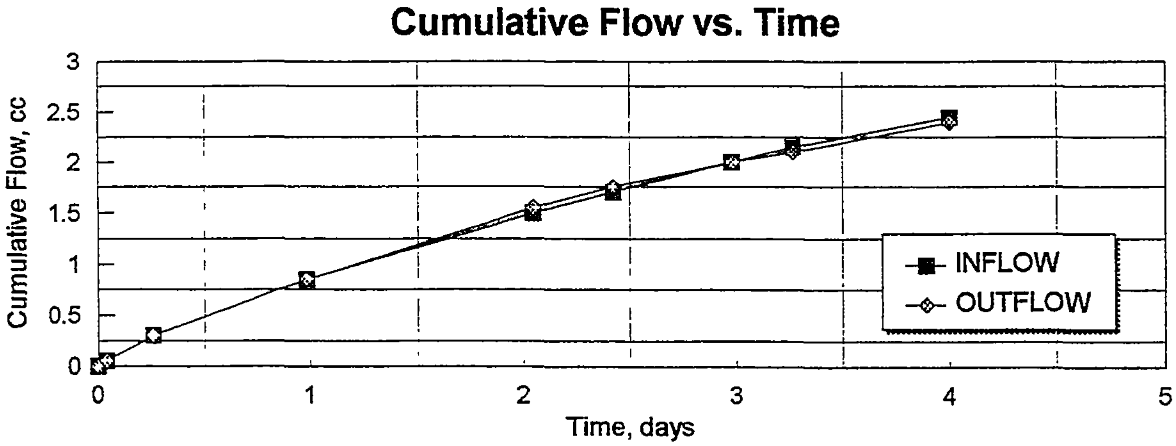


Figure 1

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 2

FALLING HEAD PERMEABILITY TEST DATA
RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	22-Nov-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density = 116.5 pcf @ Water Content = 15.6%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**		
Moisture Content (%)	15.9	Moisture Content (%)	17.5	
Height (in)	3.033	Height Change (in)	-0.005	SWELL
Diameter (in)	1.400	Height (in)	3.038	
Wet weight (g)	164.00	Diameter (in)	1.402	
Void Ratio	0.49	Void Ratio	0.49	
Saturation (%)	89.8	Saturation (%)	97.4	
Dry Density (pcf)	115.4	Dry Density (pcf)	114.8	

Test Pressures

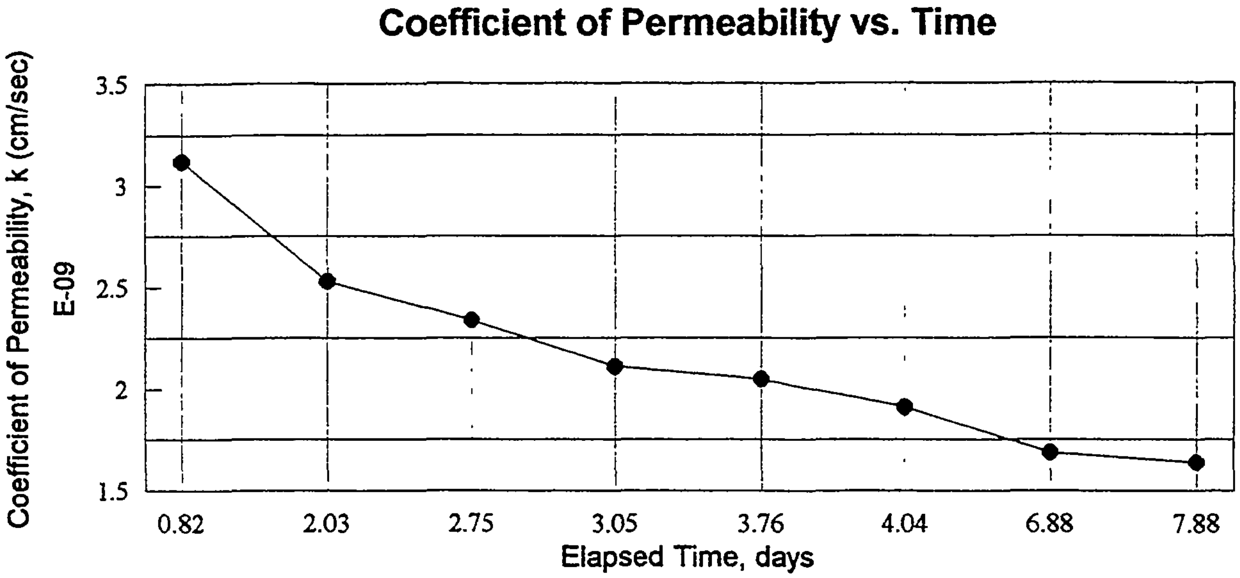
Chamber (psi)	130.00
Inflow (psi)	128.00
Outflow (psi)	126.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

Time (min)	11340.00
Initial Head (cm)	162.65
Final Head (cm)	161.15
k (cm/sec)	1.64E-09

FALLING HEAD RISING TAILWATER PRESSURE

	FROM TOP TO BOTTOM			
DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
11/22/96	0.00	0.00	0.00	-
11/23/96	0.82	0.10	0.05	3.12E-09
11/24/96	2.03	0.20	0.12	2.53E-09
11/25/96	2.75	0.25	0.10	2.34E-09
11/25/96	3.05	0.25	0.10	2.11E-09
11/26/96	3.76	0.30	0.15	2.05E-09
11/26/96	4.04	0.30	0.15	1.91E-09
11/29/96	6.88	0.45	0.30	1.69E-09
11/30/96	7.88	0.50	0.30	1.64E-09



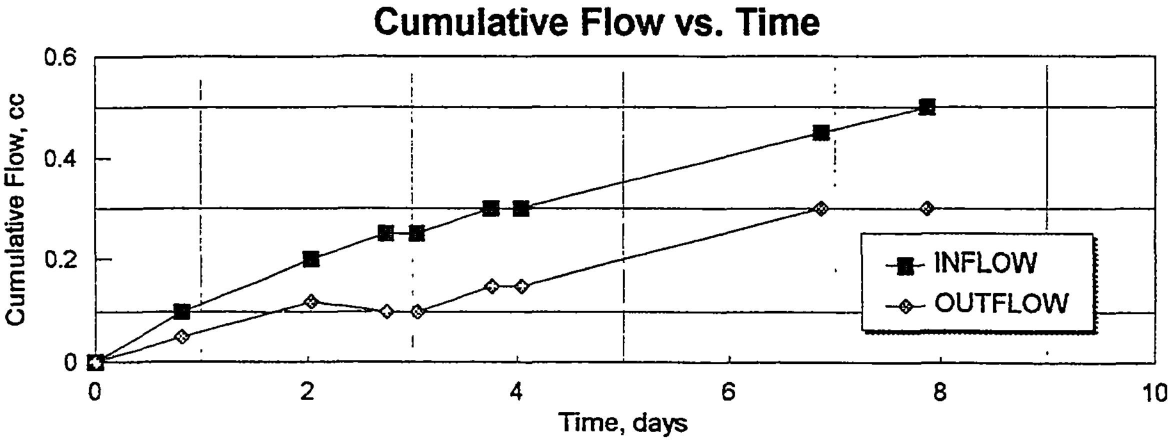


Figure 2

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 3

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	18-Nov-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1 (Dry Density = 113.5 pcf @ Water Content = 14.4%)
Depth	0.5'-6.0'

Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions

Moisture Content (%)	14.7
Height (in)	3.009
Diameter (in)	1.399
Wet weight (g)	158.09
Void Ratio	0.51
Saturation (%)	78.9
Dry Density (pcf)	113.5

Specimen Conditions After Consolidation

Moisture Content (%)	19.9	
Height Change (in)	-0.024	SWELL
Height (in)	3.033	
Diameter (in)	1.410	
Void Ratio	0.55	
Saturation (%)	99.7	
Dry Density (pcf)	110.8	

Test Pressures

Chamber (psi)	100.00
Inflow (psi)	98.00
Outflow (psi)	96.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

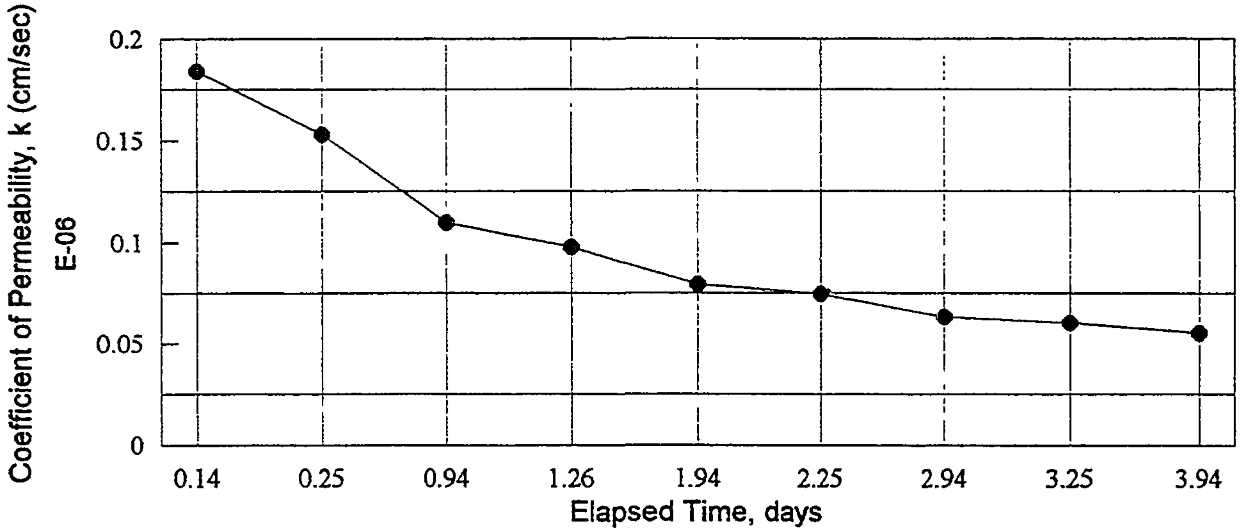
Time (min)	5677.00
Initial Head (cm)	161.12
Final Head (cm)	137.69
k (cm/sec)	5.50E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
11/18/96	0.00	0.00	0.00	-
11/18/96	0.14	0.10	0.10	1.84E-07
11/18/96	0.25	1.50	1.60	1.53E-07
11/19/96	0.94	3.90	3.90	1.10E-07
11/19/96	1.26	4.60	4.60	9.77E-08
11/20/96	1.94	5.70	5.80	7.93E-08
11/20/96	2.25	6.2	6.10	7.47E-08
11/21/96	2.94	6.80	6.80	6.32E-08
11/21/96	3.25	7.15	7.10	6.02E-08
11/22/96	3.94	7.85	7.75	5.50E-08

Coefficient of Permeability vs. Time



Cumulative Flow vs. Time

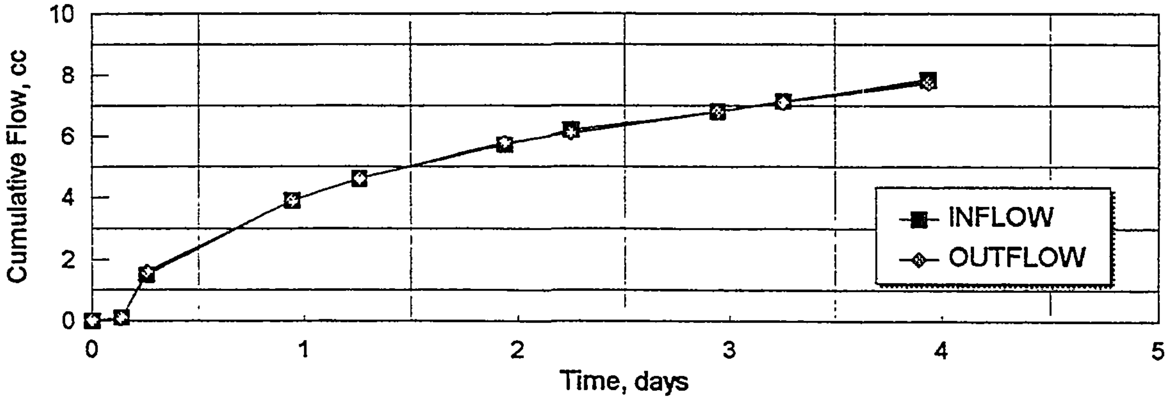


Figure 3

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 4

FALLING HEAD PERMEABILITY TEST DATA
RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	17-Nov-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1 (Dry Density = 108.5 pcf @ Water Content = 17.0%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**	
Moisture Content (%)	17.0	Moisture Content (%)	21.5
Height (in)	3.005	Height Change (in)	0.000
Diameter (in)	1.409	Height (in)	3.005
Wet weight (g)	154.37	Diameter (in)	1.409
Void Ratio	0.60	Void Ratio	0.60
Saturation (%)	77.9	Saturation (%)	98.5
Dry Density (pcf)	107.2	Dry Density (pcf)	107.2

Test Pressures

Chamber (psi)	90.00
Inflow (psi)	88.00
Outflow (psi)	86.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

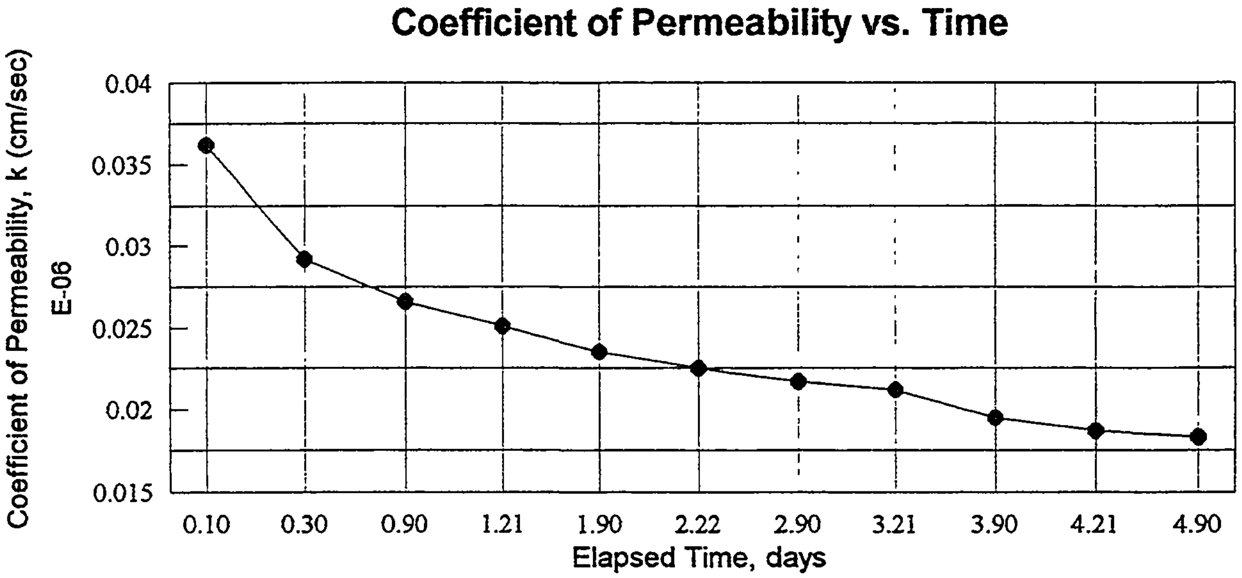
Permeability - Top to Bottom

Time (min)	7058.00
Initial Head (cm)	162.68
Final Head (cm)	152.38
k (cm/sec)	1.83E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
11/17/96	0.00	0.00	0.00	-
11/17/96	0.10	0.15	0.15	3.62E-08
11/17/96	0.30	0.35	0.35	2.92E-08
11/18/96	0.90	0.95	0.90	2.66E-08
11/18/96	1.21	1.20	1.20	2.51E-08
11/19/96	1.90	1.75	1.65	2.35E-08
11/19/96	2.22	1.95	1.90	2.25E-08
11/20/96	2.90	2.45	2.35	2.17E-08
11/20/96	3.21	2.65	2.55	2.12E-08
11/21/96	3.90	2.95	2.85	1.95E-08
11/21/96	4.21	3.05	3.00	1.87E-08
11/22/96	4.90	3.45	3.30	1.83E-08



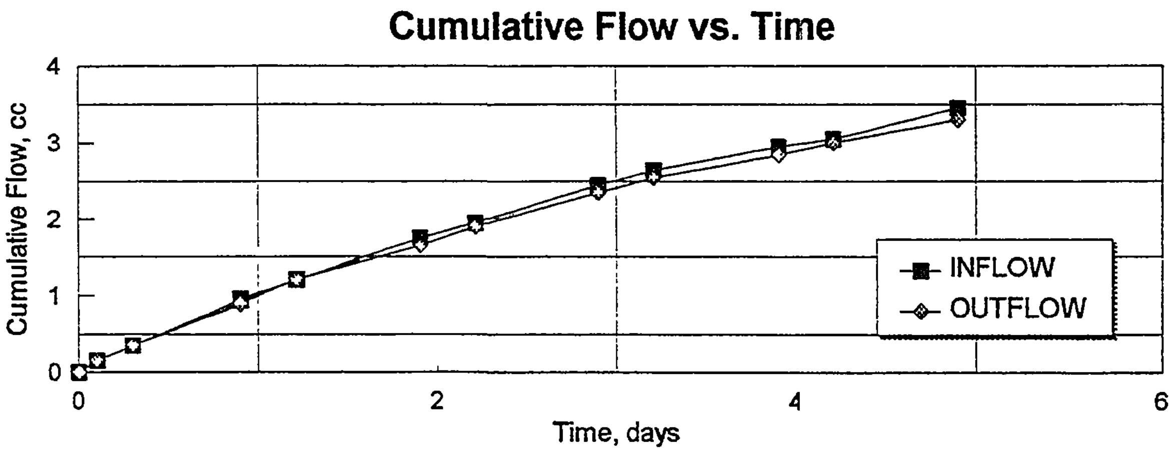


Figure 4

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 5

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	17-Nov-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1 (Dry Density = 104.0 pcf @ Water Content = 19.3%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**	
Moisture Content (%)	20.1	Moisture Content (%)	22.8
Height (in)	3.006	Height Change (in)	0.009
Diameter (in)	1.396	Height (in)	2.997
Wet weight (g)	151.10	Diameter (in)	1.392
Void Ratio	0.65	Void Ratio	0.63
Saturation (%)	85.3	Saturation (%)	99.0
Dry Density (pcf)	104.1	Dry Density (pcf)	105.1

Test Pressures

Chamber (psi)	80.00
Inflow (psi)	78.00
Outflow (psi)	76.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

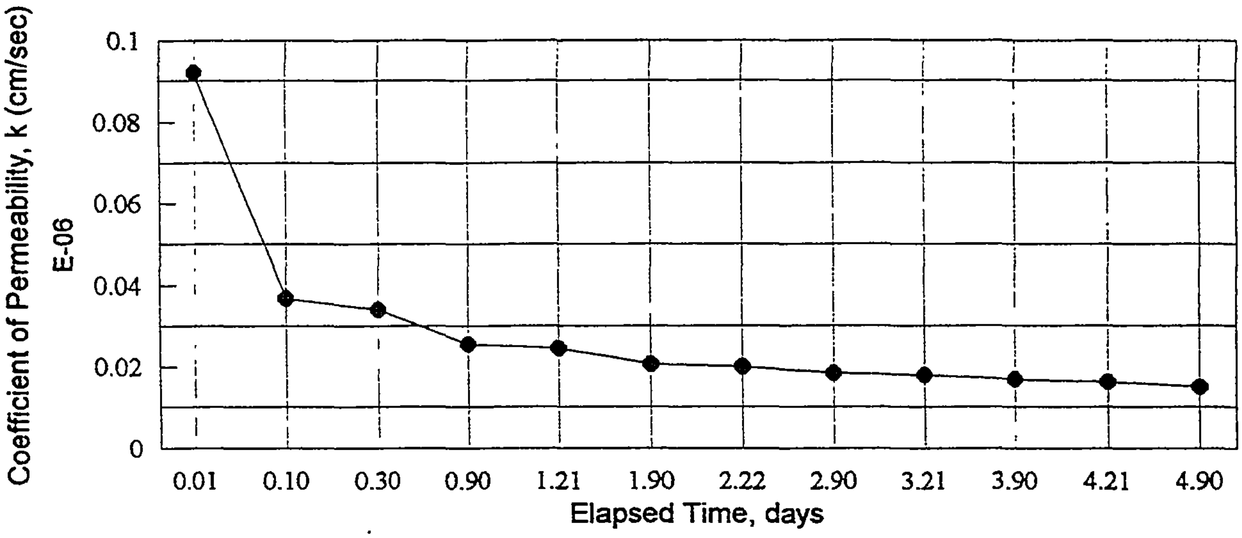
Time (min)	7058.00
Initial Head (cm)	163.39
Final Head (cm)	155.04
k (cm/sec)	1.50E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
11/17/96	0.00	0.00	0.00	-
11/17/96	0.01	0.05	0.10	9.21E-08
11/17/96	0.10	0.15	0.25	3.69E-08
11/17/96	0.30	0.40	0.50	3.40E-08
11/18/96	0.90	0.90	0.95	2.56E-08
11/18/96	1.21	1.15	1.15	2.45E-08
11/19/96	1.90	1.5	1.55	2.06E-08
11/19/96	2.22	1.70	1.75	1.99E-08
11/20/96	2.90	2.05	1.95	1.84E-08
11/20/96	3.21	2.20	2.15	1.79E-08
11/21/96	3.90	2.50	2.45	1.68E-08
11/21/96	4.21	2.60	2.55	1.62E-08
11/22/96	4.90	2.80	2.75	1.50E-08

Coefficient of Permeability vs. Time



Cumulative Flow vs. Time

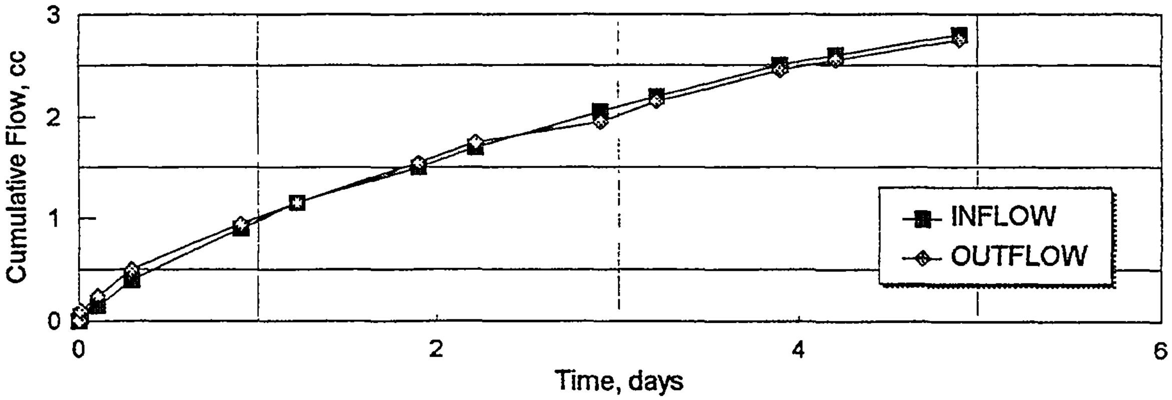


Figure 5

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 6

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	22-Nov-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density = 102.5 pcf @ Water Content = 22.5%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions

Moisture Content (%)	22.6
Height (in)	3.027
Diameter (in)	1.403
Wet weight (g)	152.91
Void Ratio	0.69
Saturation (%)	90.0
Dry Density (pcf)	101.5

Specimen Conditions After Consolidation

Moisture Content (%)	24.3
Height Change (in)	0.007
Height (in)	3.020
Diameter (in)	1.400
Void Ratio	0.68
Saturation (%)	98.4
Dry Density (pcf)	102.2

Test Pressures

Chamber (psi)	100.00
Inflow (psi)	98.00
Outflow (psi)	96.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

Time (min)	9900.00
Initial Head (cm)	163.54
Final Head (cm)	155.63
k (cm/sec)	1.01E-08

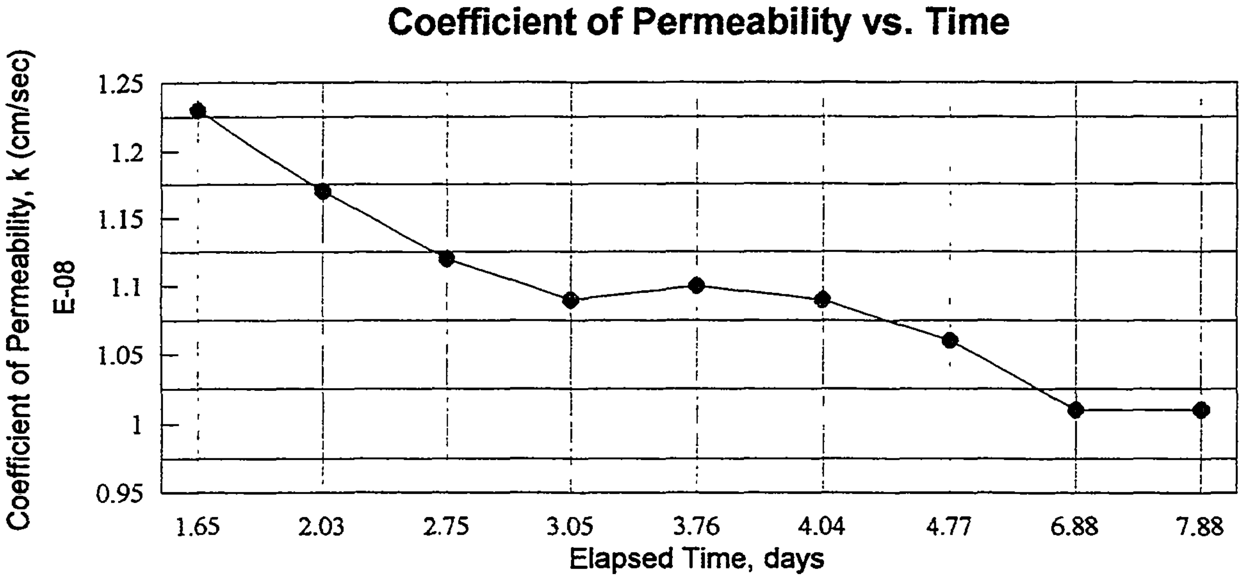
Appendix E

Remolded Hydraulic Conductivity Test Results

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
11/22/96	0.00	0.00	0.00	-
11/24/96	1.65	0.79	0.92	1.23E-08
11/24/96	2.03	0.93	1.10	1.17E-08
11/25/96	2.75	1.20	1.25	1.12E-08
11/25/96	3.05	1.30	1.60	1.09E-08
11/26/96	3.76	1.60	1.90	1.10E-08
11/26/96	4.04	1.70	2.00	1.09E-08
11/27/96	4.77	1.95	2.25	1.06E-08
11/29/96	6.88	2.65	3.05	1.01E-08
11/30/96	7.88	3.05	3.35	1.01E-08



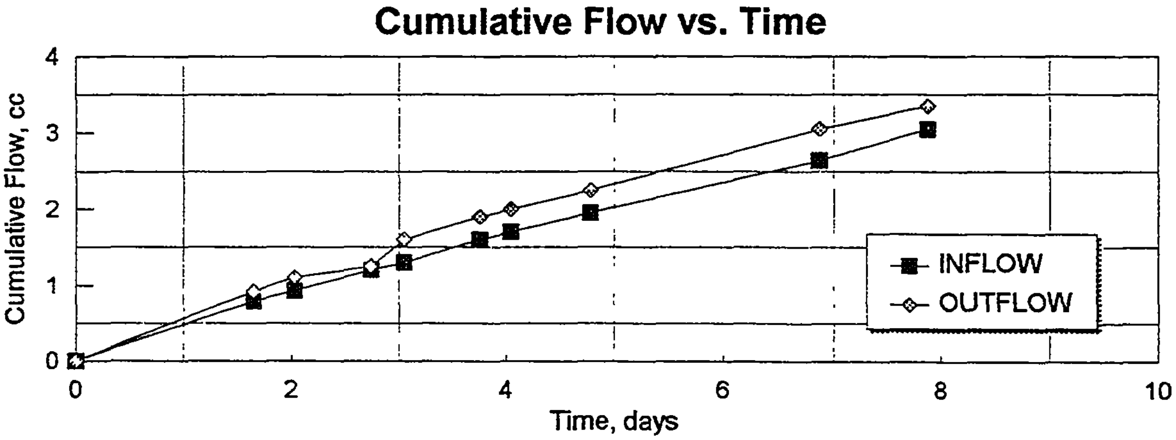


Figure 6

MR LAB NO. 4024

30 DEC 1996

DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Subject: Falling Head Rising Tailwater Permeability Tests
Report Series No. 28
Project: R.M.A.
Intended Use: Hazardous Waste Landfill
Source of Material: Borings TP 96-27&33 Bag#1

Submitted by: Chief, CEMRO-ED-GA
Date Sampled: ______, **Date Received:** 06/28/96
Method of Test or Specification: ASTM D-5084-90

References: Omaha District Request No. S-2634 (MIL) dated 08/29/96
Purchase Request No. LAB-66 dated 05/14/96

1. Subject testing has been performed in accordance with the above test method and reference. Test results are shown in Figures 1 through 6 and Tables 1 through 6. All tests were performed on specimens from composite bag samples. Preliminary results were sent on 12/23/96.

2. Falling head permeability tests were performed on remolded specimens. Specimens were remolded at the following conditions:

Dry Density = 120.0 pcf @ Water Content = 11.2%
Dry Density = 116.0 pcf @ Water Content = 12.6%
Dry Density = 111.7 pcf @ Water Content = 14.3%
Dry Density = 109.2 pcf @ Water Content = 15.6%
Dry Density = 105.0 pcf @ Water Content = 18.5%
Dry Density = 101.0 pcf @ Water Content = 21.0%

3. Unless otherwise notified, all remaining material will be disposed of 90 days after the date of this report.

Submitted by:

for DOUGLAS B. TAGGART
Director, MR Laboratory

Bahwawsi/(402)444-4325

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

#7

TABLE 1

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	20-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density = 120.0 pcf @ Water Content = 11.2%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**		
Moisture Content (%)	11.7	Moisture Content (%)	18.6	
Height (in)	3.009	Height Change (in)	-0.065	SWELL
Diameter (in)	1.400	Height (in)	3.074	
Wet weight (g)	162.54	Diameter (in)	1.430	
Void Ratio	0.43	Void Ratio	0.53	
Saturation (%)	74.1	Saturation (%)	96.7	
Dry Density (pcf)	119.6	Dry Density (pcf)	112.2	

Test Pressures

Chamber (psi)	90.00
Inflow (psi)	88.00
Outflow (psi)	86.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

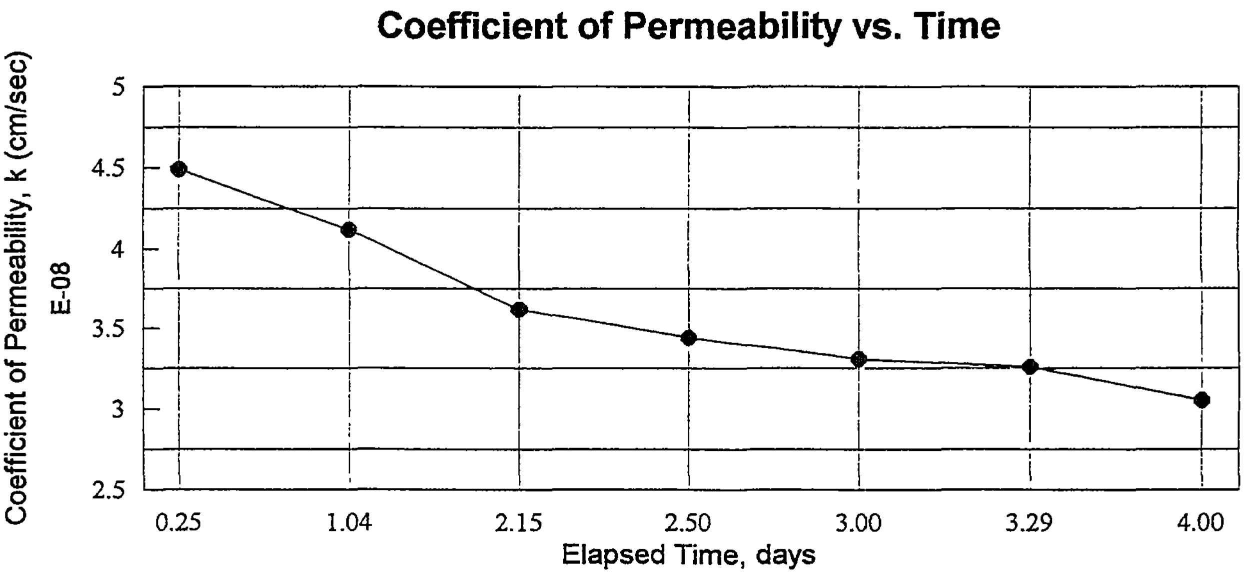
Permeability - Top to Bottom

Time (min)	5760.00
Initial Head (cm)	163.36
Final Head (cm)	149.33
k (cm/sec)	3.05E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/20/96	0.00	0.00	0.00	-
12/20/96	0.25	0.45	0.60	4.49E-08
12/21/96	1.04	1.70	1.75	4.12E-08
12/22/96	2.15	3.05	3.00	3.62E-08
12/22/96	2.50	3.35	3.30	3.44E-08
12/23/96	3.00	3.85	3.75	3.31E-08
12/23/96	3.29	4.15	4.05	3.26E-08
12/24/96	4.00	4.70	4.65	3.05E-08



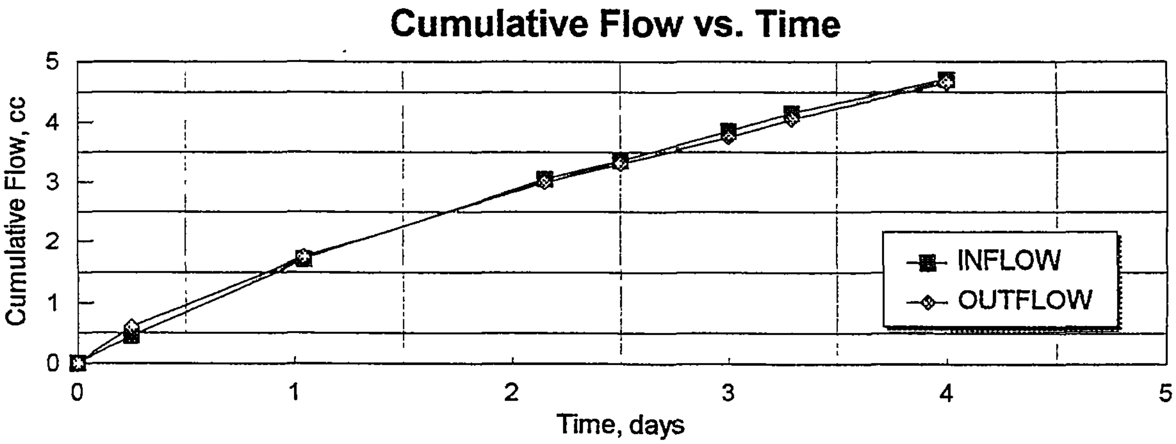


Figure 1

#8

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 2

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	24-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density =116.0pcf @ Water Content =12.6%)
Depth	0.5'-6.0'

Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**	
Moisture Content (%)	12.6	Moisture Content (%)	19.6
Height (in)	3.004	Height Change (in)	0.039
Diameter (in)	1.400	Height (in)	2.965
Wet weight (g)	159.21	Diameter (in)	1.382
Void Ratio	0.47	Void Ratio	0.42
Saturation (%)	73.1	Saturation (%)	100.0
Dry Density (pcf)	116.4	Dry Density (pcf)	121.1

Test Pressures

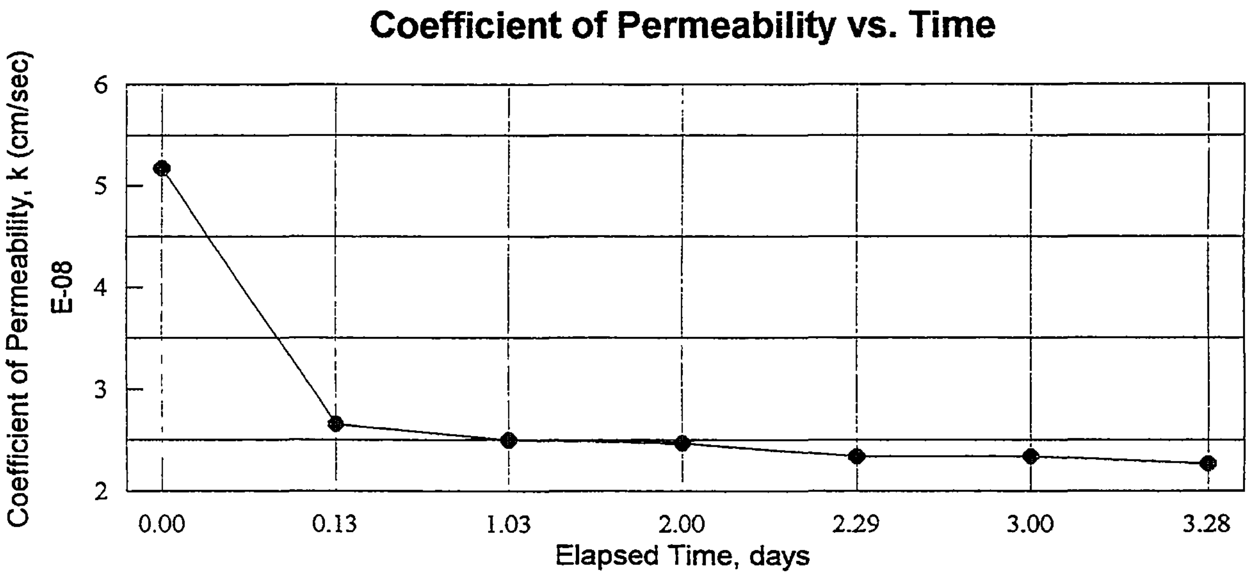
Chamber (psi)	110.00
Inflow (psi)	108.00
Outflow (psi)	106.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

Time (min)	5760.00
Initial Head (cm)	162.50
Final Head (cm)	152.35
k (cm/sec)	2.27E-08

FALLING HEAD RISING TAILWATER PRESSURE

		FROM TOP TO BOTTOM		
DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/24/96	0.00	0.00	0 00	-
12/24/96	0.13	0.25	0.25	5.17E-08
12/25/96	1.03	1.05	1.05	2.66E-08
12/26/96	2.00	1.90	1 85	2.50E-08
12/26/96	2.29	2.15	2.10	2.47E-08
12/27/96	3.00	2.65	2.60	2.34E-08
12/27/96	3.28	2.90	2.80	2.34E-08
12/28/96	4.00	3.40	3.30	2.27E-08


Coefficient of Permeability vs. Time

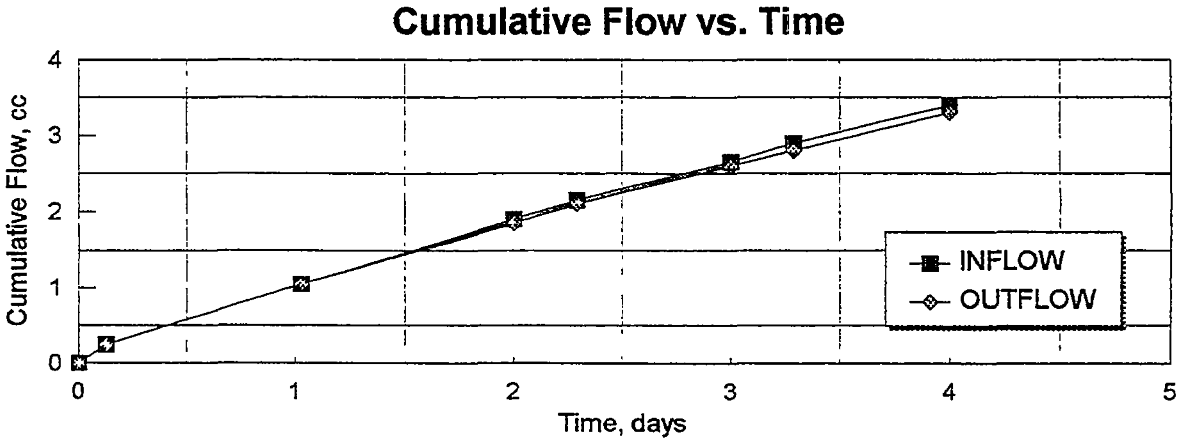

Cumulative Flow vs. Time

Figure 2

#9

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 3

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	24-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density =111.7pcf @ Water Content =14.3%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**	
Moisture Content (%)	14.4	Moisture Content (%)	21.2
Height (in)	2.995	Height Change (in)	0.019
Diameter (in)	1.412	Height (in)	2.976
Wet weight (g)	155.46	Diameter (in)	1.403
Void Ratio	0.56	Void Ratio	0.53
Saturation (%)	71.3	Saturation (%)	100.0
Dry Density (pcf)	110.3	Dry Density (pcf)	112.5

Test Pressures

Chamber (psi)	110.00
Inflow (psi)	108.00
Outflow (psi)	106.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

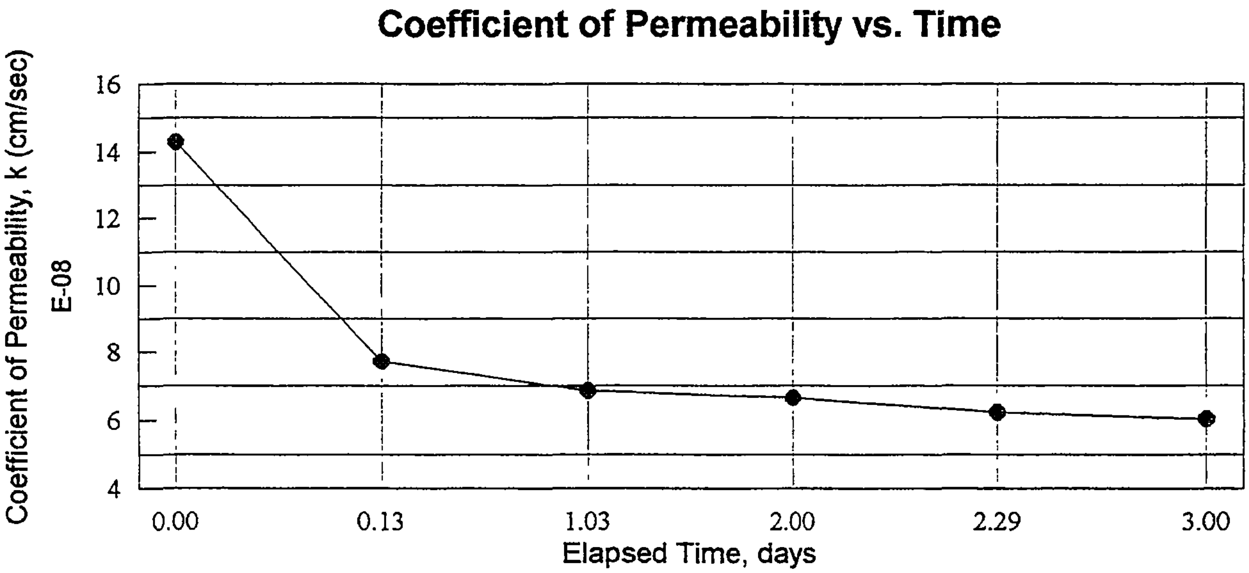
Permeability - Top to Bottom

Time (min)	4730.00
Initial Head (cm)	161.42
Final Head (cm)	139.63
k (cm/sec)	6.04E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/24/96	0.00	0.00	0.00	-
12/24/96	0.13	0.70	0.75	1.43E-07
12/25/96	1.03	3.00	3.05	7.73E-08
12/26/96	2.00	5.15	5.40	6.84E-08
12/26/96	2.29	5.70	5.95	6.65E-08
12/27/96	3.00	6.90	7.20	6.22E-08
12/28/96	3.28	7.30	7.65	6.04E-08



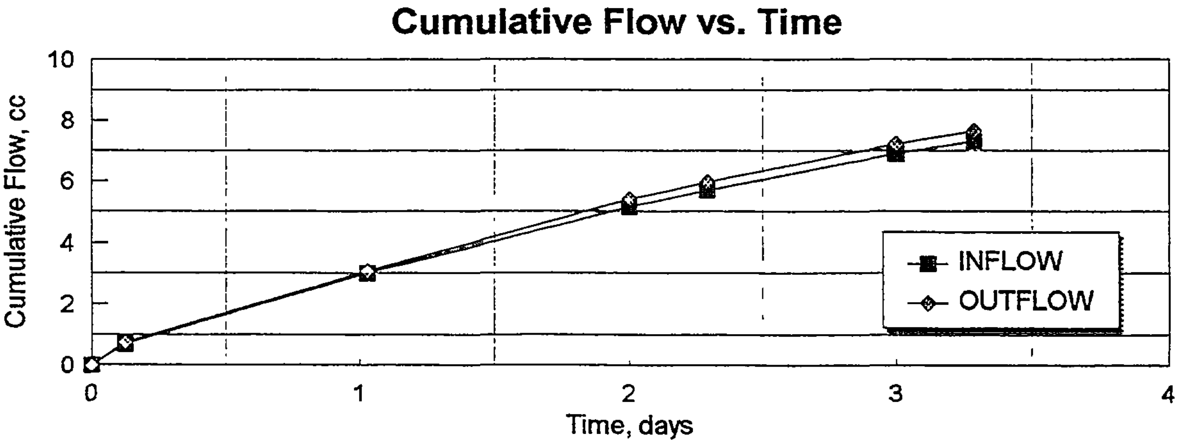


Figure 3

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

#10

TABLE 4

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	24-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density =109.2pcf @ Water Content =15.6%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions

Moisture Content (%)	15.7
Height (in)	3.001
Diameter (in)	1.411
Wet weight (g)	153.70
Void Ratio	0.59
Saturation (%)	72.9
Dry Density (pcf)	107.8

Specimen Conditions After Consolidation

Moisture Content (%)	22.3
Height Change (in)	0.007
Height (in)	2.994
Diameter (in)	1.408
Void Ratio	0.58
Saturation (%)	100.0
Dry Density (pcf)	108.6

Test Pressures

Chamber (psi)	110.00
Inflow (psi)	108.00
Outflow (psi)	106.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

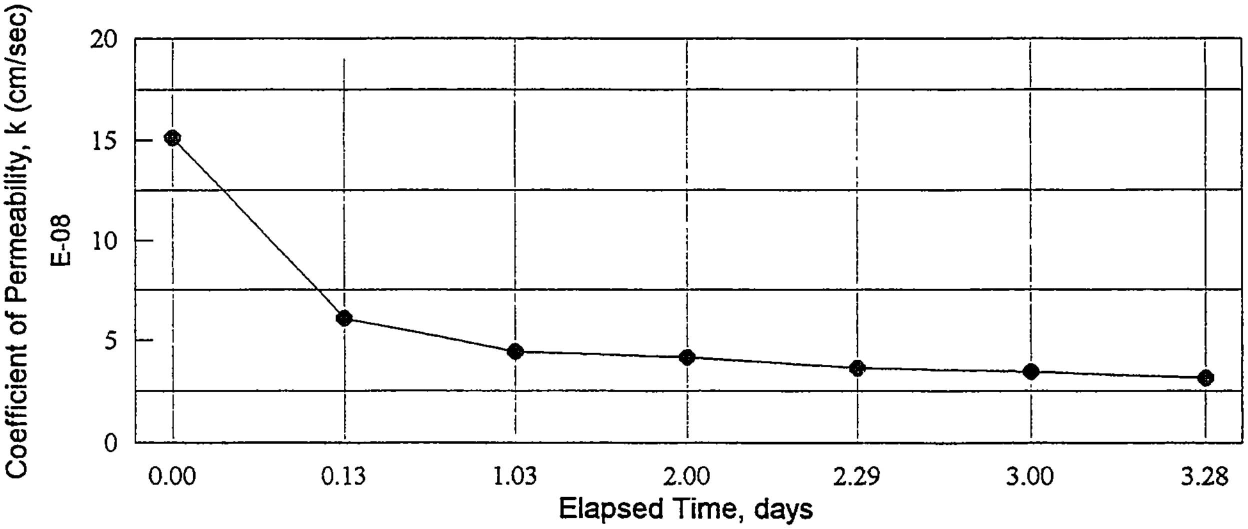
Time (min)	5760.00
Initial Head (cm)	163.57
Final Head (cm)	149.24
k (cm/sec)	3.13E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/24/96	0.00	0.00	0.00	-
12/24/96	0.13	0.75	0.75	1.51E-07
12/25/96	1.03	2.45	2.40	6.08E-08
12/26/96	2.00	3.45	3.40	4.44E-08
12/26/96	2.29	3.70	3.60	4.17E-08
12/27/96	3.00	4.20	4.15	3.63E-08
12/27/96	3.28	4.35	4.30	3.44E-08
12/28/96	4.00	4.80	4.70	3.13E-08

Coefficient of Permeability vs. Time



Cumulative Flow vs. Time

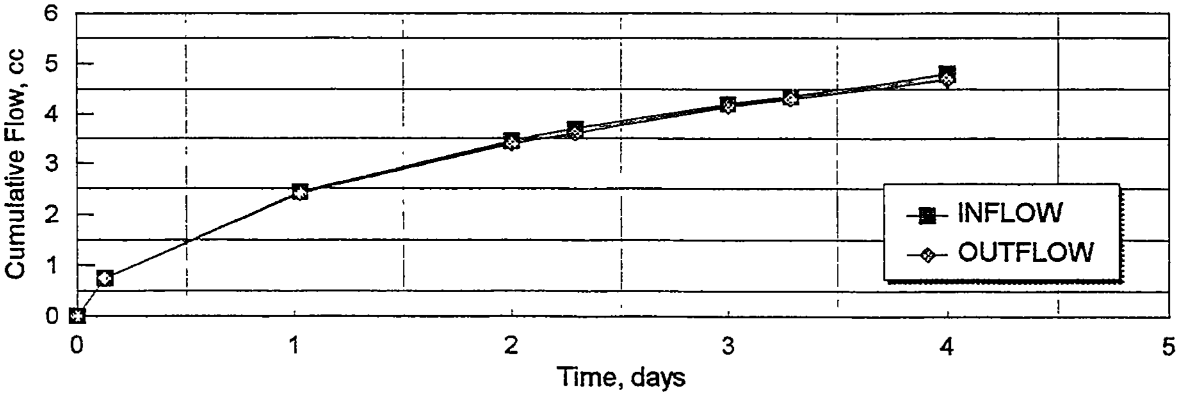


Figure 4

#11

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 5

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	20-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density =105.0 pcf @ Water Content =18.5%)
Depth	0.5'-6.0'

Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions

Moisture Content (%)	18.8
Height (in)	2.995
Diameter (in)	1.409
Wet weight (g)	151.55
Void Ratio	0.65
Saturation (%)	79.6
Dry Density (pcf)	104.0

Specimen Conditions After Consolidation

Moisture Content (%)	22.0
Height Change (in)	0.012
Height (in)	2.983
Diameter (in)	1.403
Void Ratio	0.63
Saturation (%)	96.0
Dry Density (pcf)	105.3

Test Pressures

Chamber (psi)	80.00
Inflow (psi)	78.00
Outflow (psi)	76.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

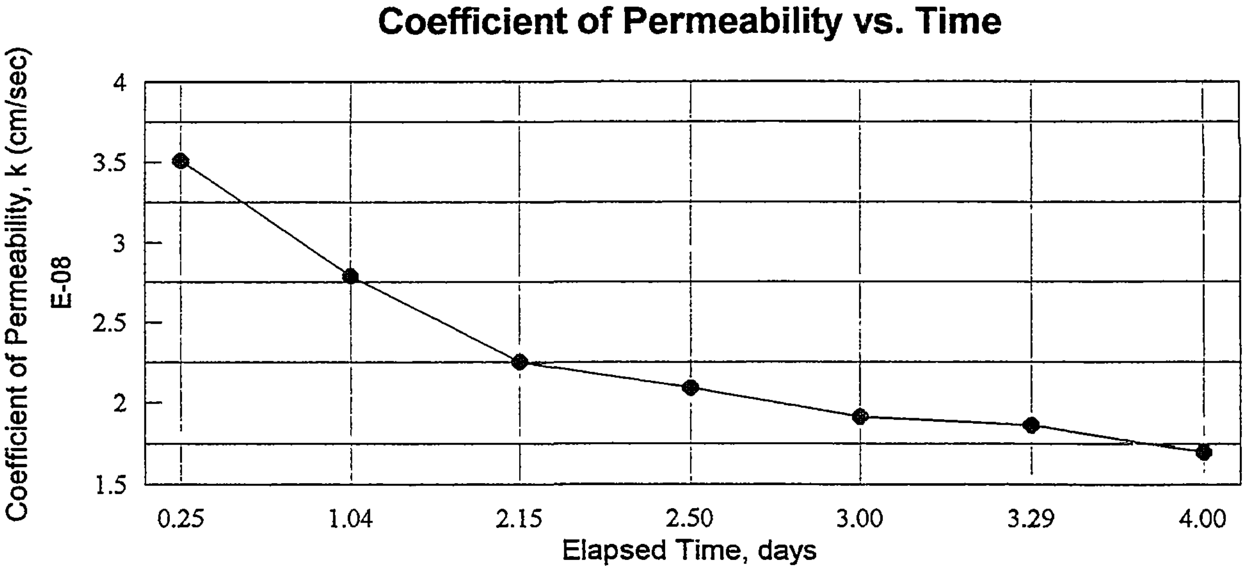
Permeability - Top to Bottom

Time (min)	5760.00
Initial Head (cm)	163.84
Final Head (cm)	155.93
k (cm/sec)	1.70E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/20/96	0.00	0.00	0.00	-
12/20/96	0.25	0.35	0.50	3.51E-08
12/21/96	1.04	1.15	1.20	2.79E-08
12/22/96	2.15	1.91	1.90	2.25E-08
12/22/96	2.50	2.05	2.05	2.09E-08
12/23/96	3.00	2.25	2.30	1.91E-08
12/23/96	3.29	2.40	2.40	1.86E-08
11/24/96	4.00	2.65	2.65	1.70E-08



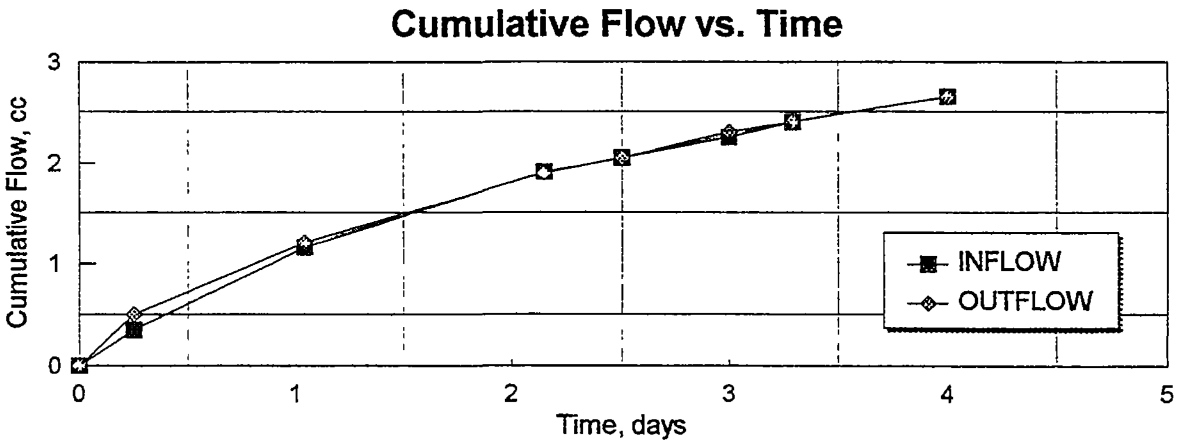


Figure 5

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

#12

TABLE 6

FALLING HEAD PERMEABILITY TEST DATA
RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	20-Dec-96
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-27&33
Sample No.	Bag#1(Dry Density =101.0 pcf @ Water Content =21.0%)
Depth	0.5'-6.0'
Liquid Limit	38
Plastic Limit	14
Specific Gravity	2.75
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**	
Moisture Content (%)	21.4	Moisture Content (%)	25.5
Height (in)	2.988	Height Change (in)	0.000
Diameter (in)	1.407	Height (in)	2.988
Wet weight (g)	148.83	Diameter (in)	1.407
Void Ratio	0.71	Void Ratio	0.71
Saturation (%)	83.2	Saturation (%)	99.1
Dry Density (pcf)	100.5	Dry Density (pcf)	100.5

Test Pressures

Chamber (psi)	90.00
Inflow (psi)	88.00
Outflow (psi)	86.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

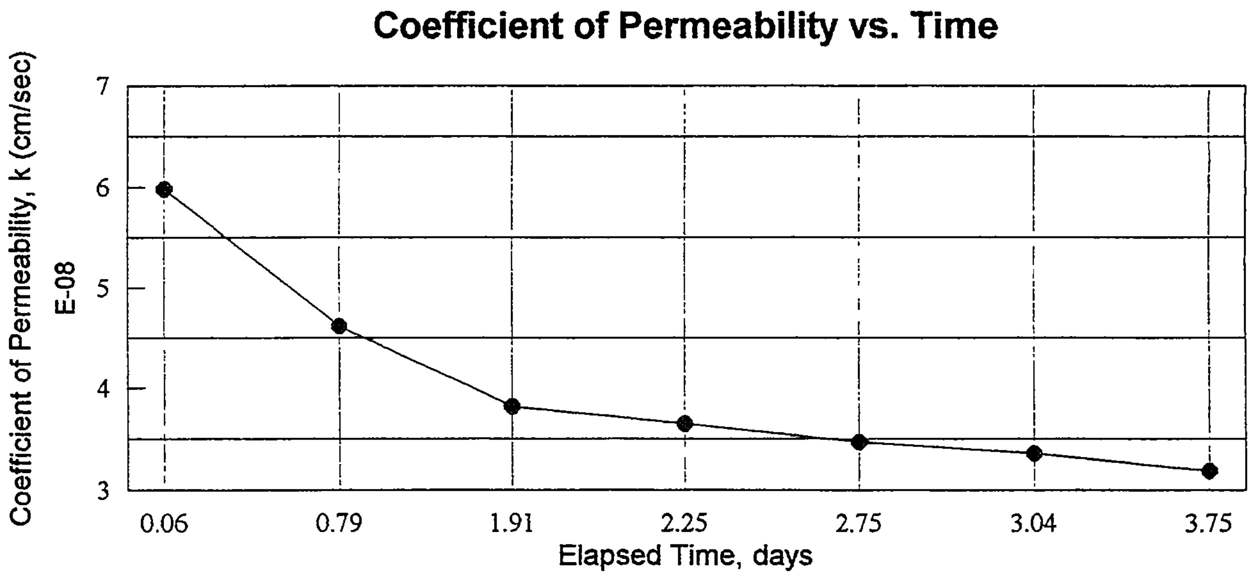
Permeability - Top to Bottom

Time (min)	5400.00
Initial Head (cm)	163.75
Final Head (cm)	150.02
k (cm/sec)	3.19E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
12/20/96	0.00	0.00	0.00	-
12/20/96	0.06	0.15	0.20	5.98E-08
12/21/96	0.79	1.45	1.45	4.62E-08
12/22/96	1.91	2.85	2.85	3.82E-08
12/22/96	2.25	3.20	3.15	3.65E-08
12/23/96	2.75	3 70	3.70	3.47E-08
12/23/96	3.04	3.95	4.00	3.36E-08
12/24/96	3.75	4.60	4.60	3.19E-08



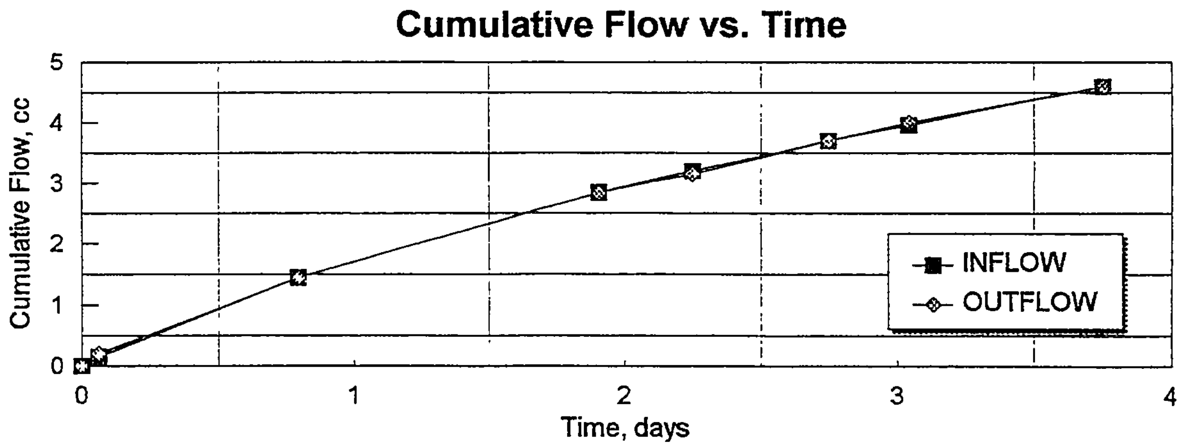


Figure 6

MR LAB NO. 4024

05 FEB 1997

DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Subject: Falling Head Rising Tailwater Permeability and Compaction Tests
Report Series No. 29
Project: R.M.A.
Intended Use: Hazardous Waste Landfill
Source of Material: Borings TP 96-68 Bag#1 (PT240022)

Submitted by: Chief, CEMRO-ED-GA
Date Sampled: ______, **Date Received:** 06/28/96
Method of Test or Specification: ASTM D-5084-90 and ASTM D-698 Method A

References: Omaha District Request No. S-2634 (MIL) dated 08/29/96
Purchase Request No. LAB-66 dated 05/14/96

1. Subject testing has been performed in accordance with the above test method and reference. Test results are shown in Figures 1 through 4 and Tables 1 through 2. All tests were performed on specimens from composite bag samples. Preliminary results were sent on 01/31/96.

2. Falling head permeability tests were performed on remolded specimens. Specimens were remolded at the following conditions:
100% Maximum Density @ +1.0% Optimum Water Content
95% Maximum Density @ +4.0% Optimum Water Content

3. Unless otherwise notified, all remaining material will be disposed of 90 days after the date of this report.

Submitted by:

Douglas B. Taggart
DOUGLAS B. TAGGART
Director, MR Laboratory

Bahwawsi/(402)444-4325

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 1

FALLING HEAD PERMEABILITY TEST DATA

RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	29-Jan-97
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-68
Sample No.	Bag#1(100% max. den. @ +1.0% opt.)
Depth	2.5'-3.0'
Liquid Limit	37
Plastic Limit	22
Specific Gravity	2.69
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**		
Moisture Content (%)	16.3	Moisture Content (%)	19.0	
Height (in)	3.004	Height Change (in)	-0.003	SWELL
Diameter (in)	1.414	Height (in)	3.007	
Wet weight (g)	158.60	Diameter (in)	1.415	
Void Ratio	0.52	Void Ratio	0.53	
Saturation (%)	83.5	Saturation (%)	96.5	
Dry Density (pcf)	110.1	Dry Density (pcf)	109.8	

Test Pressures

Chamber (psi)	90.00
Inflow (psi)	88.00
Outflow (psi)	86.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

Permeability - Top to Bottom

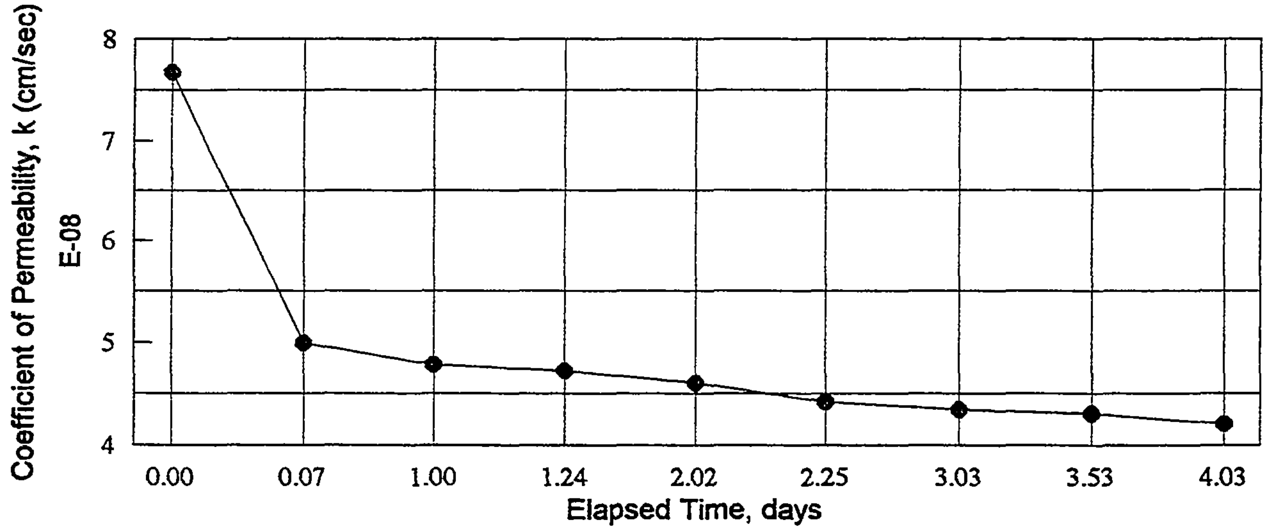
Time (min)	6520.00
Initial Head (cm)	160.56
Final Head (cm)	139.51
k (cm/sec)	4.21E-08

FALLING HEAD RISING TAILWATER PRESSURE

FROM TOP TO BOTTOM

DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
01/29/97	0.00	0.00	0.00	-
01/29/97	0.07	0.20	0.20	7.67E-08
01/30/97	1.00	1.95	1.95	4.99E-08
01/30/97	1.24	2.30	2.30	4.78E-08
01/31/97	2.02	3.65	3.65	4.72E-08
01/31/97	2.25	3.95	4.00	4.60E-08
02/01/97	3.03	5.05	5.10	4.42E-08
02/01/97	3.53	5.75	5.80	4.35E-08
02/02/97	4.03	6.45	6.50	4.31E-08
02/02/97	4.53	7.05	7.10	4.21E-08

Coefficient of Permeability vs. Time



Cumulative Flow vs. Time

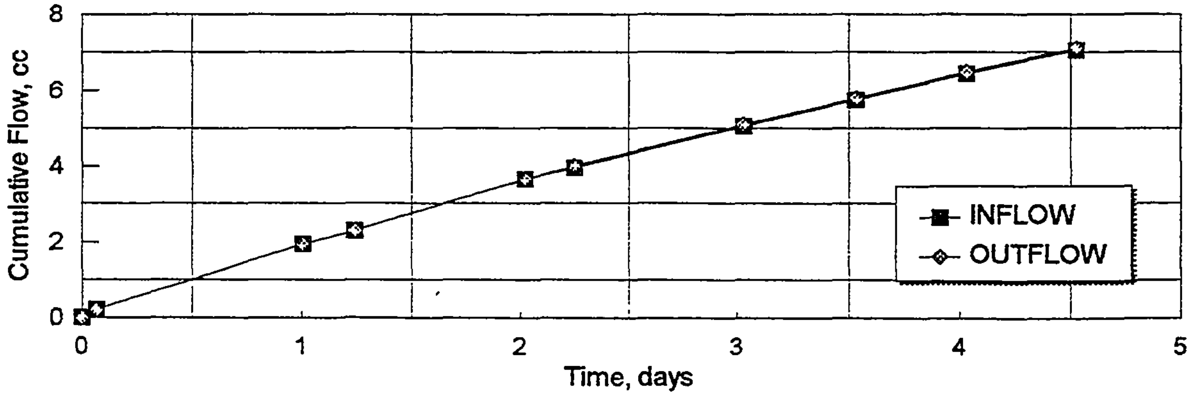


Figure 1

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

TABLE 2

FALLING HEAD PERMEABILITY TEST DATA
RISING TAILWATER PRESSURE (ASTM D-5084 METHOD C)

Date	29-Jan-97
Project Name	RMA, Hazardous Waste Landfill
MRD Lab No.	4024
Boring No.	TP 96-68
Sample No.	Bag#1(95% max. den. @ +4.0% opt.)
Depth	2.5'-3.0'

Liquid Limit	37
Plastic Limit	22
Specific Gravity	2.69
Classification	Sandy Lean Clay, CL

Initial Specimen Conditions		**Specimen Conditions After Consolidation**		
Moisture Content (%)	18.8	Moisture Content (%)	20.7	
Height (in)	2.961	Height Change (in)	-0.009	SWELL
Diameter (in)	1.412	Height (in)	2.970	
Wet weight (g)	154.91	Diameter (in)	1.416	
Void Ratio	0.57	Void Ratio	0.58	
Saturation (%)	89.1	Saturation (%)	95.7	
Dry Density (pcf)	107.1	Dry Density (pcf)	106.1	

Test Pressures

Chamber (psi)	90.00
Inflow (psi)	88.00
Outflow (psi)	86.00
B - Value	1.00
Diff. Head (psi)	2.00
Effective Consolidation Pressure (psi)	3.00

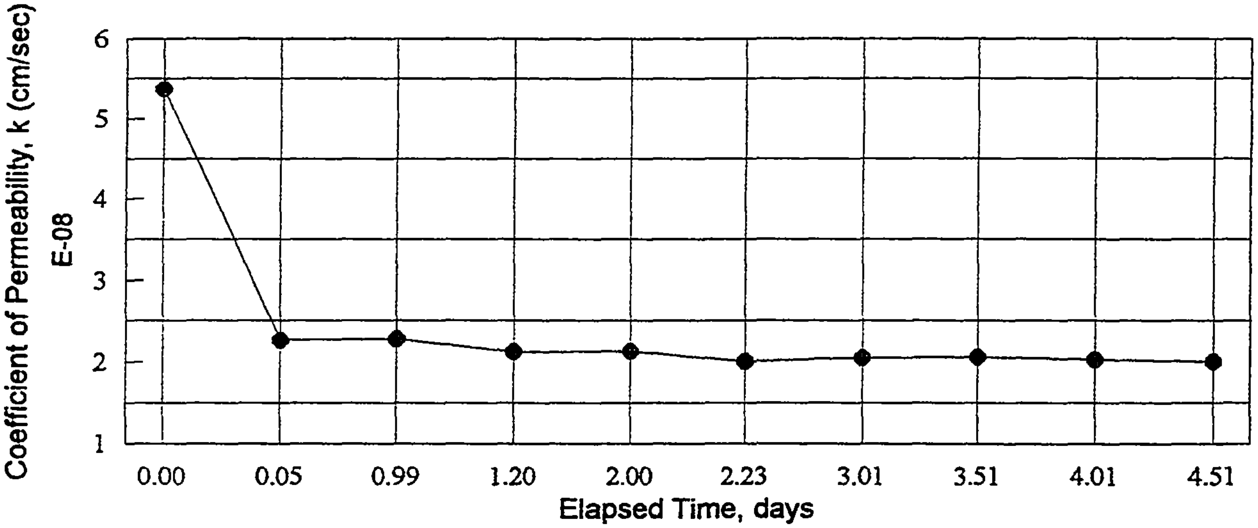
Permeability - Top to Bottom

Time (min)	7135.00
Initial Head (cm)	162.65
Final Head (cm)	151.01
k (cm/sec)	2.01E-08

FALLING HEAD RISING TAILWATER PRESSURE

		FROM TOP TO BOTTOM		
DATE	ELAPSED TIME, days	CUMULATIVE INFLOW, cc	CUMULATIVE OUTFLOW,cc	k cm/sec
01/29/97	0.00	0.00	0.00	-
01/29/97	0.05	0.10	0.20	5.37E-08
01/30/97	0.99	0.90	1.00	2.26E-08
01/30/97	1.20	1.10	1.20	2.28E-08
01/31/97	2.00	1.70	1.65	2.12E-08
01/31/97	2.23	1.90	1.85	2.13E-08
02/01/97	3.01	2.40	2.45	2.01E-08
02/01/97	3.51	2.85	2.85	2.05E-08
02/02/97	4.01	3.25	3.15	2.06E-08
02/02/97	4.51	3.60	3.55	2.03E-08
02/03/97	4.95	3.90	3.85	2.01E-08

Coefficient of Permeability vs. Time



Cumulative Flow vs. Time

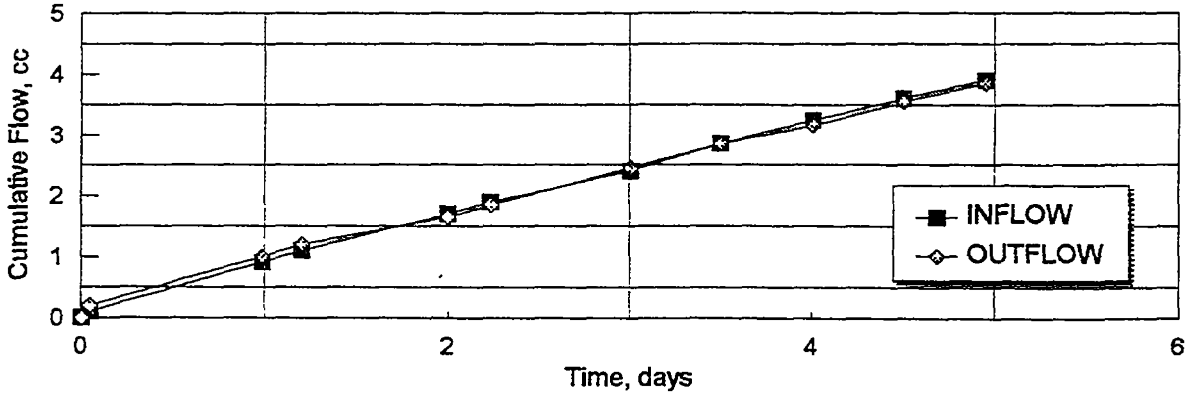
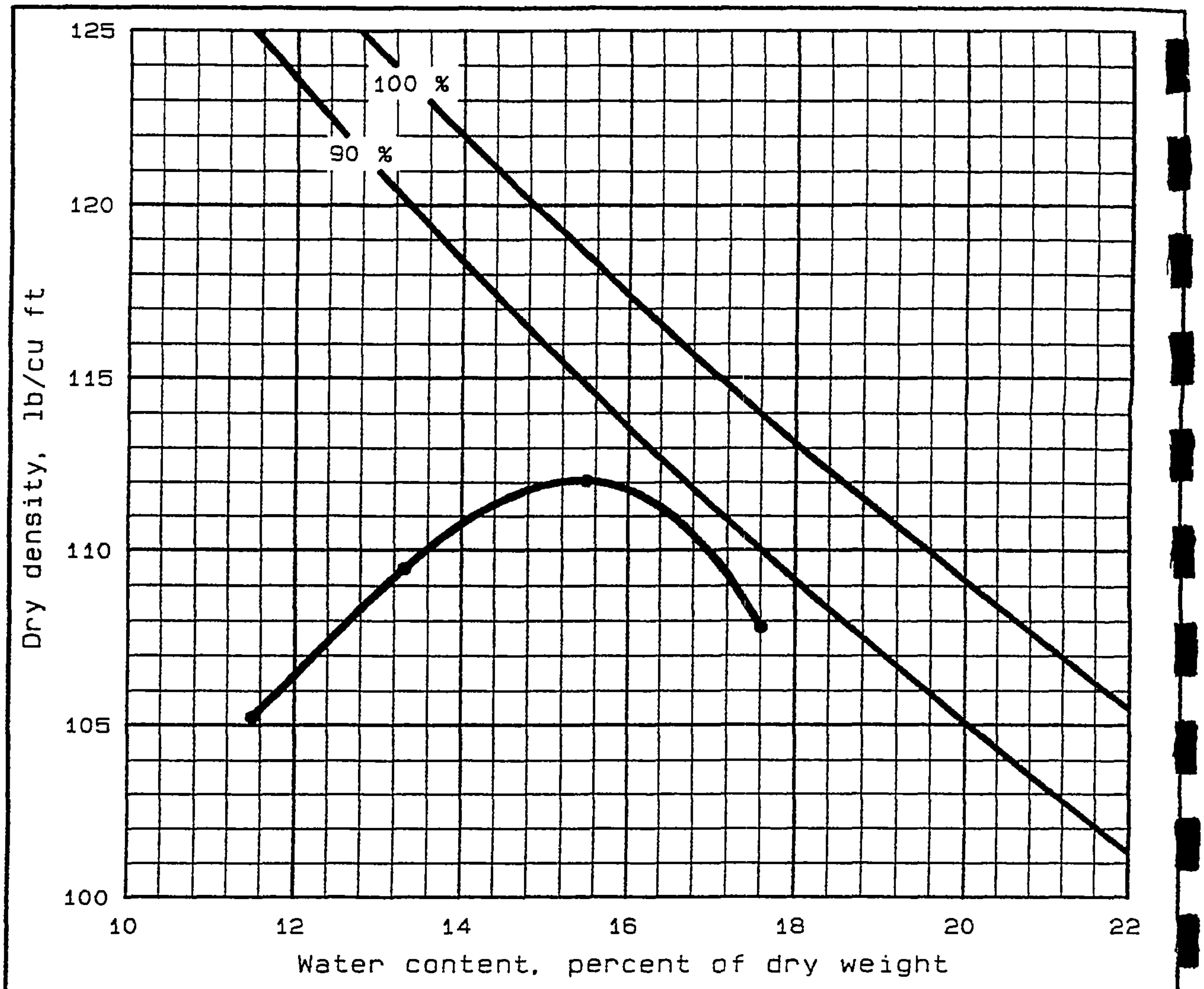


Figure 2

WORK ORDER NO.
Req. No.
Contract No.

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586



Standard compaction test ASTM D698 Method A
25 blows per each of 3 layers, with 5.50 lb. sleeve rammer
and 12.0 inch drop. 4.0 inch diameter mold

Sample No.	Elev/ Depth	Classification	G	LL	PL	% > No.4	% > 3/4 in.
B-1	2.5'-		2.69	37	15		
	3.0'						

Sample No.	B-1			
Water content, percent	1.4	air-dried		
Optimum water content, percent	15.4			
Max dry density, lb/cu ft	112.1			

Remarks

Project: Rocky Mountain Arsenal;
Hazardous Waste Landfill
Lab No.: 4024

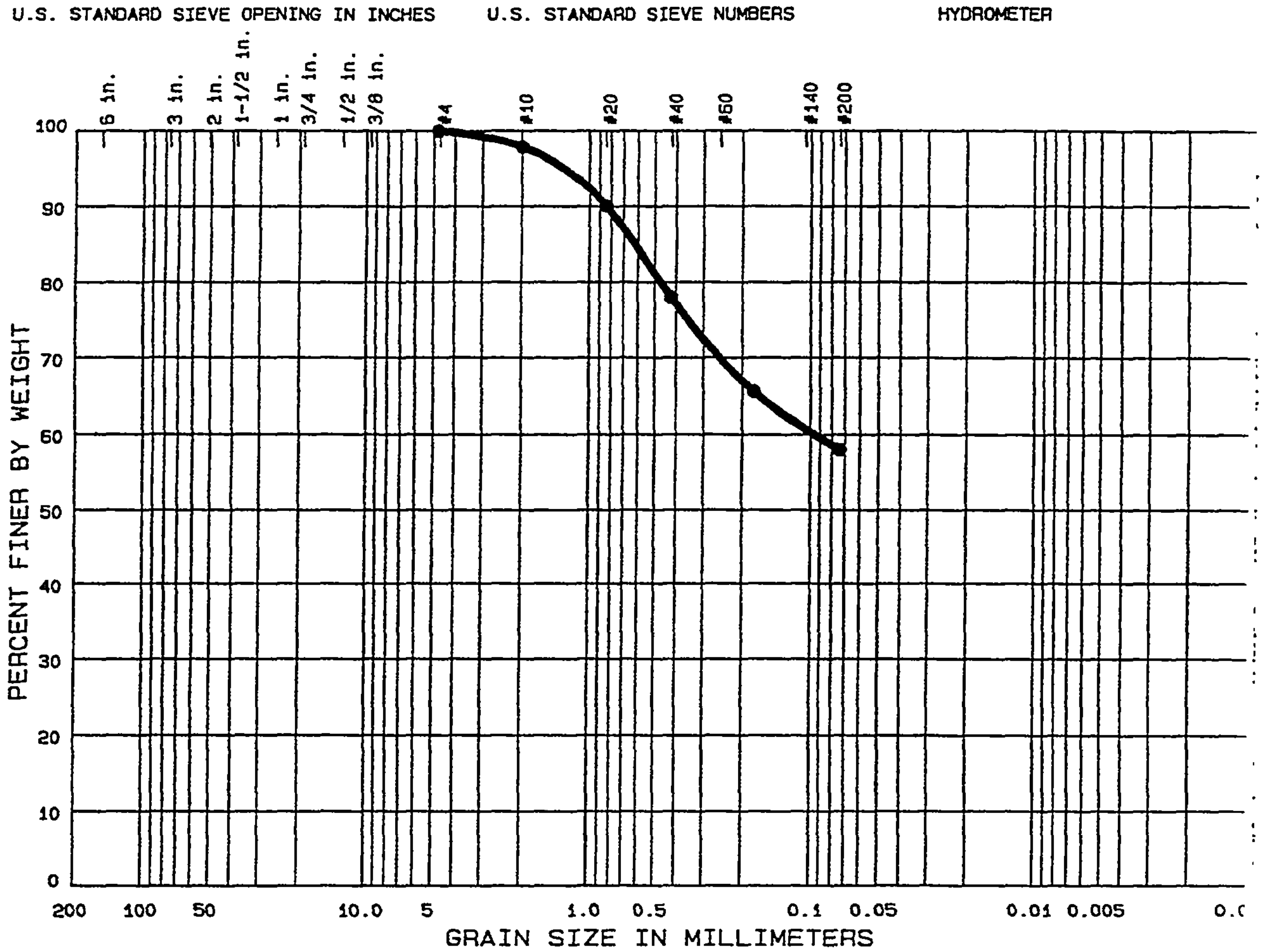
Area.

Boring No : TP96-68 B-1
Date: 1/21/97

COMPACTION TEST REPORT

FIG 08

W.O. No. 4024
Req. No. LAB-66
Contract No.



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	0.0	42.0	58.0

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	%Fines C_c	C_u
●	BAG# 1	2.5'-3.0'		37	15	22	56	
	TP 96-68	2.5-3.0' jar	70%	31	19	13	54	

CLASSIFICATION

● SANDY CLAY, CL

Remarks:

Project R.M.A. HAZARDOUS WASTE LANDFILL
Gs = 2.69
Lab No. 4024
Area
Boring No. TP 96-68 Date 2/05/97

GRADATION CURVES

CORPS OF ENGINEERS, MISSOURI RIVER DIVISION LAB
420 SOUTH 18th STREET - OMAHA, NE 68102-2586

FIG 04

Appendix F

CQA FORMS

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR:
DATE:
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM:
Temperature - AM
Work Performed/In - Progress:

Materials Delivered Onsite:

Inspection/Testing/Sampling:

Testing/Sampling Results:

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments:

CQA Monitor:
CQA Engineer:

LABORATORY SAMPLE LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR:

DATE:

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Sample Number	Date	Tests to be Performed	Location

LABORATORY TEST DATA LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
CQA ENGINEER: Brad Coleman, P.E.
CQA MONITOR:
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation
Material Types:

LOCATION: Adams County, Colorado
PROJECT NO: 21907 206050.1
DATE:
Sources:

	INDEX PROP. ASTM D 4318			**PARTICLE-SIZE ANALYSIS ASTM D 422** % PASSING INDICATED U.S. STANDARD SIEVE											
Sample No	LL(%)	PL(%)	PI										RETAINED ON PAN	PASS/ FAIL	SOIL CLASSIFICATION ASTM D 2487

FIELD DENSITY TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

CQA ENGINEER: Brad Coleman, P.E.

CQA MONITOR:

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

LOCATION: Adams County, Colorado

PROJECT NO: 21907 206050.1

DATE:

					In Situ Value		Reference Value					
Test No.	Date	Location	Elev. or Lift	Test Method	Dry Density (PCF)	Moisture Content	Curve No.	Max. Dry Density (PCF)	Optimum Moisture %	Differ. From Opt. Moisture %	Pass/ Fail	Remarks

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: ______
DATE: ______
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase Clay Liner Other ______
Percent Compaction Required: ______
Moisture Content Required: ______
Test Location: ______
Test No.: ______

FIELD TEST DATA ASTM D 1556

A	Density of Sand (PCF)		H	Volume of Hole = G/A (CFT	
B	Initial Weight of Sand (LBS)		I	Weight of Wet Soil (LBS)	
C	Final Weight of Sand (LBS)		J	Wet Density = I/H (PCF)	
D	Wt of Sand in Funnel & Hole = B-C (LBS)		K	Moisture Content (%)	
E	Volume of Funnel (CFT)		L	Dry Density = J/(I+K) (PCF)	
F	Weight of Sand in Funnel = A x E (LBS)			Percent Compaction (%)	
G	Weight of Sand in Hole = D-F (LBS)				

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No.	Dry Density (LB/CFT)	Moisture Content (%)
Results from above	Dry Density (LB/CFT)	Moisture Content (%)
Difference +/-		

LABORATORY DATA

Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216

Tare No.		Tare Weight (grams)	
Tare Plus Wet Soil (grams)		Weight of Dry Soil (grams)	
Tare Plus Dry Soil (grams)		Moisture Content (K) (%)	
Weight of Water (grams)			

PHOTOGRAPHIC LOG

PROJECT: RMA 93-03 Test Fill 3 Construction LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E. PROJECT NO: 21907 206050.1

CQA MONITOR:________ DATE:________

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Photo No.	Date	Time	Initials	LOCATION	COMMENTS

Appendix G

RESPONSE TO U.S. ENVIRONMENTAL PROTECTION AGENCY AND COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT COMMENTS

RESPONSES TO U.S. ENVIRONMENTAL PROTECTION AGENCY COMMENTS ON DRAFT FINAL WORK PLAN FOR THE TEST FILL CONSTRUCTION PROGRAM
FEASIBILITY STUDY SOILS SUPPORT PROGRAM
ROCKY MOUNTAIN ARSENAL
JANUARY 31, 1997

SPECIFIC COMMENTS

Comment No. 1, Section 1.2, page 1-2

This section describes the purpose and scope of the proposed test fill program which includes constructing, testing and evaluating a test fill in the northeast portion of the corrective action management unit of the Rocky Mountain Arsenal. It is not clear what will become of the test fill after the program is completed. The scope should include a description of the disposition of the test fill after the program is completed.

Response

An additional bullet item has been added to the scope of the test fill program in Section 1.2 to address this comment.

Comment No. 2, Section 4.3, page 4-3

This section shows a list of hydraulic conductivity test results. The values for points 1, 2, and 8 do not correspond with the values reported in Appendix E. The test results presented in this section should be corrected.

Response

These values have been corrected.

Comment No. 3, Section 5.7, page 5-7, paragraph 2

This paragraph states that the subgrade will be proof-rolled with a loaded piece of heavy equipment and unacceptable areas will be repaired. This information is inadequate. The equipment type, minimum size and weight to be used to proof-roll the subgrade should be identified. In addition, criteria for identifying unacceptable areas should be provided.

Response

A second paragraph has been added to Section 5.2 to respond to this comment.

Comment No. 4, Section 5.3, page 5-2

This section states that soil to be used for fill will contain no more than 5 percent calcium carbonate. It is not clear whether this means 5 percent by weight or volume. In addition, no method of determining calcium carbonate content is identified in the document. The document should define terms clearly and identify test methods and procedures to be used during the test fill program.

This section also states that soils to be used as liner materials will contain less than 1 percent organic materials. However, the organic content of all samples reported in Table 4.6 Appendix B exceeds 1 percent. In addition, there are no organic content test results corresponding to the hydraulic conductivity tests which form the basis for the test fill compaction criteria shown in Figure 3. The organic content testing results appear not to support the 1 percent criterion. This document should present a discussion of the relationship among the organic content test results reported in Table 4.6, the organic content of the soils represented in Figure 3, and the 1 percent organic content criterion stated in this section.

Response

Sections 5.3 and 6.3 have been revised to respond to this comment.

Comment No. 5, Section 5.4, page 5-2, paragraph 1

This paragraph states that a minimum hydration time of 24 hours will be required prior to soil compaction. The schedule for test fill construction is not known at this time. However, the potential for soil freezing during the 24-hour hydration period should be considered, and procedures to deal with freezing conditions should be developed.

Response

A paragraph has been added to Section 5.4 to address this comment.

Comment No. 6

Not provided by EPA.

Response

Not Applicable.

Comment No. 7, Section 6.6.4, page 6-8, paragraph 3

This paragraph states that loose lift thickness will be difficult to measure. The reason for this is not clear. Loose lift thickness should be easy to measure using a standard metal rod and 12-inch ruler. The reason for the apparent difficulty in measuring loose lift thickness should be provided.

Response

The third paragraph of Section 6.6.4 addresses this comment.

Comment No. 8, Figure 2

This figure shows the plan view and cross sections of the test fill. It should also show the approximate vertical and horizontal locations of samples to be collected and tests to be performed on the test fill.

Response

The first paragraph of Section 6.6.2 responds to this comment.

RESPONSES TO CDPHE COMMENTS ON
DRAFT FINAL WORK PLAN FOR THE TEST FILL CONSTRUCTION PROGRAM
FEASIBILITY SOILS SUPPORT PROGRAM
ROCKY MOUNTAIN ARSENAL
FEBRUARY 28, 1997

GENERAL COMMENTS

Comment No. 1

As previously stated, CDPHE views the new test fill as supplementing, not replacing the earlier field studies. The Work Plan should specify how information gathered from Test Fill 3 will be related to previous work on Test Fills 1 and 2.

Response

The information gathered from Test Fill 3 will not be directly related to previous work on Test Fills 1 and 2. Additional rationale as to why has been added to Section 1.1.

Comment No. 2

Insufficient information is provided relative to the materials which did not meet the Table 1 criteria. It is currently unclear where this material exists in relation to the acceptable material and how it will be separated during Test Fill 3 and subsequent landfill compacted clay liner (CCL) construction. The work plan states that the material will be visually screened by the Engineer during excavation. Liquid limit and plasticity index are difficult to determine based on visual observations. Additional delineation of the borrow areas based on currently available material properties is suggested.

Response

All information relative to the materials that did not meet the Table 1 criteria is now included in Tables 2, 3, and 4. In addition, Section 3.0 has been revised to address this comment and related comments below.

Comment No. 3

Test Fill 3 will be constructed using material from within the footprint of the double-lined landfill. The geotechnical screening indicates that 92 percent of this borrow material meets the criteria established for geotechnical parameters. The two remaining borrow source areas, Borrow Area 5 and the CAMU Area have substantially lower passing percentages, 73 percent and 79 percent, respectively. CDPHE is concerned the screening methods used to separate unacceptable material from acceptable material in the Double-lined Cell Excavation Area (92 percent passing material) may not adequately represent the difficulties involved with separating material taken from Borrow Area 5 (73 percent passing) and the CAMU Area (79 percent passing). Please provide an explanation detailing how this will be addressed.

Response

Section 3.0 has been revised to address this comment.

Comment No. 4

The Army should prioritize the borrow source areas based on the their geotechnical properties. CDPHE realizes that the objective is to give the CCL contractor flexibility in selecting the borrow source to be used, however, the geotechnical information clearly identifies a preferred ranking of the borrow sites.

Response

This comment is addressed in the second bullet item of Section 3.4.

Comment No. 5

It appears that sufficient information will exist after the completion of the test fill program to develop draft specifications or construction QA criteria for liner construction. Will the draft specifications be submitted as part of the Test Fill Summary Report?

Response

A new paragraph addressing this comment is included as the third to last paragraph of Section 1.2.

Comment No. 6

The work plan should include more information for field staff to plan and record the field work. Standardized forms and protocols for the experimental activities are needed.

Response

Standardized forms have been added as an appendix. Additional information has been added on experimental activities.

Comment No. 7

Table 1 should be modified to indicate that the Liquid Limit (LL) and Plasticity Index (PI) of the borrow soil will plot above the "A" line on the USCS Plasticity Chart. Inclusion of material with a LL greater than or equal to 30 and PI greater than or equal to 11 could introduce silts into the test fill matrix. Inclusion of silts (ML or MH) into the test fill borrow soil was not included in the CDD, Appendix I, Section 4.1 table which specified SC, CL or CH borrow soil types. The required USCS soil classifications (i.e., SC, CL or CH) should be added to the table.

Response

This comment has been incorporated in Table 1.

SPECIFIC COMMENTS

Comment No. 1, Section 1.2 - Purpose and Scope

Page 1-2, second item - The language should identify the location of the proposed borrow area. The work plan itself presents analyses to tier or rank the potential borrow sites.

Page 1-3 - Bullets should be added to the text which state the following:

> *"Preparing, submitting, and obtaining, approval of the Test Fill Program Drawings and Specifications"; and*
>
> *"Preparing, submitting, and obtaining approval of the Test Fill Program Summary Report."*

Response

In a meeting with CDPHE on March 6, 1997, CDPHE indicated that the comment to page 1-2 and the first bullet item requested could be disregarded. The second bullet item has been added to the text.

Comment No. 2, Section 3.0 - Borrow Area Elevation and Selection

Page 3-1 - This paragraph indicates this section "presents a rationale of why the clayey soil within these two areas have sufficiently similar geotechnical properties." CDPHE believes it would be more appropriate to present the rationale for selecting the geotechnical properties used to compare the soils. Properties selected must be able to insure the similarity of design performance as well as performance as a construction material. As an example, the parameters the Army has selected will not necessarily prove equal slope stability characteristics between the two soils being compared.

Item [1] should state: "identify borrow areas that contain clayey soils that have sufficiently similar geotechnical properties and which can be processed to attain required strengths and permeabilities for the compacted clay liner."

Item [2] should state, "identify the borrow area soils to be used for Test Fill 3."

Item [3] should state, "identify which borrow area soils the results of Test Fill 3 will be applicable to."

Response

The requested edits to items [1], [2], and [3] have been added. Section 3.0 and the information included in Tables 1-6 have been modified significantly to address the first paragraph of this comment and related comments below.

Comment No. 3, Section 3.2 - Borrow Area 5

Page 3.3 - The work plan should discuss how raw borrow area soils will be processed into suitable CCL material as a final product in this section. Processing should include screening of oversized and other deleterious material, soil mixing, and moisture conditioning.

The work plan should discuss how sandy clays mixed with clay soils during processing will be tested to show that a clay is the final product. Soil classification tests or compacted test fill oils should also be addressed.

Discussion of types (and frequency) of index property tests required to demonstrate that the end product of borrow soils processing is classified as clay (CL or CH) should also be addressed. The acceptable zone (and strength characteristics) of clay soils that contain increased gravel (up to 10% maximum by weight) and increased silt contents and equal sand content as the Figure 3 clay may not be properly represented by Figure 3. Additional modified, standard and reduced proctor test, specific gravity tests and permeability tests should be required to determine an appropriate acceptable zone for clays with silt, sand and gravel contents which differ markedly from the sandy lean clay addressed by Figure 3.

A Table which presents the Compacted Clay Liner (CCL) low-permeability index property should also be included in the work plan. This table should indicate the LL and PI of the Test Fill 3 clayey will plot above the "A" line on the USCS plasticity Chart. This table should specify grain size distribution to be greater than or equal to 50% passing the No. 200 sieve. The CCL must be composed of clay by definition.

The Army states that 44 of 60 samples taken in Borrow Area 5 meet the criteria for use as fill material. Statistics of the material are given using only the 44 samples that passed the criteria. These statistics are moot if the areas containing materials that pass the criteria cannot be delineated with confidence. A figure should be included showing the locations of passing samples and failing samples.

Response

Table 2 has been revised to show the Borrow Area 5 vertical locations of passing and failing samples. Sections 3.0, 6.0, and 7.0 have been revised to address the remainder of this comment.

Comment No. 4, Section 3.3, CAMU Area

Page 3-4 second par. - (see previous comment.)

Response

Table 3 has been revised to show the CAMU Area vertical locations of passing and failing tests. Section 3.0 has been revised in response to this comment.

Comment No. 5, Section 4.0, Preconstruciton Laboratory Testing and Data Interpretation

Page 4.1 - The AZ illustrated on Figure 3 is only valid for potential borrow soils exhibiting similar geotechnical characteristics. Are all soils that can be characterized as meeting the criteria on Table 1 described by the same AZ curve? Please elaborate.

Response

No. Section 4.4 has been revised to elaborate on this subject.

Comment No. 6, Section 4.1 - Laboratory Index Property and Proctor Testing

In paragraph 2 and relative to Sample B-1 of Test Pit PT2500016, please change "38" to "28" and "62" to "72" in paragraph 2.

Response

This comment has been incorporated into Section 4.1.

Comment No. 7, Section 4.4 - Final Acceptable Zone Development

Page 4-4, second par. - Please elaborate on how slope stability will be evaluated, to determine where to place the lower limit of the AZ. Also discuss the potential for additional three-point Proctor tests if soil conditions change significantly.

Response

The third paragraph of Section 4.4 has been added to respond to this comment.

Comment No. 8, Section 5.3 - Soil Liner Material Requirements

Page 5-2 - The text should address how permeability may be affected due to specified differences in gravel grain size between the upper and lower lifts(s). Please justify the 10 percent gravel content, and explain how materials with this amount of gravel can meet the acceptance criteria of the three-point Proctor that had insignificant gravel.

The text states, "Such concretion, nodules, or other deleterious material will be less than 1 inch in largest diameter." Please change "diameter" to "dimension".

Each compacted lift should be a maximum of six inches or no greater than the depth of the compactor tines.

Response

Section 5.3 has been revised to address the first two paragraphs of the comment. The third item in Section 5.5 has been revised to address the last paragraph.

Comment No. 9, Section 5.4 - Soil Liner Conditioning

Page 5-3 - The hydration time of 24 hours is provided for moisture addition only for 3 percent or greater. Where was this guidance obtained and what hydration time would be allowed for, say 2.9 percent?

Response

The appropriate reference is now cited in Section 5.4. The hydration time for 2.9 percent moisture would be rounded to 3 percent and require hydration for 24 hours. Conversely, a moisture addition of 2.4 percent would be rounded to 2 percent and not require a minimum hydration time.

Comment No. 10, Section 5.5 - Soil Liner Placement and Compaction

Representative process soil samples should be collected and classified to demonstrate that suitable clay material will be placed in Test Fill 3. Please clarify if and when these sample will be collected. How will the various materials that are combined in a common stockpile be tested for index properties? This may be important if small amounts of unsuitable material are encountered.

Response

Section 6.3 has been revised to address this comment.

Comment No. 11, Section 5.5 - Soil Liner Placement and Compaction

The text states that each compacted lift will be a nominal 6 inches or less, please clarify that the maximum lift will not exceed the length of the compactor feet.

Response

The third item of Section 5.5 incorporates this comment.

Comment No. 12, Section 6.3 - Soil Liner Excavation and Testing

The AZ depicted in Figure 3 is applicable to one specific soil composition (a lean clay with about 38% sand and 0.3% gravel). Other sets of proctors and specific gravity tests may be required to evaluate the AZ for other specified soils which may exhibit different compositions/properties/permeabilities. Proctor tests and specific gravity test frequencies may need to be further revised in the specification,

We are concerned that one set of Proctor tests (and specific gravity test) may not be sufficient to evaluate potential changes in clay composition. The frequency of soil sampling for determination of the AZ may need to be further revised in the specifications,

The text should state that additional three-point Proctor compaction tests will be performed, if the one-point proctor compaction tests indicate an inconsistency relative to previous results.

The process evaluation should also include the removal of oversize and deleterious material from borrow soils.

Response

Sections 4.4 and 6.4 have been revised to address this comment.

Comment No. 13, Section 6.5 - Soil Liner Lift Placement

The text states, "Experimentation may be done on Lifts 2 and 3 with various thicknesses to ascertain the optimum loose lift thickness that will result in effective layer bonding between lifts and a nominal 6-inch compacted thickness. Please change nominal to maximum in the above sentence. Methods for determining compacted layer thickness should also be addressed in the text.

Response

Section 6.5 has been revised to address this comment.

Comment No. 14, Section 6.5 - Soil Liner Lift Placement

Page 6-3, second par. - Will experimentation on lift thicknesses include loose lifts that are greater than the thickness of the tines of the compactor? This section should include more detail to direct this field effort.

Response

No. Section 6.5 has been revised to address this comment.

Comment No. 15, Section 6.6 - Soil Liner Compaction and Testing

Page 6.5., fifth par. - The current work plan calls for six block samples to be obtained from the upper foot of the CCL, two samples from the middle lift and one sample from the lower lift. From the nine samples collected six will be tested. Please clarify that at least one block sample from each lift will be tested. In addition, please clarify why six of the nine block samples will be collected from the upper foot of the CCL and only 3 samples from the remaining 2 feet.

Response

Table 6 and Section 6.6.3 have been revised to address this comment.

Comment No. 16, Section 6.6 - Soil Liner Compaction and Testing

Page 6-4 - An aspect of the compaction testing which has not been explained is the direction in which the compactors will travel when preparing the test fill. This will not be important on the base of the landfill, but on the 29% slope the impacts will be substantial. Please indicate proposed direction of travel and the rationale. Further additional compactive effort will be obtained at the transition from the steep to the mild slope, when compacting longitudinally. Therefore samples taken at those locations will not be comparable to elsewhere.

Response

The third item of Section 5.5 and the first paragraph of Section 6.6.2 address this comment.

Comment No. 17, Table 1 - Low permeability Soil Index Property Criteria

Table 1 is not consistent with the minimum criteria given in Appendix I, Section 4.1 of the CDD in that the CDD addresses Test Fill 3 borrow soil. The Table 1 Titles should state, "Low-permeability Borrow Soil Index Property Criteria" and indicate the acceptable Unified Soil Classifications provided in the CDD.

Response

Table 1 has been revised accordingly.

Comment No. 18, Table 2 - Borrow Area 5 Alluvial Clay Summary of Low-permeability Soil Parameters

Please change "Clay" to "Soils" in the Table 2 title. Clayey sands are not classified as clays.

Response

Table 2 has been revised accordingly.

Comment No. 19, Table 3 - CAMU Area Clay Summary of Low-permeability Soil Parameters

Please change "Clay" to "Soils" in the Table 3 title.

Response

Table 3 has been revised accordingly.

Comment No. 20, Table 5 - Summary of Borrow Area Index Properties

Please insert "Selected" between "of" and "Borrow" in the Table 5 title. The summaries presented in Table 5 only selectively address soils that meet the Table 1 criteria.

Response

Table 5 has been revised to reflect all alluvial soil.

Comment No. 21, Table 6 - Compaction and Testing Criteria for Test Fill 3

Table 6 assumes all Test Fill 3 AZs can be evaluated by Figure 3. Provision should be made for sampling of potential material changes for additional AZ evaluation if necessary.

Response

This comment has been addressed in Section 4.4.

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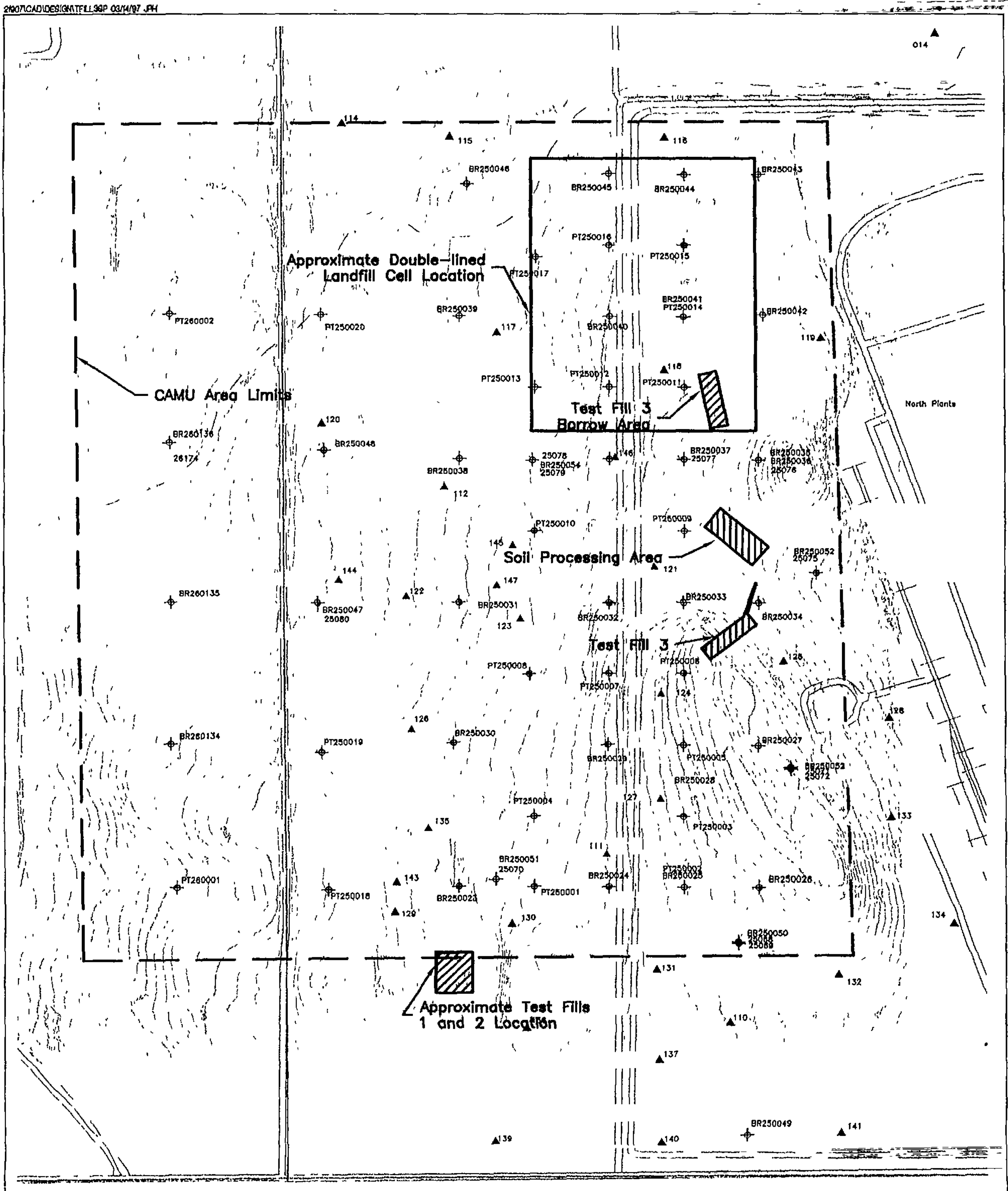


Explanation

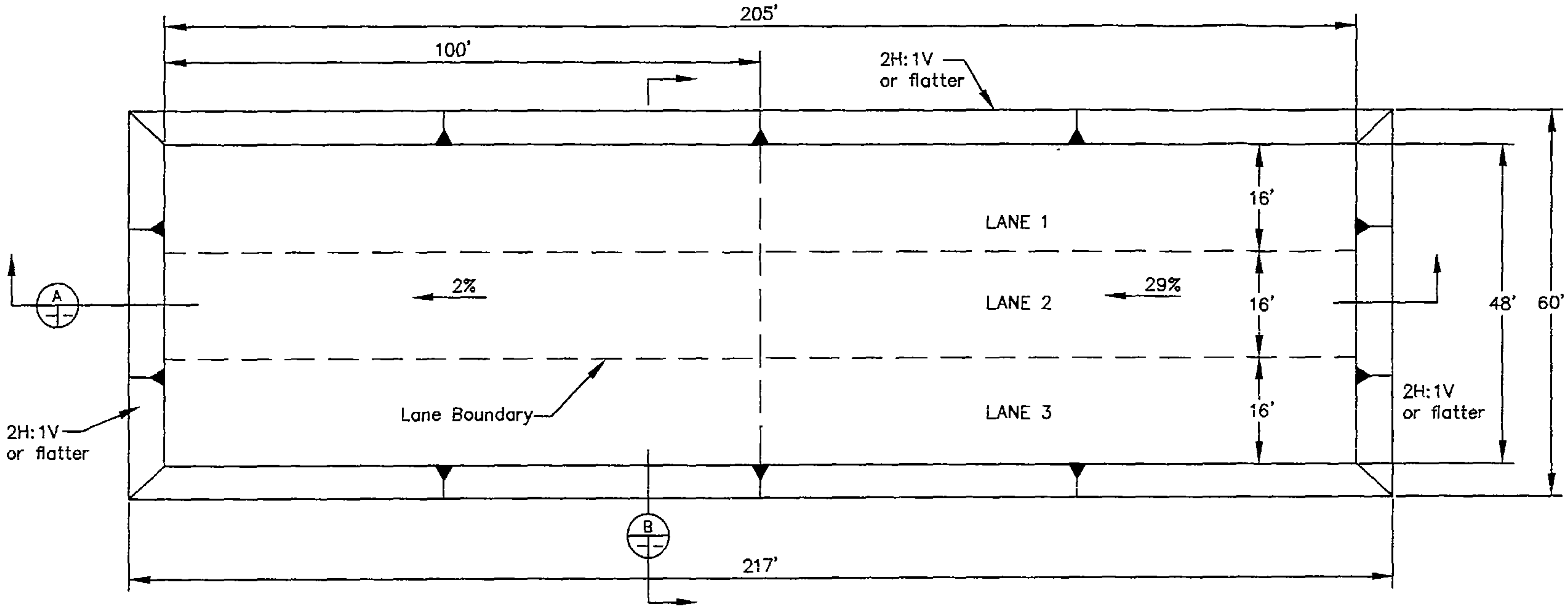
PT240020	U S Corps of Engineers geotechnical soil sample location with site Identification		Paved road
			Unpaved road
126	HLA soil boring locations with soil boring short Identification		Railroad
			Ditch or stream

N

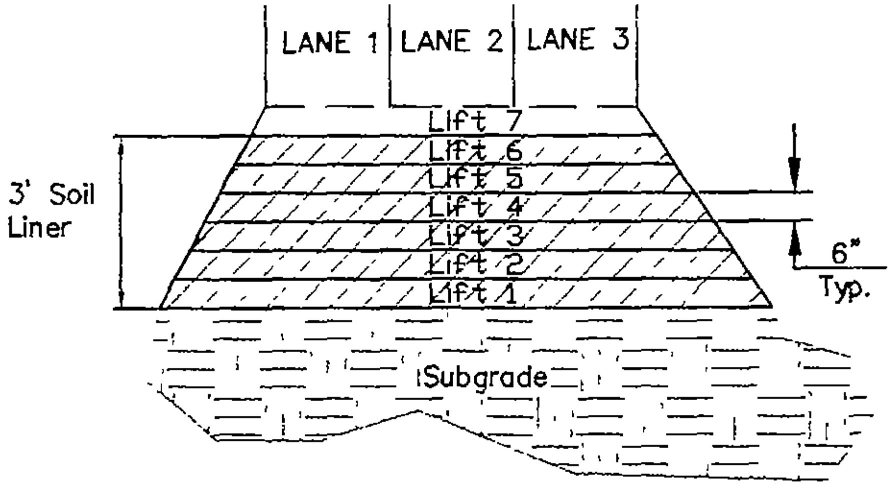
0 200 400
Scale in feet

Note: Survey is based on the NAD27/NGVD29 Coordinate System.

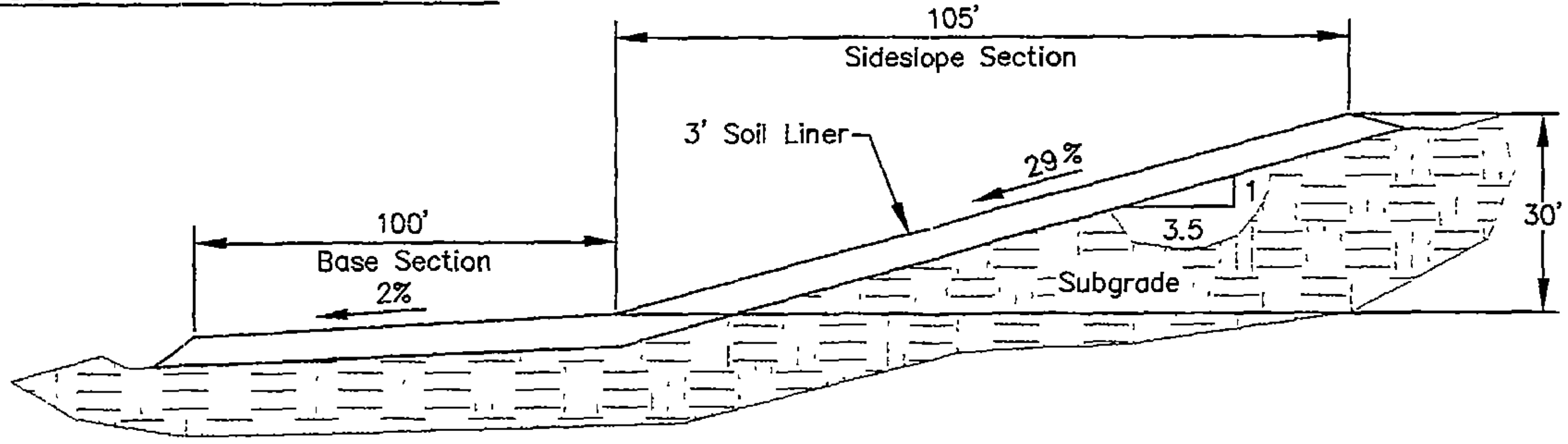
Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado Prepared by: Harding Lawson Associates	Figure 1 Site Plan Test Fill 3



Test Fill 3 Plan View



B SECTION
Not To Scale



A SECTION
Not To Scale

Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
Harding Lawson Associates

Figure 2
Test Fill 3 Plan View and Cross Sections

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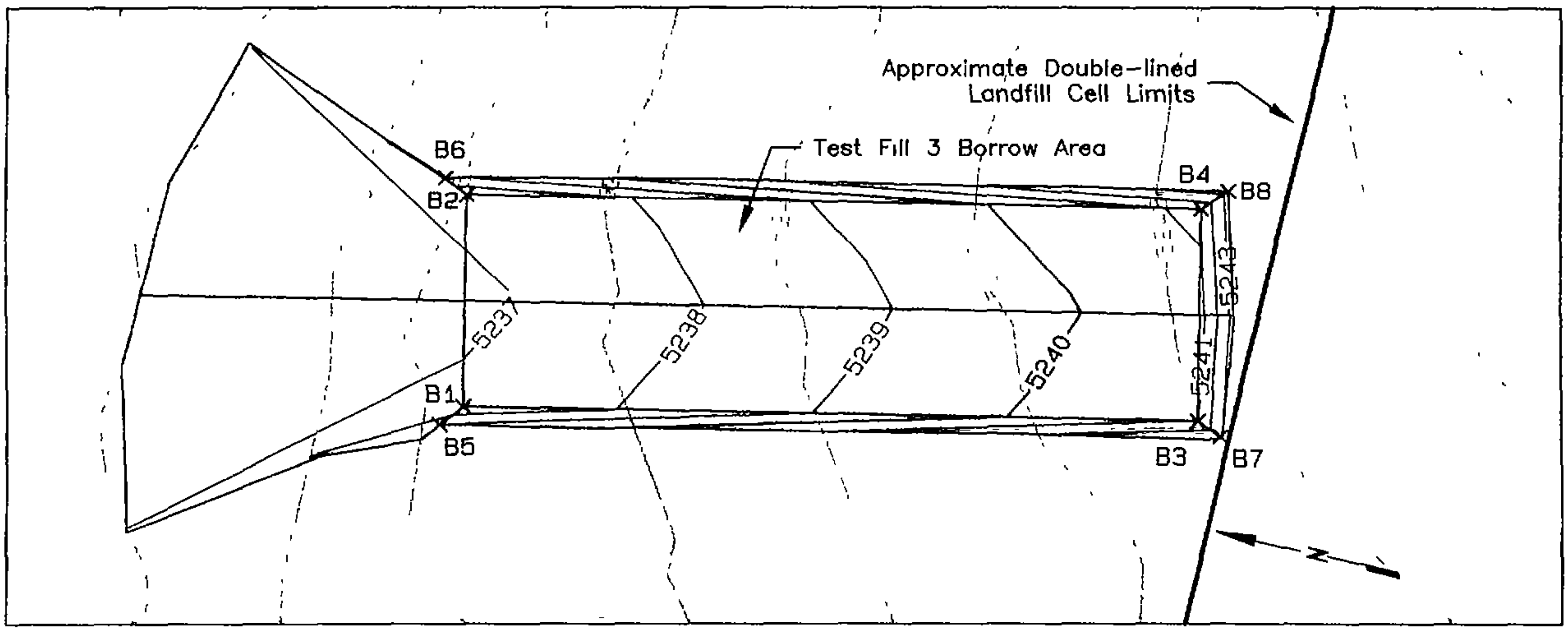
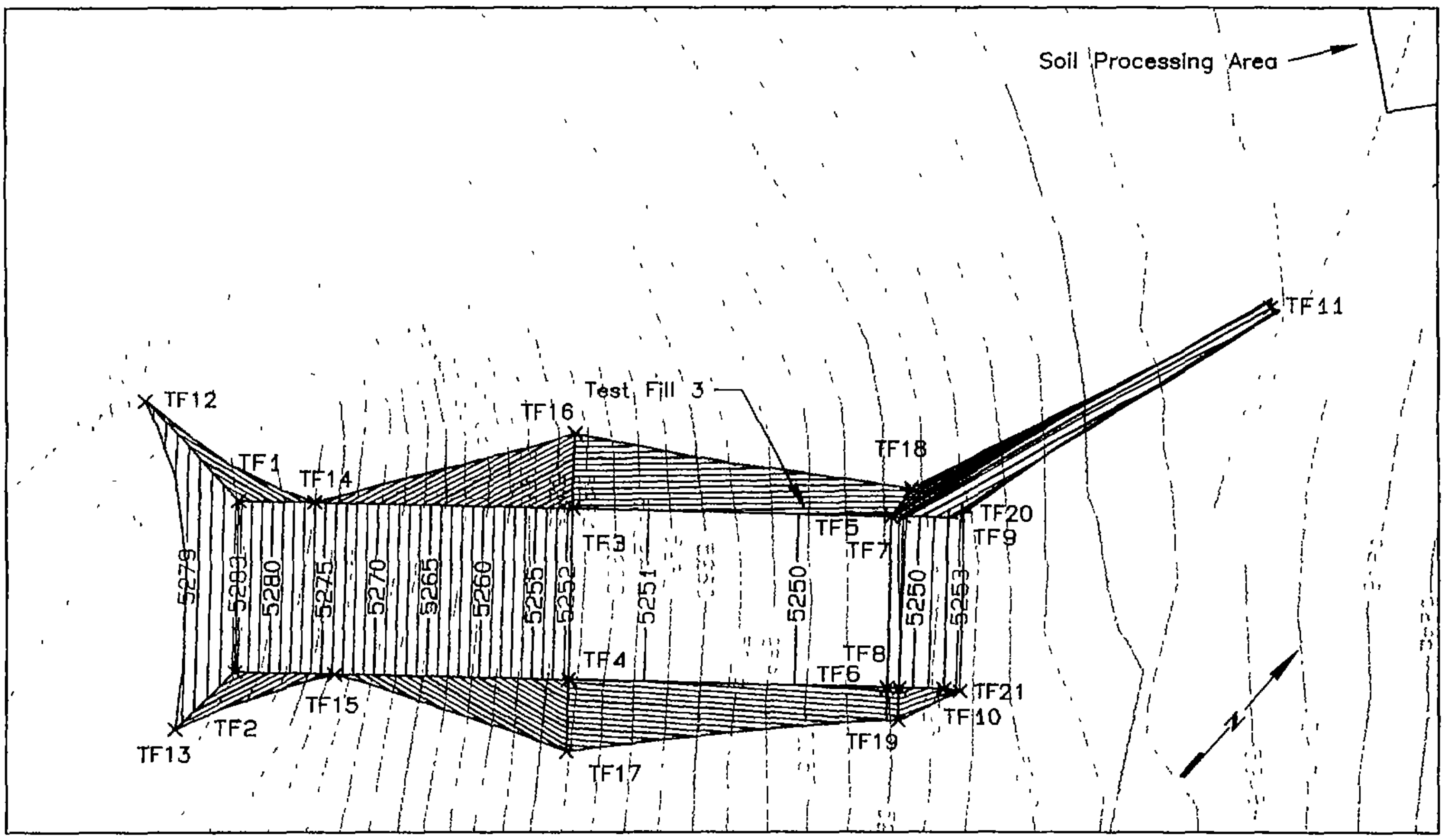


BORROW AREA EXCAVATION PLAN
1"=50'



TEST FILL 3 SUBGRADE EXCAVATION PLAN
1"=50'

Explanation

—5250—	Excavation grade contour
5250	Existing grade contour
× TF6	Test Fill Control Point
×B2	Borrow Area Control Point

Note: Survey is based on the NAD27/ NGVD29 Coordinate System.

CONSTRUCTION CONTROL POINTS

Point	North	East	Elev	Point	North	East	Elev
TF1	188101.4	2185232.8	5283 2	TF17	188103 8	2185372.7	5264 1
TF2	188054 5	2185270 2	5283 2	TF18	188248 5	2185401 5	5254 3
TF3	188170 5	2185319 7	5251 5	TF19	188183 1	2185450 2	5254 8
TF4	188123 6	2185357 0	5251 5	TF20	188252.8	2185420.1	5253.2
TF5	188236 5	2185402 6	5249 4	TF21	188204.2	2185459.4	5253.3
TF6	188189 6	2185440 0	5249 4				
TF7	188239 0	2185405 7	5248 8	B1	189246.9	2185224.6	5237 2
TF8	188192 1	2185443 1	5249 1	B2	189261 3	2185293.1	5237 1
TF9	188248 4	2185417.5	5252 0	B3	189022 4	2185271.7	5241 0
TF10	188201.4	2185454 8	5252 0	B4	189036 8	2185340.2	5241.2
TF11	188374 3	2185452.5	5248 1	B5	189252.7	2185217 2	5239 1
TF12	188108 2	2185187 1	5275 4	B6	189269 0	2185297 2	5238.8
TF13	188026 4	2185268 0	5278 4	B7	189013 6	2185267 8	5243.0
TF14	188117 2	2185252.5	5276 0	B8	189030 0	2185347 7	5243 3
TF15	188075 2	2185296.2	5273 7				
TF16	188190 8	2185303.6	5264 4				

Prepared for.
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
Harding Lawson Associates

Figure 3
Borrow Area and Test Fill 3 Excavation
Grading Plans
Test Fill 3

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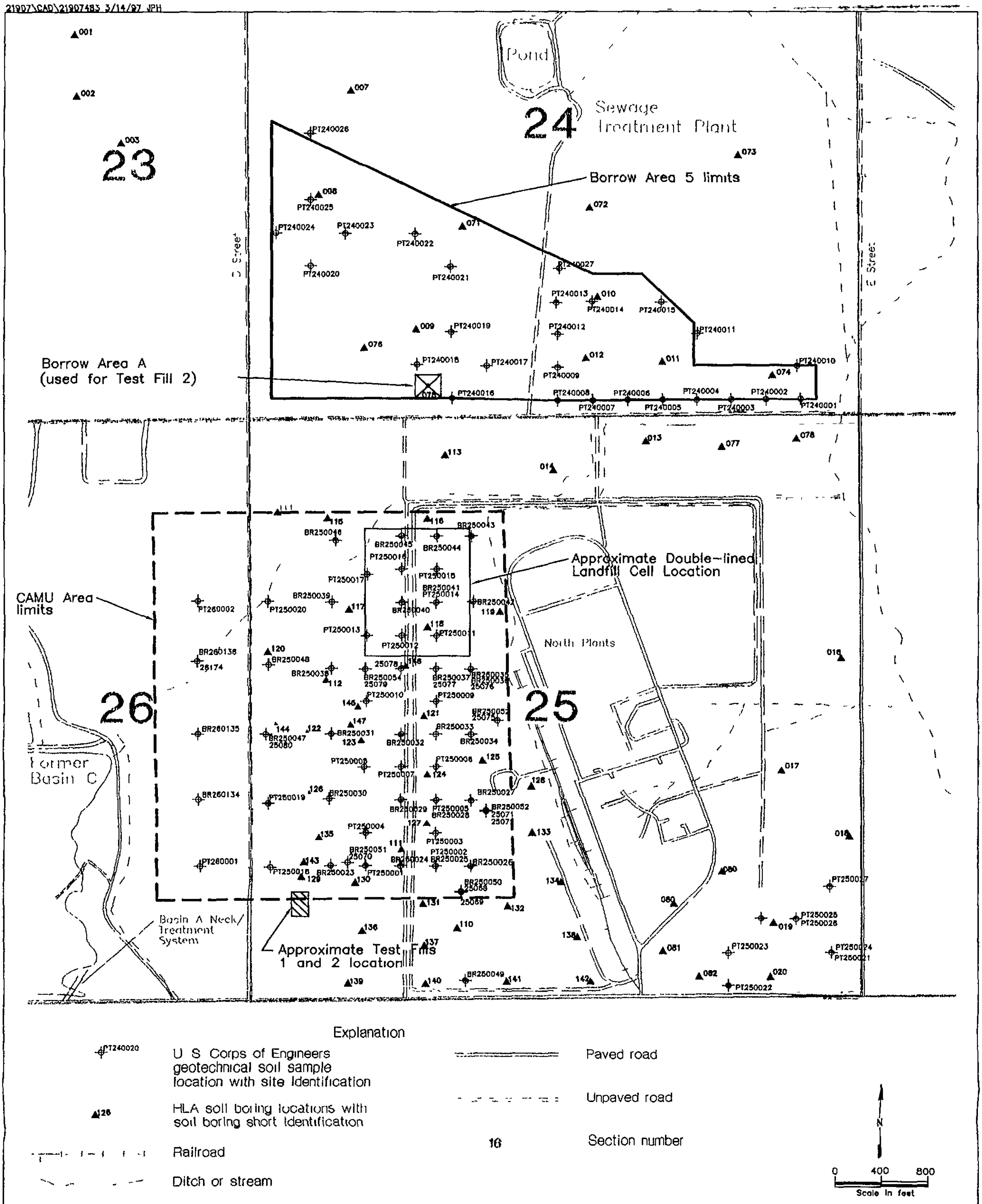
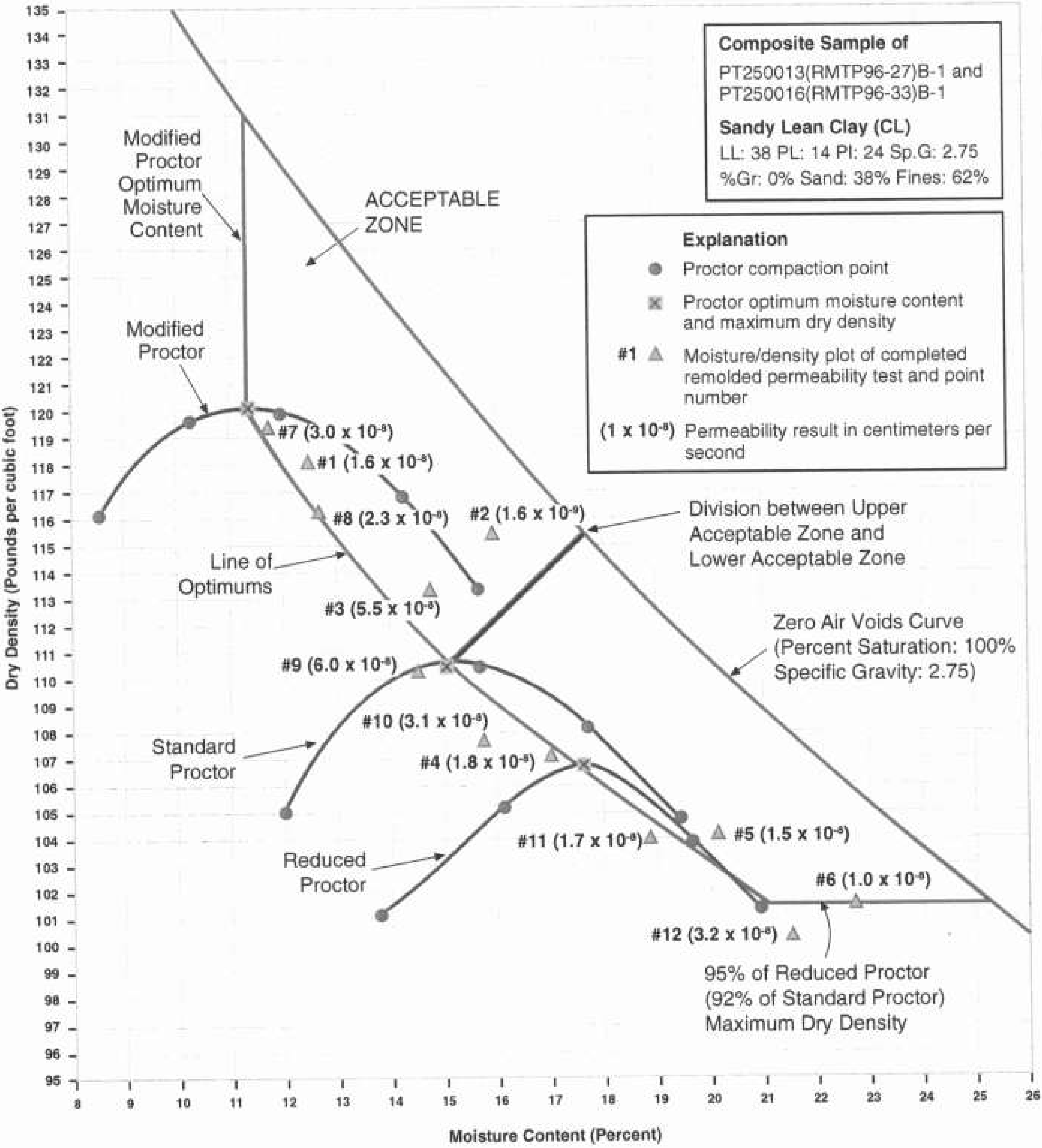


Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
Harding Lawson Associates

Figure 4

Boring and Test Pit Locations



RMA 1276.2b 6/4/97 NLM

Prepared for:
Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
Harding Lawson Associates

Figure 5

Pre-Construction Acceptable Zone
Test Fill 3 Construction Program

Appendix B

CDPHE CONDITIONAL APPROVAL OF THE FINAL WORK PLAN FOR THE TEST FILL CONSTRUCTION

STATE OF COLORADO

Roy Romer, Governor
Patti Shwayder, Executive Director

Dedicated to protecting and improving the health and environment of the people of Colorado

HAZARDOUS MATERIALS AND WASTE MANAGEMENT DIVISION

4300 Cherry Creek Dr. S.
Denver, Colorado 80222-1530
Phone (303) 692-3300
Fax (303) 759-5355

222 S. 6th Street, Room 232
Grand Junction, Colorado 81501-2768
Phone (303) 248-7164
Fax (303) 248-7198

1876

Colorado Department
of Public Health
and Environment

CERTIFIED MAIL No. ____________________
Return Receipt Requested

March 25, 1997

Mr. Charles Scharmann
Office of the Program Manager
Rocky Mountain Arsenal
AMXRM-PM, Bldg. 111
Commerce City, CO 80022-1748

Re: Final Work Plan for Test Fill Construction Program, RMA, Commerce City, CO

Dear Mr. Scharmann:

The Colorado Department of Public Health and Environment (CDPHE) has reviewed the above-referenced document, which was received March 17, 1997. Conditional approval of the Work Plan is being granted based on incorporation of the attached comments into a revised final document.

Approval is being granted to allow the Army to begin implementation of the Test Fill Program. A conditional status has been affixed to ensure that remaining deficiencies in the document are corrected. Please provide submittal of a revised Final Test Fill Workplan within 30 days of receipt of this correspondence.

If you have any questions please contact me at (303) 692-3341.

Sincerely,

Susan J. Chaki
Corrective Action Unit Leader
Federal Facilities Program

cc:
Bruce Huenefeld, PMRMA
Laura Williams, EPA
Lorraine Ross, EPA
Stephen Hamel, AGO
Ken Conright, TCHD
Ronel Finley, USFWS
Robert Foster, DOJ
Maj. Thomas Cook, RMA
Mike Anderson, Shell
Martin Kosec, HSI
Geo Trans

Final Work Plan for the Test Fill Construction Program Comments:

The document text must be modified to state that clayey sands (SC) with greater than or equal to 40 percent fines passing the No. 200 sieve are acceptable as **raw** (in situ) borrow soils. However, the **final product** of borrow soils processing **for use as test fill material** must classify as a clay (CL or CH) according to the Unified Soil Classification System (USCS). Clayey sands (SC) are not suitable test fill material. This concept must be consistent throughout the revised text.

The Table 1 title must be changed to "Raw Borrow Soil Index Property Criteria."

Field determination of suitable versus unsuitable clays (and clayey sands) for processing into finishe [illegible]-permeability test fill material based on Atterburg Limits is not practicable. The Atterburg Limits criteria must be deleted from Table 1.

Table 1 grain size distribution must be modified to have greater than 95 percent passing No. 4 sieve.

Table 1 organic and carbonate content criteria percentages must be specified either by weight or by volume, according to ASTM procedures.

The document text must be revised, if necessary, to be consistent with the above modifications to Table 1.

The document text must state that suitable test fill compacted clay liner (CCL) property index criteria will be the same as that shown on Table 1 (as modified above) with the following exceptions:

> Grain size distribution must indicate greater than or equal to 50 (instead of 40) percent passing No. 200 sieve.
>
> Clayey sands (SC) are unacceptable.

On page 1-1 (Section 1.1) "condusive" should be "conducive."

On page 3-1 (Section 3.0) Item {1} must state verbatim, "identify borrow areas that contain clayey soils that have sufficiently similar geotechnical properties and which can be processed to attain required strengths and permeabilities for the compacted clay liner."

On page 3-3 (Section 3.2) Figure 4 must be referenced in the text instead of Figure 3.

On page 4-5 (Section 4.4) the text must state that, "To ensure that the Test Fill 3 borrow area is accurately defined by Figure 6 and to evaluate the sensitivity to the line of optimums to slight changes in material properties, an additional set of Proctors (modified, standard, and reduced) will be performed prior to the commencement of Test Fill construction on a representative sample obtained from the Test Fill 3 borrow area processed soils."

On page 4-6 (Section 4.4) the text must state that, "The initial criteria used for evaluation of changes in the borrow source material will be if the one-point Proctor **optimum moisture content** varies more than ±3 percentage points and the **maximum dry density** varies more than ±5 pcf (EPA, 1993)." The text must also state that, "A more reliable technique than the one-point compaction test may be employed for estimating the optimum water content and maximum dry unit weight. This technique entails using a three-point proctor test to define a curve rather than relying on a single compaction point."

On page 5-2 (Section 5.3) the percentages of allowable organic or other deleterious materials and the allowable percentages of gypsum or caliche must be expressed (in the text) either as by weight or by volume, according to ASTM procedures.

On page 5-2 (Section 5.3) "dimension" must be inserted in place of "diameter."

On page 5-2 (Section 5.3) "5" must be inserted in place of "10."

On page 5-3 (Section 5.5) Item {3} must state, "Each compacted lift should be a maximum of six inches or no greater than the depth of the compactor tines" instead of "Each compacted lift will be a nominal 6 inches or less."

On page 6-1 (Section 6.3) the text must state that in addition to meeting the minimum requirements in Table 1, the processed soil liner material used to construct Test Fill 3 must be classified as a clay (CL or CH according to USCS) having greater than or equal to 50 percent (by weight) passing the No. 200 sieve.

On page 6-2 (Section 6.3) the third bullet from the top of the page should state "Soil Classification (ASTM D2487)."

On page 6-3 (Section 6.5) the text must state, "Experimentation may be done on Lifts 2 and 3 with various thicknesses to ascertain the optimum loose lift thickness that will result in effective layer bonding between lifts and a **maximum** 6-inch compacted thickness (or no greater than the depth of the compactor tines)."

On page 6-8 (Section 6.6.4) the text must state that loose lift thickness will be measured using a standard metal rod and 12-inch ruler or other appropriate method. The loose lift thickness will be calculated by using the average of the vertical distances measured.

On page 7-1 (Section 7.0) the text should state, "At least **three** of these undisturbed samples will be tested for index properties."

Photo No. 1

Preconstruction photograph taken from borrow area looking south. Test Fill 3 was constructed on the slope between the water tower and the top of the hill. The process area was to the left of the water tower.

Photo No. 2

Borrow area overburden removal (looking northward).

Photo No. 3

Test Fill 3 subgrade excavation (looking eastward from the top of the slope).

Photo No. 4

Test Fill 3 structural fill placement and compaction (looking westward from bottom of slope).

Photo No. 5

Structural fill "foundation layer" compaction.

Photo No. 6

Process area soil liner conditioning using a Caterpillar SS250 Soil Stabilizer. The borrow area is in the background.

Photo No. 7

Applying moisture in the process area. Tractor and Rome disc in the background.

Photo No. 8

Process area soil liner conditioning using a tractor pulling a Rome disc

Photo No. 9

Spreading of a loose lift on the test fill.

Photo No. 10

Checking loose lift thickness using a nuclear gauge drive pin as a depth probe.

Photo No. 11

Compacting a lift on the test fill.

Photo No. 12

Nuclear gauge testing of the in-place moisture content and dry density.

Photo No. 13

Sandcone correlation test being performed at nuclear gauge test location.

Photo No. 14

Verifying the test fill thickness.

Photo No. 15
Smooth drum rolling the test fill surface.

Photo No. 16

Excavation around a block sample location (area beneath ring in center of photograph). The backhoe in the background was used to excavate the trench around the sample location.

Photo No. 17

Hand trimming around the block sample. As the sample was trimmed, the sampling ring was slid over the sample using hand pressure.

Photo No. 18

Removing the bottom of the block sample from the test fill.

Photo No. 19

Preparing block sample for transportation to the field laboratory. Shrink wrap was taped to both of the trimmed sample ends. Plywood sheets were then tied to each end to minimize the potential for disturbance.

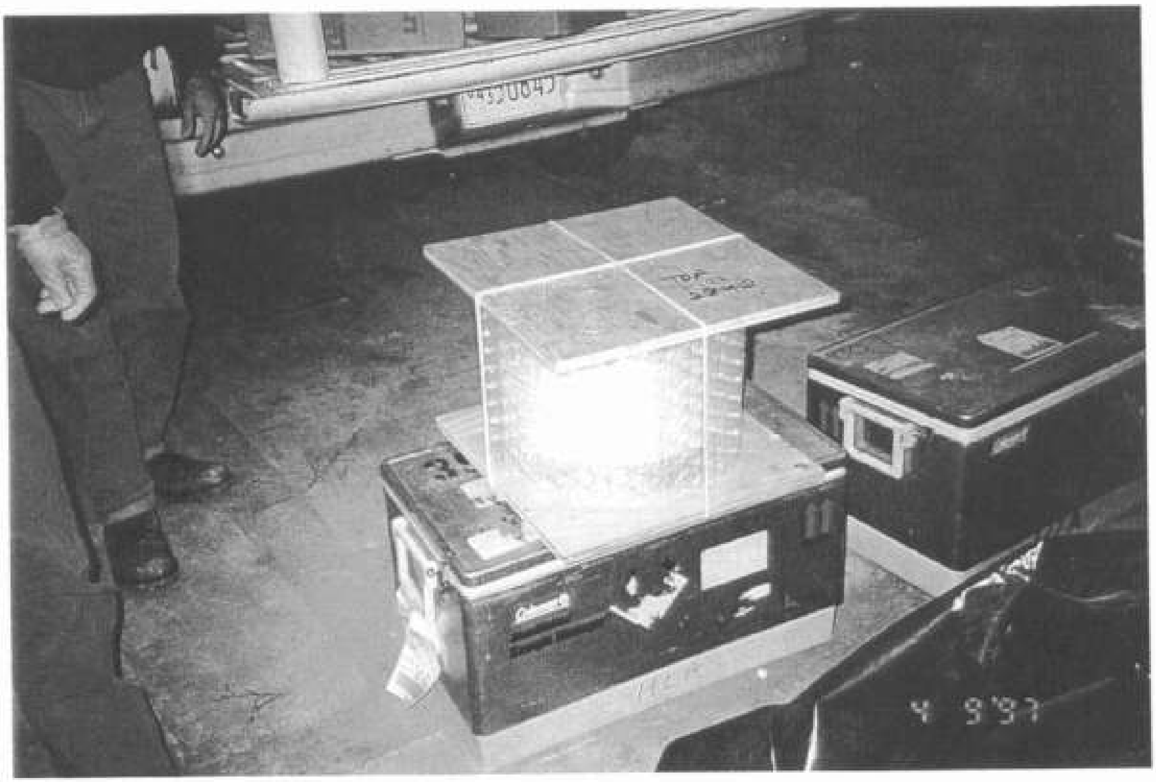


Photo No. 20

Preparing block sample for transportation to the testing laboratory. Bubble wrap was taped around the sample prior to placing in a plastic-lined and moistened shipping box.

Appendix D

DAILY FIELD REPORTS

Mon.

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams Countv. Colorado
CQA ENGINEER: Brad Coleman. P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR:
DATE: 3/24/97
OWNER/CLIENT: Program Manager Rockv Mountain Arsenal Remediation

Weather - ~~AM~~: overcast, cool, mod. wind early am - rain by ≈ 9 AM freezing/rain & strong wind - PM
Temperature - ~~AM~~ ~~&~~ 20 - 40°
Work Performed/In - Progress: clear & grub process area & borrow area
· shifted borrow area ≈ 50'W & 100'N
remove borrow area overburden

Materials Delivered Onsite: 825c, rome disc, grader, 621, D7H

Inspection/Testing/Sampling: N/A set up lab
B. Grippa & G. Winey - surveyed borrow & test fill w/ metal detector

Testing/Sampling Results: ~~N/A~~ (BC) - found a pop can but nothing else

Deficiencies/Non-Conformances Note: MACA (UXO clearance contractor) was supposed to meet me @ 8 AM - Didn't show - MACA said clearance wasn't necessary Ben Wachob verified this w/ Ken Proper - ~~#~~ surveyed area w/ metal detector regardless

Corrective Actions Noted:

Comments: 7am safety mtg
- gave M. McClain status rpt ≈ 11am
- registered personal vehicle & checked out site trucks

CQA Monitor:
CQA Engineer:
onsite 7:00 - 2:15

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: Robert A. Grippa

DATE: 3/24/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: Overcast, rain, sleet, snow - very windy

Temperature - AM Cold 20's, Windchill -

Work Performed/In - Progress: Test Fill Construction - Kick Off
Perform metal detector & visual scan of newly restaked Borrow Area & Test Fill 3 - found Nothing, Set up soils lab arrange equipment.

Materials Delivered Onsite:

Inspection/Testing/Sampling:

Testing/Sampling Results:

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 1430 - Depart RMA for HLA office, meet w/ Marcus Johnshoy concerning Nuclear Density Gauge information. Order supplies for sampling
8.5 Hrs

CQA Monitor: Robert A Grippa

CQA Engineer: BAC

Tues

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: B Coleman

DATE: 3/25/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - ~~AM~~: Clear, slight breeze 40-70°F

Temperature - ~~AM~~ 40-70°F

Work Performed/In - Progress: overburden removal from Borrow area
graded haul roads
set up Nuc. gauge storage in Hydrazine Bldg
top soil rmvl TFill 3

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: calibrated wt of density sand in cone & plate
calibrated density of sand

Testing/Sampling Results: 3.70 lb = wt of sand in cone & plate
91.66 lb/ft³ = density of sand

Deficiencies/Non-Conformances Note: N/A

Corrective Actions Noted: observed caliche/roots in ~~over~~ Borrow area @ ≈1-2' depth
- wasted these materials
- good clay @ ≈ 3'-4'

Comments: 7AM safety mtg - S. Fletcher (MACA) gave UXO safety talk
≈2pm - gave M. McClain status rpt
≈4pm - dlvd. DF early ops Plans to B Wachob
≈2pm Met w/ G. Condon (~~SS~~ RVOSSHO) - gave floor plan of gauge storage
my safety certs & added my name to Permit
≈2pm - ~~left~~ gave status rpt. to D. Iken (CDPHE)'s voice mail

CQA Monitor:

CQA Engineer: B Col

onsite 7:00 - 4:15

TUES

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams Countv, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABALDO
DATE: 3/25/97
OWNER/CLIENT: Program Manager Rockv Mountain Arsenal Remediation

Weather - AM: SUNNY, BREEZY, COOL.
Temperature - AM 45°F TO 70°F
Work Performed/In - Progress: CALIBRATED STAND, REVIEW OPERATION ON NUC GAUGE LOOK OVER TEST FILL 3 CONSTRUCTION AREA.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: NA

Testing/Sampling Results: NA

Deficiencies/Non-Conformances Note: NA

Corrective Actions Noted: NA

Comments: NUC GAUGE IS WORKING PROPERLY.

CQA Monitor: Rudy J Tabaldo
CQA Engineer: BAC

ON SITE 0900-1215
1415-1800

Two

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: ROBERT A. GRIPPA
DATE: 3/25/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: Clear, cool - breezy

Temperature - AM 20's → 40's PM

Work Performed/In - Progress: Work w/ Alan Steckleberg shooting cut outs Mobe out Nuclear Density Gauge, Brad Coleman & Rudy Tabaldo post signs & contact Greg Cardan (RMA)

Materials Delivered Onsite:

Inspection/Testing/Sampling:

Testing/Sampling Results:

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 1400 - Depart RMA for HLA office - pickup more supplies - paperwork, sample buckets & equipment

9.5 Hrs

CQA Monitor: Robert A. Grippa

CQA Engineer: BAC

Wed

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR:

DATE: 3/26/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - ≈ 40°F @ 7am ≈ 70°F @ 2pm - ≈ 50°F @ 6pm

Temperature clear, calm

Work Performed/In - Progress: Top soil rmvd of TF#3, lab set up
excavate subgrade of TF#3

Materials Delivered Onsite: 4x4 tractor

Inspection/Testing/Sampling: 7am - inspected borrow area w/ A. Steckleburg
approx 4' down on S. end & 3' @ N. end - observed caliche
@ surface in extreme N. end - Al said he won't excavate -
Majority is dk. brown CL to CH

Testing/Sampling Results: Sampled TF 3 subgrade & performed Std. proctor
- checked gauge operation/calibration by performing 2 nuclear tests w/
sandcones

Deficiencies/Non-Conformances Note: N/A

Corrective Actions Noted: N/A

Comments: 7am safety mtg.
met w/ John Balzer & Jacob's program manager - They want HLA construction
to meet w/ Jacobs foreman (Auer) to discuss our equipment needs -
relayed this to A. Steckleburg

CQA Monitor:

CQA Engineer:

onsite 7am - 7pm

Wcl

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABALDO
DATE: 3/26/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, BREEZY, WARM PM: SUNNY, CALM, WARM
Temperature - AM 50 TO 70° F
Work Performed/In - Progress: ORGANIZE FILES & SOIL LAB. 1010 OBTAIN PROCTOR SAMPLE FROM TEST FILL #3 SUBGRADE. CAL. #1 CONE & PLATE, TEST PROCESS AREA.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: 1415 START STD PROCTOR TEST ON SUBGRADE MATERIAL FROM TF#3 1710 CONDUCT TWO PRACTICE TEST ON PROCESS AREA USING NUC GAUGE & SAND CONE

Testing/Sampling Results: PROCTOR TEST ①: MAX DRY DEN. = 107%, OPT. MOIST = 17.8%

PRACTICE
TEST #1 NUC: DRY DEN. = 98.2, MOIST = 9.6%, COMPACTION = 91.8%
TEST #1 SAND CONE: DRY DEN = 94.8, MOIST = 9.9%, COMPACTION = 88%
TEST #2 NUC: DRY DEN = 103.4, MOIST = 13.7%, COMPACTION = 96.6%
TEST #2 SAND CONE: DRY DEN = 102.0 ~~82.~~, MOIST = 16.7 11.6%, COMPACTION = 95.3 76.0%

Deficiencies/Non-Conformances Note: NA

Corrective Actions Noted: NA

Comments: SAFETY MEETING 0700

CQA Monitor: Rudy J Tabaldo
CQA Engineer: BAC
START 0700 - 1200
1230 - 1900 STOP

Wed

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E. PROJECT NO: 21907 206050.1

CQA MONITOR: Robert A. Grippa DATE: 3/26/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: Clear Skies, warm & breezy

Temperature - AM 50's → 70's

Work Performed/In - Progress: Subgrade excavation of Test Fill 3

Materials Delivered Onsite:

Inspection/Testing/Sampling: Subgrade Proctor - 5 pt pounded, moistures taken microwave & Oven. Perform ~~1~~ RAG sample/practice Nuke tests & Sand cones in process area

Testing/Sampling Results: Comparable moistures between Nuke & sand cones.

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 0830-Depart RMA to run Alan S. to Wagner P/U H2O truck HLA P/U office supplies, ACE Hardware & RMA Procurement for field supplies. 1200 Returns to RMA review Nuke gauge manual, Soil lab to run proctor & moisture samples Run moistures on sand cone

13 Hrs

CQA Monitor: Robert A Grippa

CQA Engineer: BC

Thurs

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: BCol

DATE: 3/27/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: 50 - 70°F

Temperature - AM clear, lt. to moderate winds

Work Performed/In - Progress: grading TFill 3 subgrade - removal of cut mat'l

Materials Delivered Onsite: ~~NA~~ SS250 dlvd on site

Inspection/Testing/Sampling: weighed oven moistures & calculated moist. contents for S/C & Proctor

Testing/Sampling Results: Oven/micro/nuclear moisture contents correlated relatively well - see lab data sheets

Deficiencies/Non-Conformances Note: Directed const. to wet & compact the subgrade 3.5:1 slope section - soil is too granular - will not hold water - 825c will not climb
Decided to try placing a ≈10" foundation layer over the granular layer -
Called M. McClain & he gave OK to do so - Told him we will start tomorrow

Corrective Actions Noted: ~~Compaction of~~ BC Probably Need to provide a cohesive subgrade layer for the 825c to travel the 3.5:1 slope

Comments:

CQA Monitor:

CQA Engineer:

on site ≈830 - ≈1700

THURS

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABALDO
DATE: 3/27/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, BREEZY, WARM   PM: SUNNY, SCATTERED CLOUDS, WINDY, WARM

Temperature - AM 40°F TO 65°F

Work Performed/In - Progress: FINISH MOIST. TESTS, CLEAN UP LAB, CAL #1 & #2 COMP & SOG. REVIEW WORK PLAN & NUC MANUAL. DRAW GRAPH ON MOISTURE CONTENT. TAKE PICTURES OF TEST FILL #3 ACTIVITIES.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: 0730 WEIGHT TARE & DRY SOIL FOR STD PROCTOR AND PRACTICE TESTS DONE ON PROCESS AREA. (3/26/97)

Testing/Sampling Results: STD PROCTOR: OVEN RESULTS FOR MOIST. CONTENT SHOWN ON LAB. COMPACTION TEST FORM. PRACTICE TESTS 1 & 2 RESULTS FOR OVEN MOIST. CONTENT ON SAND CONE FORM.

Deficiencies/Non-Conformances Note: NA.

Corrective Actions Noted: NA.

Comments: 0700 SAFETY MEETING, 1530 CREW STILL CUTTING AWAY @ TEST FILL AREA. PROCESS AREA READY TO GO AND BORROW AREA LOOKS READY TO GO. N.W. CORNER OF BORROW AREA STILL SHOWING CALICHE. TOOK 10 PICTURES TODAY OF ACTIVITIES.

CQA Monitor: Rudy J Tabaldo
CQA Engineer: BAC   START 0700 - 1200
1230 - 1900

Thurs

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E. PROJECT NO: 21907 206050.1
CQA MONITOR: Robert A. Grippa DATE: 3/27/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: Partly Cloudy - Windy cold front moving in
Temperature - AM
Work Performed/In - Progress: Continue excavation of subgrade for Test Fill 3 - 1330 → 1830 operated H_2O Truck

Materials Delivered Onsite:

Inspection/Testing/Sampling:

Testing/Sampling Results:

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 1230 - Pickup film & video cassette, prep camera & video recorder for Brad Coleman to shoot photos

7.0 Hrs

CQA Monitor: Robert A Grippa
CQA Engineer: BAC

Fri

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E. PROJECT NO: 21907 206050.1

CQA MONITOR: BColeman DATE: 3/28/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: clear slight breeze

Temperature - AM 45-78°F

Work Performed/In - Progress: fine grading of base & lower slope portion of TF113 excavated clay from borrow area & placed over process area - began processing w/ SS250. placing structural fill on upper ≈20' of TF3 subgrade

Materials Delivered Onsite:

Inspection/Testing/Sampling: Took insitu moisture content and density tests, ~~sample~~ in borrowarea (Proctor #3) ~~a~~ took sample for microwave & oven moisture content tests

Testing/Sampling Results: Obtained Proctor result (TP2) for material being used as structural fill. perform nuke test on ~~a~~ structural fill plcd for subgr. in upper portion - failed - ~~too dry~~ -

Deficiencies/Non-Conformances Note: Structural fill too dry

Corrective Actions Noted: added moisture to structural fill

Comments: Called D. IKenberry (CDPHE) & told him about the plan to place a structural fill layer as a foundation layer on the sandy subgrade material to assist the compactor in obtaining traction - he said he had no problem w/ it
- borrowarea has the upper 1' of CL/CH & sandy lean clay below it - occasional large cobbles (≈12") - no caliche or roots observed

CQA Monitor: BColeman

CQA Engineer:

onsite 0700-1740

Harding Lawson Associates

Page 1 of 1

Fri

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: RUDY J. TABACCO

DATE: 3/28/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, BREEZY, WARM

Temperature - AM 40°F TO 65°F

Work Performed/In - Progress: LOOK OVER CONSTRUCTION ACTIVITIES, PRACTICE TEST ON BORROW AREA (P3) 0900 SCRAPER STARTS MOVING SOIL FROM BORROW AREA TO PROCESSING AREA AND THEN ~~FROM~~ BORROW AREA ~~MOVING~~ TO ~~SOIL~~ TOP ~~FROM~~ OF TEST FILL. ~~[illegible]~~ STABILIZER STARTS PROCESSING SOIL. (1340) SCRAPER MOVES PROCESS SOIL ON TO TEST FILL. 1630 SHUT DOWN ACTIVITIES [illegible] HOMES.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: (0940) #(P3) CHECK MOISTURE ~~[illegible]~~ W/ NUC GAUGE ON BORROW ~~AREA~~ AREA ✓ DENSITY. GRAB [illegible] SOIL ~~MOISTURE~~ SAMPLE ~~[illegible]~~ FOR MOISTURE TEST @ LAB. 1430 NUC TEST ON FILL @ TOP OF TF#3, 1525 2ND NUC TEST @ TOP OF TF#3, BATTERY WENT DEAD. RETEST ON MONDAY

Testing/Sampling Results: (P3) DENSITY = 94.5 / MOIST. = 14.44%, MICRO WAVE 16.8% / OVEN = 1430 [illegible]

Deficiencies/Non-Conformances Note: NA

Corrective Actions Noted: NA

Comments: (0700) SAFETY MEETING. (1210) REMOVING SOIL FROM EAST SIDE OF BORROW AREA, NOTICED CHANGES IN SOIL, FROM FAT CLAY TO LEAN CLAY. STABILIZER MADE 4 PASSES OVER PROCESS SOIL BEFORE MOVING SOIL TO TF. H_2O TRUCK MADE 4 PASSES OVER SOIL ON PROCESS AREA. COMPACTOR MADE 1ST ATTEMPT TO GO UP SLOPE W/ STRUCTURAL FILL DOWN, FAILED. 2ND ATTEMPT MADE AFTER ADDING MORE MOISTURE AND SOIL. FAIL

CQA Monitor: Rudy J Tabacco

CQA Engineer: BAC

START: 0700 - 1715

Mon

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: BAC
DATE: 3/31/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: clear moderate winds
Temperature - AM 45-70°
Work Performed/In - Progress: Placing structural fill as foundation layer over TF113 sandy subgrade - approx. 10" loose lift 0600 to 0800
This is being done to attempt to replicate full-scale condition (subg must be finer than SM) -
A med ~~[illegible]~~ plasticity clay is being used - moisture is being added @ the process area

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: Rudy monitoring borrow excavation, processing, & struc. fill compaction

Testing/Sampling Results: Obtained 3 buckets of material from over the process table - composited the buckets into 1 sample & quartered out a sample for index tstg @ GeoSyntec the rest was used to prepare Proctor pts for Mod., std, & reduced Proctors

Deficiencies/Non-Conformances Note: To provide a ~~[illegible]~~ fine-grained ~~[illegible]~~ foundation (or subgrade) layer - The base grade is now being raised. - Surveyors will shoot the top of the found. layer tomorrow

Corrective Actions Noted:

Comments: ≈0800 - begin hauling clay from borrow to process area & moisture conditioning using the SS250 - continued most of day along w/ fine grading of structural fill placed & compacted over the TF113 subg

CQA Monitor:
CQA Engineer: B Col
onsite 0700 - 1740
office

Mon

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABALDO
DATE: 3/31/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, BREEZY, WARM. PM: PARTLY CLOUDY, BREEZY, WARM

Temperature - AM 45°F TO 70°F

Work Performed/In - Progress: LOOK OVER CONSTRUCTION ACTIVITIES, TAKE NUC TESTS, GRABS MOISTURE SAMPLES, 1640 GRAB PROCTOR SAMPLE FROM PROCESS AREA.

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: 0925 ⑤ TAKE RE TEST @ TOP OF TF #3, ①PA 1035 / ②PA 1040 / ③PA 1130 MOISTURE SAMPLES 1225 RETEST ⑥ ~~1400~~ 1315 TOP OF TF, ⑦ 1325 SLOPE OF TEST FILL, ⑧ 1335 TOP OF TF, ⑨ 1347 BASE OF TF ⑩ 1430 TOP OF TF / 1355 4PA BS ON PROCESS MATERIAL 16.26 %, 1630 5PA BS = 11.82%, 1815 (6PA) BS 10.22%, GRAB MOIST SAMP. 1825 (7PA) BS = 4.26, GRAB MOIST SAMP., 1830 (8PA) BS = 8.14, GRAB MOIST SAMP

Testing/Sampling Results: ③PA MICROTIP = 14.1% / RC ⑤ PASS, ⑥ BUS FAIL, ⑦ 1325 PASS, ⑧ RETEST OF ⑥ 1335 FAIL, ⑨ 1347 PASS, ⑩ RETEST OF ⑥ 1430 PASS

Deficiencies/Non-Conformances Note: ⑥ MOIST CONTENT: 13.3%, ⑧ 13.4%

Corrective Actions Noted: ⑥ CUT ANOTHER PAD, ⑧ TORE UP TOP, WET AGAIN THEN COMPACT AGAIN.

Comments: (0700) FINISH MOISTURE TESTS FROM FRIDAY, (0745) CREW FINISHING UP STRUCTURAL FILL, & MOVING MORE SOIL FROM BORROW AREA OVER TO PROCESS AREA FOR 1ST LIFT. (1000) NUC GAUGE NOT WORKING PROPERLY, WILL NOT TAKE TEST (*) 1215 NUC GAUGE WORKABLE. OPT MOIST. 16.6% & 107.3 MAX DENS. FOR STRUCTURAL FILL. 1410 WORKING ON 2ND LIFT IN PROCESS AREA. 1615 CALICHE OBSERVED @ SLS CORNER OF BA. DOZER REMOVES.

CQA Monitor:
CQA Engineer: BAC

START: 0700 - 1230
1300 - 1930

Tues

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR:

DATE: 4/1/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: AM - clear, windy 50's PM - overcast, getting colder ≈ 40's

Temperature - AM 55 - 35°F

Work Performed/In - Progress: hauling & processing borrow mat'l, ~~bor~~ rmvl of overburden on N. side of borrow area, fine grading of TFill subg.

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: Pounded the mod, std, & reduced Proctor pts
- numerous moisture tests done by Rudy in process area during day - targeting 16% ± 1%

Testing/Sampling Results: Surveyors surveyed TFill subg - bottom isn't quite @ 2% - decided its OK talked to J. Lametti - GeoTrans he agreed that 2% wasn't needed - just don't place on puddled water; Eddie Gray will fine grade slope - set stationing along S. side (@ ≈ 5-6') & as built ℄ of cell

Deficiencies/Non-Conformances Note: Observed caliche in borrow pit - discontinued hauling from there & extended borrow pit to North

Corrective Actions Noted: ≈ 5pm - impending precipitation - began sealing process table

Comments: Began setting up logistics for block testing

CQA Monitor:

CQA Engineer:

onsite 0650 - 1730
office

TUES

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: RUDY J. SALGADO

DATE: 4/1/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: CLOUDY, BREEZY, COLD.

Temperature - AM 35 - 45 °F

Work Performed/In - Progress: LOOK OVER CONSTRUCTION ACTIVITIES, CONDUCT NUC GAUGE TESTING INSPECT BORROW AREA. GRABS MOISTURE SAMPLES. GRABS 12 5 GAL BUCKETS FOR SAMPLES OF PROCESS MATERIAL.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: TEST TOP OF TF#3 (11) 0900, (12) 0905, (13) 0910 (SLOPE), 1340 (14) RETEST OF (12) 1345 START SAND CONES

Testing/Sampling Results: (11) DENS. = 1076, MOIST = 11.18 | (12) DENS = 103.5, MOIST = 11.07 | (13) DENS. = 105.9, MOIST = 15.44 PASS (14) PASS DENS = 114.7, MOIST = 15.11,

Deficiencies/Non-Conformances Note: (12) MOISTURE TO LOW ~~RIP SOIL THEN WET DOWN, COMPACT AGAIN.~~ (RST)

Corrective Actions Noted: (12) RIP SOIL THEN WET DOWN, COMPACT AGAIN

Comments: 0700 CREW WORKING ON TOP OF TEST FILL AND SLOPE, STRUCTURAL FILL, TRYING TO REACH FINAL GRADES. ~~SCRAPER~~ (RST) SMALL LAYER OF CALICHE OBSERVED IN BORROW AREA, WILL SCRAPE OFF LAYER AND NOT USE FOR LINER MATERIAL. CALICHE ABOUT APPROX 5' DOWN. (1100) SCRAPER WILL NOT EXCAVATE PASS 6' IN BORROW PIT, STILL SEEING CALICHE. SCRAPER WILL NOW EXTEND BORROW PIT NORTHWARD. PROCESS AREA HAS 1 LIFT READY ON NORTHSIDE.

CQA Monitor: Rudy J Salgado

CQA Engineer: BAC

START: 0700 - 1200
1230 - 1800

Wed

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: BCol
DATE: 4/2/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: overnight wet snow, on & off rain/sleet
Temperature - AM ≈ 35°-40°
Work Performed/In - Progress: excavation of borrow clay & clay processing

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: Rudy providing moisture control on process area & inspecting borrow pit Completed mod./std/& reduced proctors - drew new AZ based on Proctors for TFill CCL plcmt

Testing/Sampling Results: New line of optimums is within 1% of old. Proctors correlate w/ WPlan proctor within WPlan criteria

Deficiencies/Non-Conformances Note: N/A

Corrective Actions Noted: N/A

Comments: ~~N/A~~ caught up w/ paperwork & coordinated obtaining sampling supplies for block testing

CQA Monitor: BCol
CQA Engineer:

onsite 0610 - 1500
office

Wed

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams Countv, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABARDO
DATE: 4/2/97
OWNER/CLIENT: Program Manager Rockv Mountain Arsenal Remediation

Weather - AM: CLOUDY, BREEZY, SNOW ON GROUND, LIGHT SNOW FALLING, COLD

Temperature - AM 30° TO 35° F (EST)

Work Performed/In - Progress: (0940) HAULING LEAN CLAY MATERIAL FROM BORROW PIT. INSPECT WORK ON PROCESS MATERIAL / TAKE MOISTURE TEST ON PROCESS MATERIAL.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: (0940) MATERIAL LOOKS TO BE LEAN CLAY. MOISTURE CONTENT (EST) TEST ON LEAN CLAY / INSPECT PROCESS AREA FOR NUMBER OF PASSES BY H_2O TRUCK AND STABILIZER / TAKE NUMEROUS MOISTURE TEST ON PROCESS MATERIAL.

Testing/Sampling Results: (0940) MOISTURE CONTENT = 8.25% / WALK TO PROCESS AREA NOTES FOR WORKING PROCESS MATERIAL / AFTER 1 PASS BY STABILIZER WITH NO WATER MATERIAL = 10% TO 11%, with. MAKE 1 PASS W/ H_2O TRUCK & STABILIZER MOISTURE IS APPROX. @ 15%.

Deficiencies/Non-Conformances Note: NA

Corrective Actions Noted: NA.

Comments: 1100 SAFETY MEETING.

CQA Monitor: Rudy J Tabardo
CQA Engineer: BAC

START: 0700-1000
1130-1545

21907 102010.6
03123/25/97 Form-02

Harding Lawson Associates

Page 1 of 2

Thurs

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: BAC
DATE: 4/3/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: ~~B~~ Clear slight breeze

Temperature - AM 32° - 60°

Work Performed/In - Progress: preparing TFill subgr & processing clay Start lift 1 plcmt ≈1000
Start compacting Lift 1 ≈1115 (4 passes lane 1, 6 passes lane 2, 8 passes Lane 3), start lift 2 ≈ 1215
Start compacting Lift 2 ≈ 1330; Test Lift 2 ≈ 1500, Place Lift 3 ≈1400, Test Lift 2, Lane 1 ≈1700

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: Process area moisture control, 2 grab moistures from Lift 1, Lane 1
and one each from Lanes 2 & 3; Obtained 6 passing tests on Lift 1 - took 5 shelby
& performed one sandcone

Testing/Sampling Results: Check loose lift thickness w/ rake guage pin 7-8" nominal - Station
Stakes on side are marked w/ lift thkness - periodic checks w/ hand level

Deficiencies/Non-Conformances Note: Subgrade surface (≈1-2") is ~~ve~~ saturated from yesterday's
precip - skimmed off w/ D7 - wheel rolled w/ 621 afterwards - no soft spots

Corrective Actions Noted: slope test 122 failed density slightly - did 2 add'l passes (8 total) - retest
passed

Comments: Test pads ~~were~~ cut exhibited good to excellent layer bonding, moisture
content is relatively consistant

Depth indicator on gauge quit working @ 1730 - stopped testing & repaired
gauge

CQA Monitor:
CQA Engineer:
onsite 0650 - 2000

Thurs 1/2

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABACDO
DATE: 4/3/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, CALM, COOL

Temperature - AM 40 TO 60 °F

Work Performed/In - Progress: LOOK OVER CONSTRUCTION ACTIVITIES. TAKE NUC GAUGE TESTS, GRAB MOISTURE SAMPLES, INSPECT BORROW PIT MATERIAL. 0935 SCRAPER STARTS HAULING 1ST LIFT 1230 LAYING 2ND LIFT (1625) START MIXING 3RD LIFT

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: 0745 INSPECT BORROW MATERIAL STILL LOOKS TO BE LEAN CLAY. 0830 TAKE SEVERAL MOISTURE SAMPLES W/ NUC GAUGE ON PROCESS MATERIAL. 0913 RETEST NORTH HALF OF SECTION CD FOR MOISTURE. 1000 GRAB TWO MOISTURE SAMPLES FOR MICROWAVE FROM BASE + SLOPE OF 1ST LIFT LANE 1 (1300) MOISTURE TEST ON ~~2ND LIFT~~ (RST) CD MATERIAL FOR 2ND LIFT. (1215) GRAB 2 MORE MOISTURE TEST FROM LANE 2 & 3 1ST LIFT. TAKE NUC TEST ON 1ST LIFT, 2 PER LANE PLUS SHELBY TUBE SAMP.

Testing/Sampling Results: CD SECTION OF PROCESS MATERIAL, THE MOISTURE LOOKS GOOD. ~~[illegible]~~ SOUTH HALF OF CD 15% TO 18%.. NORTH HALF MOIST = 12.0%. RETEST ON N HALF OF CD IS 16.07%, 1010 MICROWAVE TEST = BASE = 18.3% & SLOPE = 15.2%. (1300) 14.51% MOIST. TEST 122 ~~NOT~~ ~~THE~~ (RST) DENS = 112.7, MOIST = 14.9%

Deficiencies/Non-Conformances Note: NORTH HALF OF OF SECTION CD TO LOW ON MOISTURE (1300) WILL LOSE ABOUT 1 TO 2% MOIST. WHERE MOVING MATERIAL FROM PROCESS AREA TO TEST FILL TEST 122 NOT IN VAZ, COMPACTION LOW.

Corrective Actions Noted: 0850 STABILIZER & H2O TRUCK MAKE 1 PASS OVER NORTH HALF OF SECTION CD TO BRING MOISTURE UP (1300) WILL HYDRATE CD MATERIAL. FOR TEST 122 WILL MAKE 2 MORE PASSES

Comments: 0700 SAFETY MEETING. 0730 DOZER ROUGHING UP TEST FILL FOR 1ST LIFT. ~~SCRAPER [illegible]~~ DOZER HAD TO FOLLOW SCRAPER TO SHAVE 1ST LIFT DOWN TO 8".

CQA Monitor: Rudy J. Tabacdo
CQA Engineer: BAC
START: 0700

Thurs 2/2

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABARDO
DATE: 4/3/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - ~~AM~~: PM SUNNY, WINDY, WARM
Temperature - AM 65°F TO 50°F
Work Performed/In - Progress: LAYING LIFT 3. TAKE NUC TEST FOR LIFT 2

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: 122A RETEST, INSPECTED EACH LIFT FOR 8" THICKNESS. TEST LANE 1 LIFT 2. 3RD LIFT IS COMPACTED DOWN.

Testing/Sampling Results: 122A PASS. LANE 1 PASS FOR 2ND LIFT

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 1815 WHILE TRYING TO TEST LOCATION 222, NUC GAUGE WILL NOT LOCK INTO DEPTH POSITIONS. COULD NOT TAKE TEST. BRAD COLEMAN WILL WORK @ NUC GAUGE. SHUT DOWN ACTIVITIES.

CQA Monitor:
CQA Engineer: BAC

Fri

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: BColeman

DATE: 4/4/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: partly-mostly cloudy 40-50°F PM: Noon-RAIN ~1400

Temperature - AM 40-50°F

Work Performed/In - Progress: 0740: ~~Begin~~ Resume testing Lift 2; hauling clay to process area & clay processing; 0940 Place Lift 4; 1230 Test Lift 3; ≈1330 shutdown field activities

Materials Delivered Onsite: ~~N/A~~ 4x4 International tractor from motor pool

Inspection/Testing/Sampling: All Lift 2 tests passed w/o additional passes; All lift 3 tests passed w/o add'l passes - 2 of 6 tests in LAZ - remainder in VAZ
Prepared Lifts 1, 2, & 3 Shelby tubes for shipment; Cleaned lab

Testing/Sampling Results: See above; nominal 8" loose lifts - verified by metals probe
5-6" compacted lifts - observed in pads cut through upper lift for nuclear testing
layer bonding lifts 3/4 is good but not quite as good as previous lifts cuz differences in moisture contents of lift

Deficiencies/Non-Conformances Note: Moderate rainfall during testing of Lift 3 - could not take sandcone

Corrective Actions Noted: Obtained 6 Shelby tubes on Lift 3 instead of 5 tubes & 1 sandcone

Comments: 0700 Safety mtg; M. Wescott onsite @ ≈1200

CQA Monitor:

CQA Engineer:

onsite 0640 - 1600

Fri

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABARADO
DATE: 4/4/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, WINDY, COOL   PM: CLOUDY, BREEZY, COOL, RAIN

Temperature - AM 40° TO 60° F

Work Performed/In - Progress: FINISH TESTING 2ND LIFT. CREW LAYING DOWN NEW MATERIAL FROM BORROW PIT TO BE PROCESS (1030) START LAYING DOWN 4TH LIFT OF ALREADY PROCESS MATERIAL (4/3/97)

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: 0800 TAKE NUC TEST ON 2ND LIFT & DO 1 SAND CONE. INSPECTED BORROW MATERIAL, STILL EXCAVATING LEAN CLAY FROM NORTH END OF PIT. (1030) TEST ~~ON~~ PROCESS MATERIAL FOR MOISTURE. ✓ ~~FOR~~ 8" LIFTS. TAKE NUC TEST ON 3RD LIFT AND GRAB SHELBY TUBES.

Testing/Sampling Results: 0800 2ND LIFT PASS / (1030) MOISTURE TEST ON PROCESS MATERIAL IS 18% TO 20% / TEST ON 3RD LIFT, PASSES.

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 0700 SAFETY MEETING (1200) START RAINING, WILL HAVE TO TEST 3RD LIFT IN THE RAIN. (1330) FINISH TESTING LIFT HEAD TO HYDRAZINE TO SEND SHELBY TUBES.

CQA Monitor:
CQA Engineer: BAC   START: 0700 -

Sun.

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: BAC
DATE: 4/6/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: 0700 low 20°'s F clear, slight breeze 1000-32°F

Temperature - AM

Work Performed/In - Progress: ≈0830 approx. 2" frost in ground, start equipment & begin removing upper 2" of clay from Test Fill surface (Lift 4) & process area surface; ~~Fro~~ 1200 hrs place Lift 5; 1500 Test Lift 4, 1600 place Lift 6, 1800 test lift 5
1400 compact lift 5

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: 1200 - monitor loose lift thkns & for presense of frost within Lift 5 - ~~Some m~~ occasional frost particles observed (temp ≈45°) - wait to compact - reinspect @ 1330 hrs - no frost observed in placed clay

Testing/Sampling Results: measured compacted lift thkns in a number of nuclear test pads - 5-6" loose lift thkns held @ 8"

Deficiencies/Non-Conformances Note: Standing water @ extreme SE corner of TF-1 - removed w/frost material; compactor appears to bog down on clay placed on slope in LAZ - field moist/densities passed - some tearing observed (Lifts 4 & 5)

Corrective Actions Noted: Frost gone by 10-1100 hrs from Test Fill surface (Lift 4) - 2 add'l passes of 825 on Lift 4 for scarification/frost rmvl.

Comments: 2 add'l passes w/825 done on Lift 4 (total 6L1, 8L2, 10L3) to texturize surface for Lift 5 plcmt; Rome disc used to reprocess mat'l in process area - moisture 15-20% Disc appears to be working well - placed this clay in Lane 1 of Lift 6 - will test Monday (4/7) - moisture appears relatively consistant w/ clod sizes up to 6" but nominally 2-3"

CQA Monitor: B Coleman
CQA Engineer:

onsite 0650 -

Sun

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABALDO
DATE: 4/6/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: SUNNY, WINDY, COOL

Temperature - AM 30° TO 50° F

Work Performed/In - Progress: SCRAPE OFF FROST FROM TEST FILL. MAKE PASSES THROUGH PROCESS MATERIAL W/ DISC / (1215) START LAYING 5TH LIFT / (1610) START LAYING DOWN 6TH LIFT.

Materials Delivered Onsite: NA.

Inspection/Testing/Sampling: (1100) INSPECT PROCESS MATERIAL, TAKE MOISTURE TEST W/ NUC GAUGE. (1300) INSPECT 5TH LIFT FOR 8" THICKNESS. TEST 4TH LIFT W/ NUC GAUGE & GRAB SHELBY TUBE SAMPLES / DO SAND CONE @ TEST LOCATION 411 / (1730) TEST 5TH LIFT W/ NUC GAUGE AND GRAB SHELBY TUBE SAMPLES / DO SAND CONE @ TEST LOCATION 531

Testing/Sampling Results: (1100) 20% TO ~~[illegible]~~ 25% MOISTURE CONTENT FOR 5TH LIFT / 4TH LIFT PASSES ~~TESTS~~, RESULTS ARE WITHIN ACCEPTABLE ~~[illegible]~~ ZONE / 5TH LIFT PASSED TEST, RESULTS ARE WITHIN ACCEPTABLE ZONE

Deficiencies/Non-Conformances Note: NA

Corrective Actions Noted: NA

Comments: ~~[illegible]~~ (1930) LAST LIFT DOWN FOR TODAY, SEAL TEST FILL. HEAD BACK TO HYDRAZINE TO MEASURE SAND CONES.

CQA Monitor: Rudy J Tabaldo
CQA Engineer: BAC

ACT: 1100 - 2015

Mon

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: BAC
DATE: 4/7/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: 30°F @ 0700 40°F @ ≈0830 ≈55°F @ 1230 hrs
Temperature - AM partly cloudy
Work Performed/In - Progress: frost mat'l rm'l & clay processing; place lift 7 ≈0900 hrs
Start regrading borrow area; 1030 compact lift 7, 1300 Grade test fill

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling: loose lift msmts, ~~B~~ process area moisture tests
took sample for std Proctor

Testing/Sampling Results: 8" max loose lift measured w/ probe, 6" max compacted lift measured in test pads; Lift 6 tests passed

Deficiencies/Non-Conformances Note: ≈1" frost early AM - removed

Corrective Actions Noted: N/A

Comments: A. Stott (BO)

CQA Monitor:
CQA Engineer: onsite 0650 - 1300

Mon

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABALDO
DATE: 4/7/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: PARTLY CLOUDY, WINDY, COOL

Temperature - AM 30° TO 50° F

Work Performed/In - Progress: (0800) LAYING DOWN 7TH LIFT. / (1030) START COMPACTING 7TH LIFT. SCRAPER BACK FILLING BORROW PIT. (1230) GRADING TEST FILL DOWN TO APPROX. 3' MIN. PACK SHELBY TUBES FOR SHIPMENT. (1530) WORK ON PAPER WORK.

Materials Delivered Onsite: NA

Inspection/Testing/Sampling: (0750) TEST PROCESS MATERIAL W/ NUC GUAGE FOR MOIST. / (0845) TEST REST OF PROCESS MATERIAL FOR MOIST / (0930) GRAB STD. PROCTOR OF 7TH LIFT / APPROX. (1100) START TESTING 6TH LIFT W/ NUC GUAGE & GRAB SHELBY TUBE SAMPLES / DO SAND CONE @ 621 LOCATION. (1330) START WORKING ON STD. PROCTOR # 3

Testing/Sampling Results: (0750) MOIST. CONTENT = 15% TO 18% / (0845) TEST REST OF PROCESS MATERIAL MOIST = 18% TO 21% / ~~TEST~~ 6TH LIFT PASSES TEST, RESULTS ARE WITHIN ACCEPTABLE ZONE.

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 0700 HEALTH & SAFETY MEETING (0830) ANITA LITTLEWOLF ON SITE FOR SAFETY AUDIT.

CQA Monitor: Rudy J Tabaldo
CQA Engineer: BAC

START : 0700 - 2000

Harding Lawson Associates

Tues

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E.

PROJECT NO: 21907 206050.1

CQA MONITOR: BAC

DATE: 4/8/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: 0700 ≈20°F light snow ≈1100 ≈ above freezing

Temperature - AM ≈1300 45°F

Work Performed/In - Progress: ~~Re.~~ Replacing & grading overburden in borrow area; Removing lift 7 & start removing block samples; packaging block samples; smooth rolled surface - shaped nicely

Materials Delivered Onsite: smooth drum roller CP563 Cat 825C offsite, disc & tractor offsite

Inspection/Testing/Sampling: ~~Cl~~ Rudy checked CCL thkns w/ hand level ≈3.2 to 3.3' thick inspected layer bonding & clay thickness - no visible laminations between lifts watched mat'l excavated & walls of excavations for presense of oversized mat'ls

Testing/Sampling Results: min 3.0' in ~~test~~ block sample pits excavated to subgrade to obtain the 3 samples located in the bottom 1' of the test fill; also removed 2 samples in upper 1' & 1 sample in middle foot

Deficiencies/Non-Conformances Note: ≈1000 Called D. Ikenberry (CDPHE) - told him that temp. were below freezing & I therefore didn't want to remove all of lift 7 so that it could be a frost barrier until we covered it - this will mean not testing the final smooth-rolled surface (we have tested top of Lift 6) so that we can excavate block samples ASAP & cuz can't test frozen surface - told him we would smooth-roll surface

Corrective Actions Noted: graded top of test fill to between 3.0 & 3.4' thick - Doug I said not grading to 3' & not testing smooth-rolled surface is OK & to make note of it Observed 0-5 oversized (1"-6") rocks in ~~to~~ block sample excavations rocks were well separated & no visible voids around the rocks

Comments: Marty Cesnik (Geotrans) onsite in PM
Dr. Majdi Othman (GeoSyntec) onsite to oversee block sampling, packaging, & shipment
- 1000 hr nuclear guage offsite
- asked Pat Henry (FWS) in voicemail to come by site to ensure we reclaimed disturbed areas to his satisfaction

CQA Monitor:

CQA Engineer:

onsite 0700 - 2030

TUES

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABACDO
DATE: 4/8/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: CLOUDY, BREEZY, COLD, FREEZING RAIN

Temperature - AM 25° TO 35° F

Work Performed/In - Progress: REMOVING FROST OFF TEST FILL. (360) / STILL BACK FILLING BORROW PIT. 1045 BLOCK SAMPLING

Materials Delivered Onsite: (0910) SMOOTH ROLLER ON SITE.

Inspection/Testing/Sampling: 0845 SHOOT GRADE w/ HAND LEVEL AFTER REMOVING FROST. (1045) WILL GRAB 5 BLOCK SAMPLES.

Testing/Sampling Results: 0845 TEST FILL @ 3'.4 (APPROX). SHAVE ANOTHER 2/10.

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 0700 HALO SAFETY MEETING (1830) FINISH BLOCK SAMPLING, STILL BACK FILL BORROW PIT. 1920 FINISH BACK FILLING HOLES FOR BLOCK SAMPLING, STOP BACKFILLING BORROW PIT, CONT. 4/9/97

CQA Monitor:

CQA Engineer: BAC

START : 0700

Wed

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: BAC
DATE: 4/9/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: ≈30° @ 0730hr
Temperature - AM partly cloudy slight breeze
Work Performed/In - Progress: removing remaining 3 block samples, filling/grading borrow area; surveying top of test fill, limits of borrow & process area, & block sample horizontal locations; ship the 9 block sample

Materials Delivered Onsite: N/A

Inspection/Testing/Sampling:

Testing/Sampling Results:

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments:

CQA Monitor: Brad
CQA Engineer:

onsite 0700-

Wed

DAILY FIELD REPORT

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: RUDY J. TABACCO
DATE: 4/9/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Weather - AM: CLOUDY, BREEZY, COLD
Temperature - AM 30° TO 40°F
Work Performed/In - Progress: BLOCK SAMPLING, BACK FILL BORROW PIT. (1130) STD PROCTOR
1400 COVER TEST FILL w/ VISQUEEN

Materials Delivered Onsite:

Inspection/Testing/Sampling: 0750 START BLOCK SAMPLING / (1130) START POUNDING STD. PROCTOR.

Testing/Sampling Results:

Deficiencies/Non-Conformances Note:

Corrective Actions Noted:

Comments: 0700 SAFETY MEETING, 0800 SURVEYS ON SITE TO SURVEY BLOCK SAMPLE LOCATIONS.

CQA Monitor:
CQA Engineer: BAC
START: 0700

Appendix E

CALIBRATION AND STRUCTURAL FILL TEST RESULTS

SUBGRADE
FIELD DENSITY TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

CQA ENGINEER: Brad Coleman, P.E. (BAC)

CQA MONITOR: RJT

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

LOCATION: Adams County, Colorado

PROJECT NO: 21907 206050.1

~~DATE:~~ MATERIAL: TEST FILL 3 STRUCTURAL FILL

				In Situ Values			Proctor Values						
Test No.	Date	Horizontal Location	Vertical Location	Wet Density (PCF)	Dry Density (PCF)	Moisture Content (%)	Curve No.	Max. Dry Density (PCF)	Optimum Moisture (%)	Differ. From Opt. Moisture (%)	Percent of Proctor (%)	Pass/ Fail	Remarks
1	3/28	10'S ℄ 2'W TF1	2'below FG	110.4	101.3	9.0	1	108.0	16.6	-7.6	94	Fail	top of slope
1A	3/31	Retest #1		129.3	113.6	13.8	"	"	"	-2.8	105	Pass	scarified, moisturized & recompacted
2	"	5'N ℄ 3'W TF1	1'below FG	113.3	100.0	13.3	"	"	"	-3.3	93	Fail	top of slope
3	"	5'S ℄ 30'E TF1	@ FG	128.6	112.2	14.6	"	"	"	-2.0	104	Pass	slope section
4	"	1'N ℄ 30'E TF3	@ FG	124.4	109.4	13.7	"	"	"	-2.9	101	Pass	base section
2A	"	Retest #2		126.3	108.1	16.8	"	"	"	+0.2	100	Pass	scarified, moisturized & recompacted
5	4/1	15'S ℄ 5'W TF1	@ FG	119.7	107.6	11.2	"	"	"	-5.4	100	Fail	top, area moisturized & recompacted
5A	"	Retest #5		132.0	114.7	15.1	"	"	"	-1.5	106	Pass	sandcone correlation test done
5A(S/C)	"	15'S ℄ 5'W TF1	@ FG	133.8	116.9	14.4	"	"	"	-2.2	108	Pass	worksheet attached
6	"	20'S ℄ 40'E TF1	@ FG	122.0	105.9	15.4	"	"	"	-1.2	98	Pass	on slope

℄ = centerline (E-W) of Test Fill Subgrade

TF1, TF3: control point locations

FG: finish grade

21907 102010.6
02253/31/97 FORM 21

Harding Lawson Associates

Page __of__

Structural Fill

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: Rory J. Tabacno (BAC)
DATE: 4/1/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill [✓ Subgrade] Subbase Clay Liner Other
Percent Compaction Required: 107.3
Moisture Content Required: 16.6
Test Location: TOP OF TEST FILL
Test No.: 5A/5C

FIELD TEST DATA ASTM D 1556

A	Density of Sand	(PCF)	[illegible]	H	Volume of Hole = G/A	(CFT	.0592
B	Initial Weight of Sand	(LBS)	14.55	I	Weight of Wet Soil	(LBS)	7.92
C	Final Weight of Sand	(LBS)	5.42	J	Wet Density = I/H	(PCF)	133.8
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	9.13	K	Moisture Content	(%)	14.4 14.4
E	Volume of Funnel	(CFT)		L	Dry Density = J/(I+K)	(PCF)	116.9 116.9
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	108 108
G	Weight of Sand in Hole = D-F	(LBS)	5.43				micro; oven

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No.	~~Dry~~ Wet Density	132.0	(LB/CFT)	Moisture Content 15.1	(%)
Results from above	~~Dry~~ Wet Density	133.8	(LB/CFT)	Moisture Content micro 14.4 / oven 14.4	(%)
Difference +/-		+1.8		-0.7 / -0.7	

LABORATORY DATA

Sample No. 1	Lab Maximum Dry Density (LB/CFT)	108.0
ASTM [✓ D 698] OR D 1557	Optimum Moisture Content (%)	[illegible]
Method [✓ A] B C D		

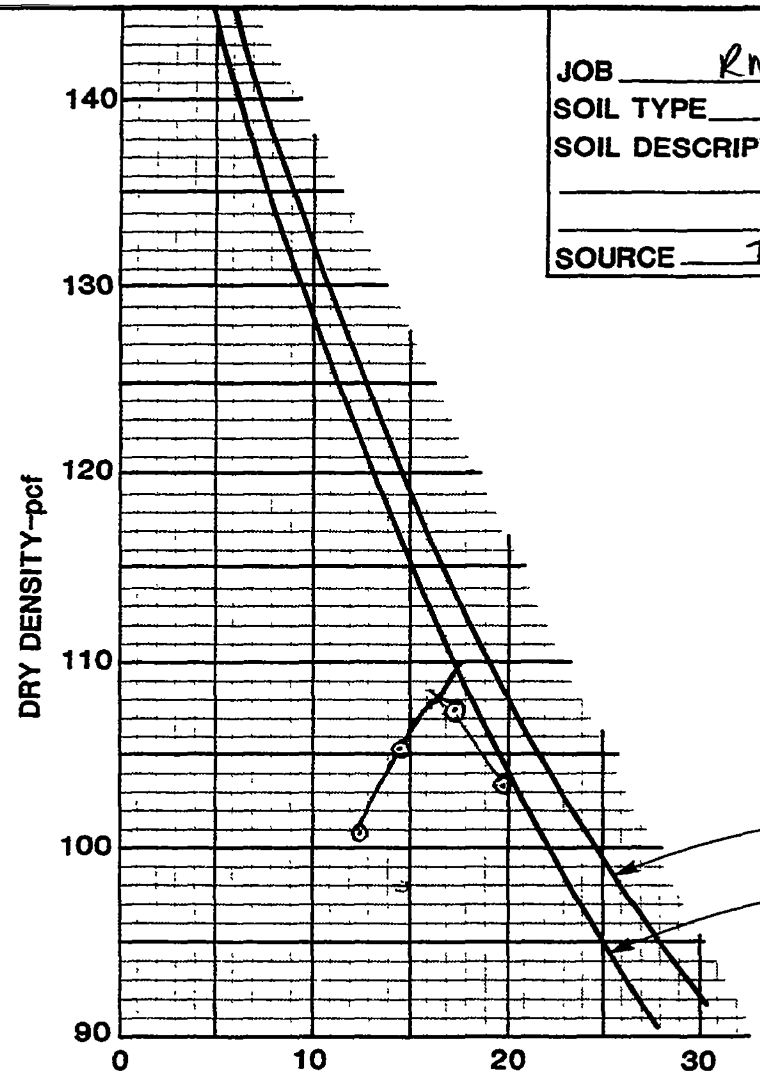
LABORATORY MOISTURE CONTENT ASTM D 2216

					micro	oven
Tare No. [illegible]	micro	oven	Tare Weight	(grams)	74.9	11.3
Tare Plus Wet Soil (grams)	174.9	61.3	Weight of Dry Soil	(grams)	87.4	43.7
Tare Plus Dry Soil (grams)	162.3	55.0	Moisture Content (K)	(%)	14.4	14.4
Weight of Water (grams)	12.6	6.3				

STRUC. FILL MAT'L

LABORATORY COMPACTION TEST

JOB RMA TEST FILL #3 NO. 1
SOIL TYPE CL DATE 3/26/97 BY BAC/RJT
SOIL DESCRIPTION LEAN CLAY w/ SILT
SOURCE TEST FILL #3 SUBGRADE/Structural fill



☐ ASTM D1557-78 ( )

☐ California 216 F

☒ Other (specify) D 698

MAXIMUM DRY DENSITY 108.0 PCF

OPTIMUM MOISTURE CONTENT 16.6 %

⊙ Laboratory Compaction Point

△ Field Check Point

100% Saturation (G_S = 2.68)

90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

	1 +4		2 +6		3 +8		4 +10		5	6
MOLD AND WET SOIL	13.24		13.48		13.66		13.58			
MOLD	9.46		9.46		9.46		9.46			
WET SOIL	3.78		4.02		4.20		4.12			
FACTOR* 4"Φ30 / 6"Φ	.0662	.0294	.0662	.0294	.0662	.0294	.0662	.0294	.0662 .0294	.0662 .0294
WET DENSITY	113.4		120.6		126.0		123.6			
PAN NO.	OVEN A	MICRO	OVEN B	MICRO	OVEN C	MICRO	OVEN D	MICRO		
PAN AND WET SOIL	61.1	109.8	63.2	230	67.8	246.6	50	163.6		
PAN AND DRY SOIL	56.1	98.8	57.1	218.7	60.0	231.7	43.6	149.2		
MOISTURE LOSS	5.0	11.0	6.1	11.3	7.8	14.9	6.4	14.4		
PAN TARE	16.0	16.5	15.5	147.9	15.0	147.9	11.3	74.9		
DRY SOIL	40.1	82.3	41.6	70.8	45.0	83.8	32.3	74.3		
MOISTURE CONTENT	12.4	13.4	14.6	16.0	17.3	17.8	19.8	19.4		
DRY DENSITY	100.9	100.0	105.2	104.0	107.4	107.0	103.2	103.5		

HARDING LAWSON & ASSOCIATES

Calibration Check

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: Rudy S. Tafoya (BAC)
DATE: 3/26/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase Clay Liner Other In situ soil
Percent Compaction Required: N/A
Moisture Content Required: N/A
Test Location: Calibration check
Test No.: Per CC #2

FIELD TEST DATA ASTM D 1556

A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.0645	
B	Initial Weight of Sand	(LBS)	14.83	I	Weight of Wet Soil	(LBS)	6.72	
C	Final Weight of Sand	(LBS)	5.14	J	Wet Density = I/H	(PCF)	104.2	
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	9.69	K	Moisture Content	(%)	micro 9.9	oven 8.5
E	Volume of Funnel	(CFT)		L	Dry Density = J/(I+K)	(PCF)	94.8	96
F	Weight of Sand in Funnel = A x E	(LBS)	3.78		Percent Compaction	(%)	87.7	88.8
G	Weight of Sand in Hole = D-F	(LBS)	5.91					

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No.	Wet ~~Dry~~ Density	107.6	(LB/CFT)	Moisture Content	9.6 % (%)
Results from above	Wet ~~Dry~~ Density	104.2	(LB/CFT)	Moisture Content	Micro 9.9% / oven 8.5% (%)
Difference +/-		-3.4			+0.3 / -1.1

LABORATORY DATA

Sample No. 1	Lab Maximum Dry Density (LB/CFT)	108.0
[✓ ASTM D 698] OR D 1557	Optimum Moisture Content (%)	16.5%
Method [✓ A] B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216

					Micro	Oven
Tare No.	Micro	Oven	Tare Weight	(grams)	74.9	15.7
Tare Plus Wet Soil (grams)	139.6	73.2	Weight of Dry Soil	(grams)	58.9	53
Tare Plus Dry Soil (grams)	133.8	68.7	Moisture Content (K)	(%)	9.9	8.5
Weight of Water (grams)	5.8	4.5				

Calibration Check

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E. / BAC
PROJECT NO: 21907 206050.1
CQA MONITOR: [illegible]
DATE: [illegible]
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill [✓ Subgrade] Subbase Clay Liner Other________

Percent Compaction Required:________ Moisture Content Required:________

Test Location: Process Area Subgrade/Cal. Check
Test No.: Practice #2

FIELD TEST DATA ASTM D 1556

A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.0717
B	Initial Weight of Sand	(LBS)	[illegible]	I	Weight of Wet Soil	(LBS)	8.[illegible]
C	Final Weight of Sand	(LBS)	4.56	J	Wet Density = I/H	(PCF)	119.0
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	10.27	K	Moisture Content	(%)	micro oven 15.4 11.6
E	Volume of Funnel	(CFT)		L	Dry Density = J/(I+K)	(PCF)	103.1 [illegible]
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	95.4 98.7
G	Weight of Sand in Hole = D-F	(LBS)	6.57				

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No.	Wet ~~Dry~~ Density	117.6	(LB/CFT)	Moisture Content	13.7	(%)
Results from above	Wet ~~Dry~~ Density	119.0	(LB/CFT)	Moisture Content	micro / oven 15.4 / 11.6	(%)
Difference +/-		+1.4			+1.7 / -2.1	

LABORATORY DATA

Sample No. 2	Lab Maximum Dry Density (LB/CFT)	108.0
[✓ ASTM D 698] OR D 1557	Optimum Moisture Content (%)	16.5%
Method [✓ A] B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216

					micro	oven
Tare No. AN	micro wave	oven	Tare Weight	(grams)	147.9	11.3
Tare Plus Wet Soil (grams)	247.9	60.09	Weight of Dry Soil	(grams)	86.6	43.7
Tare Plus Dry Soil (grams)	234.5	55.0	Moisture Content (K)	(%)	15.4	11.6
Weight of Water (grams)	13.4	5.09				

Harding Lawson Associates
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SHEET 1 OF 1
JOB NO. 21907
DATE 3/25/97
PROJECT RMA 93-03 TFill
COMPUTED BY RJT
SUBJECT Cone/Plate calibration/ Density Calibration
CHECKED BY BAC

TRIAL	#1	#2	#3	#4	#5	#6	Average
① wt sand cone & jug before test (lb)	13.45	9.75	6.06	14.63	10.93	7.26	
② wt. after test (lb	9.75	6.06	2.36	10.93	7.24	3.55	
③ wt sand used (①-②)	3.70	3.69	3.70	3.70	3.67	3.71	3.70

③ is weight of sand in cone & plate 3.70 lb

	#1	#2	#3	#4	#5	#6	
wt sand & mold	15.30 ~~14.02~~	15.25	15.28	15.29	15.25	15.28	
tare	8.40	8.40	8.40	8.40	8.40	8.40	Average
wt. sand	6.90	6.85	6.88	6.89	6.85	6.88	6.88

~~vol. mol~~

Ave wt. of sand in mold (lb): 6.88
~~&~~ volume of mold (~~pcf~~ ft^3): $1/13.333$ ft^3

Ave. density of sand (lb/ft^3): 91.66 pcf

Harding Lawson Associates
Engineering and
Environmental Services

SHEET 1 OF 1
JOB NO. 21907
DATE 3/26/97
PROJECT RMA 93-03 TEST FILL
SUBJECT CONE #2 / PLATE CALIBRATION
COMPUTED BY RJT
CHECKED BY BAC

TRIAL	#1	#2	#3	#4	#5	#6	#7	AVE
WT. SAND CONE & JUG BEFORE TEST (lb)	14.29	10.51	9.43	5.65	15.23	11.46	7.69	
WT. AFTER TEST (lbs)	10.51	6.72	5.65	1.84	11.46	7.69	3.91	
WT. SAND USED	3.78	3.79	3.78	3.81	3.77	3.77	3.78	3.78

WIEGHT ~~OF~~ SAND IN CONE & PLATE 3.78 lb

Harding Lawson Associates
Daily Log
Soil/moisture Density Gauge
Rocky Mountain Arsenal

Date/Time Out	STD COUNT: ~~Name~~		Date/Time In	Name
	H2O Moisture	wet Density		
3/26/97 - 1700 RST RAG	9932	30501	3/26/97 - 1800	
3/28/97 - 0930 RST MAC	9813	30470	3/28/97 - 1700	
3/31/97 - 0920 RST	9981	30723		
0931 RST	9518 RE TEST	30562	3/31/97 - 1900	
4/1/97 - 0850 RST	9712	30440	4/1/97 - 1800	
4/2/97 - 0900 RST	9871	30437	4/2/97 - 1530	
4/3/97 - 0830 RST	9863	30460	4/3/97 - 1930	
4/4/97 - 0750 RST	9796	30336	4/4/97 - 1300	
~~4/5/97 - 1430~~	~~9570~~ (RST)	~~29586~~	~~4/6/97 - 2000~~	
4/6/97 1145 RST/MKW	9804	30294	4/6/97 - 2000	
4/7/97 0730 RST/MKW	9967	30271	4/7/97 2000	
4/8/97 1000	9923	30265		

Appendix F
COMPACTED CLAY LINER FIELD TEST RESULTS

Compacted Clay Liner

FIELD DENSITY TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

CQA ENGINEER: Brad Coleman, P.E. BAC

CQA MONITOR: RJT

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

LOCATION: Adams County, Colorado

PROJECT NO: 21907 206050.1

DATE: 4/3 & 4/4/97

Test No.	Date	Horizontal Location	Vertical Location	In Situ Values			Proctor Values			Differ. From Opt. Moisture (%)	Percent of Proctor (%)	Pass/Fail	Remarks	# Passes
				Wet Density (PCF)	Dry Density (PCF)	Moisture Content (%)	Curve No.	Max. Dry Density (PCF)	Optimum Moisture (%)					
111	4/3/97	Lane1 2'N℄ 0+75	Lift 1	129.9	111.7	16.3	See Attached Field Acceptable Zone					Pass		4
112	"	Lane1 3'N℄ 1+40	"	131.1	113.2	15.7						Pass		4
121	"	Lane2 on℄ 0+50	"	130.3	112.2	16.1						Pass		6
122	"	Lane2 1'S℄ 1+75	"	129.3	112.5	14.9						Fail		6
131	"	Lane3 2'N℄ 0+35	"	132.5	116.2	14.0						Pass		8
131 (s/c)	"	Sandcone correlation	"	129.0	112.4	14.8						"		8
132	"	Lane3 2'N℄ 1+74	"	126.1	107.5	17.3						"		8
122A	"	Retest #122	"	130.5	113.2	15.3						"	2 more passes done	8
211	"	Lane1 3'N℄ 0+15	Lift 2	130.5	112.2	16.3						"		4
212	"	Lane1 1'N℄ 1+25	"	134.5	115.7	16.2						"		4
221	4/4/97	Lane2 5'S℄ 0+65	"	134.5	118.1	14.0						"		6
221 (s/c)	"	Sandcone correlation	"	135.9	117.2	16.0						"		6
222	"	lane2 4'N℄ 1+68	"	130.4	111.7	16.7						"		6
231	"	lane3 1'S℄ 0+67	"	132.7	113.5	16.9						"		8
232	"	lane3 4'S℄ 1+87	"	132.7	113.9	16.5						"		8
311	"	lane1 1'S℄ 0+30	Lift 3	132.6	113.2	17.1						"		4

℄: centerline of lane

CCL

FIELD DENSITY TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

CQA ENGINEER: Brad Coleman, P.E. BDC

CQA MONITOR: RJT

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

LOCATION: Adams County, Colorado

PROJECT NO: 21907 206050.1

DATE: 4/4 & 4/6/97

Test No.	Date	Horizontal Location	Vertical Location	*In Situ* Values Wet Density (PCF)	Dry Density (PCF)	Moisture Content (%)	Proctor Values Curve No.	Max. Dry Density (PCF)	Optimum Moisture (%)	Differ. From Opt. Moisture (%)	Percent of Proctor (%)	Pass/ Fail	Remarks	No. of Passes
312	4/4/97	Lane1 on ℄ 1+25	Lift 3	135.9	118.3	15.0	see	attached	field	acceptable zone		Pass		4
322	"	Lane2 2'S℄ 2+00	Lift 3	126.5	105.4	20.0						Pass	see note	6
321	"	Lane2 on ℄ 0+53	"	132.1	112.5	17.9						"		6
331	"	Lane3 2'N℄ 0+60	"	132.1	111.7	18.3						"		8
332	"	Lane3 3'N℄ 1+80	"	128.9	106.7	20.8						"		8
411	4/6/97	Lane1 2'L℄ 0+30	Lift 4	130.5	110.3	18.3						"		4
411 (S/C)	"	Sandcone correlation	"	132.7	111.6	18.9						"		4
412	"	lane1 on℄ 1+50	"	131.9	111.2	18.6						"		4
422	"	lane2 1'S℄ 1+80	"	127.4	106.0	20.2						"		6
421	"	lane2 on℄ 0+68	"	129.9	109.4	18.7						"		6
431	"	lane3 3'S℄ 0+85	"	126.3	104.7	20.6						"		8
432	"	lane3 1'S℄ 1+40	"	128.2	107.0	19.8						"		8
511	"	lane1 on℄ 0+48	Lift 5	128.6	109.0	18.0						"		4
512	"	lane1 1'N℄ 1+60	"	126.2	107.7	17.2						"		4
522	"	lane2 4'S℄ 1+77	"	126.4	105.3	20.0						"		6
521	"	lane2 2'N℄ 0+23	"	128.1	108.2	18.4						"		6

Note: ℄ = centerline of lane
No sandcone done on lift 3 due to rainfall

CCL

FIELD DENSITY TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
CQA ENGINEER: Brad Coleman, P.E. BAC
CQA MONITOR: KJT
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

LOCATION: Adams County, Colorado
PROJECT NO: 21907 206050.1
DATE: 4/6&4/7/97

				In Situ Values			Proctor Values							
Test No.	Date	Horizontal Location	Vertical Location	Wet Density (PCF)	Dry Density (PCF)	Moisture Content (%)	Curve No.	Max. Dry Density (PCF)	Optimum Moisture (%)	Differ. From Opt. Moisture (%)	Percent of Proctor (%)	Pass/Fail	Remarks	No. of Passes
532	4/6/97	lane 3 4'N℄ 1+70	Lift 5	131.2	110.1	19.1	See attached field acceptable zone					Pass		8
531	4/6/97	lane 3 1'S℄ 0+60	"	131.4	110.8	18.6						"		8
531 (S/C)	4/6/97	Sandcone correlation	"	129.4	107.5	20.3						"		8
611	4/7/97	lane 1 on ℄ 0+40	Lift 6	125.5	104.6	20.0						"		4
612	"	lane 1 2'S℄ 1+99	"	130.2	111.3	17.0						"		4
622	"	lane 2 1'S℄ 1+50	"	129.9	110.3	17.8						"		6
621	"	lane 2 on ℄ 0+32	"	128.9	110.0	17.2						"		6
621 (S/C)	"	Sandcone correlation	"	127.6	108.3	17.8						"		6
631	"	lane 3 2'N℄ 0+77	"	124.6	105.3	18.3						"		8
632	"	lane 3 1'S℄ 1+55	"	130.3	111.3	17.2						"		8

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction BAC
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: Ruby J. TABACDO
DATE: 4/3/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase [✓ Clay Liner] Other______
Percent Compaction Required: N/A
Moisture Content Required: N/A
Test Location: Lane 1, Lift 3, 2'R of ℄, Sta 0+35 ~~TEST FILL~~
Test No.: 131

FIELD TEST DATA ASTM D 1556

A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.0614
B	Initial Weight of Sand	(LBS)	14.05	I	Weight of Wet Soil	(LBS)	7.82
C	Final Weight of Sand	(LBS)	4.72	J	Wet Density = I/H	(PCF)	12[illegible]
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	9.33	K	Moisture Content	(%)	micro [illegible] / oven 14.8
E	Volume of Funnel	(CFT)		L	Dry Density = J/(1+K)	(PCF)	112.2 / 112.4
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	N/A
G	Weight of Sand in Hole = D-F	(LBS)	5.63				

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No. 131	Wet ~~Dry~~ Density	132.5	(LB/CFT)	Moisture Content	14.0	(%)
Results from above	Wet ~~Dry~~ Density	129.0	(LB/CFT)	Moisture Content	micro 14[illegible] / oven 14.8	(%)
Difference +/-		-3.5			+0.9 / +0.8	

LABORATORY DATA N/A

Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216

					micro	oven
Tare No. D	micro	oven	Tare Weight	(grams)	147.9	7.9
Tare Plus Wet Soil (grams)	247.9	107.9	Weight of Dry Soil	(grams)	87	87.1
Tare Plus Dry Soil (grams)	234.9	95.00	Moisture Content (K)	(%)	14.9	14.8
Weight of Water (grams)	13.0	12.9				

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E. BAC PROJECT NO: 21907 206050.1

CQA MONITOR: Rudy J. [illegible] DATE: 4/4/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase [✓ Clay Liner] Other

Percent Compaction Required: N/A Moisture Content Required: N/A

Test Location: TEST FILL #3 ~~Lane~~, Lift 2, Lane 2, 5'L℄, Sta 0+65 Test No.: 221

FIELD TEST DATA ASTM D 1556								
A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.0585	
B	Initial Weight of Sand	(LBS)	13.71	I	Weight of Wet Soil	(LBS)	7.95	
C	Final Weight of Sand	(LBS)	4.64	J	Wet Density = I/H	(PCF)	135.9	
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	9.07	K	Moisture Content	(%)	micro 16.8	oven 16.0
E	Volume of Funnel	(CFT)		L	Dry Density = J/(1+K)	(PCF)	116.4	117.2
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	N/A	
G	Weight of Sand in Hole = D-F	(LBS)	5.37					

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017							
Test No. 221	Wet ~~Dry~~ Density	134.5	(LB/CFT)	Moisture Content	14.0		(%)
Results from above	Wet ~~Dry~~ Density	135.9	(LB/CFT)	Moisture Content	micro 16.8	oven 16.0	(%)
Difference +/-		+ 1.4			+2.8	+2.0	

LABORATORY DATA		
Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216							
						micro	oven
Tare No. A		micro	oven	Tare Weight	(grams)	147.9	8.1
Tare Plus Wet Soil	(grams)	247.9	[illegible]	Weight of Dry Soil	(grams)	85.6	86.2
Tare Plus Dry Soil	(grams)	233.5	[illegible]3	Moisture Content (K)	(%)	16.8	16.0
Weight of Water	(grams)	14.4	13.8				

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E. BRC PROJECT NO: 21907 206050.1
CQA MONITOR: Rory J. Tarado DATE: 4/6/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase [✓ Clay Liner] Other
Percent Compaction Required: N/A Moisture Content Required: N/A
Test Location: ~~Test Fill #3~~ Lift 4, Lane 1, 2'L℄, Sta 0+30 Test No.: T 11

FIELD TEST DATA ASTM D 1556							
A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.07353
B	Initial Weight of Sand	(LBS)	14.79	I	Weight of Wet Soil	(LBS)	10.51
C	Final Weight of Sand	(LBS)	4.35	J	Wet Density = I/H	(PCF)	132.7
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	10.44	K	Moisture Content	(%)	oven 18.9 / micr 18.5
E	Volume of Funnel	(CFT)	—	L	Dry Density = J/(I+K)	(PCF)	112.0
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	N/A
G	Weight of Sand in Hole = D-F	(LBS)	6.74				

Tare - 1.47

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017						
Test No.	Wet ~~Dry~~ Density	130.5	(LB/CFT)	Moisture Content	18.6	(%)
Results from above	Wet ~~Dry~~ Density	132.7	(LB/CFT)	Moisture Content	Micro 18.5 / oven 18.9	(%)
Difference +/-		+2.2			-0.1 / +0.3	

LABORATORY DATA		
Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216	oven	micro		oven	Micro
Tare No.	ATW		Tare Weight (grams)	8.10	74.9
Tare Plus Wet Soil (grams)	193.8	197.4	Weight of Dry Soil (grams)	156.2	103
Tare Plus Dry Soil (grams)	164.3 ~~148.2~~	178.2	Moisture Content (K) (%)	18.9	18.5
Weight of Water (grams)	29.5	19.2			

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction
LOCATION: Adams County, Colorado
CQA ENGINEER: Brad Coleman, P.E.
PROJECT NO: 21907 206050.1
CQA MONITOR: Rum 3. TABAUO
DATE: 4/6/97
OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase [✓ Clay Liner] Other
Percent Compaction Required: N/A
Moisture Content Required: N/A
Test Location: ~~Test Fill # 3~~ Lift 5 Lane 3 Sta 0+40 on ℄
Test No.: 531

FIELD TEST DATA ASTM D 1556								
A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.08521
B	Initial Weight of Sand	(LBS)	14.86	I	Weight of Wet Soil	(LBS)	11.07
C	Final Weight of Sand	(LBS)	3.35	J	Wet Density = I/H	(PCF)	129.3
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	11.51	K	Moisture Content	(%)	20.3 / micr 19.5
E	Volume of Funnel	(CFT)	—	L	Dry Density = J/(I+K)	(PCF)/	108.2
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	N/A
G	Weight of Sand in Hole = D-F	(LBS)	7.81				

Tare 1.67

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017						
Test No.	~~Dry~~ Wet Density	131.4	(LB/CFT)	Moisture Content	18.3	(%)
Results from above	~~Dry~~ Wet Density	129.4	(LB/CFT)	Moisture Content	micro 19.5 / oven 20.3	(%)
Difference +/-		-2.0			+1.2 / +2.0	

LABORATORY DATA		
Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

		oven	micro			oven
LABORATORY MOISTURE CONTENT ASTM D 2216						
Tare No.		F-TW		Tare Weight	(grams)	7.9
Tare Plus Wet Soil	(grams)	196.9	2264	Weight of Dry Soil	(grams)	157.1
Tare Plus Dry Soil	(grams)	165.0	2040	Moisture Content (K)	(%)	20.3
Weight of Water	(grams)	31.9	248			

FIELD SAND CONE TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E. BAC

PROJECT NO: 21907 206050.1

CQA MONITOR: Rudy J. TABACCO

DATE: 4/7/97

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase Clay Liner Other

Percent Compaction Required:

Moisture Content Required:

Test Location: Test Fill # 3 Lane 2 Lift one Sta 0+25

Test No.: 621

FIELD TEST DATA ASTM D 1556

A	Density of Sand	(PCF)	91.66	H	Volume of Hole = G/A	(CFT	.0479
B	Initial Weight of Sand	(LBS)	14.81	I	Weight of Wet Soil	(LBS)	6.11
C	Final Weight of Sand	(LBS)	6.72	J	Wet Density = I/H	(PCF)	127.6
D	Wt of Sand in Funnel & Hole = B-C	(LBS)	8.09	K	Moisture Content	(%)	Oven 17.8 / micro 19.4
E	Volume of Funnel	(CFT)		L	Dry Density = J/(I+K)	(PCF)	108.3 / 106.9
F	Weight of Sand in Funnel = A x E	(LBS)	3.70		Percent Compaction	(%)	
G	Weight of Sand in Hole = D-F	(LBS)	4.39				

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No.	~~Dry~~ Wet Density	128.9	(LB/CFT)	Moisture Content	17.2	(%)
Results from above	~~Dry~~ Wet Density	127.6	(LB/CFT)	Moisture Content	oven 17.8 / micro 19.4	(%)
Difference +/-		-1.3			+0.6 / +2.2	

LABORATORY DATA

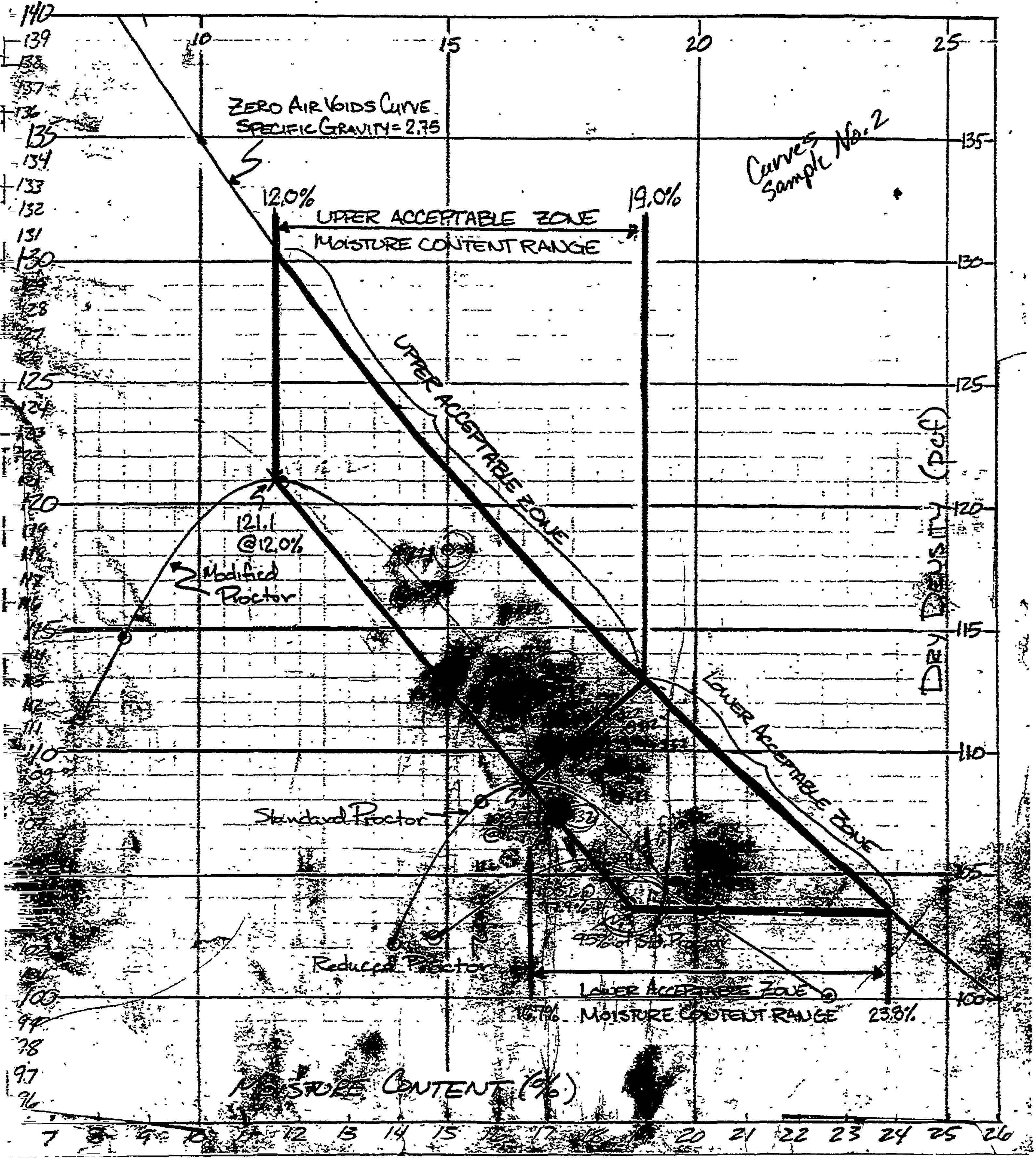
Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216

Tare No.		oven #1 / micro	Tare Weight	(grams)	oven 74.6 / micro 74.9
Tare Plus Wet Soil	(grams)	301.1 / 217.7	Weight of Dry Soil	(grams)	192.3 / 119.6
Tare Plus Dry Soil	(grams)	266.9 / 194.5	Moisture Content (K)	(%)	17.8 / 19.4
Weight of Water	(grams)	34.2 / 23.2			

Harding Lawson Associates
Engineering and
Environmental Services

SHEET 1 OF 1
JOB NO. 21907.206050.1
DATE 4/2/97
PROJECT RMA93-03
SUBJECT TEST FILL #3 ACCEPTABLE ZONE
COMPUTED BY BAC
CHECKED BY



LABORATORY COMPACTION TEST

JOB RMA Test Fill 3 SAMPLE NO. 2
SOIL TYPE CL DATE 4/1/97 BY BAC
SOIL DESCRIPTION light brown - brown sandy lean clay
SOURCE composite process table sample

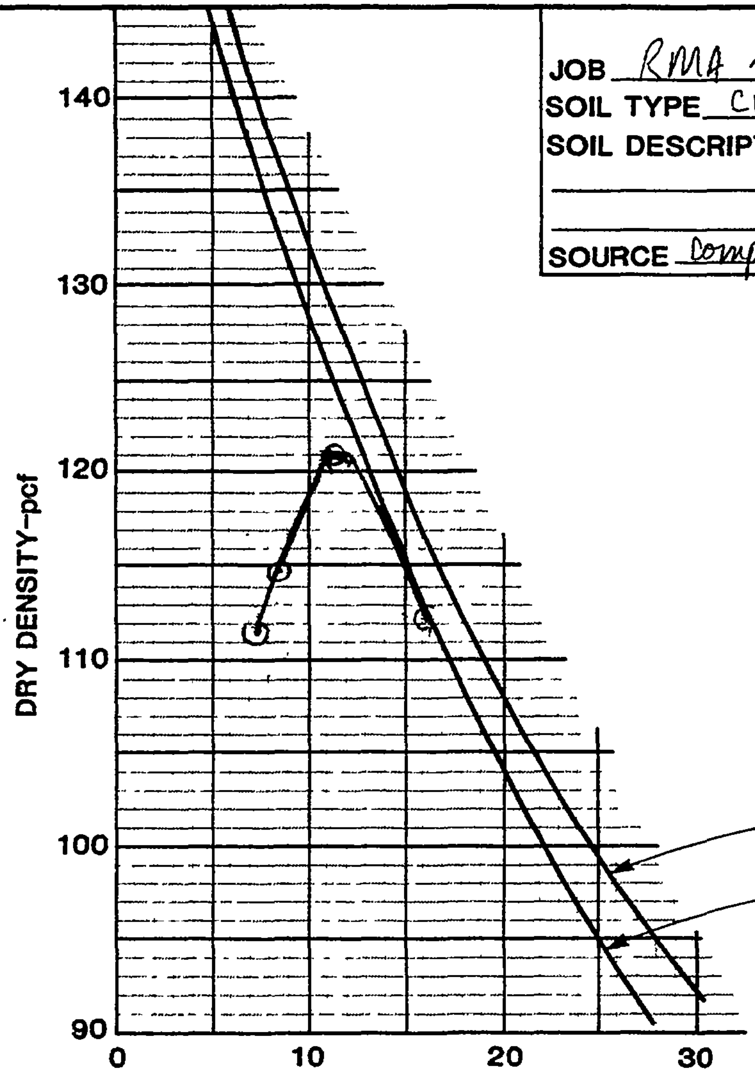
☒ ASTM D1557-78 (A) Modified Proctor

☐ California 216 F

☐ Other (specify)

MAXIMUM DRY DENSITY 121.1 PCF

OPTIMUM MOISTURE CONTENT 12.0 %



⊙ Laboratory Compaction Point

▲ Field Check Point

100% Saturation (G_S = 2.68)

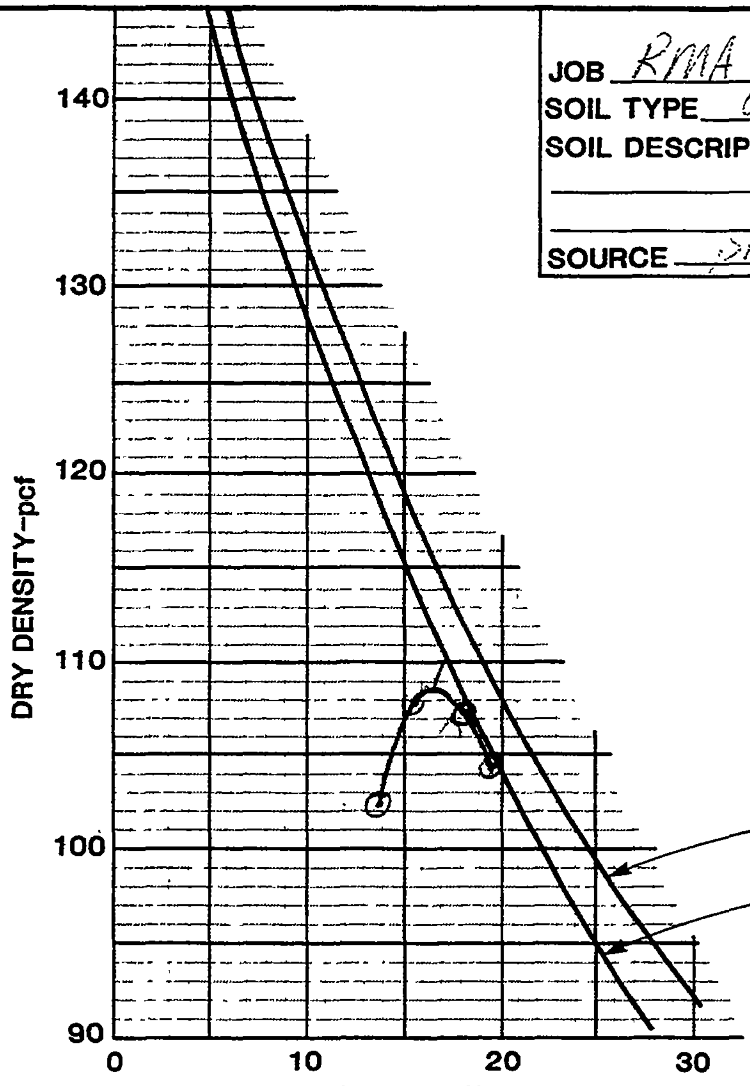
90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

	+0 1		+2 of 2 dry back		+4 3		Dry back 4		5	6
MOLD AND WET SOIL	13.96		13.61		13.82		13.46			
MOLD	9.46		9.46		9.46		9.46			
WET SOIL	4.50		4.15		~~13.82~~ 4.36		4.00			
FACTOR* 4"Φ / 6"Φ	.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294	.0662 / .0294
WET DENSITY	135.0		124.6		130.8		120.0			
PAN NO.	micro	oven F	micro	oven #2	micro	oven #1	micro	oven A		
PAN AND WET SOIL	294.3	258.4	379.4	562.5	337.5	428.7	403.1	409.1		
PAN AND DRY SOIL	277.7	232.3	357.4	528.4	308.9	379.1	382.7	380.7		
MOISTURE LOSS	16.6	26.1	22.0	34.1	28.6	49.6	20.4	28.4		
PAN TARE	147.9	8.1	147.9	127.7	147.9	74.3	147.9	8.1		
DRY SOIL	129.8	224.2	209.5	400.7	161.0	304.8	235.8	372.6		
MOISTURE CONTENT	12.8	11.6	10.5	8.5	17.8	16.3	8.7	7.6		
DRY DENSITY	119.7	121.0	112.8	114.8	111.0	112.5	110.4	111.5		

HARDING LAWSON & ASSOCIATES

LABORATORY COMPACTION TEST



JOB RMA Test Fill 3 **SAMPLE NO.** 2
SOIL TYPE CL **DATE** 4/1/97 **BY** RGC
SOIL DESCRIPTION lt. brown [illegible] sandy lean clay
SOURCE [illegible]

☐ ASTM D1557-78 ( )

☐ California 216 F

☒ Other (specify) [illegible]

STANDARD PROCTOR

MAXIMUM DRY DENSITY 108.7 **PCF**

OPTIMUM MOISTURE CONTENT 16.7 **%**

⊙ Laboratory Compaction Point

△ Field Check Point

100% Saturation ($G_S = 2.68$)

90% Saturation ($G_S = 2.68$)

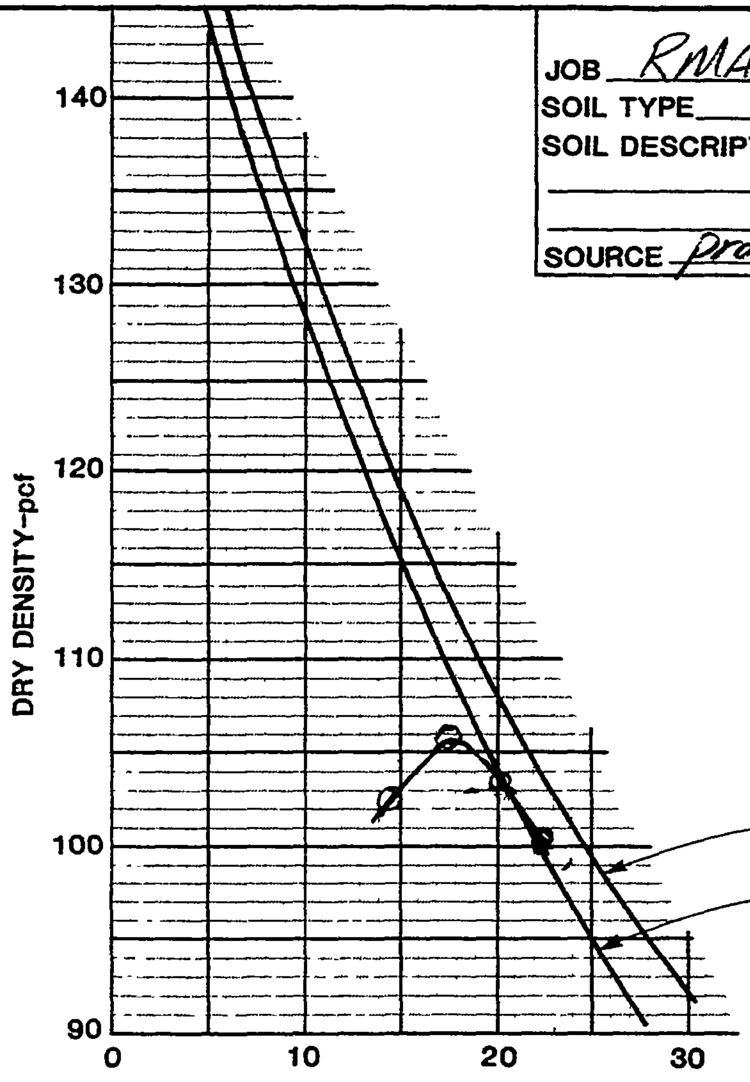
(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

RELATIVE MOISTURE CONTENT %

	+0 1		+2 2		+4 3		+6 4		5	6
MOLD AND WET SOIL	13.34		13.62		13.69		13.61			
MOLD	9.46		9.46		9.46		9.46			
WET SOIL	3.88		4.16		4.23		4.15			
FACTOR* 4"Φ / 6"Φ	.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294	.0662 / .0294
WET DENSITY	116.4		124.5		126.9		124.5			
PAN NO.		55		E		D		1		
PAN AND WET SOIL	312.2	656.7	324.6	[illegible]	345.3	346.9	352.7	538.8		
PAN AND DRY SOIL	304.7	600.6	299.8	313.5	315.1	295.0	317.4	471.1		
MOISTURE LOSS	7.5	56.1	24.8	47.7	30.2	51.9	35.3	67.7		
PAN TARE	147.9	195.7	147.9	[illegible]	147.9	7.9	147.9	123.3		
DRY SOIL	56.8	404.9	151.9	305.5	167.2	287.1	168.5	347.8		
MOISTURE CONTENT	13.2	13.9	16.3	15.6	18.1	18.1	20.8	19.5		
DRY DENSITY	102.8	102.2	107.3	108.0	107.5	107.5	103.0	104.2		

HARDING LAWSON & ASSOCIATES

LABORATORY COMPACTION TEST



JOB RMA Test Fill 3 SAMPLE NO. 2
SOIL TYPE CL DATE 4/1/97 BY BAC
SOIL DESCRIPTION lt brown - brown sand. lean clay
SOURCE process area

Reduced Proctor

☐ ASTM D1557–78 ( )

☐ California 216 F

☒ Other (specify) Reduced D698 ([illegible])

MAXIMUM DRY DENSITY 105.6 PC

OPTIMUM MOISTURE CONTENT 17.9 %

⊙ Laboratory Compaction Point

▲ Field Check Point

100% Saturation (G_S = 2.68)

90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

	+4 1		+6 2		+8 3		+2 4		5	6
MOLD AND WET SOIL	13.61		13.60		13.55		13.38			
MOLD	9.46		9.46		9.46		9.46			
WET SOIL	4.15		4.14		4.09		3.92			
FACTOR* 4"Φ / 6"Φ	.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294	.0662 / .0294
WET DENSITY	124.5		124.2		122.7		117.6			
PAN NO.	micro	oven S-1	micro	oven B	micro	oven C	micro	oven S-4		
PAN AND WET SOIL	347.1	671.6	361.3	399.8	349.3	371.6	363.8	636.1		
PAN AND DRY SOIL	315.5	599.6	324.5	334.2	311.0	304.6	334.2	579.4		
MOISTURE LOSS	31.6	72.0	36.8	65.6	38.3	67.0	29.6	56.7		
PAN TARE	147.9	196.4	147.9	8.1	147.9	8.1	147.9	193.5		
DRY SOIL	167.6	403.2	176.6	326.1	163.1	296.5	186.3	385.9		
MOISTURE CONTENT	18.9	17.9	20.8	20.1	23.5	22.6	15.9	14.7		
DRY DENSITY	104.7	105.6	102.8	103.4	99.4	100.1	101.5	102.5		

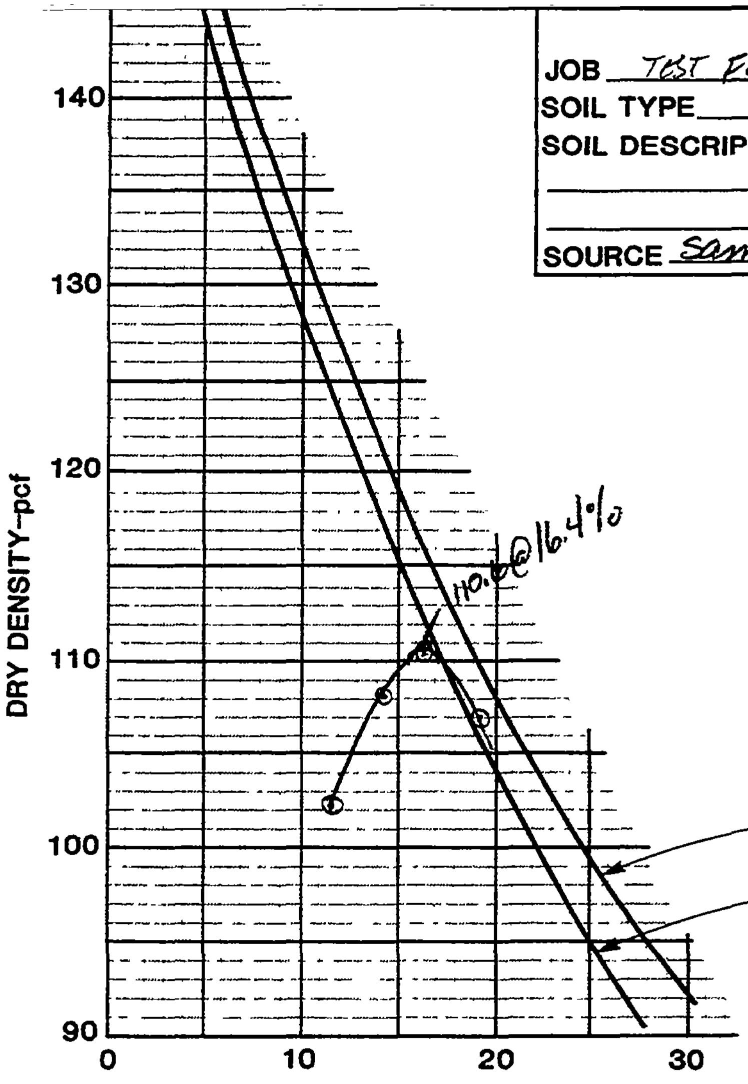
HARDING LAWSON & ASSOCIATES

Check Proctor

LABORATORY COMPACTION TEST

JOB TEST FILL CONST. #3 NO. #3
SOIL TYPE CLAY DATE 4/~~[illegible]~~/97 BY LST/asKa
SOIL DESCRIPTION Sandy lean clay

SOURCE sampled from Lifts 6 & 7



☐ ASTM D1557–78 ( )

Standard Proctor

☐ California 216 F

☒ Other (specify) ASTM D698 (Std)

MAXIMUM DRY DENSITY 110.6 PCF

OPTIMUM MOISTURE CONTENT 16.4 %

⊙ Laboratory Compaction Point

△ Field Check Point

100% Saturation (G_S = 2.68)

90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

	1 4%	2 6%	3 8%	4 10%	5	6
MOLD AND WET SOIL	13.27	13.58	13.75	13.71		
MOLD	9.46	9.46	9.46	9.46		
WET SOIL	3.81	4.12	4.29	4.25		
FACTOR* 4"ϕ / 6"ϕ 30	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294
WET DENSITY	114.3	123.6	128.7	127.5		
PAN NO.	A	F	D	B		
PAN AND WET SOIL	108.1	108.1	107.9	108.1		
PAN AND DRY SOIL	97.6	95.6	93.8	92.0		
MOISTURE LOSS	10.5	12.5	14.1	16.1		
PAN TARE	8.1	8.1	7.9	8.1		
DRY SOIL	89.5	87.5	85.9	83.9		
MOISTURE CONTENT	11.7	14.3	16.4	19.2		
DRY DENSITY	102.3	108.1	110.6	107.0		

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#1 74.3 tare
255.8 dry & tare

Nuclear - oven - micro moisture content check - no sandcone done BAC

MOISTURE CONTENT
~~FIELD SAND CONE~~ TEST LOG

PROJECT: RMA 93-03 Test Fill 3 Construction

LOCATION: Adams County, Colorado

CQA ENGINEER: Brad Coleman, P.E. BAC

PROJECT NO: 21907 206050.1

CQA MONITOR: Rudy J. [illegible]

DATE: 3/2897

OWNER/CLIENT: Program Manager Rocky Mountain Arsenal Remediation

Material Type: (circle one) Fill Subgrade Subbase [✓ Clay Liner] insitu borrow soil Other

Percent Compaction Required: N/A

Moisture Content Required: N/A

Test Location: BORROW AREA

Test No.: ~~[illegible]~~ 3

FIELD TEST DATA ASTM D 1556

A	Density of Sand (PCF)		H	Volume of Hole = G/A (CFT	
B	Initial Weight of Sand (LBS)		I	Weight of Wet Soil (LBS)	
C	Final Weight of Sand (LBS)		J	Wet Density = I/H (PCF)	
D	Wt of Sand in Funnel & Hole = B-C (LBS)		K	Moisture Content (%)	
E	Volume of Funnel (CFT)		L	Dry Density = J/(1+K) (PCF)	
F	Weight of Sand in Funnel = A x E (LBS)			Percent Compaction (%)	
G	Weight of Sand in Hole = D-F (LBS)				

COMPARISON WITH NUCLEAR METHODS ASTM D 2922 AND D 3017

Test No.	3	Dry Density	94.5	(LB/CFT)	Moisture Content	14.6		(%)
Results from above		Dry Density		(LB/CFT)	Moisture Content	MICRO 16.8	OVEN 14.3	(%)
Difference +/-						+2.2	-0.3	

LABORATORY DATA

Sample No.	Lab Maximum Dry Density (LB/CFT)	
ASTM D 698 OR D 1557	Optimum Moisture Content (%)	
Method A B C D		

LABORATORY MOISTURE CONTENT ASTM D 2216

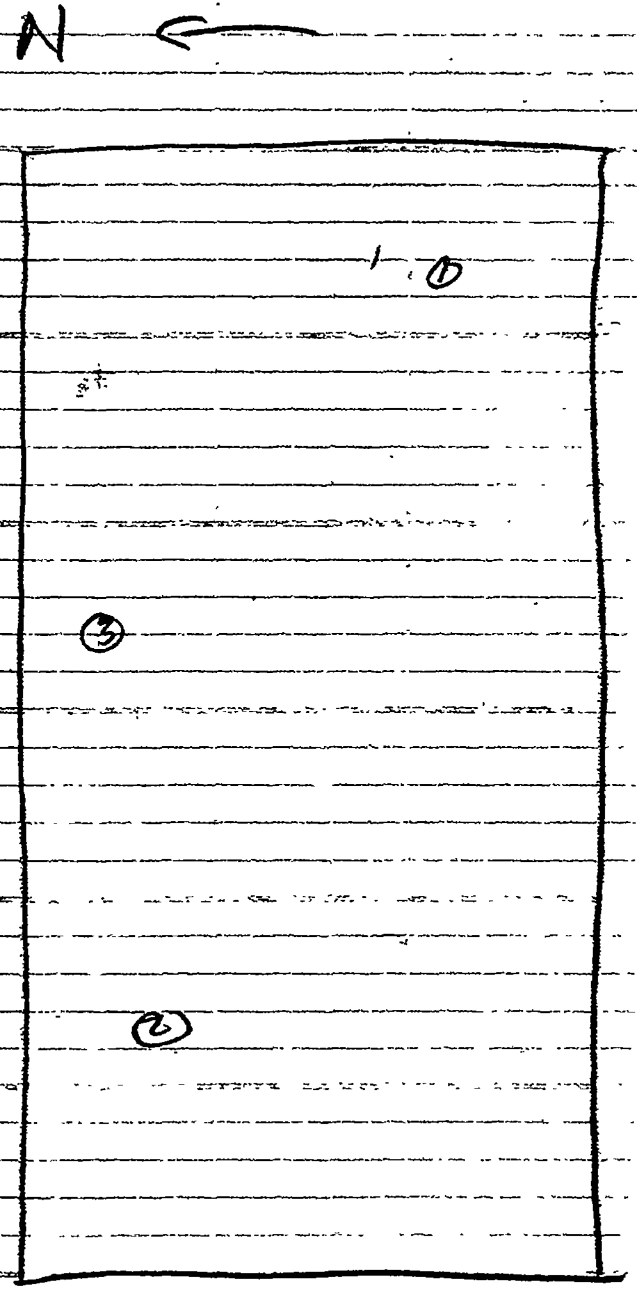
	MICRO	OVEN		MICRO	OVEN
Tare No. A			Tare Weight (grams)	147.9	8.1
Tare Plus Wet Soil (grams)	207.5	108.1	Weight of Dry Soil (grams)	51	875
Tare Plus Dry Soil (grams)	198.9	95.6	Moisture Content (K) (%)	16.8	14.3
Weight of Water (grams)	8.6	12.5			

Harding Lawson Associates
Engineering and
Environmental Services

SHEET 1 OF 1
JOB NO. 21907, 2060101
DATE 3/28/97
COMPUTED BY
CHECKED BY R.J. TABALDO EAG

PROJECT TEST FILL #3
SUBJECT SOIL PROCESSING AREA
Moisture Content Control testing

OPT = 16.6



1510 ① BS = 12.7% MOIST.

1515 ② BS = 13.2% MOIST.

1520 H_2O TRUCK MAKES 1 MORE PASS, GRAB MOISTURE SAMPLES FROM TEST SPOTS 1 & 2

1525 STABILIZER STARTS MAKING PASS OVER SOIL. ALREADY 4 PASSES

1530 ③ BS = 11.6%

1540 H_2O TRUCK MAKES 1 MORE PASS ~~AND~~ STABILIZER MAKES ONE MORE PASS, DOZER TOOK SOUTH HALF OF PROCESS SOIL BEFORE STABILIZER COULD MAKE THE 5 PASS.

1550 BS = 13.15% MOIST

1600 WILL STORE SOIL UP

Note:
BS = nuclear test in backscatter mode

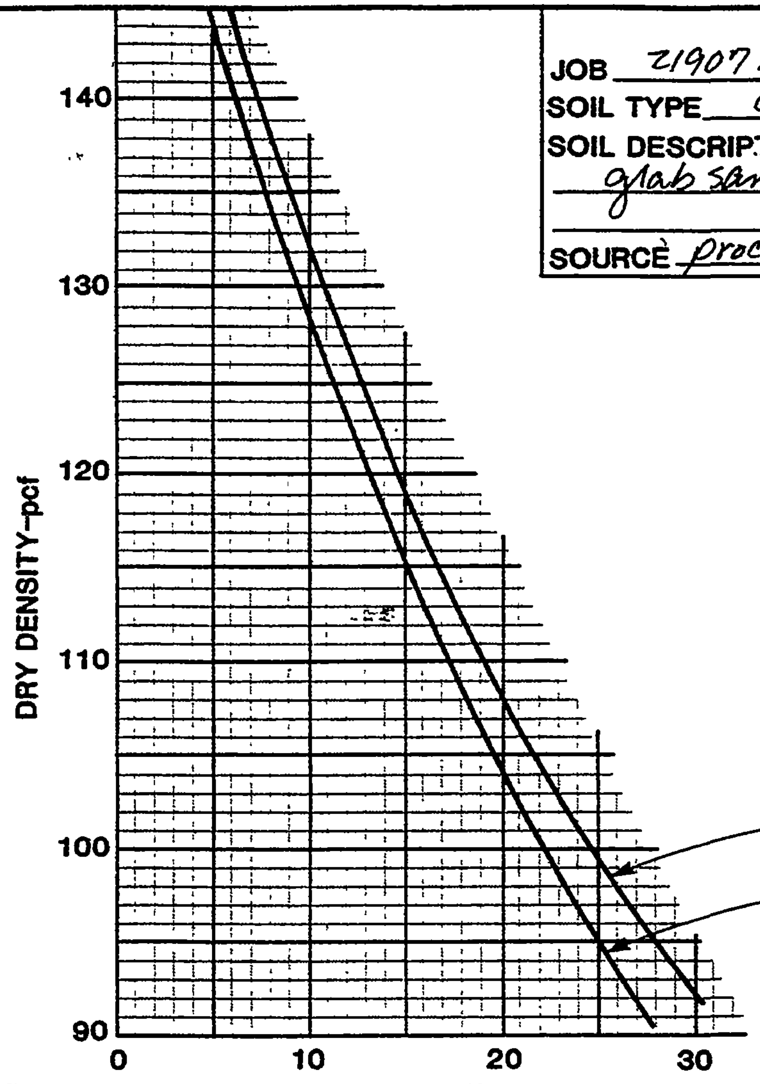
LABORATORY COMPACTION TEST

JOB 21907. 206850.1 3/28d NO. (BAC)

SOIL TYPE CL DATE 3/31 BY RJT

SOIL DESCRIPTION clay material moisture content grab samples

SOURCE process area



☐ ASTM D1557-78 ( )

☐ California 216 F

☐ Other (specify) ____________

MAXIMUM DRY DENSITY ____________ PCF

OPTIMUM MOISTURE CONTENT ________ %

⊙ Laboratory Compaction Point

▲ Field Check Point

100% Saturation (G_S = 2.68)

90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

	1	2	3	4	5	6
MOLD AND WET SOIL						
MOLD						
WET SOIL						
FACTOR* 4"ϕ / 6"ϕ	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294
WET DENSITY	3/28/97	3/28/97	3/31/97			
PAN NO.	B oven	C oven	oven F micro			
PAN AND WET SOIL	108.1	108.1	108.1 174.9			
PAN AND DRY SOIL	96.6	98.6	96.6 162.5			
MOISTURE LOSS	11.5	9.5	11.5 12.4			
PAN TARE	8.1	8.1	8.1 74.9			
DRY SOIL	88.5	90.5	88.5 87.6			
oven MOISTURE CONTENT	13.9	10.5	12.9 14.1			
~~DRY DENSITY~~ nuclear moisture	12.7	13.2	N/A			

HARDING LAWSON & ASSOCIATES

Harding Lawson Associates
Engineering and
Environmental Services

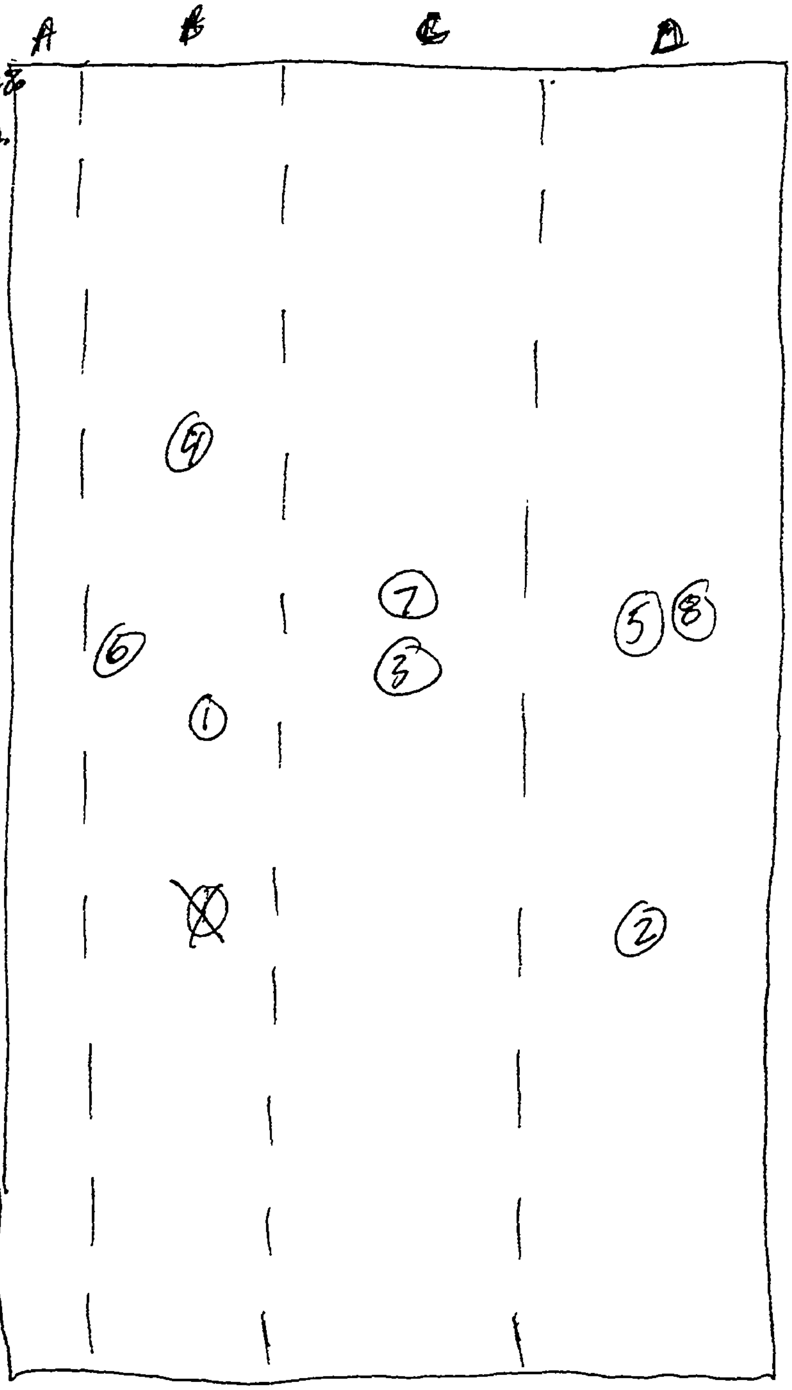
SHEET 1 OF 1
JOB NO. 21907, 206050.1
DATE 3/31/97
PROJECT TG 113
COMPUTED BY R.J. TABACCO
SUBJECT PROCESS AREA MOISTURE CONTROL
CHECKED BY BAC

LIFTS = APPROX. 1'

[illegible]15 ⑥ BS= 10.22%
GRAB MOIST SAMP.

[illegible]25 ⑦ BS= 11.26
GRAB MOIST. SAMP

1830 ⑧ BS = 8.14
GRAB MOIST SAMP.



BS= back scatter nuclear test

1035 PA ① GRAB MOISTURE SAMPLE

1040 PA ② GRAB MOISTURE MOISTURE

1045 STRIP B HAD 3 PASSES BY STAB. STRIP D HAD 2 PASSES BY STAB, STRIP C DOWN BUT NO PASSES YET. H_2O TRUCK MAKES 2 PASSES OVER BCD

1050 SCRAPER LAYING DOWN STRIP A.

1100 H_2O TRUCK 1 MORE PASS OVER BCD & A DOZER, GRADER & STAB NOW PROCESSING SOIL

1130 GRAB MOISTURE SAMPLE PA ③ MICROWAVE = 14.1%

1355 ④ BS = 16.26

1405 H_2O TRUCK 1 PASS A&B

1410 SCRAPER BEGIN MOVE SOIL OVER FROM BORROW PIT TO C&D, SCRAPERS 1ST LIFT, NOW WORK ON 2ND.

1450 H_2O TRUCK 2 PASSES AGAIN C&D, START STAB.

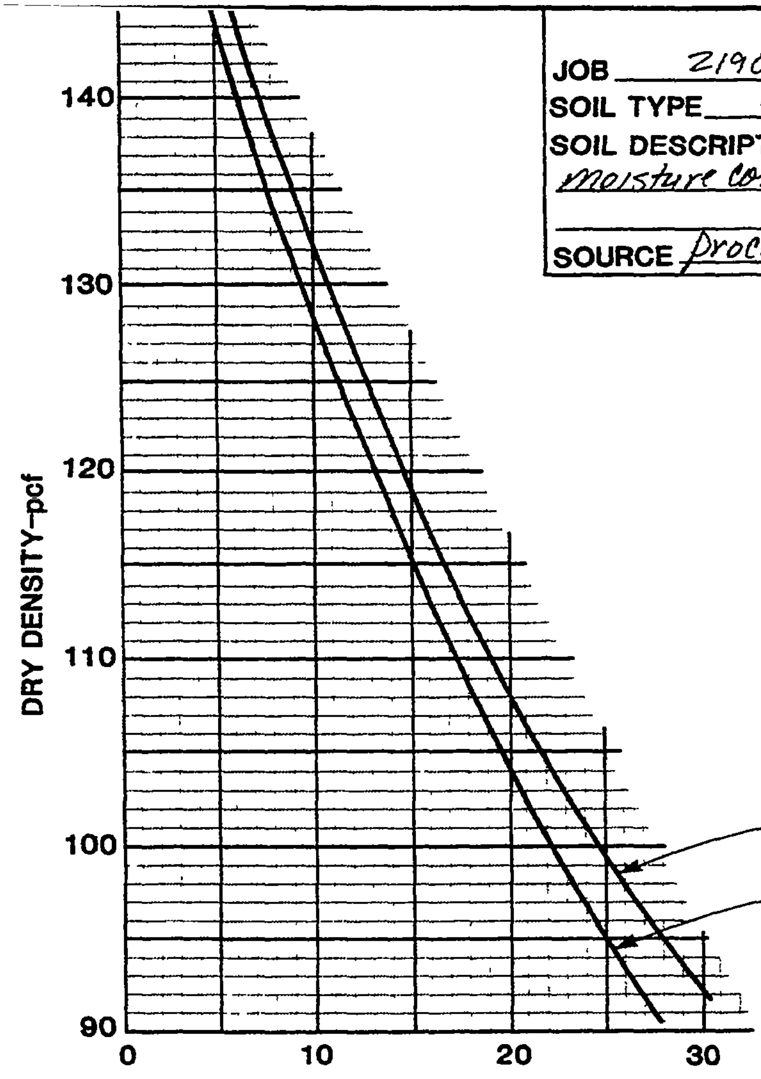
1500 H_2O TRUCK 2 PASSES AGAIN OVER A&B

1600 H_2O TRUCK 2 PASSES AGAIN OVER C&D & AB, STAB 1 PASS OVER C&D [illegible] AB

1620 GRADER MAKES PASS OVER CD

1630 BS = 11.82% ⑤

LABORATORY COMPACTION TEST



JOB 21907 206050.1 NO.
SOIL TYPE CL DATE 4/1/97 BY RJT (BA
SOIL DESCRIPTION clay process material –
moisture content grab samples

SOURCE process area

☐ ASTM D1557-78 ( )

☐ California 216 F

☐ Other (specify) ______

MAXIMUM DRY DENSITY ______ PC

OPTIMUM MOISTURE CONTENT ______ %

⊙ Laboratory Compaction Point

△ Field Check Point

100% Saturation (G_S = 2.68)

90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

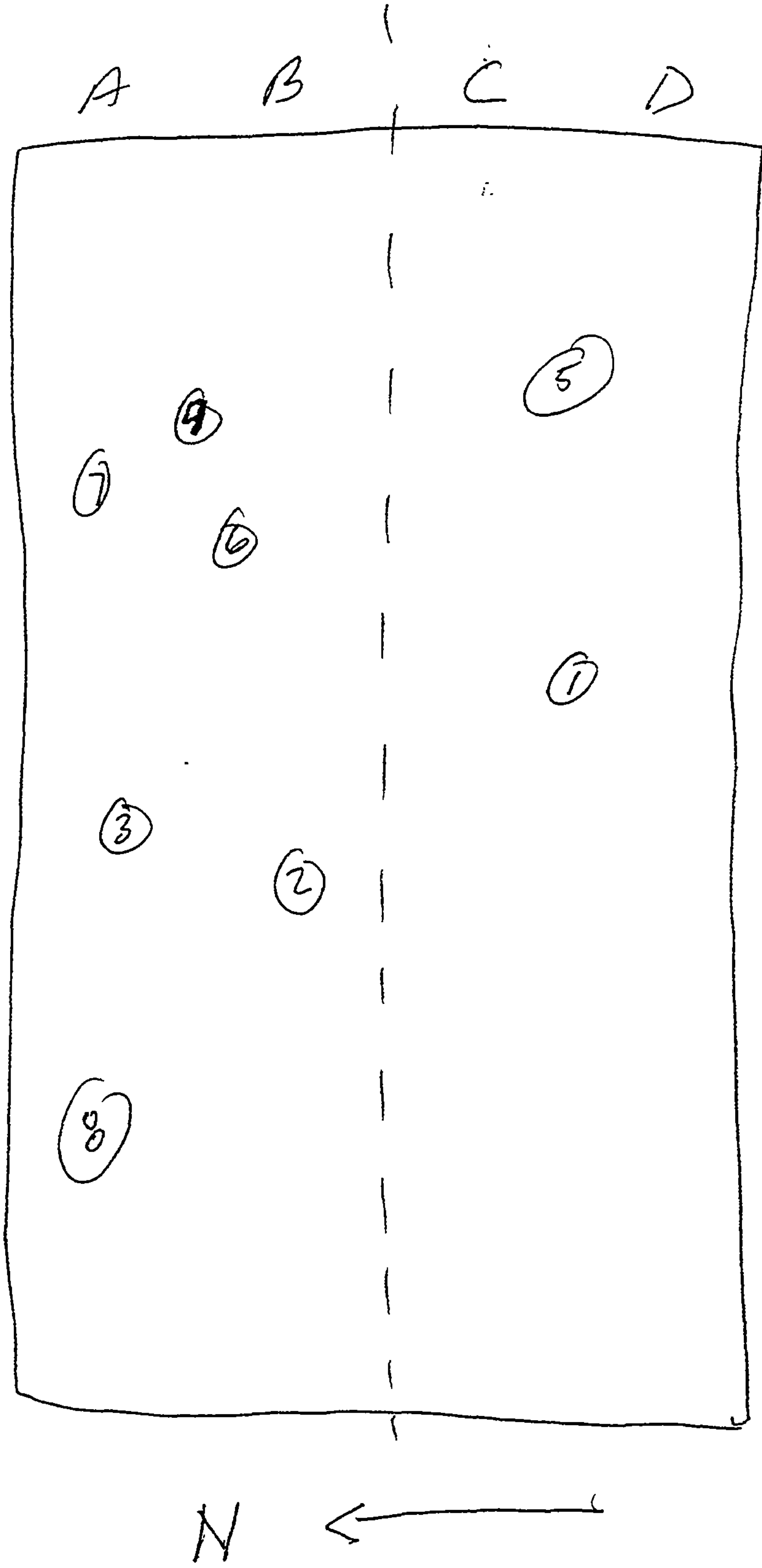
	1		2		3		4	5	6
MOLD AND WET SOIL									
MOLD	MOISTURE SAMPLE of PROCESS MATERIAL								
WET SOIL									
FACTOR* 4"Φ / 6"Φ	.0662 / .0294		.0662 / .0294		.0662 / .0294		.0662 / .0294	.0662 / .0294	.0662 / .0294
WET DENSITY	micro	oven	micro	oven	micro	oven	micro 4/1/97		
PAN NO.	E	⑥	A	⑦	D	⑧	① 1010		
PAN AND WET SOIL	247.9	108.2	247.9	108.1	174.9	107.9	247.9		
PAN AND DRY SOIL	237.2	98.7	237.2	97.3	166.6	100.8	235.6		
MOISTURE LOSS	10.7	9.5	10.7	10.8	8.3	7.1	12.3		
PAN TARE	147.9	8.2	147.9	8.1	74.9	7.9	147.9		
DRY SOIL	89.3	90.5	89.3	89.2	91.7	92.9	82.7		
MOISTURE CONTENT	11.98	10.49	11.9	12.1	9.0	7.6	14.0		
DRY DENSITY									

Ave = 10.22 Ave = 11.26 Ave = 8.14 Ave 14.9

HARDING LAWSON & ASSOCIATES

Harding Lawson Associates
Engineering and
Environmental Services

SHEET ~~[illegible]~~ 1 OF ~~[illegible]~~ 1
JOB NO. 21907,200650.1
DATE 4/1/97
PROJECT
COMPUTED BY R.J. TABALAO
CHECKED BY BAC
SUBJECT Process Area. Moisture Control



0800 STABILIZER MAKES PASS OVER SECOND ~~[illegible]~~ PROCESS AREA. C

0845 H2O TRUCK MAKES 1 PASS OV C & D

0945 STAB. & H2O TRUCK MAKES PASS OVER PROCESS AREA TOGETHE

1010 ① BS = 14.9 %, GRAB MOIST. SA

1125 STAB. & H2O TRUCK MAKES PASS OVER B & A

1415 ② BS = 13.8%

1420 ③ BS = 12.74%

1425 ④ BS = 13.64

1500 ⑤ NUC TEST 6"
DENS = 104.7, MOIST = 13.71
COMPACTOR MADE 8 PASSES OVER ⑤ SPOT BEFORE TEST.

1515 SCRAPER WILL BRING ANOTHER LIFT ON C & D AFTER COMP. C & D STAB & H2O MAKE 1 MORE PASS OVER A & B.

1605 ⑥ BS = 19.28

1644 ⑦ BS = 15.49

1647 ⑧ BS = 17.02

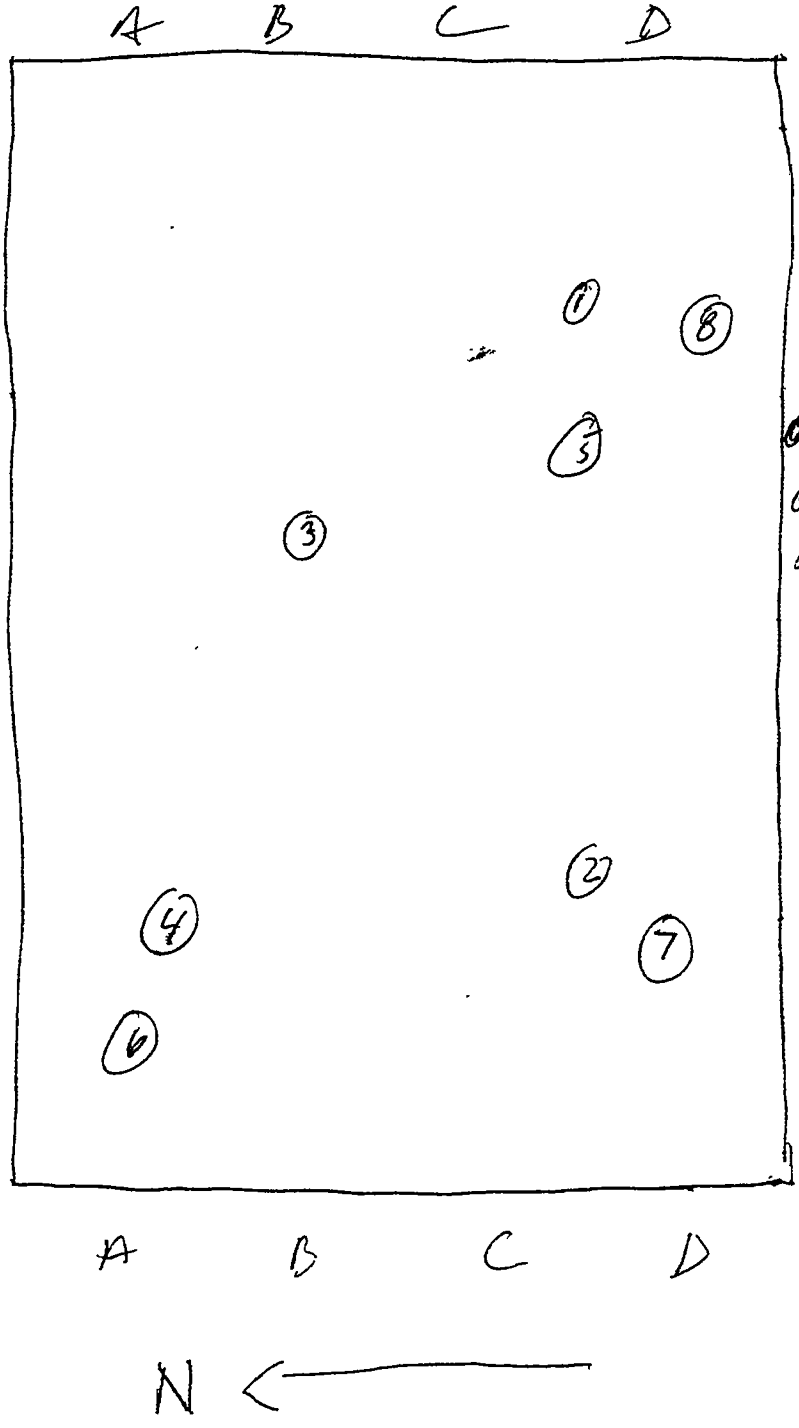
1650 SCRAPER WILL COME OFF AB CD

BS = backscatter test

Harding Lawson Associates
Engineering and
Environmental Services

SHEET 1 OF 1
JOB NO. 21907, 206050.1
DATE 4/2/97
PROJECT TEST FILL #3
COMPUTED BY ~~4/2/97~~ R.J. THOMAS
SUBJECT PROCESS AREA. Moisture Control
CHECKED BY BAC

APPROX 10" LIFTS



0800 SCRAPER BEGINS MOVING CLAY OVER FROM BORROW PIT TO AB. STABILIZER MAKES ONE PASS OVER CD.

0845 H2O TRUCK & STAB. MAKE 1 PASS OVER CD TOGETHER

0915 STAB. MAKES PASS OVER B & A

① BS = 18.45%

0920 ② BS = 17.7 %

0922 ③ BS = 13.69%

0935 STAB. & H2O TRUCK MAKE 1 PASS OVER AB

1145 SCRAPER BEGINS MOVING CLAY FROM BORROW PIT TO CD

1200 ④ BS = 13.78%

STAB. MAKES 1 PASS OVER CD.

1330 STAB & H2O TRUCK MAKE 1 PASS OVER ~~SOUTH~~ WEST ONE OF AB. COMPACTOR PASSES OVER E

1335 ⑤ BS = 10.83%

1400 ⑥ BS = 15.96%

COMPACTOR MAKES PASSES OVER W ENDS OF AB NOW

1420 STAB. & H2O TRUCK MAKES 1 PASS OVER CD, STARTING FROM C

1440 ⑦ BS = 15.54%

1450 ⑧ BS = 15.05%

1560 COMPACTOR STARTS COMPACTING CD. SCRAPER SEALING OFF AB THEN WILL MOVE OVER TO CD AND SEAL.

BS = backscatter test

LABORATORY COMPACTION TEST

JOB 21907 206050.1 NO.

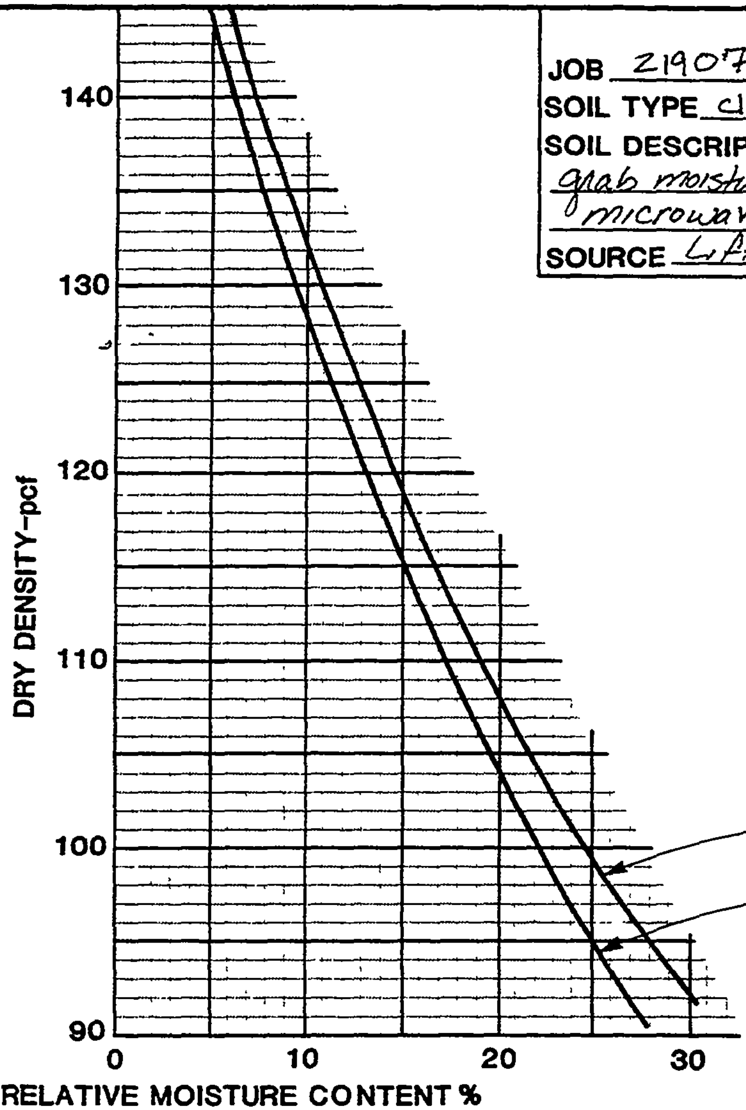
SOIL TYPE clay DATE 4/3/97 BY RJT BAC

SOIL DESCRIPTION sandy lean clay

grab moisture samples from clay placed for Lifts 1 & 2

microwave moisture content tests

SOURCE Lifts 1 & 2 (before compaction)



☐ ASTM D1557–78 ( )

☐ California 216 F

☐ Other (specify)

MAXIMUM DRY DENSITY PCF

OPTIMUM MOISTURE CONTENT %

⊙ Laboratory Compaction Point

△ Field Check Point

100% Saturation (G_S = 2.68)

90% Saturation (G_S = 2.68)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

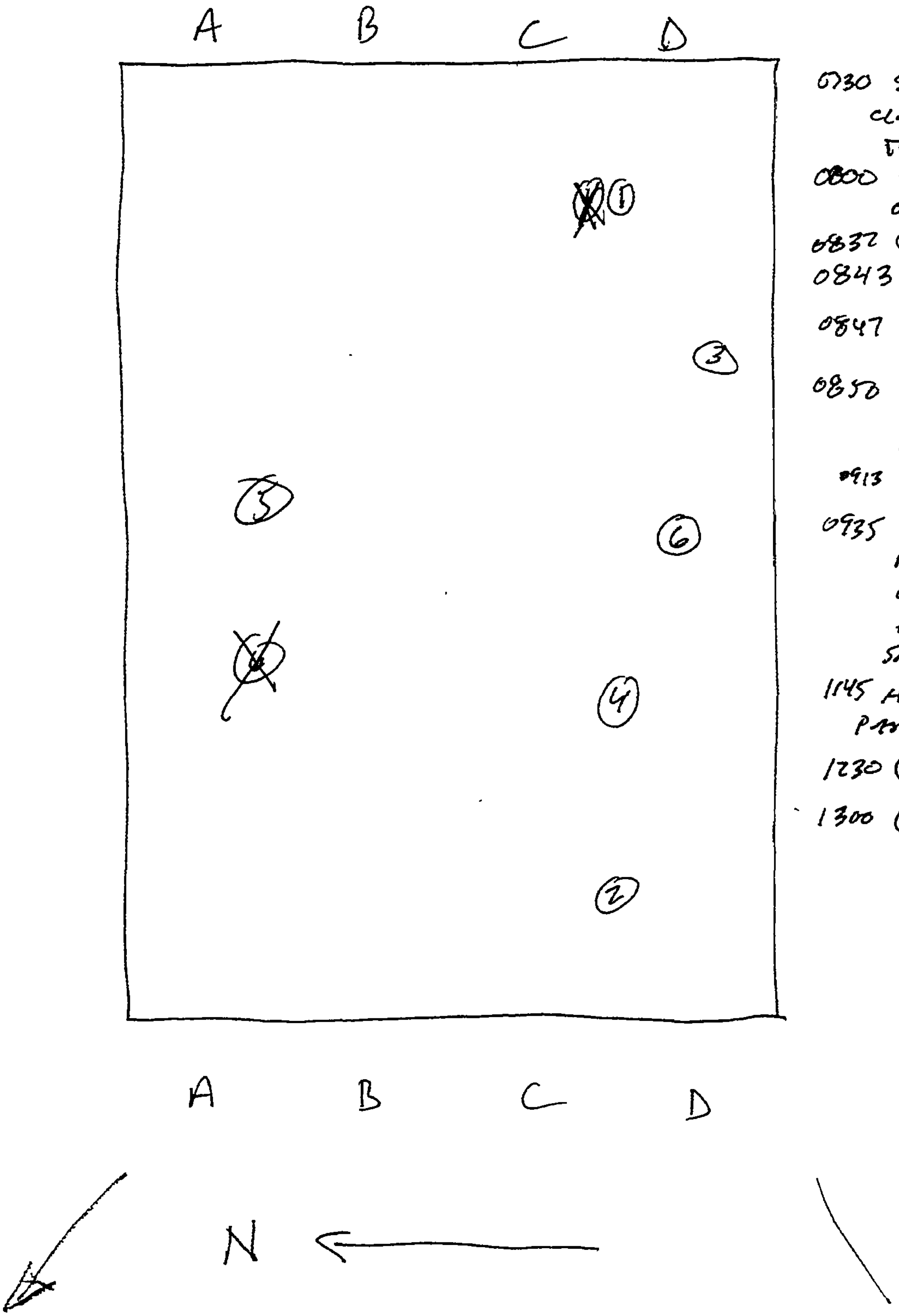
	1	2	3	4	5	6
MOLD AND WET SOIL						
MOLD						
WET SOIL						
FACTOR* 4"Φ / 6"Φ	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294
WET DENSITY	4/3/97 → Lift 1	Lift 1	Lift 1	Lift 2	4/3/97 Lift 2	~~4/3/97~~
PAN NO.	BASE 0150	SLOPE	11 C BASE	B 12	B 13	
PAN AND WET SOIL	242.9	174.9	108.1	108.2	108.1	
PAN AND DRY SOIL	232.4	161.5	92.7	94.3	94.3	
MOISTURE LOSS	15.5	13.2	15.4	13.9	13.8	
PAN TARE	147.9	74.9	8.1	8.2	8.1	
DRY SOIL	84.5	86.6	84.6	86.1	86.2	
MOISTURE CONTENT	18.3	15.2	18.2	16.1	16.0	
DRY DENSITY						
	MICRO	MICRO	MICRO	MICRO	MICRO	

HARDING LAWSON & ASSOCIATES

Harding Lawson Associates
Engineering and
Environmental Services

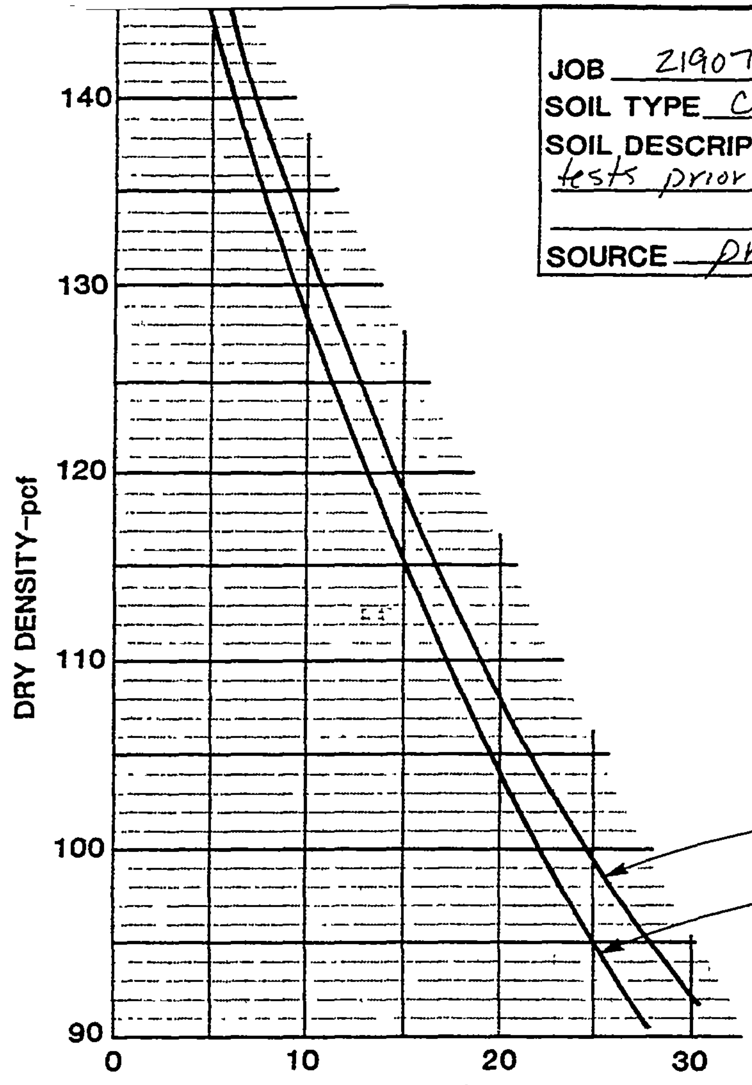
PROJECT TEST FILL #3
SUBJECT PROCESS AREA Moisture Control

SHEET 1 ~~3~~ OF ~~3~~ 1
JOB NO. 21907, 20650.1
DATE 4/3/97
COMPUTED BY R.J. TABALDO
CHECKED BY BAC



0730 SCRAPER BRINGS MO S
CLAY OVER FROM BORROW PIT
TO AB
0800 STABILIZER MAKES 1 P S
OVER CD
0832 ① BS = 18.32
0843 ② BS = 12.08
0847 ③ BS = 15.01
0850 STAB. & H_2O TRUCK MA
1 PASS ON WEST EN
OF CD
0913 ④ BS = 16.07
0935 SCRAPER STARTS HAUL
PROCESS MATERIAL FROM D
OVER TO TEST FILL 1ST L T.
H_2O TRUCK MAKES
SPRAYS NORTH HALF OF CD
1145 H_2O & STAB. MAKE
PASSES OVER AB
1230 ⑤ BS = 16.57%
1300 ⑥ BS = 14.52%
STAB & H_2O TRUCK MA
2 PASS OVER CD

LABORATORY COMPACTION TEST



JOB 21907 206050.1 NO.

SOIL TYPE CL DATE 4/6/97 BY RJT (BAC)

SOIL DESCRIPTION process area clay moist. content tests prior to placing lift 5

SOURCE process area

☐ ASTM D1557-78 ( )

☐ California 216 F

☐ Other (specify) ________

MAXIMUM DRY DENSITY ________ PCF

OPTIMUM MOISTURE CONTENT ______ %

⊙ Laboratory Compaction Point

△ Field Check Point

100% Saturation ($G_S = 2.68$)

90% Saturation ($G_S = 2.68$)

(*For weight of wet soil in grams and volume = 1/30 cu. ft.)

	1	2	3	4	5	6
MOLD AND WET SOIL						
MOLD						
WET SOIL						
FACTOR* 4"Φ / 6"Φ	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294	.0662 / .0294
WET DENSITY	4/6/97	4/6/97				
PAN NO.	microwave	microwave				
PAN AND WET SOIL	247.9	174.9				
PAN AND DRY SOIL	229.4	156.9				
MOISTURE LOSS	18.5	18.0				
PAN TARE	147.9	74.9				
DRY SOIL	81.5	82.0				
MOISTURE CONTENT	22.7	22.0				
DRY DENSITY						

HARDING LAWSON & ASSOCIATES

Appendix G

COMPACTED CLAY LINER LABORATORY TEST RESULTS

GEOSYNTEC CONSULTANTS

Geomechanics & Environmental Laboratory
2658 Holcomb Bridge Road • Suite 110
Alpharetta, Georgia 30201 • USA
Tel. (770) 645-6575 • Fax (770) 645-6570

4 August 1997

Mr. Brad Coleman, P.E.
Harding Lawson Associates
707 17th Street, Suite 2400
Denver, Colorado 80202

Subject: Laboratory Testing
Report No. 4 - Additional Shelby Tube Sample Permeability Testing
Rocky Mountain Arsenal

Dear Mr. Coleman:

GeoSyntec Consultants (GeoSyntec) in Atlanta, Georgia, is pleased to present the attached test results (Table 1) for the above referenced project. A blank shown on the table indicates that the test was not performed, the parameter is not applicable, or that the test resulted in insufficient data to report the designated parameter. Attachment A presents the general information pertinent to the testing program, and the policy of GeoSyntec regarding the limitations and the use of the test results.

GeoSyntec appreciates the opportunity to provide testing services for this project. Should you have any questions regarding the attached test results or if you require additional information, please do not hesitate to contact either of the undersigned.

Sincerely,

Cuneyt Gokmen, E.I.T.
Assistant Program Manager
Environmental Testing

Nader S. Rad

Nader S. Rad, Ph.D., P.E.
Laboratory Director

Attachment

GL0232/GEL97138

TABLE 1

HYDRAULIC CONDUCTIVITY TEST RESULTS
ADDITIONAL SHELBY TUBE SAMPLE PERMEABILITY TESTING

HARDING LAWSON ASSOCIATES
ROCKY MOUNTAIN ARSENAL

REPORT NO. 4

Client Sample ID	Lab Sample No	Moisture Content ASTM D 2216 (%)	Grain Size			Atterberg Limits ASTM D 4318			Soil Classification ASTM D 2487	Specific Gravity ASTM D 854 (-)	Flexible Wall Falling Head ASTM D 5084				Remarks
			Percent Passing #200 Sieve ASTM D 1140 (%)	ASTM D 422							Test Specimen Initial Conditions		Consol Pressure (psi)	Hydraulic Conductivity (cm/s)	
				Sieve Figure No	Hydrom Figure No.	LL (%)	PL (%)	PI (-)			Dry Unit Weight (pcf)	Moisture Content (%)			
112	97D12										109 3	17.7	3	4 7E-8	
													10	8 9E-9	
121	97D13										107 9	18 2	3	8 3E-9	
													10	2 9E-9	

ATTACHMENT A

Sample Identification, Handling, Storage and Disposal

Laboratory Test Standards

Application of Test Results

SAMPLE IDENTIFICATION, HANDLING, STORAGE AND DISPOSAL

Test materials were sent to GeoSyntec Consultants (GeoSyntec) Geomechanics and Environmental Laboratory in Atlanta, Georgia by the client or its representative(s). Samples delivered to the laboratory were identified by client sample identification (ID) numbers which had been assigned by representative(s) of the client. Upon being received at the laboratory, each sample was assigned a laboratory sample number to facilitate tracking and documentation.

Based on the information provided to GeoSyntec by the client or its representative(s) and, when applicable, procedural guidelines recommended by an industrial hygiene consultant, the following Occupational Safety and Health Administration (OSHA) level of personal protection was adopted for handling and testing of the test materials:

[X] test materials were not contaminated. no special protection measures were taken;
[ ] level D
[ ] level C
[ ] level B

In accordance with the health and safety guidelines of GeoSyntec, contaminated materials are stored in a designated containment area in the laboratory. Non-contaminated materials are stored in a general storage area in the laboratory.

GeoSyntec Geomechanics and Environmental Laboratory will continue storing the test materials for a period of 30 days from the date of this report or a year from the time that the samples were received, which ever is shorter. Thereafter: (i) contaminated materials will be returned to the client or its designated representative(s); and (ii) the materials which are not contaminated will be discarded unless long-term storage arrangements are specifically made with GeoSyntec Geomechanics and Environmental Laboratory.

LABORATORY TEST STANDARDS

At the request of the client, the laboratory testing program was performed utilizing the guidelines provided in the following test standards:

[X] **moisture content** - American Society for Testing and Materials (ASTM) D 2216 "*Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures*";

[ ] **moisture content** - ASTM D 4643 "*Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Method*";

[ ] **particle-size analysis** - ASTM 422, "*Standard Method for Particle-Size Analysis of Soils*";

[ ] **percent passing No. 200 sieve** - ASTM D 1140, "*Standard Test Method for Amount of Material in Soil Finer Than No. 200 (75 microns) sieve*";

[ ] **Atterberg limits** - ASTM D 4318, "*Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*";

[ ] **soil classification** - ASTM D 2487, "*Standard Test Method for Classification of Soils for Engineering Purposes*";

[ ] **soil pH** - ASTM D 4972, "*Standard Test Method for pH of Soils*";

[ ] **soil pH** - United States Environmental Protection Agency (USEPA) SW-846 Method 9045, Revision 1, 1987, Standard Test Method for Measurement of "*Soil pH*";

[ ] **specific gravity** - ASTM D 854, "*Standard Test Method for Specific Gravity of Soils*";

[ ] **carbonate content** - ASTM D 3042, "*Standard Method for Insoluble Residue in Carbonate Aggregates*";

[ ] **soundness** - ASTM C 88, "*Standard Test Method for Soundness of Aggregates by use of Sodium Sulfate or Magnesium Sulfate*";

[ ] **loss-on-ignition (LOI)** - ASTM D 2974, "*Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*";

[ ] **standard Proctor compaction** - ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*";

[ ] **reduced energy Proctor compaction** - modified ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*", using 15 blows;

[ ] **modified Proctor compaction** - ASTM D 1557, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop*";

[ ] **maximum relative density** - ASTM D 4253, "*Standard Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*";

[ ] **minimum relative density** - ASTM D 4254, "*Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*";

[ ] **mass per unit area** - ASTM D 3776, "*Standard Test Method for Mass Per Unit Area (weight) of Woven Fabric*";

[ ] **thickness measurement** - ASTM D 1777, "*Standard Test Method for Measuring Thickness of Textile Materials*";

[ ] **free swell** - United States Pharmacopeia National Formulary (USP-NF) XVII, "*Swell Index of Clay*",

[ ] **fluid loss** - American Petroleum Institute (API)-13B, "*Section 4, Bentonite*";

[ ] **marsh funnel** - API-13B, "*Section 4, Field Testing of Oil Mud Viscosity and Gel Strength*";

[ ] **pinhole dispersion** - ASTM D 4647, "*Standard Test Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test*";

[ ] **gradient ratio** - ASTM D 5101, "*Standard Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio*";

[ ] **hydraulic conductivity ratio** - Draft ASTM D 35.03.91.01, "*Standard Test Method for Hydraulic Conductivity Ratio (HCR) Testing*";

[ ] **hydraulic transmissivity** - ASTM D 4716, "*Standard Test Method for Constant Head Hydraulic Transmissivity (In-plane flow) of Geotextiles and Geotextile Related Products*";

[ ] **one-dimensional consolidation** - ASTM D 2435, "*Standard Test Method for One-Dimensional Consolidation Properties of Soil*";

[ ] **one-dimensional swell/collapse** - ASTM D 4546, "*Standard Test Method for One-Dimensional Swell or Settlement Potential of Cohesive Soils*";

[ ] **unconfined compressive strength (UCS)** - ASTM D 2166, " *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil*";

[ ] **triaxial compressive strength ($\overline{\text{ICU}}$)** - ASTM D 4767, "*Standard Test Method for Triaxial Compression Test on Cohesive Soils*";

[ ] **triaxial compressive strength (UU)** - ASTM D 2850, "*Standard Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression*";

[ ] **rigid wall constant head hydraulic conductivity** - ASTM D 2434, "*Standard Test Method for Permeability of Granular Soils (Constant Head)*";

[X] **flexible wall falling head hydraulic conductivity** - ASTM D 5084, "*Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*";

[ ] **flexible wall falling head hydraulic conductivity** - U. S. Army Corp of Engineers; EM-1110-2-1906, "*Standard Test Method for Permeability Tests, Appendix VII*";

[ ] **index flux of GCL** - proposed ASTM method rough draft # 1, 6/18/94, "*Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter*";

[ ] **flexible wall falling head hydraulic conductivity** - Geosynthetic Research Institute (GRI) GCL-2, "*Standard Test Method for Permeability of Geosynthetic Clay Liners (GCLs)*";

[ ] **permeability/compatibility** - USEPA Method 9100 SW-846, Revision 1, 1987, Standard Test Method for Measurement of "*Saturated Hydraulic Conductivity, Saturated Leachate Conductivity and Intrinsic Permeability*",

[ ] **capillary-moisture** - ASTM D 2325, "*Standard Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus*"; and

[ ] **capillary-moisture** - ASTM D 3152, "*Standard Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus*"

APPLICATION OF TEST RESULTS

The reported test results apply to the field materials inasmuch as the samples sent to the laboratory for testing are representative of these materials. This report applies only to the materials tested and does not necessarily indicate the quality or condition of apparently identical or similar materials. The testing was performed in accordance with the general engineering standards and conditions reported. The test results are related to the testing conditions used during the testing program. As a mutual protection to the client, the public, and GeoSyntec, this report is submitted and accepted for the exclusive use of the client and upon the condition that this report is not used, in whole or in part, in any advertising, promotional or publicity matter without prior written authorization from GeoSyntec.

GeoSyntec Consultants

Geomechanics & Environmental Laboratory
2658 Holcomb Bridge Road • Suite 110
Alpharetta, Georgia 30201 • USA
Tel. (770) 645-6575 • Fax (770) 645-6570

17 April 1997

Mr. Brad Coleman, P.E.
Harding Lawson Associates
707 Seventeenth Street, Suite 2400
Denver, Colorado 80202

Subject: Laboratory Testing
Report No. 1 - Index Testing
Rocky Mountain Arsenal

Dear Mr. Coleman:

GeoSyntec Consultants (GeoSyntec) in Atlanta, Georgia, is pleased to present the attached test results (Table 1 and Figures 1 through 10) for the above referenced project. A blank shown on the table or any of the figures indicates that the test was not performed, the parameter is not applicable, or that the test resulted in insufficient data to report the designated parameter. Attachment A presents the general information pertinent to the testing program, and GeoSyntec's policy regarding the limitations of and the use of the test results.

GeoSyntec appreciates the opportunity to provide testing services for this project. Should you have any questions regarding the attached test results or if you require additional information, please do not hesitate to contact either of the undersigned.

Sincerely,

Cuneyt Gokmen, E.I.T.
Assistant Program Manager
Environmental Testing

Nader S. Rad

Nader S. Rad, Ph.D., P.E.
Laboratory Director

Attachment

GL0232/GEL97063

Corporate Office:
621 N.W. 53rd Street • Suite 650
Boca Raton, Florida 33487 • USA
Tel. (561) 995-0900 • Fax (561) 995-0925

Regional Offices:
Atlanta, GA • Boca Raton, FL • Chicago, IL
Columbia, MD • Huntington Beach, CA • San Antonio, TX
Walnut Creek, CA • Paris, France

Laboratories:
Atlanta, GA
Boca Raton, FL
Huntington Beach, CA

TABLE 1

SUMMARY OF INDEX PROPERTIES
INDEX TESTING

HARDING LAWSON ASSOCIATES
ROCKY MOUNTAIN ARSENAL

Client Sample ID	Lab Sample No.	Moisture Content ASTM D 2216 (%)	Grain Size			Atterberg Limits ASTM D 4318			Soil Classification ASTM D 2487	Specific Gravity ASTM D 854 (-)	Loss On Ignition ASTM D 2974 (%)	Soil pH ASTM D 4972		Compaction								
			Percent Passing #200 Sieve ASTM D 1140 (%)	ASTM D 422										Standard Proctor ASTM D 698			Reduced Energy Proctor modified ASTM D 698$^{(1)}$			Modified Proctor ASTM D 1557		
				Sieve Figure No	Hydrom Figure No	LL (%)	PL (%)	PI (-)				H_2O (-)	$CaCl_2$ (-)	Max Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Fig No	Max Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Fig No.	Max Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Fig No
TP-1	97C22	13 1	89 5	1	1	50	18	32	CL - Lean Clay													
TP-2	97C23	8.7	76.8	2	2	36	16	20	CL - Lean Clay with Sand					108.0	17 0	3						
TP-3	97C24	16.1	86 4	4	4	52	18	34	CH - Fat Clay													
TP-4	97C25	13.0	90 4	5	5	52	19	33	CH - Fat Clay													
NO. 2, TEST FILL 3	97D03	14 0	73 0	6	6	42	16	26	CL - Lean Clay with Sand	2 71												
COMPOSITE SOIL	97D04	15 3	68.7	7	7	42	17	25	CL - Sandy Lean Clay	2 68				108 0	16 8	8	104 8	19 0	9	116 5	14 2	10

Notes:

1. Standard Proctor rammer using 15 blows (i e , Reduced Energy)

GEO SYNTEC CONSULTANTS

Geomechanics and Environmental Laboratory
Atlanta, Georgia

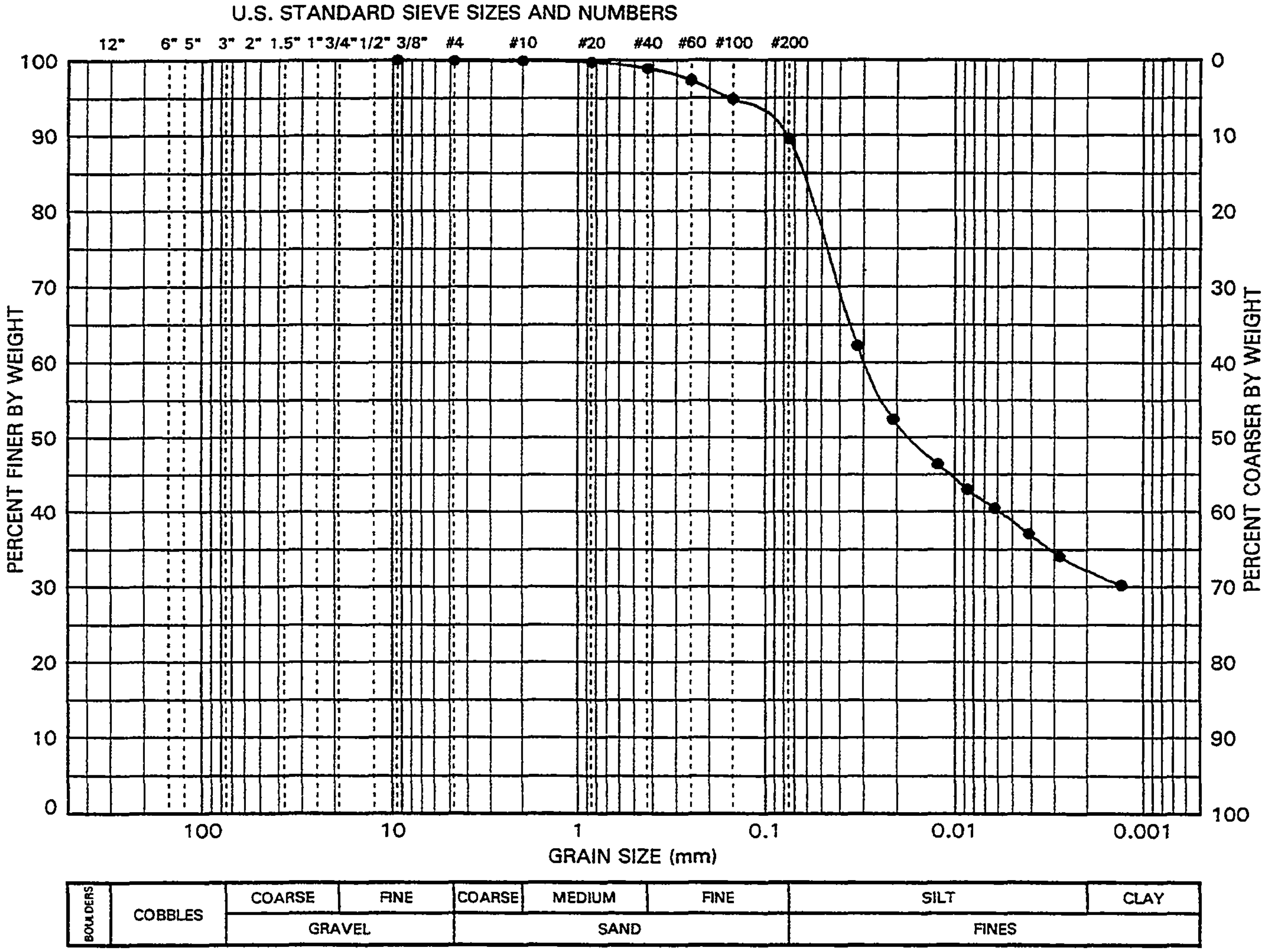
FIGURE 1

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

GS FORM:
4PS2 04/17/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	TP-1	LIQUID LIMIT (%)	50	GRAVEL (%)	0.1
LAB. SAMPLE NO.	97C22	PLASTIC LIMIT (%)	18	SAND (%)	10.4
SAMPLE DEPTH (ft)		PLASTICITY INDEX	32	FINES (%)	89.5
SOIL CLASSIFICATION:				SILT (%)	57.1
CL - Lean Clay				CLAY(%)	32.4
				COEFF. UNIFORMITY (Cu)	
				COEFF. CURVATURE (Cc)	

SOIL FRACTIONS

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)														PARTICLE DIAMETER (mm)				
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	100	99	97	95	90	76	52	39	32	

NOTES:

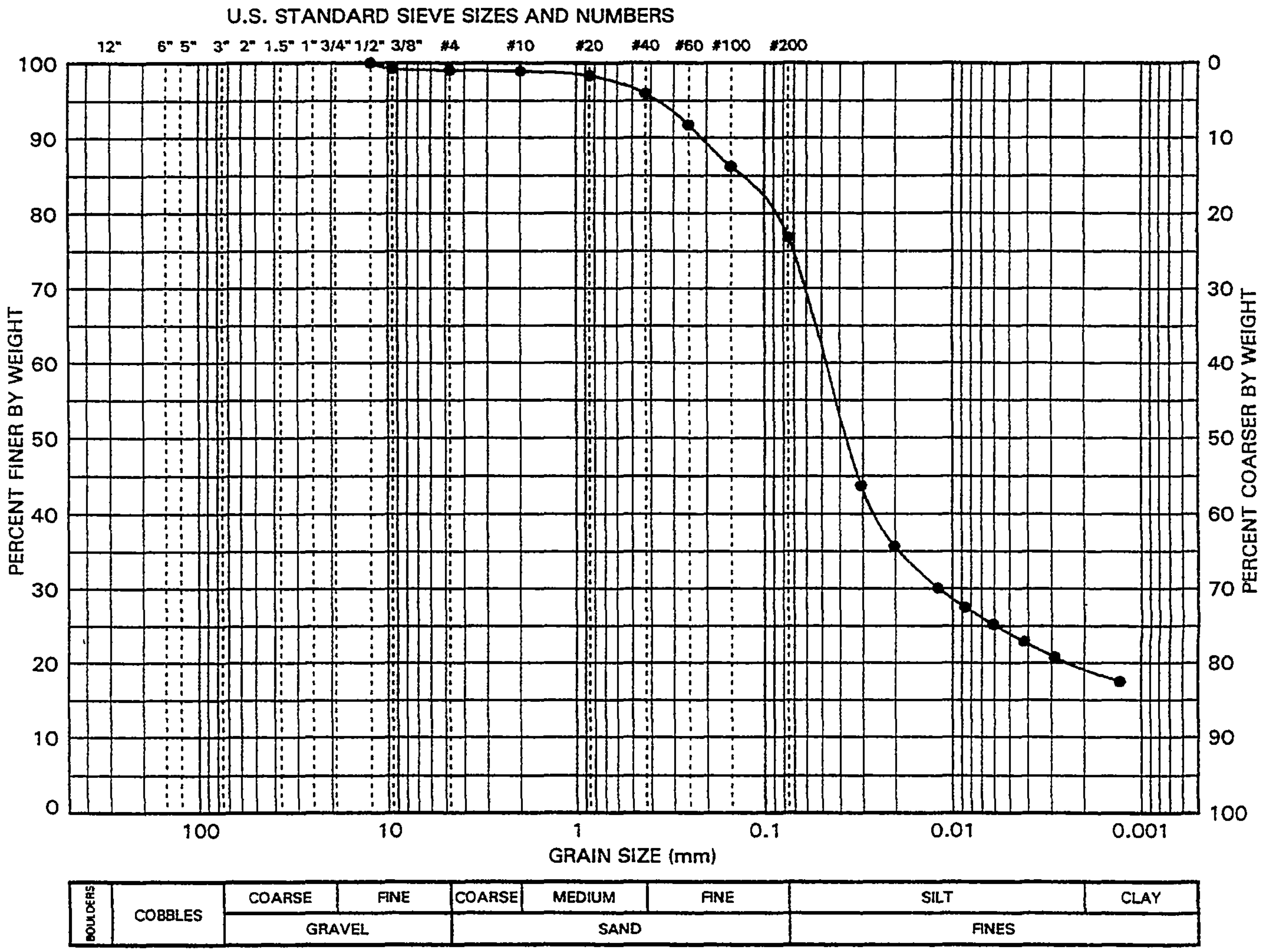
GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

FIGURE 2
PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

GS FORM:
4PS2 04/17/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	TP-2	LIQUID LIMIT (%)	36	GRAVEL (%)	1.0
LAB. SAMPLE NO.	97C23	PLASTIC LIMIT (%)	16	SAND (%)	22.2
SAMPLE DEPTH (ft)		PLASTICITY INDEX	20	FINES (%)	76.8
SOIL CLASSIFICATION:				SILT (%)	57.5
CL - Lean Clay with Sand				CLAY(%)	19.3
				COEFF. UNIFORMITY (Cu)	
				COEFF. CURVATURE (Cc)	

SOIL FRACTIONS

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	99	99	99	98	96	92	86	77	62	36	24	19	

NOTES:

GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

FIGURE 3

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

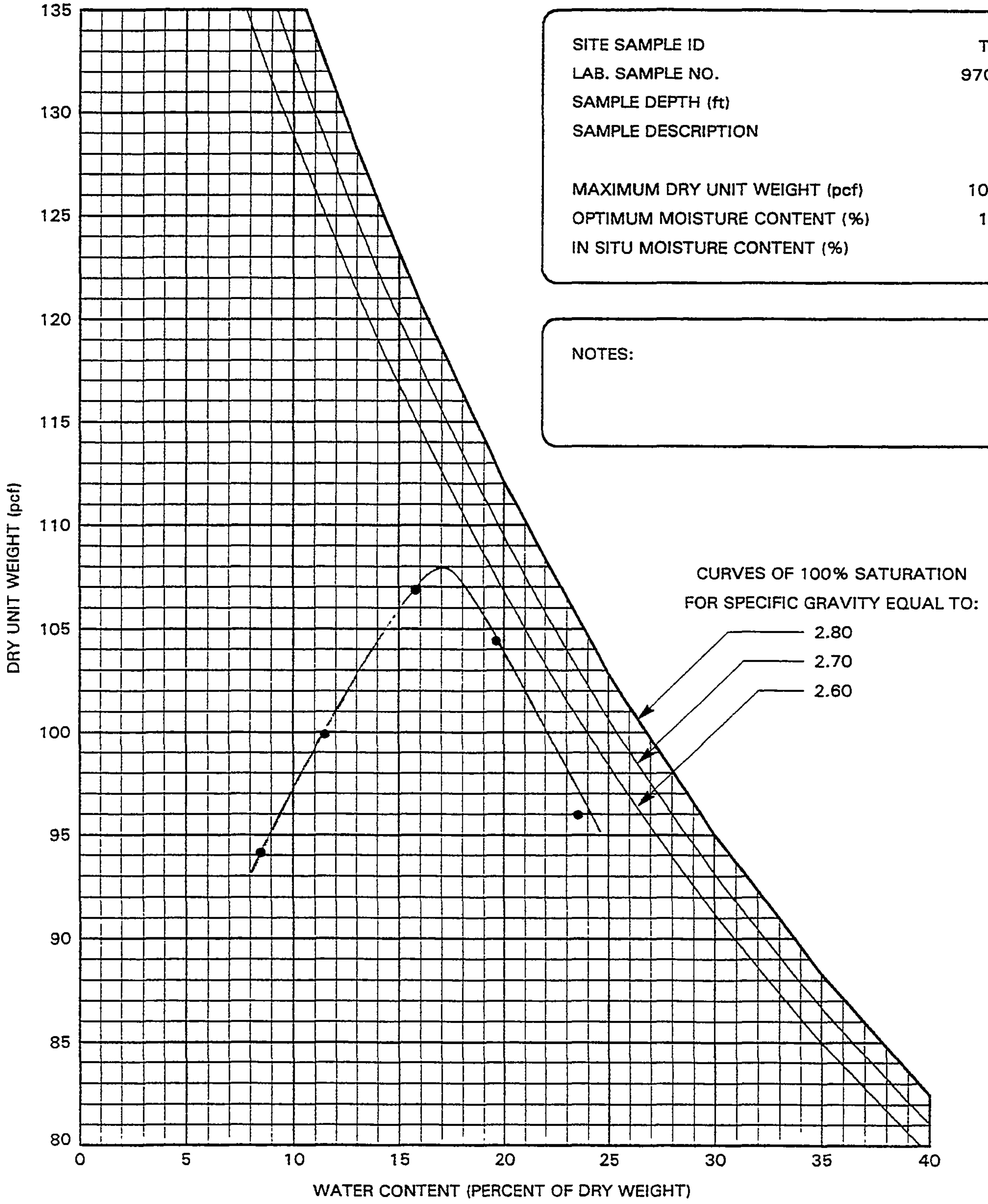
GS FORM:
4MD1 04/17/97

MOISTURE-DENSITY RELATIONSHIP, COMPACTION TESTING

ASTM D-698-A

SITE SAMPLE ID	TP-2
LAB. SAMPLE NO.	97C23
SAMPLE DEPTH (ft)	
SAMPLE DESCRIPTION	
MAXIMUM DRY UNIT WEIGHT (pcf)	108.0
OPTIMUM MOISTURE CONTENT (%)	17.0
IN SITU MOISTURE CONTENT (%)	

NOTES:



GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

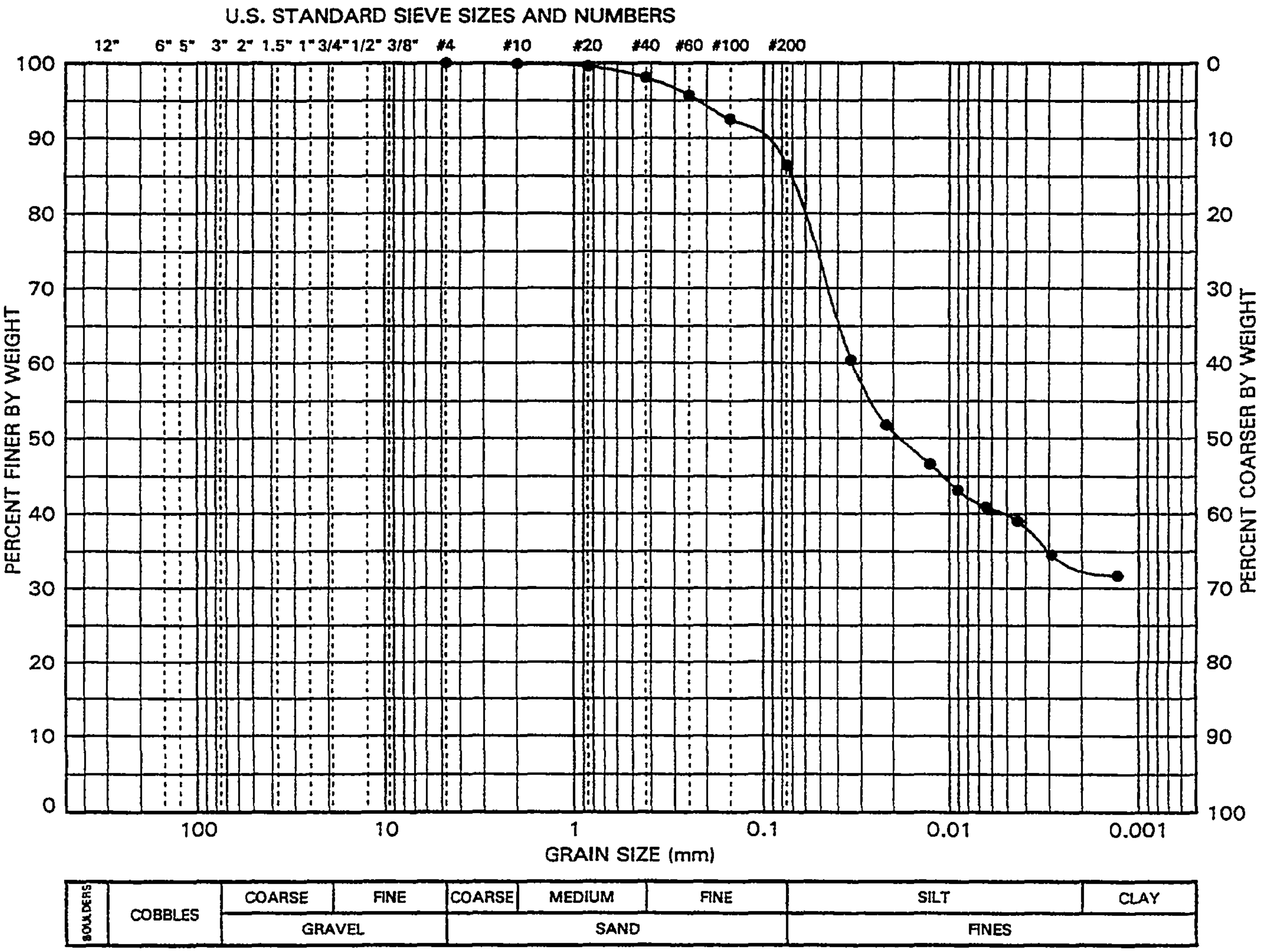
FIGURE 4

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

GS FORM:
4PS2 04/17/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	TP-3	LIQUID LIMIT (%)	52	GRAVEL (%)	0.0
LAB. SAMPLE NO.	97C24	PLASTIC LIMIT (%)	18	SAND (%)	13.6
SAMPLE DEPTH (ft)		PLASTICITY INDEX	34	FINES (%)	86.4
SOIL CLASSIFICATION:				SILT (%)	53.2
CH - Fat Clay				CLAY(%)	33.2
				COEFF. UNIFORMITY (Cu)	
				COEFF. CURVATURE (Cc)	

SOIL FRACTIONS

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	100	98	96	93	86	73	51	40	33	

NOTES:

GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

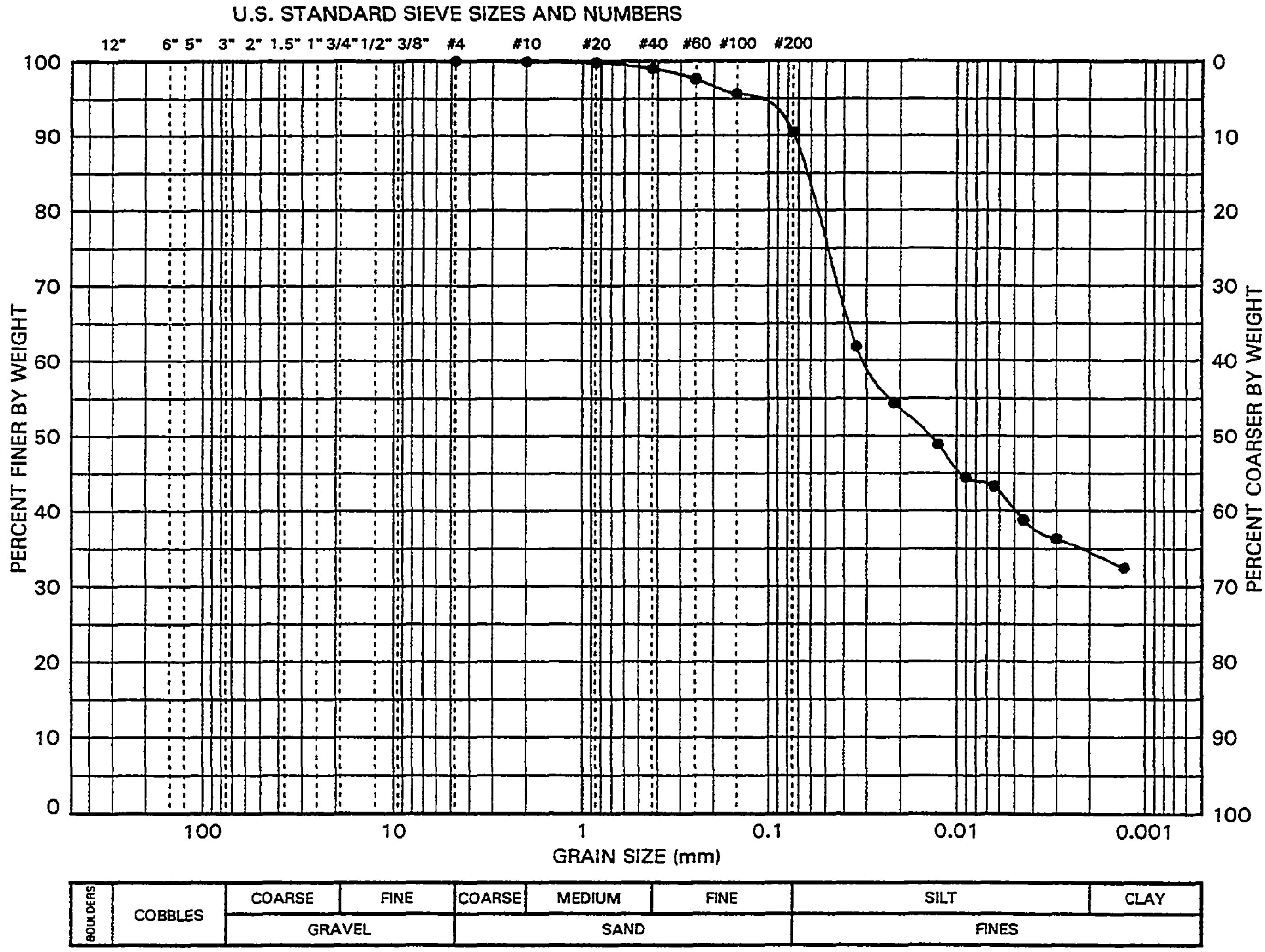
FIGURE 5

PROJECT:	Rocky Mountain Arsenal
PROJECT NO.:	GL0232
DOCUMENT NO.:	GEL97063

GS FORM:
4PS2 04/17/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	TP-4	LIQUID LIMIT (%)	52	SOIL FRACTIONS	GRAVEL (%)	0.0
LAB. SAMPLE NO.	97C25	PLASTIC LIMIT (%)	19		SAND (%)	9.6
SAMPLE DEPTH (ft)		PLASTICITY INDEX	33		FINES (%)	90.4
SOIL CLASSIFICATION: CH - Fat Clay					SILT (%)	55.9
					CLAY(%)	34.5
					COEFF. UNIFORMITY (Cu)	
					COEFF. CURVATURE (Cc)	

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	100	99	98	96	90	76	54	40	34	

NOTES:

GEOSYNTEC CONSULTANTS

Geomechanics and Environmental Laboratory
Atlanta, Georgia

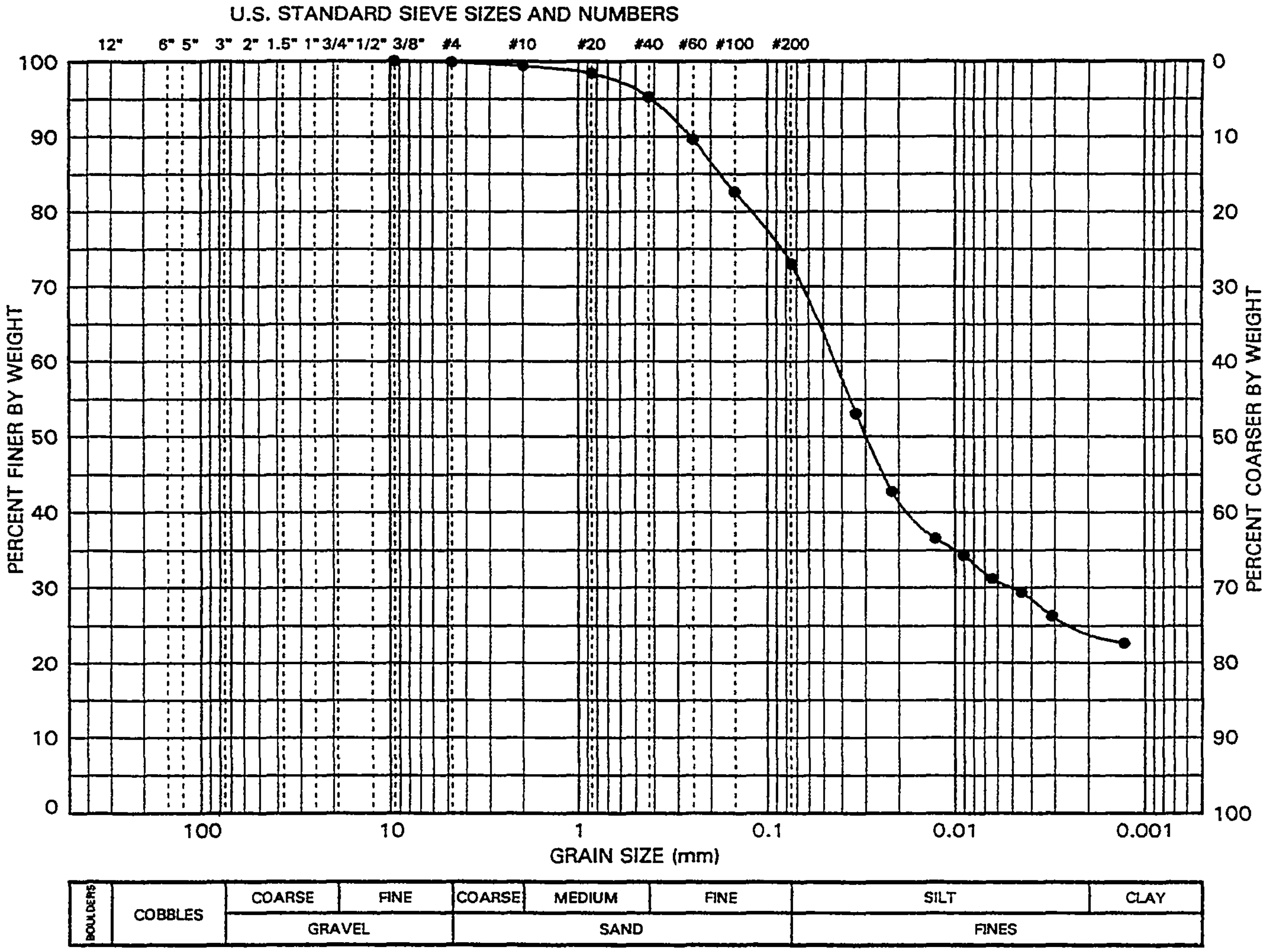
FIGURE 6

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

GS FORM:
4PS2 04/17/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	*	LIQUID LIMIT (%)	42	GRAVEL (%)	0.1
LAB. SAMPLE NO.	97D03	PLASTIC LIMIT (%)	16	SAND (%)	26.9
SAMPLE DEPTH (ft)		PLASTICITY INDEX	26	FINES (%)	73.0
SOIL CLASSIFICATION:				SILT (%)	48.5
CL - Lean Clay with Sand				CLAY(%)	24.5
				COEFF. UNIFORMITY (Cu)	
				COEFF. CURVATURE (Cc)	

SOIL FRACTIONS

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	99	98	95	90	83	73	63	42	30	24	

NOTES: * NO.2,TEST FILL 3

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Atlanta, Georgia

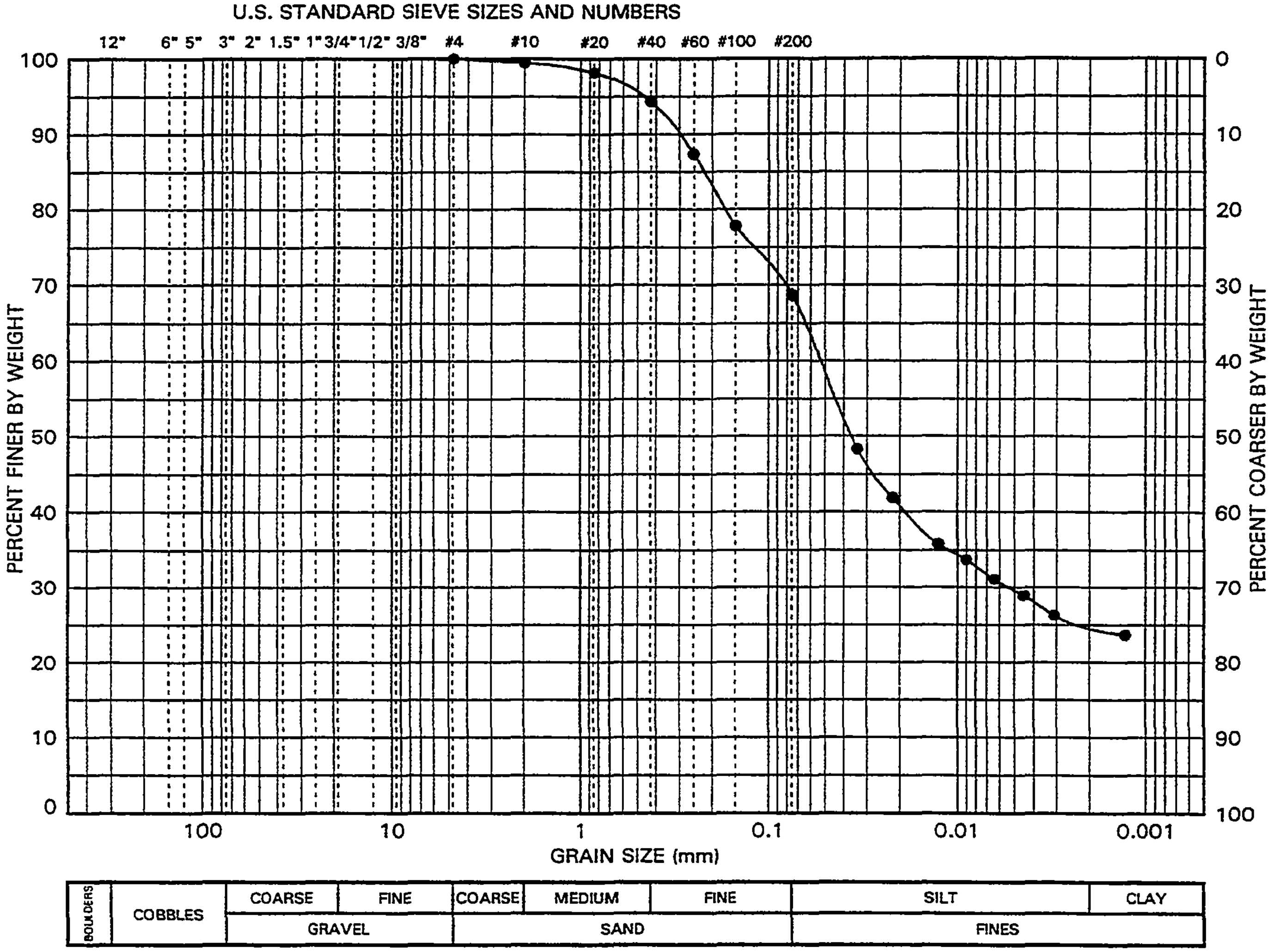
FIGURE 7

PROJECT:	Rocky Mountain Arsenal
PROJECT NO.:	GL0232
DOCUMENT NO.:	GEL97063

GS FORM:
4PS2 04/17/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	*	LIQUID LIMIT (%)	42
LAB. SAMPLE NO.	97D04	PLASTIC LIMIT (%)	17
SAMPLE DEPTH (ft)		PLASTICITY INDEX	25

SOIL CLASSIFICATION:
CL - Sandy Lean Clay

SOIL FRACTIONS	GRAVEL (%)	0.0
	SAND (%)	31.3
	FINES (%)	68.7
	SILT (%)	43.7
	CLAY(%)	25.0
COEFF. UNIFORMITY (Cu)		
COEFF. CURVATURE (Cc)		

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)														PARTICLE DIAMETER (mm)				
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	98	94	87	78	69	58	41	30	25	

NOTES: * COMPOSITE SOIL

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Atlanta, Georgia

FIGURE 8

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

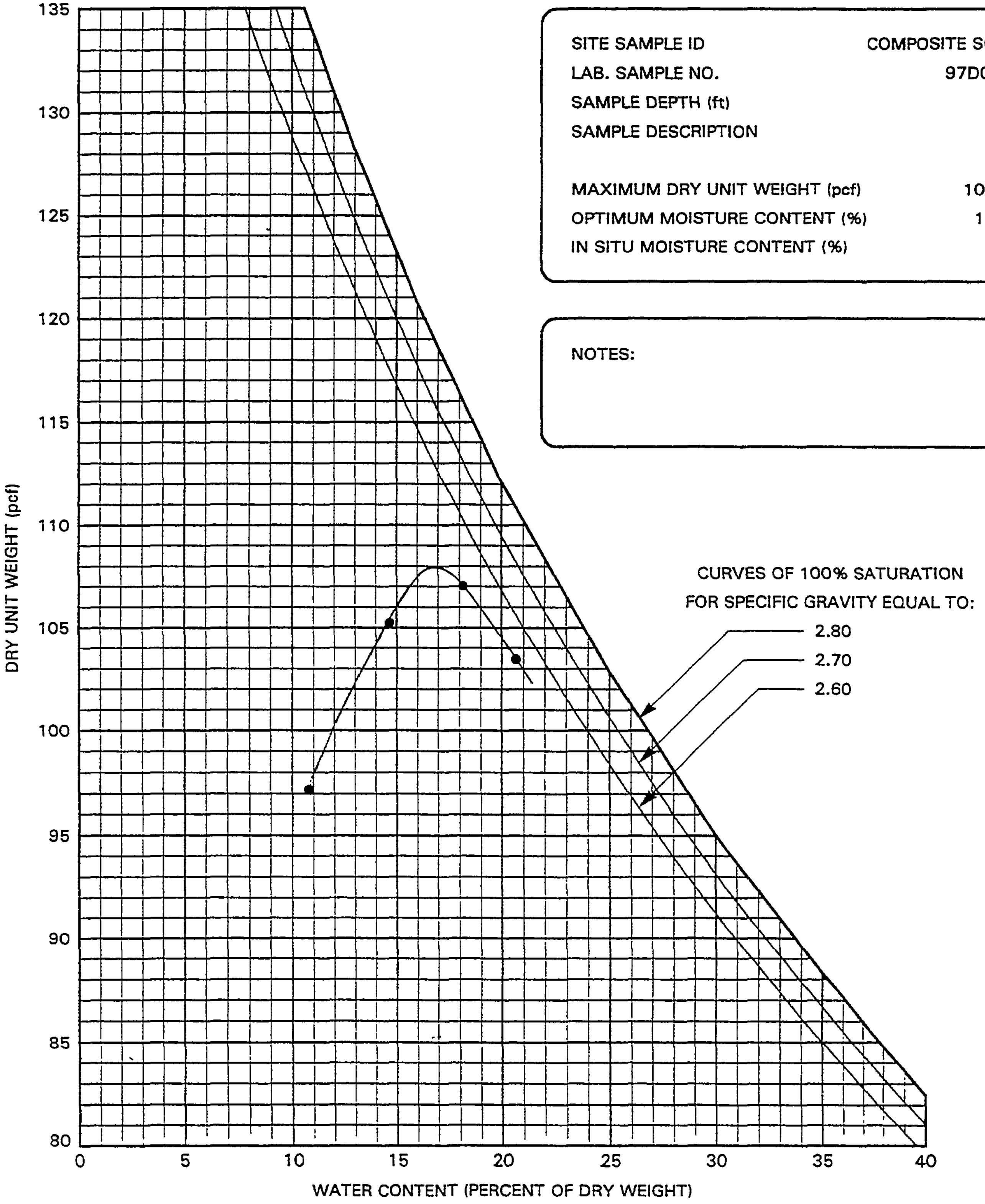
GS FORM:
4MD1 04/17/97

MOISTURE-DENSITY RELATIONSHIP, COMPACTION TESTING

ASTM D-698-A

SITE SAMPLE ID	COMPOSITE SOIL
LAB. SAMPLE NO.	97D04S
SAMPLE DEPTH (ft)	
SAMPLE DESCRIPTION	
MAXIMUM DRY UNIT WEIGHT (pcf)	108.0
OPTIMUM MOISTURE CONTENT (%)	16.8
IN SITU MOISTURE CONTENT (%)	

NOTES:



GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

FIGURE 9

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

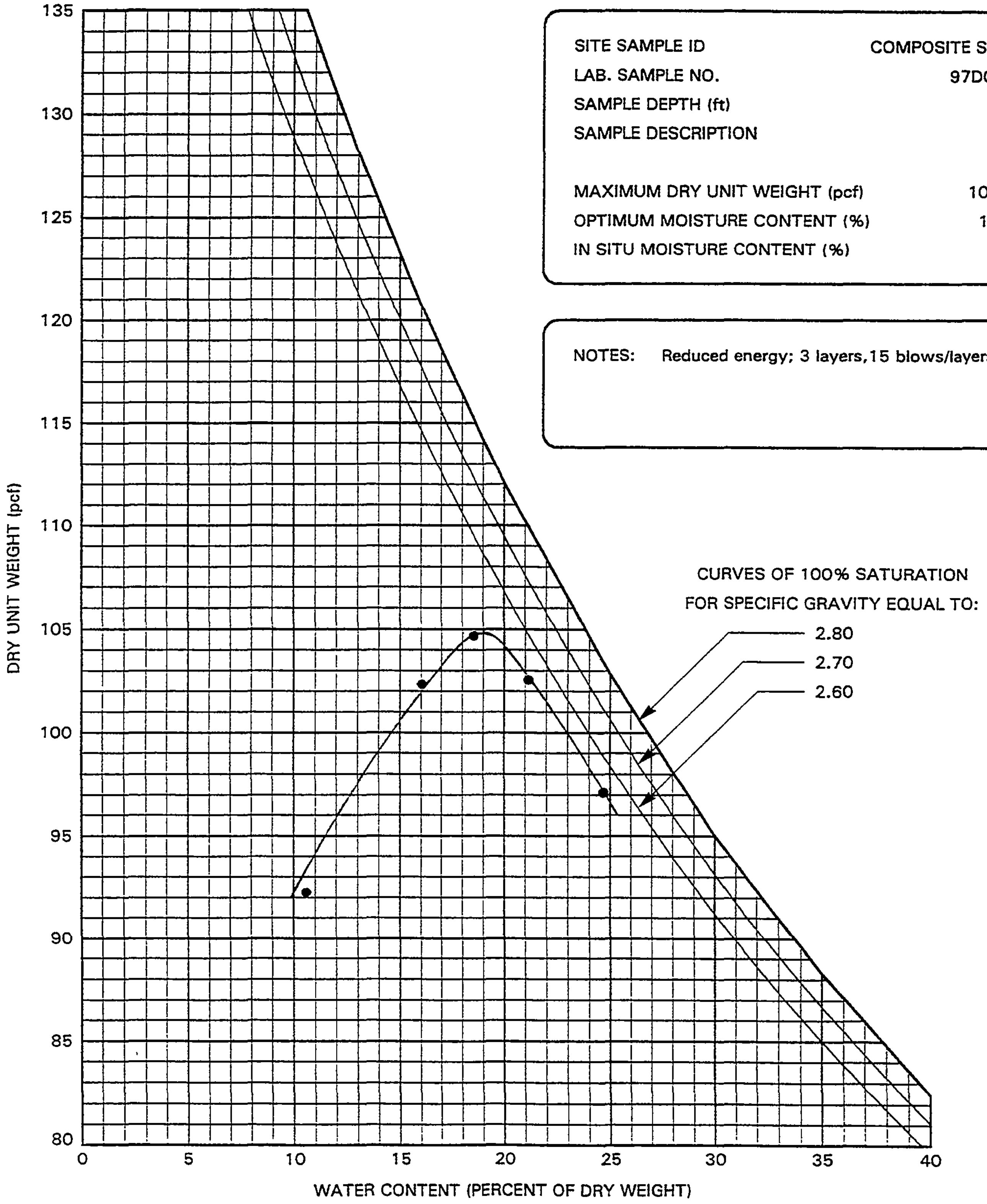
GS FORM:
4MD1 04/17/97

MOISTURE-DENSITY RELATIONSHIP, COMPACTION TESTING

ASTM D-698-A + Low energy

SITE SAMPLE ID	COMPOSITE SOIL
LAB. SAMPLE NO.	97D04R
SAMPLE DEPTH (ft)	
SAMPLE DESCRIPTION	
MAXIMUM DRY UNIT WEIGHT (pcf)	104.8
OPTIMUM MOISTURE CONTENT (%)	19.0
IN SITU MOISTURE CONTENT (%)	

NOTES: Reduced energy; 3 layers, 15 blows/layers.



GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

FIGURE 10

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97063

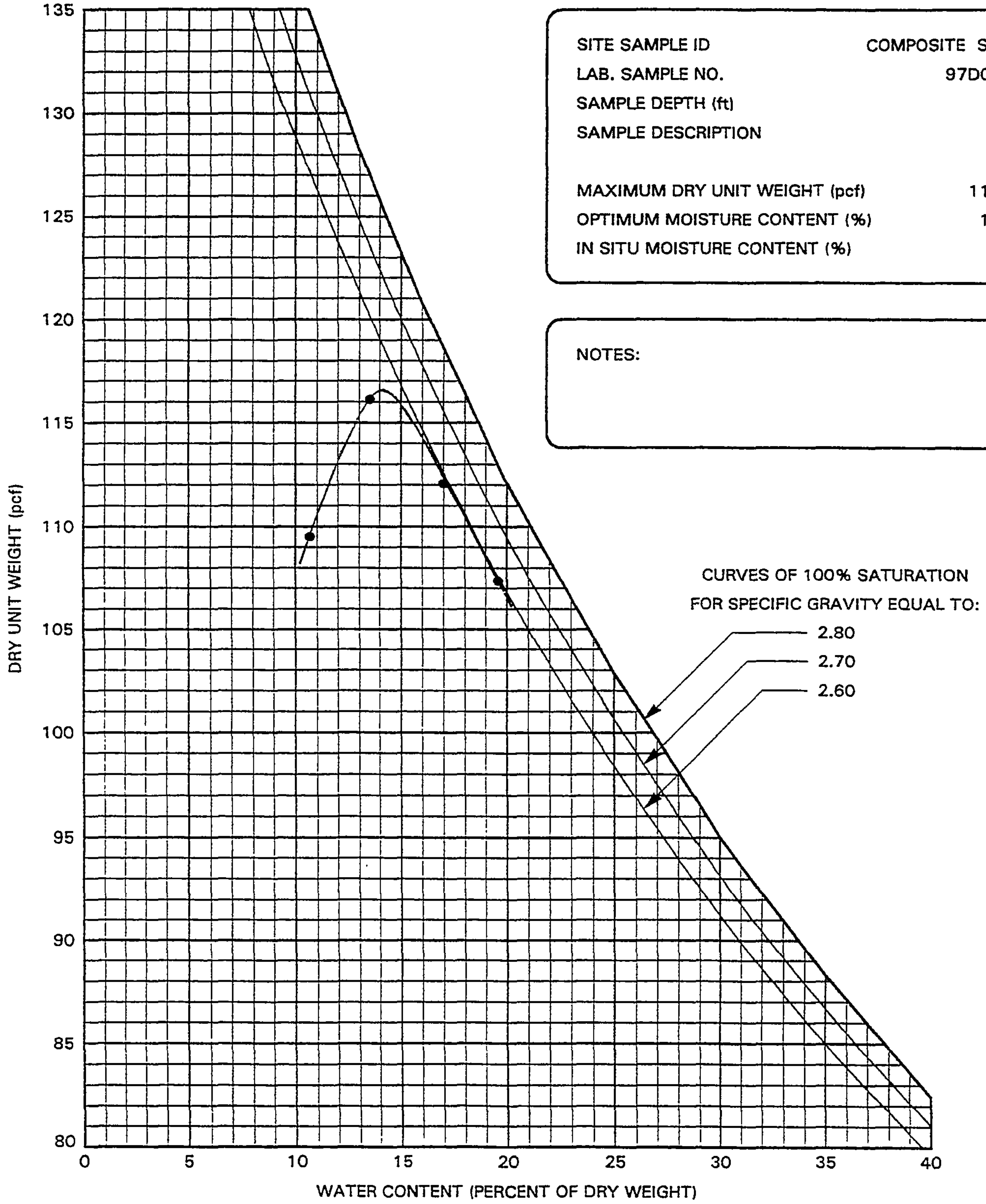
GS FORM:
4MD1 04/17/97

MOISTURE-DENSITY RELATIONSHIP, COMPACTION TESTING

ASTM D 1557 A

SITE SAMPLE ID	COMPOSITE SOIL
LAB. SAMPLE NO.	97D04M
SAMPLE DEPTH (ft)	
SAMPLE DESCRIPTION	
MAXIMUM DRY UNIT WEIGHT (pcf)	116.5
OPTIMUM MOISTURE CONTENT (%)	14.2
IN SITU MOISTURE CONTENT (%)	

NOTES:



ATTACHMENT A

Sample Identification, Handling, Storage and Disposal

Laboratory Test Standards

Application of Test Results

SAMPLE IDENTIFICATION, HANDLING, STORAGE AND DISPOSAL

Test materials were sent to GeoSyntec Consultants (GeoSyntec) Geomechanics and Environmental Laboratory in Atlanta, Georgia by the client or its representative(s). Samples delivered to the laboratory were identified by client sample identification (ID) numbers which had been assigned by representative(s) of the client Upon being received at the laboratory, each sample was assigned a laboratory sample number to facilitate tracking and documentation.

Based on the information provided to GeoSyntec by the client or its representative(s) and, when applicable, procedural guidelines recommended by an industrial hygiene consultant, the following Occupational Safety and Health Administration (OSHA) level of personal protection was adopted for handling and testing of the test materials:

[X] test materials were not contaminated, no special protection measures were taken:
[ ] level D
[ ] level C
[ ] level B

In accordance with the health and safety guidelines of GeoSyntec, contaminated materials are stored in a designated containment area in the laboratory Non-contaminated materials are stored in a general storage area in the laboratory

GeoSyntec Geomechanics and Environmental Laboratory will return contaminated materials to the client or designated representative(s), at the clients' cost, 30 days following the completion of the testing program, unless special arrangements for proper disposal have been made with the laboratory. Materials which are not contaminated will be discarded 90 days after they were received at the laboratory, unless long-term storage arrangements are specifically made with GeoSyntec Geomechanics and Environmental Laboratory

LABORATORY TEST STANDARDS

At the request of the client, the laboratory testing program was performed utilizing the guidelines provided in the following test standards

[X] **moisture content** - American Society for Testing and Materials (ASTM) D 2216 "*Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures*".

[ ] **moisture content** - ASTM D 4643 "*Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Method*".

[X] **particle-size analysis** - ASTM 422, "*Standard Method for Particle-Size Analysis of Soils*".

[X] **percent passing No. 200 sieve** - ASTM D 1140, "*Standard Test Method for Amount of Material in Soil Finer Than No. 200 (75 microns) sieve*".

[X] **Atterberg limits** - ASTM D 4318, "*Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*".

[X] **soil classification** - ASTM D 2487, "*Standard Test Method for Classification of Soils for Engineering Purposes*";

[ ] **soil pH** - ASTM D 4972, "*Standard Test Method for pH of Soils*".

[ ] **soil pH** - United States Environmental Protection Agency (USEPA) SW-846 Method 9045, Revision 1, 1987, Standard Test Method for Measurement of "*Soil pH*";

[X] **specific gravity** - ASTM D 854, "*Standard Test Method for Specific Gravity of Soils*",

[ ] **carbonate content** - ASTM D 3042, "*Standard Method for Insoluble Residue in Carbonate Aggregates*";

[ ] **soundness** - ASTM C 88, "*Standard Test Method for Soundness of Aggregates by use of Sodium Sulfate or Magnesium Sulfate*";

[ ] **loss-on-ignition (LOI)** - ASTM D 2974, "*Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*",

[X] **standard Proctor compaction** - ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*",

[X] **reduced energy Proctor compaction** - modified ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*", using 15 blows;

[X] **modified Proctor compaction** - ASTM D 1557, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in (457-mm) Drop*";

[ ] **maximum relative density** - ASTM D 4253, "*Standard Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*";

[ ] **minimum relative density** - ASTM D 4254, "*Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*",

[ ] **mass per unit area** - ASTM D 3776, "*Standard Test Method for Mass Per Unit Area (weight) of Woven Fabric*";

[ ] **thickness measurement** - ASTM D 1777, "*Standard Test Method for Measuring Thickness of Textile Materials*",

[ ] **free swell** - United States Pharmacopeia National Formulary (USP-NF) XVII, "*Swell Index of Clay*";

[ ] **fluid loss** - American Petroleum Institute (API)-13B, "*Section 4, Bentonite*",

[ ] **marsh funnel** - API-13B, "*Section 4, Field Testing of Oil Mud Viscosity and Gel Strength*";

[ ] **pinhole dispersion** - ASTM D 4647, "*Standard Test Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test*",

[ ] **gradient ratio** - ASTM D 5101, "*Standard Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio*",

[ ] **hydraulic conductivity ratio** - Draft ASTM D 35.03.91 01, "*Standard Test Method for Hydraulic Conductivity Ratio (HCR) Testing*";

[ ] **hydraulic transmissivity** - ASTM D 4716, "*Standard Test Method for Constant Head Hydraulic Transmissivity (In-plane flow) of Geotextiles and Geotextile Related Products*",

- ☐ **one-dimensional consolidation** - ASTM D 2435, *"Standard Test Method for One-Dimensional Consolidation Properties of Soil"*;
- ☐ **one-dimensional swell/collapse** - ASTM D 4546, *"Standard Test Method for One-Dimensional Swell or Settlement Potential of Cohesive Soils"*,
- ☐ **unconfined compressive strength (UCS)** - ASTM D 2166, *" Standard Test Method for Unconfined Compressive Strength of Cohesive Soil"*;
- ☐ **triaxial compressive strength ($\overline{\text{ICU}}$)** - ASTM D 4767, *"Standard Test Method for Triaxial Compression Test on Cohesive Soils"*;
- ☐ **triaxial compressive strength (UU)** - ASTM D 2850, *"Standard Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression"*;
- ☐ **rigid wall constant head hydraulic conductivity** - ASTM D 2434, *"Standard Test Method for Permeability of Granular Soils (Constant Head)"*,
- ☐ **flexible wall falling head hydraulic conductivity** - ASTM D 5084, *"Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter"*,
- ☐ **flexible wall falling head hydraulic conductivity** - U.S. Army Corp of Engineers, EM-1110-2-1906, *"Standard Test Method for Permeability Tests, Appendix VII"*,
- ☐ **index flux of GCL** - proposed ASTM method rough draft # 1, 6/18/94, *"Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter"*;
- ☐ **flexible wall falling head hydraulic conductivity** - Geosynthetic Research Institute (GRI) GCL-2, *"Standard Test Method for Permeability of Geosynthetic Clay Liners (GCLs)"*;
- ☐ **permeability/compatibility** - USEPA Method 9100 SW-846, Revision 1, 1987, Standard Test Method for Measurement of *"Saturated Hydraulic Conductivity, Saturated Leachate Conductivity and Intrinsic Permeability"*;
- ☐ **capillary-moisture** - ASTM D 2325, *"Standard Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus"*, and
- ☐ **capillary-moisture** - ASTM D 3152, *"Standard Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus"*.

APPLICATION OF TEST RESULTS

The reported test results apply to the field materials inasmuch as the samples sent to the laboratory for testing are representative of these materials. This report applies only to the materials tested and does not necessarily indicate the quality or condition of apparently identical or similar materials. The testing was performed in accordance with the general engineering standards and conditions reported. The test results are related to the testing conditions used during the testing program As a mutual protection to the client, the public, and GeoSyntec, this report is submitted and accepted for the exclusive use of the client and upon the condition that this report is not used, in whole or in part, in any advertising, promotional or publicity matter without prior written authorization from GeoSyntec

GEOSYNTEC CONSULTANTS

Geomechanics & Environmental Laboratory
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Alpharetta, Georgia 30201 • USA
Tel. (770) 645-6575 • Fax (770) 645-6570

2 May 1997

Mr. Brad Coleman, P.E.
Harding Lawson Associates
707 17th Street, Suite 2400
Denver, Colorado 80202

Subject: Laboratory Testing
Report No. 2 - Shelby Tube Samples
Rocky Mountain Arsenal

Dear Mr. Coleman:

GeoSyntec Consultants (GeoSyntec) in Atlanta, Georgia, is pleased to present the attached test results (Table 1 and Figure 1) for the above referenced project. A blank shown on the table or on the figure indicates that the test was not performed, the parameter is not applicable, or that the test resulted in insufficient data to report the designated parameter. Attachment A presents the general information pertinent to the testing program, and the policy of GeoSyntec regarding the limitations of and the use of the test results.

GeoSyntec appreciates the opportunity to provide testing services for this project. Should you have any questions regarding the attached test results or if you require additional information, please do not hesitate to contact either of the undersigned.

Sincerely,

Cuneyt Gokmen, E.I.T.
Assistant Program Manager
Environmental Testing

Nad S. Rad

Nader S. Rad, Ph.D., P.E.
Laboratory Director

Attachment

GL0232/GEL97064

TABLE 1

HYDRAULIC CONDUCTIVITY AND INDEX TEST RESULTS
SHELBY TUBE SAMPLES

HARDING LAWSON ASSOCIATES
ROCKY MOUNTAIN ARSENAL

REPORT NO. 2

Client Sample ID	Lab Sample No	Moisture Content ASTM D 2216 (%)	Grain Size			Atterberg Limits ASTM D 4318			Soil Classification ASTM D 2487	Specific Gravity ASTM D 854 (-)	Flexible Wall Falling Head ASTM D 5084				Remarks
			Percent Passing #200 Sieve ASTM D 1140 (%)	ASTM D 422		LL (%)	PL (%)	PI (-)			Test Specimen Initial Conditions		Consol Pressure (psi)	Hydraulic Conductivity (cm/s)	
				Sieve Figure No.	Hydrom Figure No.						Dry Unit Weight (pcf)	Moisture Content (%)			
111	97D11										112 6	16 3	3	1.2E-8	
													10	5 3E-9	
122	97D14										113.8	15 1	3	1.9E-6	
													10	9.8E-7	
132	97D15										106 9	15 7	3	2 0E-5	
													10	2 1E-6	
231	97D19										111.1	17 8	3	2 0E-8	
													10	4.7E-9	
312	97D22										115 9	16 2	3	6 1E-9	
													10	1.7E-9	

TABLE 1 (continued)

HYDRAULIC CONDUCTIVITY AND INDEX TEST RESULTS
SHELBY TUBE SAMPLES

HARDING LAWSON ASSOCIATES
ROCKY MOUNTAIN ARSENAL

REPORT NO. 2

Client Sample ID	Lab Sample No	Moisture Content ASTM D 2216 (%)	Grain Size			Atterberg Limits ASTM D 4318			Soil Classification ASTM D 2487	Specific Gravity ASTM D 854 (-)	Flexible Wall Falling Head ASTM D 5084				Remarks
			Percent Passing #200 Sieve ASTM D 1140 (%)	ASTM D 422							Test Specimen Initial Conditions		Consol Pressure (psi)	Hydraulic Conductivity (cm/s)	
				Sieve Figure No	Hydrom Figure No	LL (%)	PL (%)	PI (-)			Dry Unit Weight (pcf)	Moisture Content (%)			
412	97D27										111 2	18 4	3	6 0E-9	
													10	2 3E-9	
511	97D32										109 4	19 1	3	1 2E-8	
													10	3 7E-9	
611	97D40	22 0	75 3	1		47	16	31	CL - Lean Clay with Sand		104 8	22 0	3	6 4E-8	
													10	1 6E-8	

GEO SYNTEC CONSULTANTS

Geomechanics and Environmental Laboratory
Atlanta, Georgia

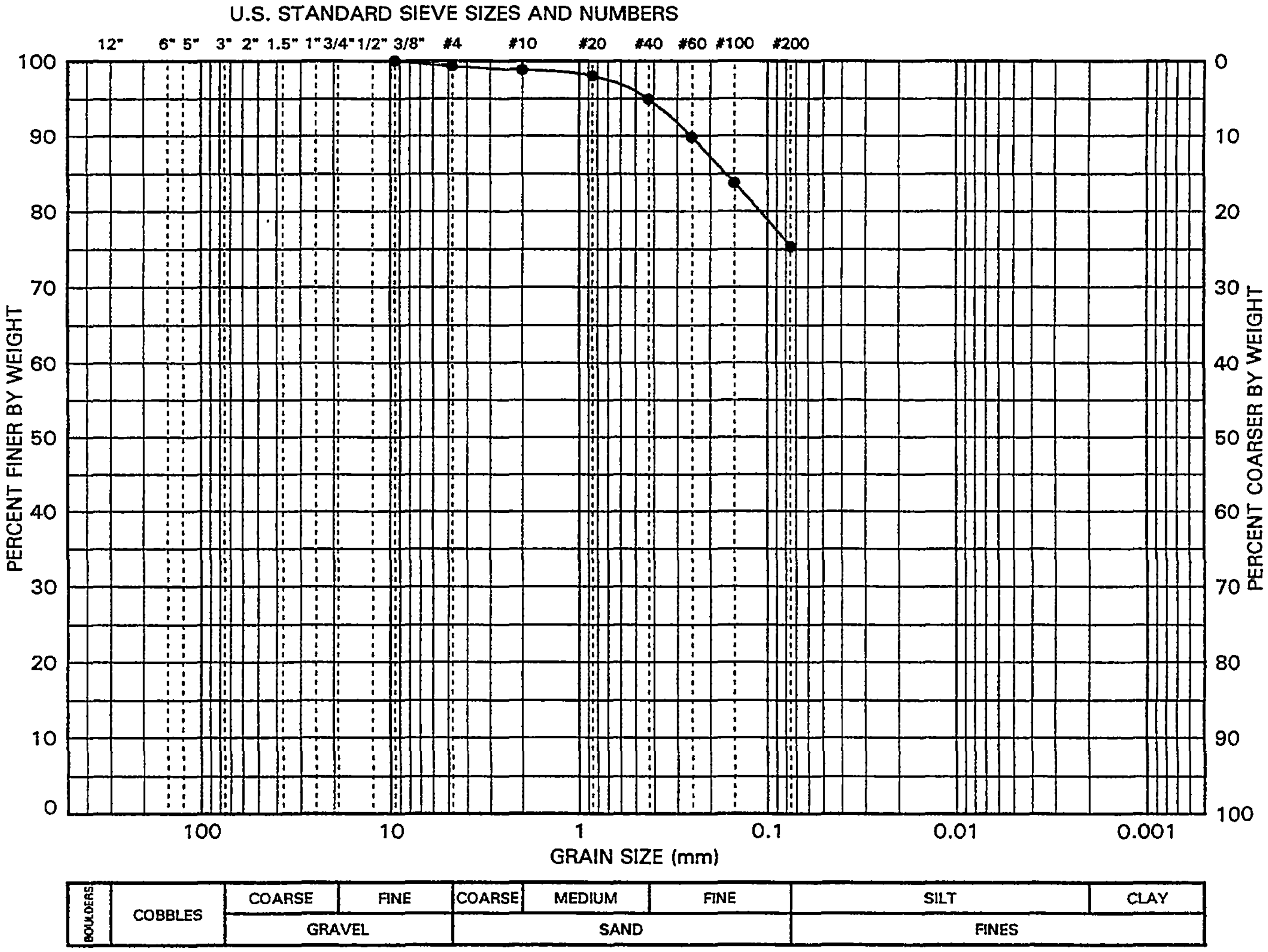
FIGURE 1

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97064

GS FORM:
4PS2 04/30/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	611	LIQUID LIMIT (%)	47	GRAVEL (%)	0.7
LAB. SAMPLE NO.	97D40	PLASTIC LIMIT (%)	16	SAND (%)	24.0
SAMPLE DEPTH (ft)		PLASTICITY INDEX	31	FINES (%)	75.3
				SILT (%)	
				CLAY(%)	

SOIL FRACTIONS

SOIL CLASSIFICATION:
CL - Lean Clay with Sand

COEFF. UNIFORMITY (Cu)

COEFF. CURVATURE (Cc)

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	99	99	98	95	90	84	75					

NOTES:

ATTACHMENT A

Sample Identification, Handling, Storage and Disposal

Laboratory Test Standards

Application of Test Results

SAMPLE IDENTIFICATION, HANDLING, STORAGE AND DISPOSAL

Test materials were sent to GeoSyntec Consultants (GeoSyntec) Geomechanics and Environmental Laboratory in Atlanta, Georgia by the client or its representative(s). Samples delivered to the laboratory were identified by client sample identification (ID) numbers which had been assigned by representative(s) of the client. Upon being received at the laboratory, each sample was assigned a laboratory sample number to facilitate tracking and documentation.

Based on the information provided to GeoSyntec by the client or its representative(s) and, when applicable, procedural guidelines recommended by an industrial hygiene consultant, the following Occupational Safety and Health Administration (OSHA) level of personal protection was adopted for handling and testing of the test materials:

[X] test materials were not contaminated, no special protection measures were taken;
[ ] level D
[ ] level C
[ ] level B

In accordance with the health and safety guidelines of GeoSyntec, contaminated materials are stored in a designated containment area in the laboratory. Non-contaminated materials are stored in a general storage area in the laboratory.

GeoSyntec Geomechanics and Environmental Laboratory will continue storing the test materials for a period of 30 days from the date of this report or a year from the time that the samples were received, which ever is shorter. Thereafter: (i) contaminated materials will be returned to the client or its designated representative(s); and (ii) the materials which are not contaminated will be discarded unless long-term storage arrangements are specifically made with GeoSyntec Geomechanics and Environmental Laboratory.

LABORATORY TEST STANDARDS

At the request of the client, the laboratory testing program was performed utilizing the guidelines provided in the following test standards:

[X] **moisture content** - American Society for Testing and Materials (ASTM) D 2216 "*Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures*";

[ ] **moisture content** - ASTM D 4643 "*Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Method*";

[X] **particle-size analysis** - ASTM 422, "*Standard Method for Particle-Size Analysis of Soils*";

[X] **percent passing No. 200 sieve** - ASTM D 1140, "*Standard Test Method for Amount of Material in Soil Finer Than No. 200 (75 microns) sieve*";

[X] **Atterberg limits** - ASTM D 4318, "*Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*";

[X] **soil classification** - ASTM D 2487, "*Standard Test Method for Classification of Soils for Engineering Purposes*";

[ ] **soil pH** - ASTM D 4972, "*Standard Test Method for pH of Soils*";

[ ] **soil pH** - United States Environmental Protection Agency (USEPA) SW-846 Method 9045, Revision 1, 1987, Standard Test Method for Measurement of "*Soil pH*";

[ ] **specific gravity** - ASTM D 854, "*Standard Test Method for Specific Gravity of Soils*";

[ ] **carbonate content** - ASTM D 3042, "*Standard Method for Insoluble Residue in Carbonate Aggregates*";

[ ] **soundness** - ASTM C 88, "*Standard Test Method for Soundness of Aggregates by use of Sodium Sulfate or Magnesium Sulfate*";

[ ] **loss-on-ignition (LOI)** - ASTM D 2974, "*Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*";

[ ] **standard Proctor compaction** - ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*";

[ ] **reduced energy Proctor compaction** - modified ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*", using 15 blows;

[ ] **modified Proctor compaction** - ASTM D 1557, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop*";

[ ] **maximum relative density** - ASTM D 4253, "*Standard Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*";

[ ] **minimum relative density** - ASTM D 4254, "*Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*";

[ ] **mass per unit area** - ASTM D 3776, "*Standard Test Method for Mass Per Unit Area (weight) of Woven Fabric*";

[ ] **thickness measurement** - ASTM D 1777, "*Standard Test Method for Measuring Thickness of Textile Materials*";

[ ] **free swell** - United States Pharmacopeia National Formulary (USP-NF) XVII, "*Swell Index of Clay*";

[ ] **fluid loss** - American Petroleum Institute (API)-13B, "*Section 4, Bentonite*";

[ ] **marsh funnel** - API-13B, "*Section 4, Field Testing of Oil Mud Viscosity and Gel Strength*";

[ ] **pinhole dispersion** - ASTM D 4647, "*Standard Test Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test*";

[ ] **gradient ratio** - ASTM D 5101, "*Standard Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio*";

[ ] **hydraulic conductivity ratio** - Draft ASTM D 35.03.91.01, "*Standard Test Method for Hydraulic Conductivity Ratio (HCR) Testing*";

[ ] **hydraulic transmissivity** - ASTM D 4716, "*Standard Test Method for Constant Head Hydraulic Transmissivity (In-plane flow) of Geotextiles and Geotextile Related Products*";

[ ] **one-dimensional consolidation** - ASTM D 2435, "*Standard Test Method for One-Dimensional Consolidation Properties of Soil*";

[ ] **one-dimensional swell/collapse** - ASTM D 4546, "*Standard Test Method for One-Dimensional Swell or Settlement Potential of Cohesive Soils*";

[ ] **unconfined compressive strength (UCS)** - ASTM D 2166, " *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil*";

[ ] **triaxial compressive strength** (**$\overline{\text{ICU}}$**) - ASTM D 4767, "*Standard Test Method for Triaxial Compression Test on Cohesive Soils*";

[ ] **triaxial compressive strength (UU)** - ASTM D 2850, "*Standard Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression*";

[ ] **rigid wall constant head hydraulic conductivity** - ASTM D 2434, "*Standard Test Method for Permeability of Granular Soils (Constant Head)*";

[X] **flexible wall falling head hydraulic conductivity** - ASTM D 5084, "*Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*";

[ ] **flexible wall falling head hydraulic conductivity** - U. S. Army Corp of Engineers; EM-1110-2-1906, "*Standard Test Method for Permeability Tests, Appendix VII*";

[ ] **index flux of GCL** - proposed ASTM method rough draft # 1, 6/18/94, "*Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter*";

[ ] **flexible wall falling head hydraulic conductivity** - Geosynthetic Research Institute (GRI) GCL-2, "*Standard Test Method for Permeability of Geosynthetic Clay Liners (GCLs)*";

[ ] **permeability/compatibility** - USEPA Method 9100 SW-846, Revision 1, 1987, Standard Test Method for Measurement of "*Saturated Hydraulic Conductivity, Saturated Leachate Conductivity and Intrinsic Permeability*";

[ ] **capillary-moisture** - ASTM D 2325, "*Standard Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus*"; and

[ ] **capillary-moisture** - ASTM D 3152, "*Standard Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus*".

APPLICATION OF TEST RESULTS

The reported test results apply to the field materials inasmuch as the samples sent to the laboratory for testing are representative of these materials. This report applies only to the materials tested and does not necessarily indicate the quality or condition of apparently identical or similar materials. The testing was performed in accordance with the general engineering standards and conditions reported. The test results are related to the testing conditions used during the testing program. As a mutual protection to the client, the public, and GeoSyntec, this report is submitted and accepted for the exclusive use of the client and upon the condition that this report is not used, in whole or in part, in any advertising, promotional or publicity matter without prior written authorization from GeoSyntec.

GEOSYNTEC CONSULTANTS

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3 June 1997

Mr. Brad Coleman, P.E.
Harding Lawson Associates
707 17th Street, Suite 2400
Denver, Colorado 80202

Subject: Laboratory Testing
Report No. 3 - Block Samples
Rocky Mountain Arsenal

Dear Mr. Coleman:

GeoSyntec Consultants (GeoSyntec) in Atlanta, Georgia, is pleased to present the attached test results (Table 1 and Figures 1 through 3) for the above referenced project. A blank shown on the table or any of the figures indicates that the test was not performed, the parameter is not applicable, or that the test resulted in insufficient data to report the designated parameter. Attachment A presents the general information pertinent to the testing program, and GeoSyntec's policy regarding the limitations of and the use of the test results.

GeoSyntec appreciates the opportunity to provide testing services for this project. Should you have any questions regarding the attached test results or if you require additional information, please do not hesitate to contact either of the undersigned.

Sincerely,

Cuneyt Gokmen, E.I.T.
Assistant Program Manager
Environmental Testing

Nader S. Rad

Nader S. Rad, Ph.D., P.E.
Laboratory Director

Attachment

GL0232/GEL97065

TABLE 1

HYDRAULIC CONDUCTIVITY AND INDEX TEST RESULTS
BLOCK SAMPLES

HARDING LAWSON ASSOCIATES
ROCKY MOUNTAIN ARSENAL

REPORT NO. 3

Client Sample ID	Lab Sample No	Moisture Content ASTM D 2216 (%)	Grain Size			Atterburg Limits ASTM D 4318			Soil Classification ASTM D 2487	Specific Gravity ASTM D 854 (-)	Block Sample - Flexible Wall Falling Head ASTM D 5084				Remarks
			Percent Passing #200 Sieve ASTM D 2216 (%)	ASTM D 422							Test Specimen Initial Conditions		Consol Pressure (psi)	Hydraulic Conductivity (cm/s)	
				Sieve Figure No	Hydrom Figure No	LL (%)	PL (%)	PI (-)			Dry Unit Weight (pcf)	Moisture Content (%)			
1211	97D53	14.7	72.6	1	1	42	15	27	CL - Lean Clay with Sand	2.66	114.1	14.7	3	2.4E-8	
													10	2.5E-9	
1231	97D55	16.6									109.4	16.6	3	6.7E-8	
													10	4.6E-9	
3423	97D56	19.8									104.7	19.8	3	3.7E-8	
													10	3.4E-9	
3433	97D58	20.9	73.1	2	2	42	15	27	CL - Lean Clay with Sand	2.66	104.8	20.9	3	6.9E-8	
													10	2.0E-9	
5613	97D59	19.5									106.4	19.5	3	7.0E-8	
													10	3.1E-9	
5621	97D60	20.6	74.4	3	3	43	16	27	CL - Lean Clay with Sand	2.70	105.3	20.6	3	9.4E-8	
													10	2.9E-9	

GEO SYNTEC CONSULTANTS

Geomechanics and Environmental Laboratory
Atlanta, Georgia

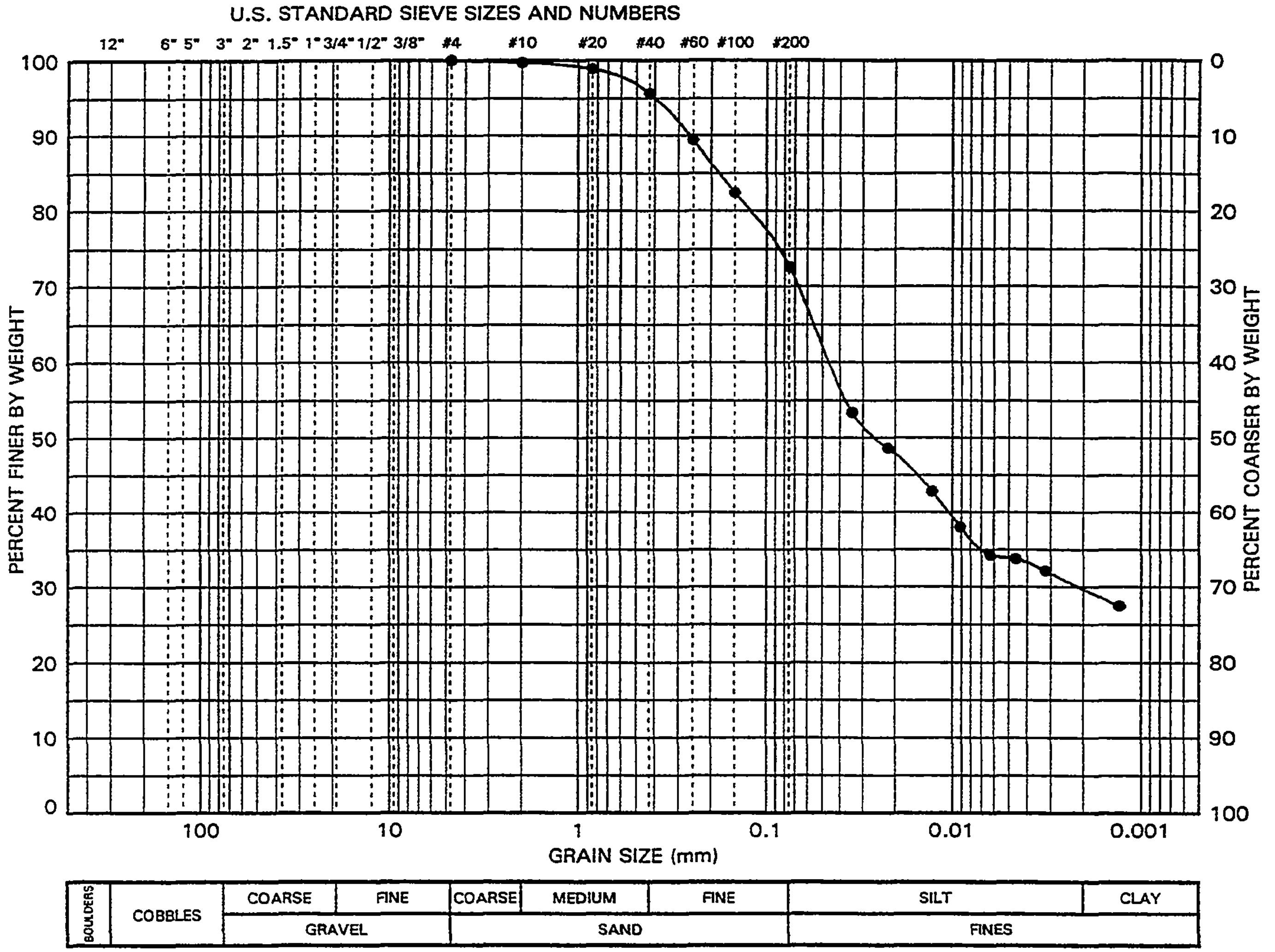
FIGURE 1

PROJECT:	Rocky Mountain Arsenal
PROJECT NO.:	GL0232
DOCUMENT NO.:	GEL97065

GS FORM:
4PS2 06/03/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	1211	LIQUID LIMIT (%)	42
LAB. SAMPLE NO.	97D53	PLASTIC LIMIT (%)	15
SAMPLE DEPTH (ft)		PLASTICITY INDEX	27

SOIL CLASSIFICATION:
CL - Lean Clay with Sand

SOIL FRACTIONS	GRAVEL (%)	0.0
	SAND (%)	27.4
	FINES (%)	72.6
	SILT (%)	42.9
	CLAY(%)	29.7
COEFF. UNIFORMITY (Cu)		
COEFF. CURVATURE (Cc)		

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	99	96	89	82	73	63	48	34	30	

NOTES:

GEO SYNTEC CONSULTANTS

Geomechanics and Environmental Laboratory
Atlanta, Georgia

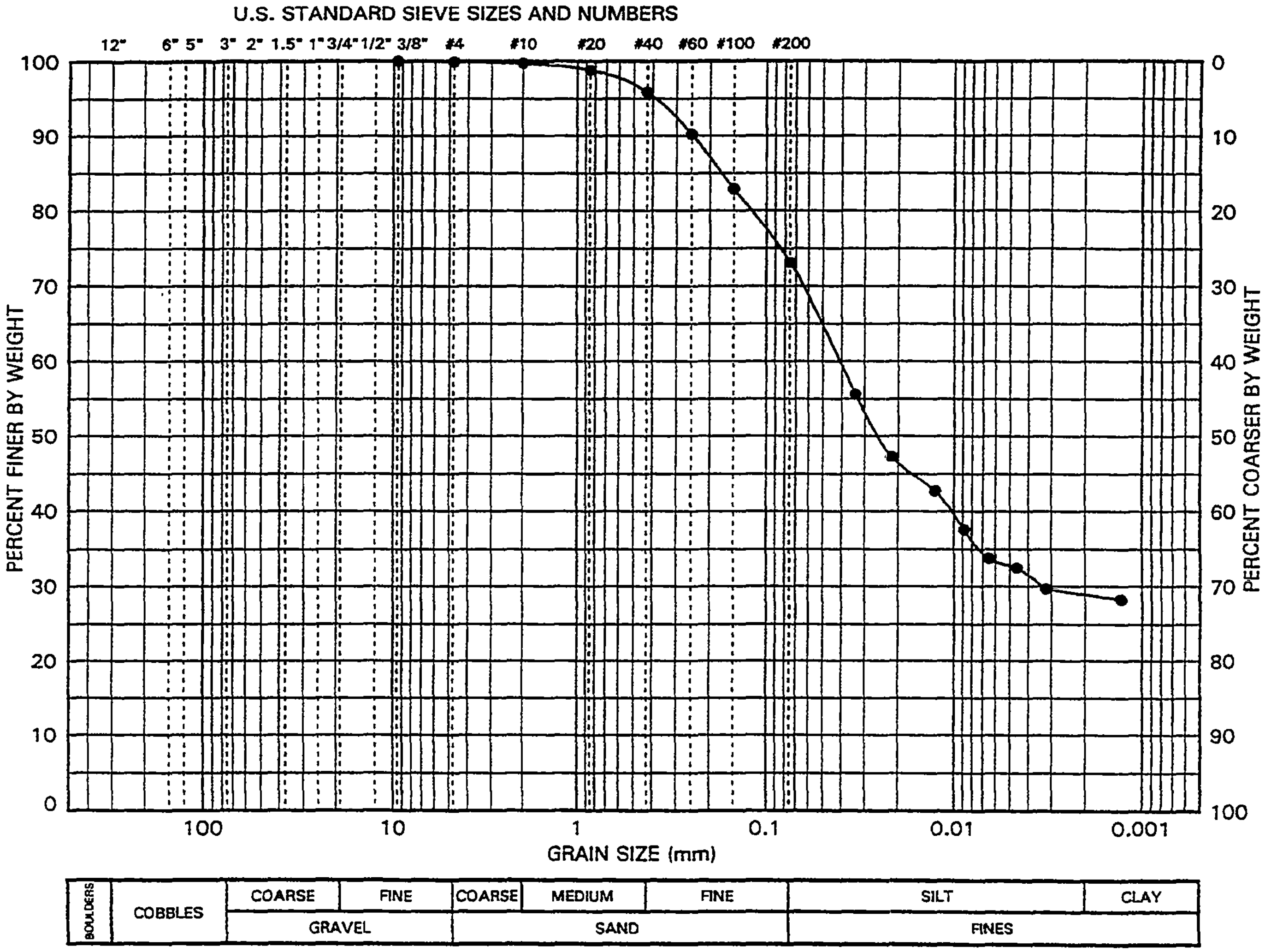
FIGURE 2

PROJECT: Rocky Mountain Arsenal
PROJECT NO.: GL0232
DOCUMENT NO.: GEL97065

GS FORM:
4PS2 06/03/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	3433	LIQUID LIMIT (%)	42
LAB. SAMPLE NO.	97D58	PLASTIC LIMIT (%)	15
SAMPLE DEPTH (ft)		PLASTICITY INDEX	27

SOIL CLASSIFICATION:

CL - Lean Clay with Sand

SOIL FRACTIONS	GRAVEL (%)	0.1
	SAND (%)	26.8
	FINES (%)	73.1
	SILT (%)	44.1
	CLAY(%)	29.0
COEFF. UNIFORMITY (Cu)		
COEFF. CURVATURE (Cc)		

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)														PARTICLE DIAMETER (mm)				
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	99	96	90	83	73	64	47	33	29	

NOTES:

GEO SYNTEC CONSULTANTS
Geomechanics and Environmental Laboratory
Atlanta, Georgia

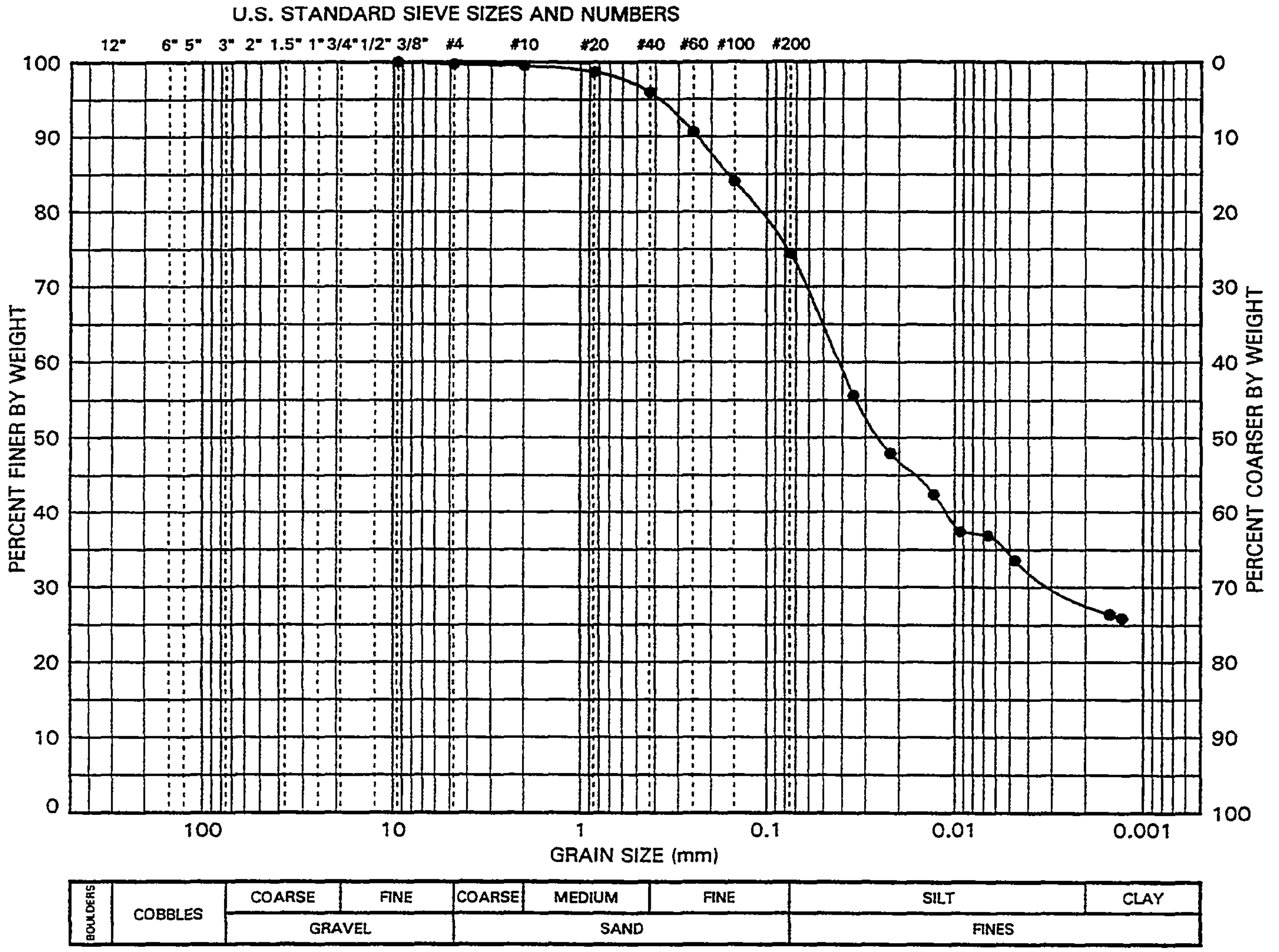
FIGURE 3

PROJECT:	Rocky Mountain Arsenal
PROJECT NO.:	GL0232
DOCUMENT NO.:	GEL97065

GS FORM:
4PS2 06/03/97

PARTICLE SIZE DISTRIBUTION AND PHYSICAL PROPERTIES

ASTM C 136, D 422, D 2487
D 3042 AND D 4318



SITE SAMPLE ID	5621	LIQUID LIMIT (%)	43
LAB. SAMPLE NO.	97D60	PLASTIC LIMIT (%)	16
SAMPLE DEPTH (ft)		PLASTICITY INDEX	27

SOIL CLASSIFICATION:
CL - Lean Clay with Sand

SOIL FRACTIONS	GRAVEL (%)	0.3
	SAND (%)	25.3
	FINES (%)	74.4
	SILT (%)	46.2
	CLAY(%)	28.2
COEFF. UNIFORMITY (Cu)		
COEFF. CURVATURE (Cc)		

PERCENT PASSING U.S. STANDARD SIEVE SIZES AND NUMBERS														PERCENT FINER THAN HYDROMETER PARTICLE DIAMETER (mm)				
3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200					
PERCENT PASSING SIEVE SIZES (mm)																		
75	50	37.5	25	19	12.5	9.5	4.75	2.00	0.850	0.425	0.250	0.150	0.075	0.050	0.020	0.005	0.002	0.001
100	100	100	100	100	100	100	100	100	99	96	91	84	74	65	47	34	28	

NOTES:

ATTACHMENT A

Sample Identification, Handling, Storage and Disposal

Laboratory Test Standards

Application of Test Results

SAMPLE IDENTIFICATION, HANDLING, STORAGE AND DISPOSAL

Test materials were sent to GeoSyntec Consultants (GeoSyntec) Geomechanics and Environmental Laboratory in Atlanta, Georgia by the client or its representative(s). Samples delivered to the laboratory were identified by client sample identification (ID) numbers which had been assigned by representative(s) of the client. Upon being received at the laboratory, each sample was assigned a laboratory sample number to facilitate tracking and documentation.

Based on the information provided to GeoSyntec by the client or its representative(s) and, when applicable, procedural guidelines recommended by an industrial hygiene consultant, the following Occupational Safety and Health Administration (OSHA) level of personal protection was adopted for handling and testing of the test materials:

[X] test materials were not contaminated, no special protection measures were taken;
[ ] level D
[ ] level C
[ ] level B

In accordance with the health and safety guidelines of GeoSyntec, contaminated materials are stored in a designated containment area in the laboratory. Non-contaminated materials are stored in a general storage area in the laboratory.

GeoSyntec Geomechanics and Environmental Laboratory will continue storing the test materials for a period of 30 days from the date of this report or a year from the time that the samples were received, which ever is shorter. Thereafter: (i) contaminated materials will be returned to the client or its designated representative(s); and (ii) the materials which are not contaminated will be discarded unless long-term storage arrangements are specifically made with GeoSyntec Geomechanics and Environmental Laboratory.

LABORATORY TEST STANDARDS

At the request of the client, the laboratory testing program was performed utilizing the guidelines provided in the following test standards:

[X] **moisture content** - American Society for Testing and Materials (ASTM) D 2216 "*Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures*";

[ ] **moisture content** - ASTM D 4643 "*Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Method*";

[X] **particle-size analysis** - ASTM 422, "*Standard Method for Particle-Size Analysis of Soils*";

[X] **percent passing No. 200 sieve** - ASTM D 1140, "*Standard Test Method for Amount of Material in Soil Finer Than No. 200 (75 microns) sieve*";

[X] **Atterberg limits** - ASTM D 4318, "*Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*";

[X] **soil classification** - ASTM D 2487, "*Standard Test Method for Classification of Soils for Engineering Purposes*";

[ ] **soil pH** - ASTM D 4972, "*Standard Test Method for pH of Soils*";

[ ] **soil pH** - United States Environmental Protection Agency (USEPA) SW-846 Method 9045, Revision 1, 1987, Standard Test Method for Measurement of "*Soil pH*";

[X] **specific gravity** - ASTM D 854, "*Standard Test Method for Specific Gravity of Soils*";

[ ] **carbonate content** - ASTM D 3042, "*Standard Method for Insoluble Residue in Carbonate Aggregates*";

[ ] **soundness** - ASTM C 88, "*Standard Test Method for Soundness of Aggregates by use of Sodium Sulfate or Magnesium Sulfate*";

[ ] **loss-on-ignition (LOI)** - ASTM D 2974, "*Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*";

[ ] **standard Proctor compaction** - ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*";

[ ] **reduced energy Proctor compaction** - modified ASTM D 698, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop*", using 15 blows;

[ ] **modified Proctor compaction** - ASTM D 1557, "*Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop*";

[ ] **maximum relative density** - ASTM D 4253, "*Standard Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*";

[ ] **minimum relative density** - ASTM D 4254, "*Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*";

[ ] **mass per unit area** - ASTM D 3776, "*Standard Test Method for Mass Per Unit Area (weight) of Woven Fabric*";

[ ] **thickness measurement** - ASTM D 1777, "*Standard Test Method for Measuring Thickness of Textile Materials*";

[ ] **free swell** - United States Pharmacopeia National Formulary (USP-NF) XVII, "*Swell Index of Clay*";

[ ] **fluid loss** - American Petroleum Institute (API)-13B, "*Section 4, Bentonite*";

[ ] **marsh funnel** - API-13B, "*Section 4, Field Testing of Oil Mud Viscosity and Gel Strength*";

[ ] **pinhole dispersion** - ASTM D 4647, "*Standard Test Method for Identification and Classification of Dispersive Clay Soils by the Pinhole Test*";

[ ] **gradient ratio** - ASTM D 5101, "*Standard Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio*";

[ ] **hydraulic conductivity ratio** - Draft ASTM D 35.03.91.01, "*Standard Test Method for Hydraulic Conductivity Ratio (HCR) Testing*";

[ ] **hydraulic transmissivity** - ASTM D 4716, "*Standard Test Method for Constant Head Hydraulic Transmissivity (In-plane flow) of Geotextiles and Geotextile Related Products*";

[ ] **one-dimensional consolidation** - ASTM D 2435, "*Standard Test Method for One-Dimensional Consolidation Properties of Soil*";

[ ] **one-dimensional swell/collapse** - ASTM D 4546, "*Standard Test Method for One-Dimensional Swell or Settlement Potential of Cohesive Soils*";

[ ] **unconfined compressive strength (UCS)** - ASTM D 2166, " *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil*";

[ ] **triaxial compressive strength ($\overline{\text{ICU}}$)** - ASTM D 4767, "*Standard Test Method for Triaxial Compression Test on Cohesive Soils*";

[ ] **triaxial compressive strength (UU)** - ASTM D 2850, "*Standard Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression*";

[ ] **rigid wall constant head hydraulic conductivity** - ASTM D 2434, "*Standard Test Method for Permeability of Granular Soils (Constant Head)*";

[X] **flexible wall falling head hydraulic conductivity** - ASTM D 5084, "*Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*";

[ ] **flexible wall falling head hydraulic conductivity** - U. S. Army Corp of Engineers; EM-1110-2-1906, "*Standard Test Method for Permeability Tests, Appendix VII*";

[ ] **index flux of GCL** - proposed ASTM method rough draft # 1, 6/18/94, "*Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter*";

[ ] **flexible wall falling head hydraulic conductivity** - Geosynthetic Research Institute (GRI) GCL-2, "*Standard Test Method for Permeability of Geosynthetic Clay Liners (GCLs)*";

[ ] **permeability/compatibility** - USEPA Method 9100 SW-846, Revision 1, 1987, Standard Test Method for Measurement of "*Saturated Hydraulic Conductivity, Saturated Leachate Conductivity and Intrinsic Permeability*";

[ ] **capillary-moisture** - ASTM D 2325, "*Standard Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus*"; and

[ ] **capillary-moisture** - ASTM D 3152, "*Standard Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus*".

APPLICATION OF TEST RESULTS

The reported test results apply to the field materials inasmuch as the samples sent to the laboratory for testing are representative of these materials. This report applies only to the materials tested and does not necessarily indicate the quality or condition of apparently identical or similar materials. The testing was performed in accordance with the general engineering standards and conditions reported. The test results are related to the testing conditions used during the testing program. As a mutual protection to the client, the public, and GeoSyntec, this report is submitted and accepted for the exclusive use of the client and upon the condition that this report is not used, in whole or in part, in any advertising, promotional or publicity matter without prior written authorization from GeoSyntec.

Appendix H

RESPONSE TO REGULATORY COMMENTS

DEPARTMENT OF THE ARMY
PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO 80022 1748

September 23, 1997

REPLY TO
ATTENTION OF:

Remedy Execution

FAX TO
BRAD COLEMAN

Ms. Susan Chaki
Colorado Department of Public
Health and Environment
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530

Dear Ms. Chaki:

Enclosed are the U.S. Army's responses to U.S. Environmental Protection Agency (EPA) and Colorado Department of Public Health and Environment's (CDPHE) July 3, 1997 comments, on the Rocky Mountain Arsenal Double-Lined Landfill Test Fill Construction Program Summary Report, Feasibility Study Soils Support Program. These comments and responses were discussed with EPA and CDPHE in a working meeting held on July 29, 1997. Some responses were modified based on these discussions.

The Double-Lined Landfill 90 Percent Design Package and Draft Final Construction Quality Assurance Plan being prepared by the Corps of Engineers have been prepared to be consistent with responses to Test Fill Report Summary comments. The Army will set up a working meeting with CDPHE and EPA in approximately two to three weeks to resolve any outstanding issues and finalize the Test Fill Report.

If you have any questions the points of contact on this project are Mr. Bruce Huenefeld at 303-289-0240, and Mr. Mark McClain at 303-853-3943.

Sincerely,

Charles T. Scharmann
RMA Committee Coordinator

Enclosures (4 copies)

Copies Furnished:

Major M. Weslyn Erickson, Chief Counsel, Program Manager Rocky Mountain Arsenal,
Attn: AMCPM-RMC, Commerce City, Colorado 80022-1748 (w/encl)
Mr. Robert H. Foster, U.S. Department of Justice, 999-18th Street, Suite 945,
North Tower, Denver, Colorado 80202 (w/encl)
Mr. Stephen G. Hamel, Attorney General's Office, CERCLA Litigation Unit,
1525 Sherman Street, 5th Floor, Denver, Colorado 80203 (w/encl)
Mr. Martin Kosec, Geotrans Inc,. 4888 Pearl East Circle, Suite 300-E,
Boulder, Colorado 80301 (w/encl 2 copies)
Mr. Michael T. Anderson, Shell Oil Company, P.O. Box 538,
Commerce City, Colorado 80037 (w/encl)
Mr. Thomas Cope, Holme Roberts and Owen, Suite 4100,
1700 Lincoln Street, Denver, Colorado 80203 (w/encl)
Mr. L. Ronel Finley, Coordinator, U.S. Fish and Wildlife Service, Rocky Mountain Arsenal,
Building 111, Commerce City, Colorado 80022-1748 (w/encl)
Mr. John Hartley, Corps of Engineers, Omaha District, 215 North 17th Street,
Omaha, Nebraska 68102-4978 (w/encl)
[redacted] Mountain Arsenal, Attn: AMCPM-RMI-D, Document Tracking
Center, Commerce City, Colorado 80022-1748 (w/encl)

DEPARTMENT OF THE ARMY
PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO 80022-1748

September 23, 1997

REPLY TO
ATTENTION OF:

Remedy Execution

Ms. Laura Williams
U.S. Environmental Protection Agency
Region VIII
Mail Code 8EPR-F
999-18th Street, Suite 500
Denver, Colorado 80202-2466

Dear Ms. Williams:

Enclosed are the U.S. Army's responses to U.S. Environmental Protection Agency (EPA) and Colorado Department of Public Health and Environment's (CDPHE) July 3, 1997 comments, on the Rocky Mountain Arsenal Double-Lined Landfill Test Fill Construction Program Summary Report, Feasibility Study Soils Support Program. These comments and responses were discussed with EPA and CDPHE in a working meeting held on July 29, 1997. Some responses were modified based on these discussions.

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If you have any questions the points of contact on this project are Mr. Bruce Huenefeld at 303-289-0240, and Mr. Mark McClain at 303-853-3943.

Sincerely,

Charles T. Scharmann
RMA Committee Coordinator

Enclosures (3 copies)

Readiness is our Profession

Copies Furnished:

Major M. Weslyn Erickson, Chief Counsel, Program Manager Rocky Mountain Arsenal,
Attn: AMCPM-RMC, Commerce City, Colorado 80022-1748 (w/o encl)
Mr. Robert H. Foster, U.S. Department of Justice, 999-18th Street,
Suite 945, North Tower, Denver, Colorado 80202 (w/o encl)
Mr. Norman Ng-A-Qui, Gannett Fleming, Inc. 999-18th Street, Suite 2520,
Denver, Colorado 80202 (w/encl)
Mr. Michael T. Anderson, Shell Oil Company, P.O. Box 538,
Commerce City, Colorado 80037 (w/o encl)
Mr. Thomas F. Cope, Holme Robert and Owen, Suite 4100, 1700 Lincoln Street,
Denver, Colorado 80203 (w/o encl)
Mr. L. Ronel Finley, Coordinator, U.S. Fish and Wildlife Service, Rocky Mountain Arsenal,
Building 111,Commerce City, Colorado 80022-1748 (w/o encl)
Mr. Thomas J. Butts, MSc, Tri-County Health Department Environmental Health Division,
4301 East 72nd Avenue, Commerce City, Colorado 80022-1488 (w/encl)
[redacted] r Rocky Mountain Arsenal, Attn: AMCPM-RMI-D, Document Tracking
Center, Commerce City, Colorado 80022-1748 (w/o encl)

U.S. Army's Responses to Colorado Department of Public Health And Environment (CDPHE) July 3, 1997, Comments on Draft Final Test Fill Construction Program Summary Report Feasibility Study Soils Support Program Rocky Mountain Arsenal (RMA) Dated June 6, 1997

In a letter dated July 3, 1997, the CDPHE provided 44 comments to the Draft Final Test Fill Construction Program Summary Report (Summary Report) submitted by the Army for regulatory review on June 6, 1997. In the letter, CDPHE requested that they Army provide a written response to the comments within 30 days of the date of the letter (July 3, 1997). On July 29, 1997, the Army met with regulatory (including CDPHE) representatives to discuss the test fill comments along with other issues related to the design of the double-lined landfill cell at the Rocky Mountain Arsenal (RMA). A written response to the comments was given at the meeting to the CDPHE representatives and representatives of the Environmental Protection Agency (EPA) and Tri-County Health Department. The Army discussed the response to comments with the regulatory representatives.

The response to comments given below has been revised based on the discussion held at the July 29, 1997 meeting and the contents of the 90 Percent Design Package. The 90 Percent Design Package includes the 90 Percent Design Drawings, the Draft Final 90 Percent Design Analysis, the Draft Final 90 Percent Design Specifications (Specifications) and the Draft Final 90 Percent Construction Quality Assurance (CQA) Plan. This revised comment response is intended to be reviewed concurrently with the 90 Percent Design Package, particularly the Specifications and CQA Plan. The responses given below have been incorporated into the Specifications and CQA Plan.

RESPONSES TO GENERAL COMMENTS

As part of the scope of the test fill program, recommended edits were given in the Summary Report to the Draft Final 30 Percent Design Specifications for compacted clay liners (CCL) (Section 02443) and for the soil CQA section (Section II) of the Draft Final 30 Percent Design CQA Plan. The intent of the recommended edits was to present only those changes necessitated by the results of the test fill program. However, CDPHE gave many valid comments to these document sections that were unrelated to the test fill program. Additionally, both CDPHE and EPA comments correctly pointed out that modification of the Earthwork/Grading specification (Section 02210) was necessary as a result of the test fill program. The U.S. Army Corp of Engineers (USACE) has revised these three document sections based on the comments and the design progression from the 30 percent stage to the 90 percent stage.

The 44 comments given by CDPHE can be divided into six groups of comments:

1. Final Specification and CQA Plan Requirements
2. Rome Disc Acceptability
3. Hydraulic Conductivity Testing and Results
4. Construction Quality Assurance and Construction Quality Control (CQC) Relationship
5. Borrow Area Evaluation and Screening
6. Miscellaneous Comments

To expedite the discussion of the comments at the July 29, 1997 meeting, the first five comment groups listed above were discussed in detail prior to discussing the 44 individual comments. Group 6 covers comments not applicable to the first five groups. The Group 6 comments were discussed individually. The response to the first five groups of comments is presented below. The Final Summary Report will be prepared after resolution of the regulatory comments.

RESPONSE TO COMMENT GROUP 1: Final Specification and CQA Plan Requirements

Many of the comments dealt with detailed requirements for CCL construction that may or may not have been part of the Test Fill Program. In an effort to streamline the regulatory review and approval process, the Army proposed to the regulatory representatives at the July 29, 1997 meeting, that the September 1993, EPA guidance document entitled "Technical Guidance Document (TGD): Quality Assurance and Quality Control (QA/QC) for Waste Containment Facilities" (EPA 1993 TGD) be used as the base reference for finalizing the details of the CCL (e.g., freezing/desiccation requirements, surface tolerances, etc.) specifications and CQA procedures. The regulatory representatives agreed to the use of the EPA 1993 TGD as the base reference for this work. The revised specifications and CQA requirements included in the 90 Percent Design Package have incorporated the guidance given in the EPA 1993 TGD.

RESPONSE TO COMMENT GROUP 2: Rome Disc Acceptability

During the July 29, 1997 meeting, the Army agreed to delete the specification that the Rome disc could be used for processing clay up to the standard Proctor optimum moisture content. This specification was replaced with a requirement that the Rome disc could be used to assist in moisture conditioning but the CCL material must be processed with a minimum two passes of the soil stabilizer regardless if the disc is used. The enclosed revised CCL specification incorporates this modification.

RESPONSE TO COMMENT GROUP 3: Hydraulic Conductivity Testing and Results

A number of comments were made in reference to the two Shelby tube samples (No. 122 and 132) that failed to achieve the target hydraulic conductivity. Much discussion and speculation as to why the two samples failed was made at the July 29, 1997 meeting with no consensus reached. The potential reasons for the failures include inadequate construction procedures or equipment, accidental sampling of the underlying foundation layer, human error during sampling, shipping, or testing, or a combination of these factors.

During the Test Fill Program, a total of 14 undisturbed (8 Shelby tube and 6 block) samples were tested to obtain their hydraulic conductivity values at both 3 per square inch (psi) and 10 psi consolidation pressures. Of these 14 samples, five (3 Shelby tubes and 2 block samples) were obtained from lift 1. The two samples that failed to obtain a hydraulic conductivity value of 1 x 10^{-7} cm/s or less were both obtained from the slope section of lift 1. Sample No. 122 was obtained from lane 2 of lift 1 and No. 132 was obtained from lane 3 of lift 1. To further evaluate the hydraulic conductivity of lift 1, two additional Shelby tubes were tested; one from the slope section of lane 1 (No. 112) and one from the base section of lane 2 (No. 121). Both easily achieved the required hydraulic conductivity. Sample No. 112 exhibited a hydraulic conductivity of 5 x 10^{-8} cm/s at a 3 psi consolidation pressure. Sample No. 121 exhibited a hydraulic conductivity of 8 x 10^{-9} cm/s at a 3 psi consolidation pressure. The laboratory results for Sample Nos. 112 and 121 will be included in the Final Summary Report.

The Army has concluded that the two failing Shelby tube test results (Nos. 122 and 132) from the slope section of lift 1 are outliers whose results have no bearing on the Army's ability to adequately construct the full-scale CCLs based on the equipment, materials, and procedures used to construct Test Fill 3. This conclusion is based on:

- The hydraulic conductivity results of the two additional Shelby tube samples (Samples Nos. 112 and 121) obtained from lift 1.
- The previously obtained passing results obtained from three other samples obtained from lift 1 (Sample Nos. 111 [Shelby tube], 1211 [block], and 123 [block]).
- No other results came close to failing the target hydraulic conductivity value.
- EPA guidance stating that the subgrade should be "knitted" into the first lift of CCL material on sidelopes (see response to Comment No. 20).

Additionally, CDPHE requested in one comment that undisturbed samples be obtained from the full-scale CCL during construction. Section 2.8.4 (p.83) of the EPA 1993 TGD states that "...that QA program for the actual soil liner should focus on establishing that the actual liner is built of similar materials and to equal or better standards compared to the test pad – laboratory hydraulic conductivity testing *is not necessary* to establish this." Regardless, since CDPHE feels the tests are necessary, the Army will commit to obtaining undisturbed samples for hydraulic conductivity testing, using Shelby tubes, at a frequency of 1 per 10,000 cubic yards. To account for potential mixing of subgrade soil with the first lift of the secondary CCL, it was agreed at the meeting that, for the first lift of the secondary CCL, no hydraulic conductivity testing would be performed on samples obtained from this lift, but that the moisture/density test frequency would be doubled. Outliner limitations for the hydraulic conductivity tests (along with the outliner limitations for number of passes, dry density, and moisture content) are now specified in Table 4 of Section 02443.

RESPONSE TO COMMENT GROUP 4: CQA and CQC Relationship

A number of comments were related to testing frequencies, approval authorities, and the contractual relationship of both the CQA and CQC parties. During the July 29, 1997 meeting, it was clarified that the QA and QC parties are separate parties with separate contractual relationships during the landfill construction. The CQC firm will contract with and report to the landfill construction contractor and the CQA firm will contract with the Program Management Contractor (PMC). The Specifications set forth the QC test frequencies and other QC requirements while the CQA Plan sets forth the QA test frequencies and other QA requirements. The test frequencies given in both of these documents are not intended to be the same. The tests and other inspection activities performed by the CQA firm will be done *in addition to* the tests and other inspection activities performed by the CQC firm.

Based on internal discussions subsequent to the July 29, 1997 meeting, it was determined that the CQA firm cannot commit government funds and, thus cannot have final approval authority of the construction. Therefore, the CQA firm will implement the requirements of the CQA Plan and make approval/disapproval recommendations to the Contracting Officer via the PMC. The Contracting Officer will be a government employee of the Remediation Venture Office (RVO) and will have final approval responsibility for the landfill construction.

RESPONSE TO COMMENT GROUP 5: Borrow Area Evaluation and Screening

The last group of comments were related to the evaluation of the borrow areas and the screening of unacceptable materials out of clayey soil to be excavated for CCL construction. During the July 29, 1997 meeting, the Army committed to continuous monitoring by CQC personnel of the soil removed from the borrow excavation by either observing the soil being placed on the processing table or by observing the soil being excavated from the borrow source (as was done during the test fill construction). In addition to the CQC monitoring, CQA personnel will also periodically monitor the excavation and process areas to verify that only CL or CH material is being excavated from the borrow area. As a final quality precaution, the specifications require that samples obtained from the constructed CCL must classify as CL or CH material and meet the other requirements of Specification 02443. Clayey soils (and also caliche, organics, sandy soils, gravel pockets) are easily identified in the field by competent field personnel.

Based on the discussion summarized above, the Army further stated that the determining the exact percentage and extent of unacceptable soil within the borrow areas is irrelevant to ensuring that the CCLs are built in accordance with the design documents provided: (a) sufficient material meeting the CCL material specifications is present (which there is - see Section 3.5 of the Work Plan); and (b) the material meeting the CCL material specifications is sufficiently similar to that used for the test fill ("similar" is quantified in the response to Comment No. 10 below).

RESPONSES TO SPECIFIC COMMENTS

Comment No. 1

The Draft Compacted Clay Liner Material specification and the Draft Soils Construction Quality Assurance document are incomplete, inconsistent and do not adequately incorporate the results of the Test Fill 3 program. As an example the list and frequency of borrow soil testing is not the same for both documents, compaction testing is proposed at once per 5,000 and 10,000 cubic yard interval frequencies respectively. The documents also do not specify the frequency and type of hydraulic conductivity testing which is necessary to document that the construction has met applicable regulatory standards. The frequency of compacted clay testing is also inadequate considering the variability of the source borrow areas.

Response

See responses to Comment Groups 1, 3, 4, and 5.

Comment No. 2

The 30% version of the specification for Compacted Clay Liner Material (Specification 02443) does not have sufficient detail for full scale operation. Additional details used during construction of the Test Fill should be added. The additions to the specification should focus on practices used during construction of Test Fill 3.

Response

The contents of the 90 Percent Design Package, the responses to the group comments above, and the responses to the specific comments below will hopefully address this statement. If not, CDPHE is requested to supply additional specific comments as to how this perceived shortcoming can be addressed.

Comment No. 3

It appears that not all of the test frequencies within Specification 02443 are consistent with those used during construction of Test Fill 3. Any deviations should be clearly identified and an explanation provided.

Response

See response to Group Comment No. 1. The test frequencies given in the Specifications are clearly not consistent with those used during the test fill construction nor were they intended to be. Section 2.10.6 of the EPA 1993 TGD state, "The same types of CQA tests that are planned for the actual liner are usually performed on the test pad. However, the frequency of testing is usually somewhat greater for the test pad. Material tests such as liquid limit, plastic limit, and percent fines are often performed at the rate of one per lift. Several water content-density tests are usually performed per lift on the compacted soil." Based on CDPHE's comments to the test fill Work Plan, the Army reduced the test fill testing frequency to a level acceptable to CDPHE but that would still allow the landfill design team to collect sufficient data to finalize the landfill design. However, no commitment to incorporating the test frequencies from the test fill into full-scale CCL construction was made nor would it be practical.

Comment No. 4

It is unclear whether lift one meets the hydraulic conductivity standard throughout. It may be prudent to collect additional samples to verify the hydraulic conductivity and to identify problems which may have resulted in the lower hydraulic conductivity of the initial tests.

Response

See response to Comment Group 3.

Comment No. 5

Please provide a comprehensive table which includes categories such as: the specifications, references, procedures, standards, QA and QC frequencies, CQA observations and requirements, and CQC requirements for construction.

Response

The landfill design team has prepared a CQA/CQC matrix table to address this comment. This table will be submitted with the 90 Percent Design in the CQA Plan documents for regulatory review.

Comment No. 6

The QA, document does not specify that the RVO/owner shall employ an qualified third party to act as an independent construction quality assurance engineer. An independent third party would not include any current members of the RVO or its subcontractors. The overall construction quality assurance document when completed must identified the registered *professional engineer functioning as the Design Engineer, the RVO's owners representative, the number and qualifications of the construction contractors construction quality assurance personnel, and the independent certifying engineer.*

Response

See response to Comment Group 4. The name of the design engineer, owner's representative, CQA Engineer, and the number and qualifications of the CQA personnel will be provided to CDPHE by the PMC, once the PMC is selected.

SPECIFIC COMMENTS

Comment No. 7, Section 2.2 - Borrow Area Evaluation

The location and frequency of unacceptable material in the borrow pit area and the details of the specifications and CQA procedures that will be implemented to ensure an acceptable CCL construction remain unclear. If the 79% of acceptable soils is not a statistically valid estimate then the Army should provide an estimate of the extent of unacceptable borrow source area material.

Response

See response to Comment Group 5. It is estimated that less than 40 percent of the alluvial soil located within the borrow areas will be unacceptable for CCL construction.

Comment No. 8, Section 2.2 - Borrow Area Evaluation

Page 2-3, paragraph 1- In addition to the Table I index property criteria for raw borrow soils the specifications in Appendix H also include standards to be determined for minimum liquid limit, minimum plasticity index and maximum plasticity index. These values should be specified along with the recommended specification modifications in Section 7.3 and a revised draft Table 1 provided for review.

Response

The Army has now included requirements for CCL soil to contain a minimum liquid limit of 30, a minimum plasticity index of 10, and a maximum plasticity index of 40 in Specification 02443. These values are consistent with guidance given by Dr. David Daniels in his CCL short course.

Comment No. 9, Section 2.2 - Borrow Area Evaluation

Page 2-3, bullet 1 - The soils also contain caliche or calcium carbonate precipitation zones which require excavation segregation.

Response

Comment noted. Both borrow areas contain these deposits. These zones will be segregated during excavation.

Comment No. 10, Section 2.2 - Borrow Area Evaluation

Page 2 -3, bullet 3 - Please quantify "similar" using existing data.

Response

"Similar" is quantified to mean that Borrow Area 5's average values for percent fines, liquid limit, and plasticity index values are each less than 10 points different from those of the Corrective Action Management Unit Area, as shown on Table 5 of the Test Fill Work Plan.

Comment No. 11, Section 2.2 - Borrow Area Evaluation

Page 2-3, bullet 4 - A basic goal of any Test Fill program is to define the extent of unacceptable material in a proposed borrow source area. If the available data is not a statistically valid basis to make this estimate then the Test Fill programs to date have a fundamental flaw and additional characterization of the borrow source area is required. Please review the existing data and provide an estimate of the percentage volume of acceptable soils meeting Table I requirements. If the existing data are inadequate then the required characterization effort should be proposed in a work plan format.

Response

See response to Comment Group 5 and Specific Comment No. 7.

Comment No. 12, Section 2.2 - Borrow Area Evaluation

Page 2-3, bullet 6 - Please specify if the addition of powdered bentonite will be used to meet the raw borrow soil physical properties requirements.

Response

The addition of powdered bentonite will not be used.

Comment No. 13, Section 3.0 - Preconstruction Laboratory Data Testing and Data Interpretation

General - The acceptable zone (AZ) plot developed for the Test Fill 3 program is applicable as long as all of the soils in the footprint of the double lined landfill are identical to the sandy lean *clay characterized. As shown in figure 7 the acceptable zone can drift as the soil properties of the raw borrow soils change. Given that approximately 380,000 cubic yards of soils will require excavation, the specifications should allow the design engineer or the construction quality assurance engineer the flexibility to generate another AZ if a significant change in soil material is observed.*

Response

This requirement is given in Part 3.4.3 of Specification 02443.

Comment No. 14, Section 4.1.1 - Ordnance Removal

General - Will UXO screening be required prior to all borrow area excavation since it was conducted as part of the Test Fill 3 program? If so this should be added to the specification in Appendix H or in the general Landfill Construction specifications.

Response

No. Unexploded Ordnance (UXO) screening will not be required. RMA had previously cleared the area for UXO. Harding Lawsen Associates only screened the surface as an additional internal safety precaution.

Comment No. 15, Section 4.3.3 - Surface Preparation and Protection

CCLs must be immediately covered and kept moist to prevent volume stability and desiccation. Desiccated sections should be removed, broken up, re-wetted and recompacted. If damage occurs, the affected soil must be removed or reconditioned as directed by the Construction Quality Assurance Engineer, not the contracting officer. The basic procedures used to prevent freezing and desiccation of the CCL need to be included as part of this specification and not delegated to the contractor's Materials Handling Plan.

Response

See response to Comment Group 1 and 4. This section of the document refers to the activities that occurred during the test fill construction, not the CQA Plan or Specifications. The USACE has incorporated basic procedures to prevent freezing and desiccation Specification 02443.

Comment No. 16, Section 5.3.1 Borrow and Process Area Monitoring

The results of the Test Fill 3 program indicate that continuous rather than periodic construction oversight of the borrow and process area will be required. The construction quality assurance engineer will monitor the work to help ensure that the required specifications for the Raw Borrow Sods are met.

Response

See response to Comment Group 5.

Comment No. 17, Section 5.3.1 Borrow and Process Area Monitoring

Page 5-3, paragraph 2 - The text clearly states the soil disc was unable to process the raw borrow soil material to the maximum clod size of 2 inches as required by the Work Plan, However, the recommended specification in Section 7-3 states "A Rome disc may be used in lieu of the soil stabilizer for conditioning up to the standard Proctor optimum moisture content."

Response

See response to Comment Group 2.

Comment No. 18, Section 5.3.1 Borrow and Process Area Monitoring

To avoid confusion in the, specifications, it is recommended that in additional section on soil processing be added to Part 1.3 of the specifications. Soil processing by a Caterpillar SS250 Soil stabilizer or its equivalent will be required of all raw borrow soils and a minimum 2 passes specified. If additional processing is required for moisture content it may be done with a Rome disc. However, this would be done In addition to and not in substitution of the required two passes of the soil stabilizer. This change is necessary for the specifications to reflect the results of the Test Fill 3 program.

Response

See response to Comment Group 2.

Comment No. 19, Section 6.0 - Post Construction Testing

One half of the hydraulic conductivity tests conducted on samples from lift one failed to meet the hydraulic conductivity standard. Although two of the failed tests were at a 3 psi consolidation pressure, it is of concern that each of the other lifts tested at 3 psi easily met the standard. The 3 psi tests provide useful information on the hydraulic, conductivity of the various Ms and should not be ignored. The hydraulic conductivity must meet the 1 X 10^{-7} cm/sec standard as measured unburdened.

Response

See response to Group Comment 3.

Comment No. 20, Section 7.2 Conclusions, First Bullet

It is likely that non-cohesive soils in the landfill subgrade will be encountered and the consequences are serious enough to require proper attention to moisture control, depth, and stability of corrected subgrade soils.

In section 6 0, third paragraph, referring to shelby test # 132, the text states the samples "inadvertently contained some of the foundation layer material". Also, in Appendix E, first page of the Section, the moisture test results are shown for the imported subgrade preparation material. All tests were several percentage points below optimum and 50% of the tests on subgrade soils failed their first test.

This suggests:

1) *closer tolerances are needed on moisture control of the subgrade prep material to prevent moisture reduction in the first layers of the CCL;*

2) *greater depths of subgrade preparation are needed when non cohesive soils are encountered, to prevent mixing and contamination to the CCL layer; and*

3) *specific procedures are needed when non-cohesive soils are found on the slopes of the subgrade excavation.*

Response

See response to Group Comment 3. The Army disagrees with CDPHE's first two inferences from the two failing Shelby tubes and structural fill test results and agrees with the third inference. Procedures for when non-cohesive soils are found on the slopes of the subgrade excavation have been incorporated into Part 3.2.1.1 of Specification 02210. The acceptable zone (AZ) moisture content range for the test fill was from 12% to approximately 23% (See Figure 6). The standard Proctor optimum moisture content was 16.6% and the range of passing moisture content results was 13.8% to 16.8%, which were well within the AZ and not several percentage points below the optimum moisture content. The moisture content of the two failing Shelby tubes was between 15% and 16% (See Figure 9). Block sample 1211 was also taken from the first lift, contained a dryer moisture content than the two failing Shelby tubes, and was nearly an order of magnitude under the required hydraulic conductivity.

As stated in the text of the summary report, both of the failing Shelby tubes were located on the slope section (See Figure 3). Per Section 2.8.1 of the EPA 1993 TGD, "For soils compacted in lifts parallel to the slope, the first lift of clay should be "knitted" into the existing subgrade to minimize a preferential flow path along the interface and to minimize development of a potential slip plane." It is unclear what a deeper depth of subgrade preparation (from that used in Test Fill 3) would do to prevent this. The only reason samples were taken from the first lift was because of CDPHE's insistence that they be taken and tested. As stated in the response to Group Comment 3, it was agreed at the meeting to not require hydraulic conductivity testing and to double the moisture/density test frequency for the first lift of the secondary CCL.

Comment No. 21, Section 7.2 - Conclusions, Second Bullet

Rocks are potential pathways for hydraulic failure in the CCL and corrective action must be taken to remove all of them.

Response

See response to Group Comment 1. The large size rocks that were observed during construction of the test fill were removed by hand. However, not all of them were observed and removed as 2 or 3 oversize rocks were observed in the excavation pits for block samples. Requirements have been incorporated into the Specifications to remove the oversized materials.

Comment No. 22, Section 7.2 - Conclusions, Third Bullet

This conclusion is not substantiated. Please delete or modify based on the following:

1) *Of the three lanes and seven lifts only one lane of one lift was developed utilizing the Rome disc for processing. This is a very small amount of soil with only one moisture test used to produce such a broad conclusion;*

In addition, proper testing controls on the mixing and processing pad were not discussed in detail. It is therefore difficult to definitively conclude that soil mixed by the disc method was adequately separated from that soil mixed by the soil stabilizer;

2) *The lift processed by the Rome disk was at a moisture content of 22% (Shelby test no 611)- This is significantly above optimum. It therefore has not been demonstrated that the Rome disk can effectively process material between the modified and the standard proctor optimum; and*

3) *According to the Construction Quality Assurance Activities, Section 5.3.1, second paragraph, "The disc was unable to process the material to the maximum clod size of 2 inches as required by the Work Plan...".*

Response

See response to Group Comment No. 2.

Comment No. 23, Section 7.2 - Conclusions, Sixth Bullet

The text suggests sample 132 may have been disturbed during shipping and handling and that this can be seen by comparing the difference between the field moisture and density test results, However. several of the samples listed on Figure 8 and 9 show similar variations between field moisture content and density and laboratory moisture content and density. Please clarify what is unique about the variations in sample 132 and how this explains the higher hydraulic conductivity-

Response

See response to Group Comment 3. The Army agrees that other samples shows similar variations. However, the other samples easily met the target value. As stated in the sixth bullet, this difference was not intended as the only reason why the sample failed but was added as additional support that the sample was somehow disturbed.

Comment No. 24, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 1.3.1 - Compaction Equipment

The compaction equipment specifications should also include a minimum weight, minimum foot length, and minimum number of passes, Should the compaction specification specify fully penetrating feet? Please discuss.

Response

The number of passes are specified in Part 3.2.3 of Specification 02443. The other requirements have been incorporated into Part 1.2.1 of Specification 02443.

Comment No. 25, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.3.3 - Compaction

Replace the [TBD] with "6"

Response

CDPHE agreed at the July 29, 1997 meeting, that a minimum of 4 passes was acceptable.

Comment No. 26, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part J. 3.2 - Scarification Equipment

Please include that prior to placement of a lift of material over an existing lift, the previous lift shall be thoroughly scarified to a nominal depth of no less than 2 inches to provide good bonding between lifts. The trafficking of a scarified surface by trucks or other equipment shall not be permitted during the period between scarification and placement of the following lift.

Response

See response to Comment Group 1. Section 2.7.1 of the EPA 1993 TGD states "When soil is scarified it is usually roughened to a depth of about 25 millimeters (1 inch)." No basis is given for doubling the required depth. The specification does not need amendment.

Comment No. 27, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 1.3.5 - Processing Equipment

The second sentence indicates an acceptance of a Rome disc to process soil up to optimum moisture content. A Rome disc cannot be used in lieu of a soil stabilizer. Please delete that sentence. This usage was not demonstrated because material processed with a Rome Disc in the test fill was placed at moisture contents significantly higher than optimum (see Appendix F, Tests No. 611 and 612). Also, maximum clod size was not achieved and demonstrated with the Rome disc, which is a requirement of the processing soil for CCL layers. This is referenced in Section 5.3.1 of the Construction Quality Assurance Activities.

Response

See response to Group Comment No. 2.

Comment No. 28, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 2- Products

Please identify the water source to be used for moisture content conditioning.

Response

The RMA potable water system.

Comment No. 29, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.3.1 - Clay Placement

This section should also include details relating to compaction of inaccessible areas such as corners and other areas inaccessible to driven compaction equipment.

Response

Specification 02443 (Parts 1.2.4 and 3.2.3) has been modified to address this.

Comment No. 30, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.3.2 - Moisture Control

This section should be modified to include clod size reduction as a requirement for adequate moisture control and adjustment. Also, this has not been achieved with a Rome disc alone. Please modify and delete the reference to sole usage of a Rome disc.

Response

The changes have been made to Specification 02443.

Comment No. 31, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.5.2 - Moisture Content and Density Tests

The 30% specification state: "If any of the retests fail, the lift of soil shall be repaired out to the limits defined by passing tests for that parameter." Please clarify. Does this imply the entire 10,000 square foot area will be repaired? Is this consistent with procedures used during construction of Test Fill 3?

Response

When a failing test is encountered, additional tests in the area of the failing location will be performed to delineate the extent of the failing area. This is what was done on the one failing test encountered in the test fill. The criteria for delineation of failing areas is included in Table 4 of Specification 02443.

Comment No. 32, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.6.1 - Weather Conditions

Clay liner material shall not be placed during periods of precipitation or other periods of unfavorable weather conditions as identified by the CQA Engineer.

Response

See response to Group Comment No. 4.

Comment No. 33, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.6.3 - Freezing and Desiccation

The daily work area shall extend a sufficient distance so as to maintain soil moisture conditions within an acceptable range to allow continuous operations. Desiccation and crusting of the lift surface shall be avoided.

Response

See Parts 3.5.4 and 3.5.5 of Specification 02443.

Comment No. 34, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.6.3 - Freezing and Desiccation

Please specify a minimum depth that shall be removed or reconditioned if freezing or desiccation occurs.

Response

See Parts 3.5.4 and 3.5.5 of Specification 02443.

Comment No. 35, Section 7.3 - Recommended Full-Scale Construction Specification Modifications: Part 3.6.3 - Freezing and Desiccation

Please define the acceptable measures that the Contractor may use to protect finished CCL work to prevent desiccation or freezing.

Response

See Parts 3.5.4 and 3.5.5 of Specification 02443.

Comment No. 36, Section 7.4 - Recommended CQA Plan Modifications: Part 2.3.2.4 - Scarification

Amendments to this section regarding number of passes of the smooth drum roller may be sufficient, however, the criteria as to suitability, cannot be left up to the geomembrane installer. The surface of the CCL is critical to the performance of the CCL as noted in the regulatory guidelines, referring to the "intimate contact" between the CCL and the synthetic geomembrane liner as a composite layer. Tolerance limits and specifications for the finished surface of the CCL and the maintenance of it until covered by the synthetic layer, should be specified in the CQA documents. Also, criteria for determining the smoothness of the CCL need to be established for CQA and CQC usage.

Response

Specifications are included in the Specifications only. The purpose of the CQA Plan is to provide the procedures to be used to assure that the Specifications are met. Surface tolerances for the CCL are given in Part 3.2.4 of Specification 02443.

Comment No. 37, Section 7.4 - Recommended CQA Plan Modifications: Figure 3

Test # 531 is shown in two locations Please correct.

Response

Figure 3 will be corrected.

Comment No. 38, Appendix A

Response to EPA and CDPHE comments on the Draft Final Work Plan for the Test FM Construction Program are presented in Appendix G which is a subappendix of Appendix A. The Appendix A Final Work Plan for the Test Fill Construction must be revised to incorporate all [sub]Appendix G comments and all Appendix B (CDPHE conditional approval) comments.

Response

CDPHE previously stated that this is unnecessary. The Work Plan will not be rewritten.

Comment No. 39, Appendix H - Table 2

Table 2 - The minimum testing frequency for percent fines, percent gravel, and liquid & plastic limit may need to be revised based on the heterogeneity of the borrow areas. Continuous construction oversight by observation should be added to the specification for borrow soil testing.

Response

See response to Group Comment Nos. 1 and 5.

Comment No. 40, Appendix H - Table 3

Table 3 - Please insert "2,500 square feet" in place of "10,000 square feet" in the table to be more consistent with test fill testing frequencies.

Response

See response to Comment No.3.

Comment No. 41, Appendix H - Table 3

The specifications do not contain any recommended maximum percentage of failing material tests and maximum allowable magnitude of any one outlier. For example, if 3% of the hydraulic conductivity samples are allowed to fail, they cannot be concentrated in one lift or one area, and no sample can have a hydraulic conductivity greater than one-half order of magnitude above the target maximum value, no matter how few outlier there are. Guidance on developing such a tables may be found in EPA's July 1993 "Technical Guidance Document Quality Assurance and Quality Control for Waste Containment Facilities."

Response

See response to Comment Group 3.

Comment No. 42, Appendix I - Section 2.1.4

Please insert "1 per 5,000 square feet/lift" in place of " 1 per 2 acres/lift" in the table. Appendix I should also-state that CQA personnel may check any CQC test at any time.

Response

See response to Group Comment No. 4 and Section II of the CQA Plan.

Comment No. 43, Appendix I - Section 2.1.4

Appendix I should state that CH will not be placed on the landfill sideslopes.

Response

No basis for this comment is given or otherwise known. However, the USACE has proposed an upper limit on the plasticity index (see response to Specific Comment No. 8).

Comment No. 44, Appendix I - Section 2.1.4

The last bullet under Section 2.3.3.1 on page 11-5 of Appendix I states, If the borrow source is highly variable, the Contracting Officer has the option of requiring a CQA Engineer be permanently assigned to observe all excavation of borrow soil in the borrow pit." Appendix I should be revised to reflect that the CO is not in charge of CQA personnel. It is the owner's/operator's responsibility to ensure that suitable borrow materials are excavated for CCL processing. Please modify text accordingly.

Response

See response to Group Comment No. 4.

U.S. Army's Responses to U.S. Environmental Protection Agency (EPA)
July 9, 1997, Comments on Draft Final Test Fill
Construction Program Summary Report
Feasibility Study Soils Support Program
Rocky Mountain Arsenal
Dated June 6, 1997

The response to comments given below has been revised based on the discussion held at the July 29, 1997, landfill design meeting and the contents of the 90 Percent Design Package. The 90 Percent Design Package includes the Draft Final 90 Percent Design Specifications (Specifications) and the Draft Final 90 Percent Construction Quality Assurance (CQA) Plan. This revised comment response is intended to be reviewed concurrently with the Specifications and CQA Plan. These documents have been revised to include the responses described below to the regulatory comments given to the Draft Final Test Fill Construction Program Summary Report.

Comment

Section 7.2, Page 7-3, First Bullet. *This paragraph concluded that a cohesive soil subgrade or foundation layer may be required on 3.5H:1V slopes because the compactors's wheels spun and damaged slopes without a cohesive soil foundation layer. However, recommended construction specification modifications do not reflect this key conclusion. Construction specifications should be modified appropriately to reflect potential constructibility concerns identified in this paragraph.*

Response

Specification 02210 has been modified accordingly (Part 3.2.1.1).

Comment

Section 7.2, Page 7-4, Last Bullet. *This paragraph refers to direct shear testing currently ongoing and indicates that no modification of the acceptable zone is necessary to ensure slope stability and bearing capacity. However, no direct shear test results support this statement. Direct Shear test results should be presented and discussed if conclusions are presented concerning the use of these results in assessing slope stability and bearing capacity.*

Response

The last bullet item will be modified to reflect this. The direct shear test results have been completed and reported in a report entitled "Draft Final Report, Direct Shear Testing, Revision B" by GeoSyntec Consultants, dated June 1197. The results of the test have been used to analyze the slope stability of the landfill. The analysis and a discussion of any required modifications to the acceptable zone based on the analysis have been incorporated into the USACE 90 Percent Design Analysis.

ROCKY MOUNTAIN ARSENAL

Enhanced Hazardous Waste Landfill Test Pads Program
Summary Report

Prepared by:
Foster Wheeler Environmental Corporation

Prepared for:
Rocky Mountain Arsenal Remediation Venture Office
Department of the Army
Shell Oil Company
U.S. Fish and Wildlife Service

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Revision	Prepared By	Reviewed By	Approved By	Date	Pages Affected
0	J J Berretz	Robert Benmark	Steve Garland	February, 2002	All

CONTENTS

Section **Page**

TABLES

FIGURES

ACRONYMS

ASTM	American Society for Testing and Materials
AZ	Acceptable Hydraulic Conductivity Zone
BA 5	Borrow Area 5
CCL	Compacted Clay Liner
cm	centimeter
CQA	Construction Quality Assurance
CQAE	Construction Quality Assurance Engineer
CQC	Construction Quality Control
ELF	Enhanced Hazardous Waste Landfill
EPA	U.S. Environmental Protection Agency
HDPE	High Density Polyethylene
HWL	Hazardous Waste Landfill
m^3	cubic meter
PI	Plasticity Index
RFI	Request for Information
sec	second
USCS	Unified Soil Classification System
yd^3	cubic yard

1.0 INTRODUCTION

The Enhanced Hazardous Waste Landfill (ELF) Test Pads Program Summary Report has been prepared in support of the ELF Design currently being prepared by the Program Management Contractor as part of the remedy for cleanup of the Rocky Mountain Arsenal. The purpose of the ELF Test Pads Program is to provide information regarding the hydraulic conductivity and compaction characteristics of the soil that will be used for the construction of three compacted clay liners (CCLs) for the ELF. This report summarizes the equipment and procedures used for the construction and testing of the Test Pads, summarizes the data, provides data evaluations, summarizes field observations, and provides suggestions for a path forward. The results of the ELF Test Pads Program will be used as input to the CCL Specification Section of the ELF Design and the ELF Construction Quality Assurance Plan.

As part of this test pad program, a borrow area Geotechnical Study (ELF Borrow Material Characterization Study) was conducted for both the northwest section of Borrow Area 5 (BA 5) and the ELF footprint (Figure 1.0-1, Site Layout). The information collected during the geotechnical study was used to select representative material for the construction of three separate test pads. The data from the geotechnical study will be included as part of the Construction Quality Assurance Engineer (CQAE) and Construction Quality Control (CQC) testing for the borrow material characterization during the ELF construction, and will be in the Certification Reports, as appropriate. This Test Pads Program Summary Report presents the borrow material geotechnical study data in summary tables.

1.1 Background

During the construction of the Hazardous Waste Landfill (HWL), it was observed that the clay material in BA 5 varied in color. In particular, large quantities of "white clay" were identified along the western boundary of the borrow area designated for HWL construction. The HWL design specification for clay liner material stated that "The CQA Engineer shall monitor clay excavation using visual-manual procedures to prevent white caliche soils from being used as clay liner materials." A Request for Information (RFI) was generated and clarified that the term "white caliche" meant white hardpan soil. Also, upon a review of the report for the Final Test Fill Construction Program Summary Report (HLA 1997), it was determined that "white clay" material was not specifically identified as being used during the construction of the HWL test fills. Consequently, white clay material could not be used for the HWL CCL construction. Since there was a range of material colors, another RFI was generated to use the Munsell Color Chart designation for unacceptable white clay material. As a result, some of the clay material in BA 5 was precluded from use in the CCL construction for the HWL Cell 2.

During the construction of the HWL it was also observed that the compaction equipment specified for the construction of the HWL CCL did not allow the use of a range of compaction equipment. One of the goals of the ELF Test Pads Program is to evaluate alternative compaction equipment in an effort to improve efficiency.

Data from the ELF Borrow Material Characterization Study were used and evaluated for this test pad program, and three test pads were constructed from these materials. Two test pads were constructed in BA 5 using the two color-based soil types found in BA 5, and one test pad was constructed in the ELF footprint from soils within the planned ELF excavation. The material selected was representative of the range of geotechnical properties for all CCL borrow material in BA 5 and ELF Footprint, including the clay material under the topsoil stockpile within the ELF footprint. The representative characteristics of the soil were determined from the data collected during the ELF Borrow Material Characterization Study, summarized in Section 2 of this report.

1.2 Objectives and Scope

The primary objectives of the ELF Test Pad Program are as follows:

- Demonstrate the construction suitability of the ELF CCL for all the clay borrow material in BA 5 and ELF footprint that meet the CL and CH soil classification and the required soil index properties, regardless of color.
- Establish the design requirements for the ELF CCL.
- Finalize the CQC and CQAE construction testing requirements.
- Define a design basis by using equipment and procedures for CCL processing, placement, and compaction to develop construction specifications with controls to consistently construct CCL to meet the 1 x 10^{-7} centimeter (cm)/second (sec) hydraulic conductivity requirements while allowing more flexibility with compaction equipment.
- Evaluate field and laboratory hydraulic conductivities, interlift bonding, and general constructability of the borrow soils.
- Define any additional test fill data needs for the future ELF construction that exist after the construction and testing of the ELF test pads.

The scope of this test pad program included the following:

- Preparing, submitting, and obtaining approval of the final test pad work plan
- Performing any preconstruction field testing and laboratory testing of the borrow material to obtain additional geotechnical data that will enhance borrow material processing and material placement
- Tabulating and analyzing the geotechnical data of the borrow material used in constructing the test pads
- Constructing the test pad using the equipment, procedures, and specifications necessary to obtain a hydraulic conductivity of 1 X 10^{-7} cm/sec or less
- Performing CQAE monitoring and testing during test pad construction
- Evaluating the performance of the borrow material by performing post-test pad construction field and laboratory testing to verify that a hydraulic conductivity of 1 X 10^{-7} cm/sec or less was achieved
- Reviewing data and identifying potential future data needs
- Preparing and submitting a summary report

1.3 Program Requirements

Basic procedural requirements were established for the ELF Test Pads Program, including the following:

- Submit a draft test pad work plan for review by the Remediation Venture Office and Regulatory Agencies.
- Incorporate the review comments in the draft test pad work plan.
- Issue the final test pad work plan and include as part of the subcontract Statement of Work prior to construction of the test pads.
- Perform field and laboratory testing prior to and during construction of the test pads, and evaluate the test pads results.
- Prepare and submit a final ELF Test Pads Program Summary Report in conjunction with the 95 percent ELF design package.

The ELF Test Pads Program was performed, and this summary report prepared, in accordance with the approved test pad work plan, titled "Enhanced Hazardous Waste Landfill Test Pad Program Work Plan (FWENC 2001)."

1.4 Report Organization

This summary report is divided into six sections, as follows:

- Section 1 presents an introduction and overview of the ELF Test Pads Program and summary report.
- Section 2 describes the ELF Borrow Material Characterization Study (Borrow Area 5 – ELF Geotechnical Study) activities, testing, and data interpretation.
- Section 3 discusses the test pad construction and Construction Quality Assurance (CQA) activities.
- Section 4 summarizes field and laboratory results.
- Section 5 contains the summary and recommendations.
- Section 6 contains references.

2.0 ELF BORROW MATERIAL CHARACTERIZATION STUDY

This section discusses the borrow material characterization conducted for the borrow material proposed for the construction of the ELF Test Pads and the material proposed for constructing the ELF CCLs.

2.1 Introduction

The ELF Borrow Material Characterization Study (Borrow Area 5 – ELF Geotechnical Study) was initiated in the northwest section of BA 5 in November of 2000 and completed in March 2001. This activity included the excavation of soils in test pits from BA 5 and the proposed ELF footprint, and testing the soils collected from the test pits in an on-site geotechnical laboratory. The data from this study were reviewed as part of the preconstruction sampling and laboratory testing for the ELF Test Pads Program. The data will be incorporated into the CQC database and the ELF CQAE Certification Report.

A review of the test pit and boring data from the United States Army Corps of Engineers Final Geotechnical Investigation Report, HWL (USACE 1997), and the ELF Geotechnical Study Report was initially conducted as part of the planning for the borrow material characterization.

Also, test pits were previously excavated in other areas of BA 5, and the information gathered from the test pits was used to determine the suitability of materials for use in the HWL construction. The information obtained from these test pits, the experience gained during the construction of the HWL, and the aforementioned investigation and reports assisted in defining the ELF Borrow Material Characterization Study. The objectives for this study were as follows:

- Collect geotechnical data for determining soil engineering properties.
- Determine soil types and distribution.
- Quantify the volume of acceptable soil available for constructing the ELF CCL.
- Establish quality control measures for future ELF construction.
- Identify the topsoil thickness.

2.2 Implementation

2.2.1 Borrow Area 5

The borrow material characterization in BA 5 included excavation of approximately two test pits for each of the 24 grids identified in Figure 2.2.1-1 (the grids were laid out with an alpha-numeric designation) to a depth of approximately 7 feet. To derive the test pit depth of 7 feet it was estimated that approximately 300,000 bank cubic yards of soil is needed for the ELF CCL, that an estimate of 40 percent of the borrow material in BA 5 will not meet the material classification requirements for CCL construction, and that 1.5 feet of topsoil will be removed from the borrow area. The configuration of the test pits shown on Figure 2.2.1-1 provided adequate spatial distribution for the geotechnical samples. The grid configuration was selected by estimating the side dimensions required to obtain approximately 5,000 cubic yards (yd^3) of soil (the U.S. Environmental Protection Agency (EPA)-recommended testing frequency for Borrow Area evaluation) with an 18-inch excavation depth (the maximum processing depth for a Caterpillar SS250). Prior to the investigation, a survey was performed to stake and number the center points for each test pit and the corners of each grid.

A backhoe was used to excavate the test pits. Each bucket load was placed next to the pit prior to collecting the geotechnical soil samples. A representative geotechnical sample for each 18-inch-depth interval was collected from the soil that was placed next to the pit. The samples were stored in sealable 5-gallon buckets. Once excavation and sampling was completed, the test pits were backfilled with the excavated material.

The test pits were continuously logged to a nominal depth of 7 feet, with an emphasis on identifying soil types and soil variability. The soil logs contain a physical description of the soil and include the Munsell Color Chart number designations. The approximate thickness of the topsoil was also identified.

The collected samples were delivered to the on-site geotechnical laboratory for testing, which was completed in March of 2001. Each sample was split with a sample splitter in accordance with manufacturer's specifications. One of the split samples was archived for possible future laboratory analysis. The following tests were performed on the other split sample:

ASTM D422	Particle Size Analysis of Soils (sieve only)
ASTM D4318	Liquid Limit, Plastic Limit and Plasticity Index of Soils

ASTM D2487	Classification of Soils for Engineering Purposes
ASTM D854	Specific Gravity of Soils

These tests established whether the soil is potentially suitable for use in CCLs, assisted in estimating the quantity of suitable clay material, and determined the engineering properties of the soil.

To gain additional information on the soil engineering properties for Acceptable Hydraulic Conductivity Zone (AZ) development, and to aid in establishing quality control measures, the following tests were conducted:

ASTM D1557	Laboratory Compaction Characteristics of Soil Using Modified Effort
ASTM D698	Laboratory Compaction Characteristics of Soil Using Standard Effort
ASTM D698	Laboratory Compaction Characteristics of Soil Using Reduced Standard Effort (15 blows per lift)

2.2.2 ELF Footprint

The test pit excavation for the ELF footprint included 11 test pits to an approximate depth of 11 feet. The depth of 11 feet was selected by reviewing the available data in the area of the proposed test pit activity. The data indicated that the average maximum depth for clay in the area should be 11 feet. The configuration of the test pits shown on Figure 2.2.1-1 provides adequate spatial distribution for the geotechnical samples. The surveying, excavation methods, logging, sampling, and testing of the test pits in the ELF footprint were the same as those described in Section 2.2.1, above. A sampling interval of 30 inches was used instead of 18 inches as in BA 5.

2.3 Borrow Areas Description

2.3.1 Borrow Area 5

Borrow Area 5 is located within the southern and southwestern portion of Section 24. The material for the ELF CCL construction will be excavated from the western portion of BA 5, Figure 1.0-1. The borrow material in this area is a combination of clays, silts, and fine-to-medium-grained sand of eolian and alluvium origin.

The eolian deposits are windblown deposits of silts, clays and fine-to-medium-grained sands which overly the alluvial deposits and have an average thickness of 3.5 to 4 feet in the western portion of BA 5. These deposits contain the greatest percentage of clays and silts and apparently have the lowest carbonate content. Since this material has a lower carbonate content, the color ranges from a Munsell 10YR6/3 to 10YR3/6 (pale brown to a dark yellowish brown, respectively), which is designated as color Type 1 for BA 5.

The alluvial deposits are eroded silts, clays and sands from the Denver Formation with approximately 10 percent less clay and silt than the overlying eolian deposits. The sands for the alluvial deposits are coarser and more angular than for the eolian deposits. The alluvial deposits appear to have a higher calcium carbonate content, giving the soil a lighter color. The color ranges from 10YR8/2 to10YR4/6, however, the color range of 10YR8/2 to 10YR7/6 is color Type 2 for BA 5.

2.3.2 ELF Footprint

The ELF footprint is located within the south central portion of Section 25, south of the HWL (Figure 1.0-1). The potential CCL material within the footprint is comprised of eolian and alluvial deposits, and the eolian deposits have an average thickness of approximately 7 feet. The color of the soil in the ELF footprint ranged from 10YR6/6 to 10YR4/6.

2.4 Test Data Summary

Samples were collected and analyzed in accordance with Sections 2.2.1 and 2.2.2. The data for these samples were compiled and summarized in the following sections.

2.4.1 Data Summary for Borrow Area 5

There were 178 geotechnical samples collected from the test pits in Borrow Area 5 which are tabulated on Table 2.4.1-1 and summarized as follows:

Range of fines passing the #200 sieve (%)	32 to 92
Average percentage of fines passing #200 sieve (%)	70.5
Number of samples with <50% fines passing #200 sieve	8
Number of samples with ≥50% fines passing #200 sieve	170
Average percentage of fines passing #200 sieve for samples ≥50% fines	72.1%
Range of Plasticity Index (PI)	6 to 28
Average PI	18.6
Range for Maximum Dry Density (Standard Proctor)(pcf)	92.5 to 120.5
Average Maximum Dry Density (Standard Proctor)(pcf)	108.8
Range for Optimum Moisture Content (Standard Proctor)(%)	11.5 to 26.5
Average Optimum Moisture Content (Standard Proctor)(%)	17.6
Range for In Situ Sample Moisture Content (%)	5.7 to 15.8
Average In Situ Sample Moisture Content (%)	9.7
Number of Specific Gravity Samples	24
Range of Specific Gravity	2.70 to 2.73
Average Specific Gravity	2.71
Munsell Color Chart Range	10YR3/6 to 10YR8/3

The test pit numbering for BA 5 was developed using an alphanumeric grid system (e.g., TP1A-1A), Table 2.4.1-1. The first two letters, TP, identify the sample location as a test pit. The next two numbers identify the grid number. The number immediately after the dash identifies the pit number within the designated grid. Since there was a maximum of two pits per grid, the pit number is either a 1 or a 2 for each grid. The letter at the end of the test pit numbering designates the depth interval. For instance, an A designates the first interval of 1 foot to 2.5 feet, a B 2.5 feet to 4 feet, and so forth. (Note: the first foot of each pit was not sampled since it was considered topsoil). The sample numbers were developed from the test pit numbers (e.g., 1A-1-AS), Table 2.4.1-1. The first two characters identify the test pit grid, the third the test pit within the grid, the fourth, the depth interval, and the last digit, the type of Proctor test conducted, e.g., S for Standard Proctor, M for Modified Proctor, and R for Reduced Proctor.

2.4.2 Data Summary for ELF Footprint

There were 44 geotechnical samples collected from the test pits in the ELF footprint, which are tabulated on Table 2.4.2-1 and summarized as follows:

Range of fines passing the #200 sieve (%)	44 to 83
Average percentage of fines passing #200 sieve (%)	63
Number of samples with <50% fines passing #200 sieve	3
Number of samples with ≥50% fines passing #200 sieve	41
Average percentage of fines passing #200 sieve for samples ≥50% fines	64.3
Range of PI	4 to 23
Average PI	14.7
Range for Maximum Dry Density (Standard Proctor)(pcf)	105 to 116.5
Average Maximum Dry Density (Standard Proctor)(pcf)	110
Range for Optimum Moisture Content (Standard Proctor)(%)	11.5 to 19.5
Average Optimum Moisture Content (Standard Proctor)(%)	16.2
Range for Sample Moisture Content (%)	6.1 to 14.6
Average Sample Moisture Content (%)	10.1
Number of Specific Gravity Samples	6
Range of Specific Gravity	2.71 to 2.72
Average Specific Gravity	2.71
Munsell Color Chart Range	10YR5/6 to 10YR6/4

The test pit numbering for ELF footprint was developed using a one-up numbering system (e.g., TP-1-A), Table 2.4.2-1. The first two characters, TP, identify the sample location as a test pit, the next character identifies the test pit, and the last character the depth (i.e., A indicates the depth interval of 1 foot to 3.5 feet, B indicates 3.5 feet to 6 feet, and so forth. Note: the first foot of each pit was not sampled since it was considered topsoil). The sample numbers were developed from the test pit numbers (e.g., TP-1-AS), Table 2.4.2-1. The first two characters, TP, identify the sample as a test sample, the third the test pit number, the fourth the depth interval, and the last character the type of Proctor test conducted, e.g., S for Standard Proctor, M for Modified Proctor, and R for Reduced Proctor.

2.5 Data Evaluation for Borrow Area 5

Data for the following four soil parameters were evaluated to determine potential acceptability of material for CCL construction and to determine what material would require further evaluation as part of an ELF Test Pads Program:

- Soil Classification/Grain Size Distribution. The grain size distribution, which is determined by using methods prescribed in ASTM D 422, assisted in classifying the soil type in accordance with ASTM D2487. The soil classification is necessary since the material used in the construction of a CCL must classify as a CL (lean clay, i.e., liquid limit less than 50) or CH (fat clay, i.e., liquid limit greater than or equal to 50). Of 178 laboratory samples, only 9 (5 percent) did not meet the soil classification requirement.
- Percent fines passing the #200 sieve. Fifty percent or greater of the fines for a soil material must pass the #200 sieve in order for it to be used as CCL material. This particular parameter was useful in delineating areas within BA 5 as potentially acceptable or unacceptable for CCL. The delineation of these areas is discussed in detail below.
- Plasticity Index (PI). The PI is the range of water content over which a soil behaves as a plastic material. Numerically, it is the difference between the liquid limit and the plastic limit. Methods prescribed in ASTM D 4318 were used to determine the PI. which must be between 10 and 40 to meet the CCL requirements. The PI was also used to further

delineate areas in BA 5 with potentially acceptable CCL material. The delineation of areas using PI is discussed in detail below.

- Soil Color. This parameter was determined using the Munsell Color Chart. The soil colors for BA 5 were separated into two groups. One ranged from 10YR 8/3 to 10YR 7/4, which is the "white clay." The other soils ranged from 10YR 6/4 to 10YR 3/6 nonwhite clay. Borrow Area 5 was delineated into areas of white clay and nonwhite clays, and this delineation is discussed in detail below. Both of the colors in BA 5 had approximately the same geotechnical index properties.

The data for soil color, PI, and percent passing the #200, discussed in Section 2.5.1, were used to create contours for every 1.5-foot-depth sampling interval. The Surfer 7.0 software was used to develop these contours, as described below.

2.5.1 Soil Color

As discussed above, there are two primary colors for clay material in BA 5, white clay and nonwhite clay. Both colors are in the Munsell Color Chart HUE 10YR and have a range of values and chroma. The white clay value and chroma range is 10YR 8/3 to 10YR 7/4, and the nonwhite is 10YR 6/3 to 10YR 3/6 with some 2.5YR6/4 to 2.5YR4/4. To contour the colors, the white clay was assigned a contouring value of 2 and the nonwhite clay a contouring value of 1. The contouring interval was 1.5.

The distribution of material color is shown on Figures 2.5.1A through 2.5.1D. The nonwhite clay, for the interval 1.0 to 2.5 feet below the surface, makes up 100 percent of the material. White clay starts to appear in the 2.5–foot to 4.0-foot interval, and makes up less than 5 percent of the material. The white clay progressively makes up a larger percentage of the material as the depth increases. This is evident in the 4.0-foot to 5.5-foot and 5.5-foot to 7.0-foot intervals, in which the white clay makes up approximately 15 percent and 25 percent of the material, respectively.

2.5.2 Plasticity Index

The PI was contoured for the range of PI values and for each depth interval on Figures 2.5.2A through 2.5.2D. The amount of material with a plasticity index less than 20 appears to be increasing with depth. This may be due to a decrease in the clay fraction with depth, which correlates to the decrease in the percent passing the #200 sieve (Section 2.5.3).

2.5.3 Percent Passing the #200 Sieve

The percent fines passing the #200 sieve were contoured for each depth interval on Figures 2.5.3A through 2.5.3D. The percentages of the fines decrease with depth. The 1-foot to 2.5-foot interval has a very high volume of material with 80 percent or more fines passing the #200 sieve, and all but approximately 2 percent having less than 50 percent passing the #200 sieve. The volume of material with 80 percent or greater fines passing the #200 sieve decreases with depth, and the volume of material with less than 50 percent fines increases with depth. This is very evident on Figure 2.5.3D, which indicates that the depth interval of 5.5 to 7.0 feet has no material with a fines percentage of 80 percent or greater and has approximately 30 percent of the material with fines less than 50 percent.

2.6 Data Evaluation for ELF Footprint

The four soil parameters discussed in Section 2.5 were evaluated for the ELF Footprint material to determine acceptability as CCL material. Further evaluation of this material was conducted as part of the ELF Test Pads Program.

The data for PI and percent passing the #200 sieve were used to create contours for every 2.5-foot-depth sampling interval starting at 1.0 foot below the surface. These contours were developed using the Surfer 7.0 program. Color for the ELF Footprint was not contoured because the color of the material in the ELF Footprint is considered as being uniform and ranges from 10YR 6/4 to 10YR 4/6. Below is a discussion and description of the contours that were developed.

2.6.1 ELF Footprint Plasticity Index

The plasticity index for each depth interval was contoured for the ELF Footprint and is presented on Figures 2.6.1A through 2.6.1D. The plasticity index increases to the northeast for each depth interval.

2.6.2 Percent Passing the #200 Sieve, ELF Footprint

The percent fines passing the #200 sieve were contoured for each depth interval on Figures 2.6.2A through 2.6.2D. The percent fines for each interval increases to the north and northeast.

2.7 Acceptable Hydraulic Conductivity Zone Development

During the Borrow Material Characterization Study, initial consideration was made in developing AZs using the same method implemented during the construction of the HWL Cell 2. However, the material designated for use in the construction of the ELF CCL has enough variability from material used for Cell 2 CCL construction that a different AZ method was implemented during the test pads construction.

The AZ developed for the ELF materials (BA 5 and ELF Footprint) was formulated by establishing the lower left boundary at 85 percent saturation with an average specific gravity of 2.71, which is the average specific gravity for the ELF CCL borrow material (Figure 2.7-1). The upper left boundary was determined using the optimum moisture content for the Modified Proctor. The right boundary is the zero air voids line for a material with an average specific gravity of 2.71. The lower boundary was established at 90% of the maximum dry density for the Modified Proctor or 100 pcf, whichever was greater. This lower boundary was reestablished by conducting Modified Proctor tests for each identifiable borrow material change. The method of using the degree of saturation and a minimum dry density in reference to a modified Proctor is agreement with the method presented by Lahti et al, (Lahti 1987). Working the material so that the nuclear dry density and the moisture content fall within the AZ will increase the level of confidence in achieving passing permeabilities (1×10^{-7} cm/sec) when confirmatory hydraulic conductivity testing is conducted. One of the primary objectives for the ELF Test Pads Program was to define a final AZ for the ELF CCL material.

3.0 TEST PADS CONSTRUCTION AND CONSTRUCTION QUALITY ASSURANCE (CQA) ACTIVITIES

This section presents the construction activities and the associated CQA activities for the test pads. The CQA activities included the following:

- Observing and documenting construction and CCL placement methods and activities
- Performing calibration tests to determine the accuracy of test equipment (e.g., laboratory soil moisture contents and sand cone density tests)
- Repairing test holes and sample pit locations and evaluating the repair methods for effectiveness
- Conducting field density and moisture tests on borrow source material, prepared subgrade material, and placed CCL material
- Collecting Shelby Tube samples for undisturbed hydraulic conductivity tests
- Collecting large block hydraulic conductivity samples
- Conducting other activities identified in the QA Matrix, Table 3.0-1

Construction activities included the construction of 3 test pads, each having a minimum 3-foot-thick CCL, to simulate compacted CCL procedures. Test Pads 1 and 2 were constructed in BA 5 and Test Pad 3 in the ELF Footprint. Figures 3.0-1 and 3.0-2 display the locations of each test pad and borrow source within BA 5 and the ELF Footprint areas. Test Pad 1 was constructed of material that is representative of the "nonwhite" clay material in BA 5 (Borrow Source 1). Test Pad 2 was constructed of material that is representative of the "white" clay material in BA 5 (Borrow Source 2) (Note: the index properties for both the "white" and "nonwhite" clay material in BA 5 are approximately the same). Test Pad 3 was constructed of clay material that is representative of the ELF Footprint material (Borrow Source 3), which is considered the same color range.

Test Pad construction for Test Pads 1 and 2, in BA 5, was initiated on August 6, 2001 and completed on September 14, 2001. Construction of Test Pad 3 within the ELF Footprint began on August 24, 2001 with the transfer of site preparation equipment (scraper and water truck) from BA 5 to the Elf Footprint. Test Pads construction and demobilization were completed on October 12, 2001.

3.1 Site Preparation

Site preparation included the initial inspection of processing, placement and compaction equipment; preconstruction survey of the test pads and borrow sources; establishment of the construction zone borders; the development of the entrance and parking areas; site clearing and grubbing; borrow source preparation; and test pads subgrade preparation. Additionally, after construction was initiated, the subcontractor laid plastic irrigation piping from the fire hydrant east of the Submerged Quench Incinerator on D Street to the BA 5 construction area. Also, the subcontractor laid an irrigation fire hose from the northwest corner of 8th and D Street to a readily accessed area southwest of the ELF footprint.

The CQA personnel observed and documented that site preparation activities were done in accordance with the Test Pads Program Work Plan. The CQA personnel also ensured compliance with Subcontractor health and safety requirements, dust control management, and general housekeeping of the project area.

3.1.1 Clearing and Grubbing

The initial earthwork activity included clearing and grubbing the top 1 foot of topsoil from test pad and borrow source locations. This ensured that no organic materials were used during the construction of the test pads. The 1-foot thickness for the topsoil was determined during the Borrow Materials Characterization Study, where measurements and observations were made to estimate the thickness of the topsoil layer over both BA 5 and ELF Footprint areas. The results of this survey indicated the thickness of the topsoil did not exceed 1 foot in either area.

Prior to and during the removal of the topsoil, water was continuously applied for dust control. Also, to prevent vegetation from being picked up on the tracks and wheels of the placement equipment, surface vegetation was removed along haul routes and from a 25-foot-wide strip around the perimeter of all borrow sources.

3.1.2 Borrow Source Activities

3.1.2.1 Borrow Source Preparation

Topsoil removed from Borrow Sources 1, 2 and 3 was temporarily stockpiled immediately north of each Borrow Source. Borrow Source 2 also required the removal of approximately 3 to 4 feet of overburden materials to get to the borrow material. A portion of the overburden materials from Borrow Source 2 was used as prepared subgrade materials for Test Pad 1 and 2. The majority of the overburden materials were temporarily stockpiled immediately west of Borrow Source 2.

During the Borrow Material Characterization Study, sample moisture contents were collected for both BA 5 and the ELF Footprint at all depths. The results of this study indicated that the natural moisture content of clay liner materials within BA 5 ranged from 5.7 to 15.8 percent with an average of 9.7 percent, and the ELF Footprint moisture content ranged from 6.1 to 14.6 percent with an average of 10.1 percent. The average optimum moisture content (Standard Proctor) for BA 5 and the ELF Footprint was 17.6 and 16.2 percent, respectively. To attain the average maximum dry density for BA 5 and the ELF Footprint, the moisture content needed to be increased approximately 7.9 and 6.1 percent, respectively.

In accordance with the ELF Test Pads Program Work Plan, the borrow sources were cross-ripped to a depth of 1.5 feet and hydrated for a minimum of 48 hours. To hydrate the borrow material, the subcontractor used two different watering systems, a water truck for Borrow Sources 1 and 3, and a sprinkler system for Borrow Source 2. After the minimum hydration time was met, the borrow material was processed using a CAT SS250 stabilizer with a minimum of 2 passes.

During the construction of Test Pad 1, the observation was made that the nuclear density test results were not falling within the AZ, regardless of the number of passes made with either the CAT 815 or the CAT 825 compactors. Therefore, the hydration time for the borrow sources was increased to a minimum of 96 hours, which allowed the material to attain the desired nuclear density test results with only 4 passes of either compactor. The extended hydration time also provided a more even moisture distribution in the clay. The borrow material also became easier to work and would more readily meet the AZ requirements when the material was hydrated and allowed to dry back to the desired moisture range.

3.1.2.2 *Testing Preprocessed Borrow Material*

Borrow material was tested after processing with the stabilizer and prior to test pad placement to confirm that the material had approximately the same index properties and Modified Proctor values that were initially identified for the borrow source from which they were collected. Three samples were collected from each borrow source. Sample locations were selected to be representative of the borrow source material.

The testing performed on each sample included Soils classification (ASTM D2487), Atterberg Limits (ASTM D4318), Particle Size Analysis (ASTM D 422), moisture content (ASTM D2216), and Modified Proctor (ASTM D1557). In addition, three samples were collected from each borrow source to conduct remolded hydraulic conductivity tests (ASTM D5084).

3.1.2.3 *Monitoring Borrow Material Processing and Testing Processed Borrow Material*

The CQA personnel monitored ripping of the material, hydration time, and the number of passes of the processing equipment. A SS-250 soil stabilizer was used to process the clay materials. Soil is processed so a more even grain size distribution is obtained by the breakup and mixing of soil. A minimum of two passes of the SS-250 was sufficient to ensure proper mixing, and the clod sizes were no larger than 2 inches. If the processed material was not used the same day as processed, clods larger than 2 inches began to form. Using material with clod sizes larger than 2 inches in CCL construction resulted in nuclear density tests falling outside the AZ. Therefore, material with clod sizes larger than 2 inches required reprocessing.

The borrow material was hydrated by using a water truck or a sprinkler system. Borrow Sources 1 and 3 were hydrated using a water truck only, and Borrow Source 2 was primarily hydrated using a sprinkler system. It was observed that the water truck did not apply water evenly, whereas the sprinkler system provided a more even distribution of water.

To confirm whether the borrow material was at the Modified Proctor optimum moisture content, two daily representative laboratory moisture content samples were collected, along with a variable number of nuclear density tests. These tests were conducted after the material hydrated for at least 48 hours. From this testing it was observed that the moisture distribution was uneven. Also, when the material was used to construct the CCL after the 48-hour hydration time, the nuclear density tests did not fall within the AZ. Therefore, the hydration time was increased to 96 hours, which attained more acceptable test results.

3.1.3 Test Pads Subgrade Preparation

The test pads subgrade preparation included the survey layout of each test pad and the removal of 1 foot of topsoil from each test pad location. The standard dimensions for each test pad were approximately 180 feet by 78 feet. From within this area, the 1 foot of topsoil was removed and placed immediately north of Borrow Sources 1 and 2, respectively. The topsoil removed from the Test Pad 3 area was placed to the west of Borrow Source 3.

After the removal of the topsoil, the subgrade area was moisture conditioned and compacted with at least three passes of the tamping foot compactor. The subgrade areas were checked for soft spots, and spot nuclear density/moisture tests were conducted to ensure that a reasonable density for the subgrade materials was achieved.

Once the foundation had been checked for acceptability, the test pads subgrade was graded to attain at least a 2 percent drainage grade in the longitudinal, lateral, and diagonal directions, depending upon the topography. Additional material to attain the proper grade for drainage was installed with lift thickness not exceeding 10 inches. The additional material was moisture conditioned and compacted with at least three passes of the compactor.

Approximately 1.5 feet of additional material was placed on the east side of the subgrade for Test Pads 1 and 2 to obtain a 2 percent east to west grade. After clearing and grubbing for Test Pad 3, the subgrade topography had a natural grade greater than 2 percent from south to north. Consequently, adding material to the Test Pad 3 subgrade was not necessary.

Two types of tests were performed on the completed subgrades; a proof roll test and density/moisture test. Each test pad subgrade was proof rolled with three passes of a filled 4000-gallon water truck with a tire pressure above 100 psi. The subgrades were considered acceptable since the surface deflections, during proof rolling, were less than 1 inch. Two nuclear density/moisture tests were conducted for each test pad-prepared subgrade. The subgrade was considered acceptable when the nuclear density/moisture tests indicated that the material had a density equal to or greater than 90 percent of the maximum dry density for the Modified Proctor and +/- 3 percent of optimum moisture content. After acceptance, the subgrade surface was scarified and moisture conditioned prior to the placement of clay liner material.

3.2 Test Pads CCL Construction

3.2.1 Placement and Compaction

Each test pad was divided into two lanes - one lane was compacted with a CAT 815 compactor and the other lane was compacted with a CAT 825 compactor. All of the test pads were built to a final thickness of 3 feet. The loose lift thickness for the first lift was 10 inches, then 8 inches for all subsequent lifts. Test Pad 1 consisted of 5 lifts, Test Pads 2 and 3 consisted of 6 lifts each. (Note: The Work Plan prescribed 7 lifts per test pad, however, the initial lifts for each test pad were placed thicker than anticipated - a maximum of six lifts was attained to maintain a 3-foot thickness.)

Prior to the placement of a subsequent lift, scarification and moisture conditioning were performed on the preceding lift to ensure proper interlift bonding. Scarification of sealed and subgrade surfaces was approximately 1 to 2 inches in depth. The 815 and 825 tamping-foot compactors were used to perform scarification within respective lanes. Near the end of each workday, a smooth drum roller was used to seal and protect clay materials from desiccation by reducing the surface exposed to the elements.

Placement equipment used for test pad construction consisted of a Caterpiller (CAT) 613C Paddlewheel Scraper and a John Deere JD-550 bulldozer with less than 7 pounds per square inch ground pressure. The CAT scraper was used to excavate and haul materials from the Borrow

Source to the Test Pad. The JD-550 bulldozer was used to spread materials into loose lifts. Compaction was achieved with 4 to 6 passes of the CAT 815 or CAT 825 for Test Pad 1 and with 4 passes on Test Pads 2 and 3. A pass is defined as the front and rear rollers of the compactor passing over a referenced point on the ground.

Initially, the CCL was placed after the material was hydrated for 48 hours and processed. However, during the construction of Test Pad 1, the AZ requirements were not being met regardless of the number of passes with the compactors. Consequently, the hydration time was increased to 96 hours, which attained favorable AZ results with only 4 passes. The 96-hour hydration time was implemented for the remaining test pads.

The measured length of the tamping feet of both compactors is 7.5 inches, which permitted the use of an 8-inch loose lift. During construction, lifts 2 and 3 of Test Pad 1 were placed slightly thicker than specified due to measurement error. Later observations of the excavation wall during large block samples removal displayed laminations caused by exceeding the loose lift requirement of 0.5 inch past the tamping foot. These laminations were only present in the first three lifts. The lifts for Test Pads 2 and 3 were placed as specified.

3.2.2 CCL Testing

The testing requirements for the CCL material were stated in the ELF Test Pads Program Work Plan and are listed in Table 3.2.2-1. Lifts 2 and subsequent lifts for each test pad were tested and sampled for all the tests listed in Table 3.2.2-1. Lift 1 was only checked for moisture content. All sample locations, excluding those for Lift 1, were selected using a random method (Section 4.0). All of the CCL testing was performed in accordance with the Work Plan.

Since the tamping foot of the compactor almost penetrated the entire lift, the lift could not be tested until a subsequent lift was placed. For example, Lift 2 could not be tested until Lift 3 was placed and compacted, and so forth. Sampling of a lift was accomplished by excavating a sampling pit through the upper compacted lift to the lift to be tested by using a bulldozer or compactor blade. Excavation of the test pit permitted the observation of the interlift bonding, the distribution of moisture, and material texture. Observations were also made to determine whether voids or fractures were present. Also noted during sample pit excavations was that materials with higher plasticity were more difficult to work than those with lower plasticity, since the higher plasticity material would stick to the blades of the heavy equipment, causing tension fractures and voids.

3.2.2.1 *Field Moisture and Density*

Field moisture and density measurements were collected using a nuclear gauge, Troxler Model Number 3440. Daily measurements of the field moisture content and dry density were made for borrow source material. These measurements assisted in determining whether the borrow material was properly hydrated. To determine proper hydration, the results were compared to the optimum moisture content of the AZ. If the moisture content of the material was below the AZ limits, additional water was added to the borrow source and reprocessed until the moisture content met the AZ requirement. Also, six nuclear density and moisture content tests were taken per lift per lane per test pad (except for the first lift) of the placed and compacted CCL material. The results of these tests were plotted on the AZ, and are discussed in Section 5.

3.2.2.2 *Sand Cones and Laboratory Moistures*

Sand Cone Test ASTM D1556 was performed to provide a primary source measurement of soil density to correlate and compare with the accuracy and reliability of the nuclear moisture/density gauge. An initial five sand cone/nuclear density correlations were performed at the beginning of test pad construction on Test Pad 1 – Lane 2. These tests were used to establish the wet density offset of the nuclear gauge. Afterwards, additional sand cone density tests were performed at the rate of one per lane per Test Pad.

Laboratory oven moisture contents (ASTM D2216) were performed as a primary source of soil moisture content information. At the beginning of construction, 10 oven moisture content and nuclear gauge moisture correlations tests were completed to ensure accuracy of the gauge and establish the moisture offset (K-factor) for the gauge. Once the K-factor was established for the nuclear gauge, oven moisture contents laboratory samples were collected during every nuclear moisture/density test to continue updating the K-factor.

3.2.2.3 *Shelby Tube Hydraulic Conductivity Sampling*

Shelby Tube samples were collected for undisturbed hydraulic conductivity tests in accordance with ASTM D 1587. Two samples were collected per lane per lift. The samples were collected using a 10-inch-long by 3-inch-diameter Shelby Tube, which was continuously pushed with a dozer blade into the CCL material using a specially designed attachment for the Shelby Tube. The tubes were sealed with paraffin wax prior to shipment to the laboratory.

3.2.2.4 *Large Block Samples*

Large block samples were collected at a frequency of 2 per lane per test pad. The samples were collected using specially fabricated wooden boxes with dimensions to hold a 14-inch by 14-inch by 14-inch soil sample. The samples were excavated using a Case 580 Super L backhoe, which cut a trench around the outside of the sample to a predetermined depth. Additional soil was removed with knives and shovels until the sampling box could slide over the block. The base of the sample was freed from the test fill with a flat shovel. Once the bottom was trimmed, the entire sample was sealed inside the box with paraffin wax to maintain the soil moisture content.

After the block sample was removed, the exposed walls of the excavation were inspected for lift bonding, voids, and the homogeneity of the material. From this inspection the following observations were made:

- In some instances, the material exhibited voids and fractures where previous tests and samples had been collected, indicating inadequate repair of sample locations.
- Some of the test pits might have been deeper than 8 inches. This would also result in a nonuniform compaction effort, which might leave voids, cracks, and laminations within the material.

3.2.3 Final Surface Preparation and Protection

Final surface preparation was performed by grading with a bulldozer and sealing with a smooth-drum roller after completion of all testing and sample collection. Moisture conditioning of the final surface occurred as required to prevent desiccation until the test pads were covered with a high-density polyethylene (HDPE) geomembrane. Prior to covering the test pads with the HDPE, the final surfaces were surveyed.

4.0 FIELD AND LABORATORY TEST RESULTS

This section presents the surveyed sample locations and a summary of the test data collected during the Test Pads construction. The data are discussed separately for each test pad, then summarized at the end of this section.

Field tests were performed, at a minimum, in accordance with Table 3.2.2-1.The following field tests were performed on Lifts 2 through 5 or 6 depending upon the Test Pad. Field tests include the Nuclear Gauge Moisture/Density tests ASTM-D3017 and D-2922 and Sand Cone Density test ASTM-D1556.

Laboratory testing included Soil Classification Test (ASTM D 2487), Specific Gravity Test (ASTM D 854), Particle Size Distribution (ASTM D 422), Atterberg Limits (ASTM D 4318), Soil Moisture Content test (ASTM D2216), Modified Proctor (ASTM D 1557) and three separate types of hydraulic conductivity testing (ASTM D 5084). The conductivity testing was performed on samples obtained from Shelby Tubes, by remolding samples to specified moistures and densities, and from samples obtained from large blocks. These tests provided information that shall be used for acceptability criteria for clay liner material.

Sampling and test location were selected through a random number generator within Microsoft Excel. An example of a sample location selection sheet is shown as Table 4.0-1. This sheet displays the lane, lift and grid system of the testing area for the test pad. Random locations (grids or lifts) were generated depending upon the test within the specified lane. The testing area dimension of each test pad is 150 feet long by 64 feet wide. The test pad is divided into two 30-foot-wide lanes with 1 foot of operational space on both sides of each lane. Each lane consists of 20 testing grids with each testing grid having a dimension of 15 feet by 15 feet. The details of the test pad plan and grid systems are illustrated on Figure 4.0-1.

4.1 Test Pad 1

Test Pad 1 was constructed of material that was representative of all material in BA 5 considered to be nonwhite clay (Munsell Color 10YR6/3 to 10YR4/6). The test results for Test Pad 1 construction are presented below.

4.1.1 Modified Proctor, Soil Classification, and Specific Gravity Test Results

Table 4.1.1-1 presents the soil data for Test Pad 1, Lanes 1 and 2. There were 19 Modified Proctor tests with soil classification testing, 1 soil classification test, and 9 specific gravity tests (7 conducted as part of the Modified Proctor tests). The results of these tests are summarized as follows:

• Percent Passing the #4- Sieve All samples	100%
• Range of Percent Passing #200 Sieve (%)	59 to 85
• Average Passing #200 Sieve (%)	73.6
• Range of PI	16 to 24
• Average PI	20.7
• Range of Maximum Dry Density (pcf)	118.5 to 126.5

• Average Maximum Dry Density (pcf)	123.1
• Range of Optimum Moisture Content (%)	10.5 to 13.9
• Average Optimum Moisture Content (%)	12.3
• Range of Specific Gravity	2.70 to 2.72
• Average Specific Gravity	2.71
• Soil Classification	CL
• Range of Sample Moisture Content (%)	7.4 to 18.9
• Average Sample Moisture Content (%)	14.9
• Range of Munsell Color	10YR6/4 to 10YR4/4

4.1.2 Nuclear Density and Shelby Tube Hydraulic Conductivity Test Data

The nuclear density test data are presented on Tables 4.1.2-1 (Lane 1, 815 Compactor) and 4.1.2-2 (Lane 2, 825 Compactor), by lift. The Shelby Tube hydraulic conductivity test data for Lanes 1 and 2 are presented on Table 4.1.2-3. The data for both the nuclear density tests and the Shelby Tube hydraulic conductivity tests are summarized on Table 4.1.2-4 by lift.

The combined moisture content and dry density data for both lanes for the nuclear density and the Shelby Tube hydraulic conductivity tests are summarized as follows:

• Range of moisture content (%)	11.6 to 21.0
• Average moisture content (%)	14.7
• Range of dry density (pcf)	101.7 to 121.3
• Average dry density (pcf)	111.7

The dry densities versus moisture contents for each lane per lift are plotted on Figures 4.1.2-1 through 4.1.2-8. These figures include the respective AZs and the plots indicate whether a sample point was within the AZ. The number of density and hydraulic conductivity tests in or out of the AZ is summarized on Table 4.1.2-4 and as follows:

• Total number of tests in AZ	42
• Total number of tests out of AZ	38

There were 17 Shelby Tube hydraulic conductivity tests with k values less than 1 x 10^{-7} cm/sec, and 3 tests with k values greater than 1 x 10^{-7} cm/sec (failing tests). As stated in the Comments column, the 3 failing tests were noted as having poor sample quality or low moisture.

4.1.3 Large Block Hydraulic Conductivity Test Data

The large block hydraulic conductivity test data for Test Pad 1 are shown on Tables 4.1.3-1 and 4.1.3-2 for Lane 2, and Tables 4.1.3-3 and 4.1.3-4 for Lane 1. There were 4 large block samples collected from Test Pad 1. Large block sample number TP1-BS-001 was collected from lane 2, grid 7, lifts 2, 3, and 4; sample number TP1-BS-002 from lane 2, grid 2, lifts 2 and 3; sample number TP1-BS-003 from lane 1, grid 8, lifts 2 and 3: and sample number TP1-BS-004 from lane 1, grid 12, lifts 2 and 3 (Figures 4.4-1 and 4.4-2). Sample TP1-BS-001 had an 8-inch

Shelby Tube sample (TP1-ST-012) collected from the same location in lift 4, lane 2, grid 7 (Figure 4.4-2). The results of the large block hydraulic conductivity tests are summarized as follows:

• Range of Initial Water Content (%)	13.5 to 17.2
• Range of Final Water Content (%)	16.6 to 19.8
• Range of Maximum Effective Stress (psi)	5 to 8
• Range of Minimum Effective Stress (psi)	2 to 5
• Average Effective Stress (psi)	5
• Range of Initial B Value	0.95 to 0.98
• Range of Final B Value	0.95 to 0.99
• Range of Hydraulic Conductivity (Average Last 4)(cm/s)	9.64E-09 to 9.49E-08

4.2 Test Pad 2

Test Pad 2 was constructed of material that was representative of all material in BA 5 considered to be white clay (Munsell Color 10YR8/3 to 10YR6/4). The test results for Test Pad 2 construction are presented below.

4.2.1 Modified Proctor, Soil Classification, and Specific Gravity Test Results

Table 4.2.1-1 presents the soil data for Test Pad 2, Lanes 1 and 2. There were 22 Modified Proctor tests with soil classification testing, 3 soil classification tests, and 2 specific gravity tests (conducted with the Modified Proctor tests). The results of these tests are summarized as follows:

• Percent passing the #4 Sieve- All samples	100%
• Range of percent passing #200 Sieve (%)	62 to 71
• Average Passing #200 Sieve (%)	65.5
• Range of PI	13 to 27
• Average PI	21.7
• Range of Maximum Dry Density (pcf)	113.5 to 124
• Average Maximum Dry Density (pcf)	120.8
• Range of Optimum Moisture Content (%)	11.5 to 16
• Average Optimum Moisture Content (%)	13.2
• Range of Specific Gravity	2.71 to 2.72
• Average Specific Gravity	2.71
• Soil Classification	CL
• Range of Sample Moisture Content (%)	9.1 to 23.8
• Average Sample Moisture Content (%)	16.8

• Range of Munsell Color	10YR8/3 to 10YR6/4

4.2.2 Nuclear Density and Shelby Tube Hydraulic Conductivity Test Data

The nuclear density test data for Test Pad 2 are presented on Tables 4.2.2-1 (Lane 1, 815 Compactor) and 4.2.2-2 (Lane 2, 825 Compactor), by lift. The Shelby Tube hydraulic conductivity test data for Lanes 1 and 2 are presented on Table 4.2.2-3. The data for both the nuclear density tests and the Shelby Tube hydraulic conductivity tests are summarized on Table 4.2.2-4 by lift.

The combined moisture content and dry density data for both lanes for the nuclear density and the Shelby Tube hydraulic conductivity tests are as follows:

• Range of moisture content (%)	14.0 to 24.0
• Average moisture content (%)	18.5
• Range of dry density (pcf)	102.1 to 124.3
• Average dry density (pcf)	108.2

The dry densities versus moisture contents for each lane per lift are plotted on Figures 4.2.2-1 through 4.2.2-10. These figures include the respective AZs and the plots indicate whether a sample point was within the AZ. The number of density and hydraulic conductivity tests in or out of the AZ is summarized on Table 4.2.2-4 and as follows:

• Total number of tests in AZ	46
• Total number of tests out of AZ	38

There were 20 Shelby Tube hydraulic conductivity tests with k values less than 1 x 10^{-7} cm/sec, and 4 tests with k values greater than 1 x 10^{-7} cm/sec (failing tests). As stated in the comments column, the 4 failing tests were noted as having poor sample quality or voids in the sample.

4.2.3 Large Block Hydraulic Conductivity Test Data

The large block hydraulic conductivity test data for Test Pad 2 are shown on Tables 4.2.3-1 and 4.2.3-2 for Lane 2, and Tables 4.2.3-3 and 4.2.3-4 for Lane 1. There were 4 large block samples collected from Test Pad 2. Large block sample number TP2-BS-001 was collected from lane 2, grid 19, lifts 2, 3, and 4; sample number TP2-BS-002 from lane 2, grid 7, lifts 2, 3 and 4; sample number TP2-BS-003 from lane 1, grid 1, lifts 2 and 3: and sample number TP2-BS-004 from lane 1, grid 4, lifts 2 and 3 (Figure 4.4-3). The results of the large block hydraulic conductivity tests are summarized as follows:

• Range of Initial Water Content (%)	17.1 to 18.7
• Range of Final Water Content (%)	17.9 to 19.5
• Range of Maximum Effective Stress (psi)	5 to 8
• Range of Minimum Effective Stress (psi)	2 to 5
• Average Effective Stress (psi)	5
• Range of Initial B Value	0.95 to 0.97

• Range of Final B Value	0.9 to 1.00
• Range of Hydraulic Conductivity (Average Last 4)(cm/s)	2.32E-08 to 7.10E-08

4.3 Test Pad 3

Test Pad 3 was constructed of material that was representative of all the clay material in the ELF Footprint. The test results for Test Pad 3 construction are presented below.

4.3.1 Modified Proctor, Soil Classification, and Specific Gravity Test Results

Table 4.3.1-1 presents the soil data for Test Pad 3, Lanes 1 and 2. There were 18 Modified Proctor tests with soil classification testing, 2 soil classification tests, and 6 specific gravity tests (conducted with the Modified Proctor tests). The results of these tests are summarized as follows:

• Percent Passing the #4 Sieve- All samples	100%
• Range of percent passing #200 Sieve (%)	44 to 86
• Average Passing #200 Sieve (%)	76.3
• Range of PI	7 to 21
• Average PI	15.6
• Range of Maximum Dry Density (pcf)	122.0 to 125.5
• Average Maximum Dry Density (pcf)	123.1
• Range of Optimum Moisture Content (%)	11.0 to 13
• Average Optimum Moisture Content (%)	12.2
• Range of Specific Gravity	2.70 to 2.72
• Average Specific Gravity	2.71
• Soil Classification	CL
• Range of Sample Moisture Content (%)	8.1 to 21.2
• Average Sample Moisture Content (%)	17.4

4.3.2 Nuclear Density and Shelby Tube Hydraulic Conductivity Test Data

The nuclear density test data are presented on Tables 4.3.2-1 (Lane 1, 815 Compactor) and 4.3.2-2 (Lane 2, 825 Compactor), by lift. The Shelby Tube hydraulic conductivity test data for Lanes 1 and 2 is presented on Table 4.3.2-3. The data for both the nuclear density tests and the Shelby Tube hydraulic conductivity tests are summarized on Table 4.3.2-4 by lift.

The combined summary of the moisture content and dry density data for both lanes for the nuclear density and the Shelby Tube hydraulic conductivity tests are as follows:

• Range of moisture content (%)	14.0 to 20.9
• Average moisture content (%)	17.7
• Range of dry density (pcf)	102.1 to 115.0

• Average dry density (pcf)	110.2

The dry densities versus moisture contents for each lane per lift are plotted on Figures 4.3.2-1 through 4.3.2-8. These figures include the respective AZs and the plots indicate whether a sample point was within the AZ. The number of density and hydraulic conductivity tests in or out of the AZ is summarized on Table 4.3.2-4 and as follows:

• Total number of tests in AZ	39
• Total number of tests out of AZ	28

There were 18 Shelby Tube hydraulic conductivity tests with results less than 1 x 10^{-7} cm/sec, and 1 test with results greater than 1 x 10^{-7} cm/sec.

4.3.3 Large Block Hydraulic Conductivity Test Data

The large block hydraulic conductivity test data for Test Pad 3 are shown on Tables 4.3.3-1 and 4.3.3-2 for Lane 2, and Tables 4.3.3-3 and 4.3.3-4 for Lane 1. There were 4 large block samples collected from Test Pad 3. Large block sample number TP3-BS-001 was collected from lane 2, grid 16, lifts 2, 3, and 4; sample number TP3-BS-002 from lane 2, grid 5, lifts 2, 3 and 4; sample number TP3-BS-003 from lane 1, grid 17, lifts 2, 3, and 4: and sample number TP3-BS-004 from lane 1, grid 16, lifts 2, 3, and 4 (Figures 4.4-5 and 4.4-6). The results of the large block hydraulic conductivity tests are summarized as follows:

• Range of Initial Water Content (%)	14.3 to 17.9
• Range of Final Water Content (%)	16.7 to 19.4
• Range of Maximum Effective Stress (psi)	8 to 8
• Range of Minimum Effective Stress (psi)	2 to 2
• Average Effective Stress (psi)	5
• Range of Initial B Value	0.96 to 0.99
• Range of Final B Value	0.98 to 0.99
• Range of Hydraulic Conductivity (Average Last 4)(cm/s)	4.04E-09 to 6.85E-09

4.4 Sampling and Testing Locations

Sampling and testing locations were selected using the random method described at the beginning of this section. After a sample or test was taken, the location was surveyed. The survey data were used to plot the sampling and testing locations onto figures. Figures 4.4-1 through 4.4-6 show the plan view of the sampling and testing locations per lift for each test pad. The grid numbers are in the lower left corner of each grid. (Note: large block hydraulic conductivity sample TP1-BS-001, Lane 2, Grid 7, Figures 4.4-1 and 4.4-2 has a Shelby Tube hydraulic conductivity test and nuclear density test in the same location.)

4.5 Data Summary for Test Pads 1, 2, and 3

This section summarized the data for Test Pads 1, 2, and 3.

4.5.1 Soil Classification and Index Properties

The ELF Test Pads Program Work Plan identified soil index property criteria that needed to be met for CCL material used in the construction of the Test Pads. These criteria are as follows:

- Maximum Particle Size, excluding the top lift – 1 inch. (Section 3).
- Maximum Particle Size for the top lift – 0.5 inch (Section 3)
- Minimum Percent Passing No. 4 Sieve – 95%
- Minimum Percent Passing No. 200 Sieve – 50%
- Range of Plasticity Index – 10 to 40
- Unified Classification System Classification – CL, CH
- No organic or deleterious material (Section 3)

As indicated on Tables 4.1.1-1, 4.2.1-1, and 4.3.1-1 the percent passing the No. 4 sieve was 100 for all of the samples from the three test pads, meeting the minimum of 95 percent passing the No. 4 sieve requirement.

The material used for the construction of Test Pads 1 and 2 met the minimum requirement of 50 percent or more passing the No. 200 sieve, as the range for all of Test Pad 1 and 2 was 50 percent to 85 percent passing the No. 200 sieve. All of the samples for Test Pad 3 met the 50 percent criterion except 1 sample, TP3-PR-002, which was a subgrade sample and not part of the CCL (Table 4.3.1-1).

The plasticity index range for both Test Pads 1 and 2 was 13 to 27, which meet the minimum requirement PI of 10 and the maximum requirement PI of 40. The plasticity indices for Test Pad 3 met the minimum and maximum PI requirements except for 2 samples, TP3-PR-001 and TP3-RP-002 (Table 4.3.1-1), which were subgrade samples and not a part of the CCL material.

The material used in the construction of the CCL for the three test pads met the Unified Soil Classification System (USCS) Classification of CL, CH. Every sample classified as a CL except TP3-PR-002, which classified as an SC-SM and was a subgrade sample (Table 4.3.1-1).

4.5.2 Modified Proctor Tests

The Modified Proctor tests were conducted to assist in determining the lower density limit of the AZ at 90 percent of the maximum dry of the Modified Proctor, and the optimum moisture content. The average Modified Proctor maximum dry density for the soil used in constructing the three test pads is 113.5 to 126.5 pcf, with an average of 122.3 pcf. The 90 percent density range is 102.1 to 113.8 pcf, with an average of 110.1 pcf. The optimum moisture range of the CCL material for the 3 test pads is 10.5 percent to 16 percent, with an average of 12.6 percent.

4.5.3 Specific Gravity Tests

The specific gravity is used to establish the right boundary for the AZ, which is also known as the zero voids curve. The zero voids curve is used to establish the lower left boundary, degree of saturation curve, which was initially established at the 85 percent saturation curve (Section 2.7 Acceptable Hydraulic Conductivity Zone Development). The range of specific gravity for the test pads was 2.70 to 2.72, with an average of 2.71. The average was used to establish the right boundary.

4.5.4 Nuclear Density Tests

The nuclear density tests were used to measured the in situ density and moisture content of the CCL, borrow source, and subgrade materials. In particular, the CCL density and moisture content measurement were used to determine whether the material met the AZ requirements. In accordance with the Test Pads work plan, the material was to be compacted until the AZ requirements were met, however, during the program it was determined to allow some of the material not meeting the requirements to be tested for hydraulic conductivity to assist in establishing a final AZ. The nuclear density test results for the three test pads were plotted on the AZs with the respective 90 percent of Modified Proctor maximum dry densities and optimum moisture contents (Figures 4.1.2-1 through 4.1.2-8, Figures 4.2.2-1 through 4.2.2-10, and Figures 4.3.2-1 through 4.3.2-8). One hundred and two of the nuclear density tests fell into the AZ and 67 tests fell outside of the AZ (Figure 4.5.4-1).

4.5.5 Shelby Tube Hydraulic Conductivity Tests

Shelby Tube samples were collected from lifts 2 through 5 on Test Pads 1 and 3, and lifts 2 through 6 on Test Pad 2. These samples were used to conduct undisturbed sample hydraulic conductivity tests to determine whether the material and methods used to construct the CCL would have acceptable permeabilities (k values). Acceptable k values are those of 1.0×10^{-7} cm/sec or less. Sixty-two hydraulic conductivity tests were conducted for the test pads and 54 had acceptable k values. When the hydraulic conductivity sample dry densities and moisture contents were plotted on the AZ, using the average 90 percent maximum dry density as the lowest density value and the average optimum moisture content as the lowest moisture value (Figures 4.5.5-1 and 4.5.5-2), all of the failing hydraulic conductivity test results ($k< 1.0 \times 10^{-7}$ cm/sec) fall outside of the AZ. All of the acceptable hydraulic conductivity results, inside the AZ, had acceptable k values.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 ELF Borrow Material Characterization Study

The objectives of the ELF Borrow Material Characterization Study were to characterize the borrow material for the area designated in BA 5 for ELF construction, and determine whether the ELF footprint had clay material acceptable for CCL construction. These objectives were accomplished by the following activities:

- Collecting geotechnical data for determining soil engineering properties
- Determining soil types and distribution
- Quantifying the volume of acceptable soil available for constructing the ELF CCL
- Establish quality control measures for future ELF construction
- Identifying the topsoil thickness

The U.S. Environmental Protection Agency (EPA) technical guidance document, Quality Assurance and Quality Control for Waste Containment Facilities (EPA 1993) recommends that the following minimum testing frequencies be met to adequately characterize a borrow source:

• Water Content	1 Test per 2000 cubic meters (m$^{3)}$ (2616 yd^3)
• Atterberg Limits	1 Test per 5000 m^3 (6540 yd^3)
• Percentage Fines	1 Test per 5000 m^3 (6540 yd^3)
• Percent Gravel	1 Test per 5000 m^3 (6540 yd^3)
• Compaction Curve	1 Test per 5000 m^3 (6540 yd^3)
• Hydraulic Conductivity	1 Test per 10000 m^3 (13080 yd^3)

The above-recommended testing frequencies, except the hydraulic conductivity, were met for BA 5 since the ELF Borrow Material Characterization Study had a testing frequency of 1 test for every 2500 yd^3. Therefore, additional characterization testing of BA 5 is not necessary, except for the hydraulic conductivity tests. The hydraulic conductivity frequency will be met during the construction of the ELF. The complete laboratory and field test data for BA 5 collected during the characterization study will be included in the ELF certification report.

The ELF Borrow Material Characterization Study determined that material suitable for CCL construction existed in the ELF Footprint. The EPA-recommended testing frequency for the material in the ELF footprint was not met. The material for CCL construction, including the clay material under the existing topsoil stockpile within the ELF Footprint, will be stockpiled during the excavation of the ELF and will be tested at the above-recommended testing frequencies during CCL construction.

5.2 ELF Test Pads Program

The primary objectives of the ELF Test Pad Program were as follows:

- Demonstrate the construction suitability for the ELF CCL of all the clay borrow material in BA 5 and ELF footprint that meet the CL and CH soil classification and the required soil index properties, regardless of color.
- Establish the design requirements for the ELF CCL.
- Finalize the CQC and CQA construction testing requirements.
- Define a design basis by using equipment and procedures for CCL processing, placement, and compaction to develop construction specifications that will provide the flexibility to construct full-scale CCLs and allow more effective construction.
- Evaluate field and laboratory hydraulic conductivities, interlift bonding, surface desiccation, and general constructability of the borrow soils.
- Define any additional test fill data needs for the future ELF construction that exist after the construction and testing of the ELF test pads.

The BA 5 and ELF Footprint borrow materials used during the construction of the test pads were representative of the materials in BA 5 and the ELF Footprint, including the clay material under the existing topsoil stockpile in the ELF Footprint. It has been demonstrated that the clay materials in BA 5 and the ELF Footprint are suitable for construction of the ELF CCL since they meet the CL and CH soil classification, the plasticity indices were between 10 and 40, the percent passing the No. 4 was 100 percent, and the percent passing the No. 200 sieve was 50 percent and higher (Section 4.5.1). Observations were made of the borrow materials constructability, interlift bonding, and surface desiccation (Section 3.0). It was determined that both a CAT 815 and CAT 825, or equivalent, can be used to meet the compaction requirements for CCL construction for the designated borrow materials.

The borrow material met the minimum hydraulic conductivity of 1.0×10^{-7} cm/sec. The hydraulic conductivity was met 100 percent of the time when the material was compacted to fall within the AZ (Section 4.5.5), and was above 105 pcf. The nuclear density tests demonstrated that the material could be compacted to fall within the AZ when the soil is adequately hydrated (Section 4.5.4). When all of the hydraulic conductivity test results are plotted together, an area can be defined where 100 percent of the hydraulic conductivity tests have acceptable k values (Figure 5.2-1). This area should become the AZ for ELF construction, is shown on Figure 5.2-1 and described as follows:

- The right boundary (Zero Air Voids) is the curve represented by the average specific gravity of 2.71.
- The lowest boundary for the AZ is 106 pcf.
- The lower left boundary is the 85 percent saturation line, defined by using the average specific gravity of 2.71.
- The upper left boundary of 12.6 percent is the Average Modified Proctor Optimum Moisture Content.

The primary objectives have been met by the aforementioned and by establishing design requirements described below. The design requirements, which include some CQA and CQC testing requirements, are recommended as the following:

- Include the following in the CCL specification:
  1. USCS Classification of CL, CH
  2. Minimum Percent Passing the No. 4 Sieve – 95
  3. Minimum Percent Passing the No. 200 Sieve – 50
  4. Minimum PI – 10
  5. Maximum PI – 40 (Note: This is subject to change depending upon the results of the Chemical Compatibility Testing Program.)
  6. Maximum Particle Size – 1 inch
  7. Maximum Particle Size for the Top Lift – 0.5 inch
  8. No organic or deleterious material
  9. A CAT 815 or 825, or equivalent, can be used for compaction with a minimum number of 4 passes.
  10. Compact CCL material until AZ requirements are met.

- Borrow material from BA 5 has met the suggested minimum EPA testing requirements, therefore, only some confirmatory CQA testing will be conducted during the ELF CCL construction.
- Borrow material from BA 5 will not contain clod sizes larger than 2 inches. If clod sizes are larger than 2 inches, the material will be reprocessed.
- Add the following to the Construction Quality Assurance Plan CQA and CQC testing requirements:

1. The CCL material excavated from the ELF footprint and stockpiled will be tested in the stockpile as borrow activities take place during ELF CCL construction, at the following frequencies:

- Water Content	1 Test per 2000 m^3 (2616 yd^3)
- Atterberg Limits	1 Test per 5000 m^3 (6540 yd^3)
- Percentage Fines	1 Test per 5000 m^3 (6540 yd^3)
- Percent Gravel	1 Test per 5000 m^3 (6540 yd^3)
- Compaction Curve	1 Test per 5000 m^3 (6540 yd^3)
– Hydraulic Conductivity	1 Test per 10000 m^3 (13080 yd^3)

2. Nuclear density testing will be conducted to ensure that the requirements for the AZ presented on Figure 5.2-1 are met.

3. Nuclear density test holes and Shelby Tube holes will be repaired by placing clay material in approximate 2-inch lifts and compacting with a tamping rod. The upper half of the hole will be backfilled and compacted in the same manner but a sledgehammer may be used in place of the tamping rod.

4. Excavated test pits will be repaired by backfilling the material in approximate 6-inch lifts and compacting with a compactor with a minimum of four passes. Prior to test pit excavation, the test pit location will be surveyed for elevation. After the test pit has been excavated, the test location will be surveyed to confirm the depth of the test. The surveying will ensure that the desired lift is being tested.

All data summarized in this report and used during the ELF CCL construction will be included in the ELF Certification Report.

6.0 REFERENCES

EPA (U.S. Environmental Protection Agency)
1993 (Sept) *Quality Assurance and Quality Control for Waste Containment Facilities*

FWENC (Foster Wheeler Environmental Corporation)
2001 (May 4) *Enhanced Hazardous Waste Landfill Test Pads Program Work Plan*

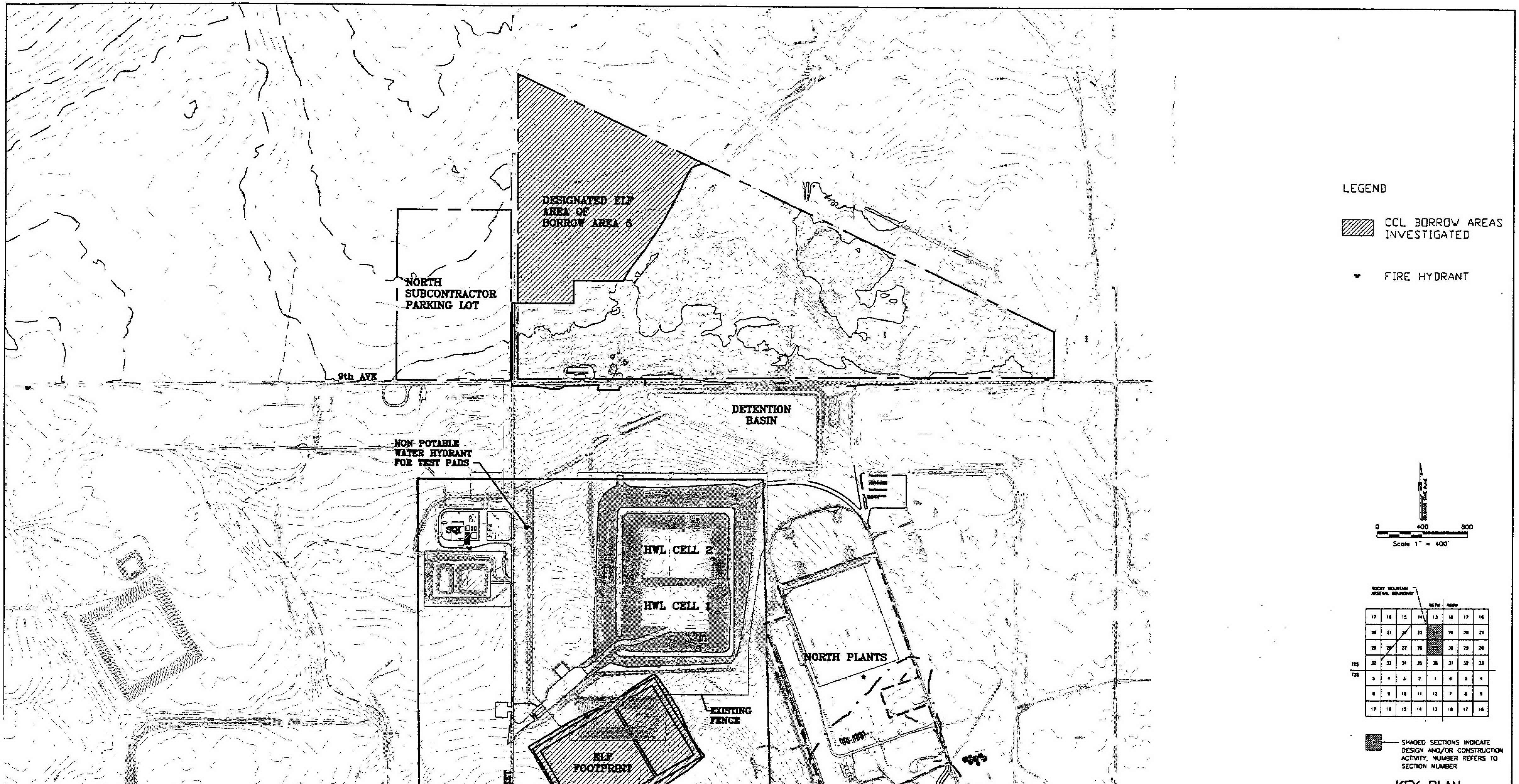
HLA (Harding Lawson Associates)

1997 (Dec 31)	*Final Test Fill Construction Program Summary Report*

USACE (U.S. Army Corps of Engineers)

1997	*Final Geotechnical Investigation Report, Hazardous Waste Landfill*

FIGURES



▨ SHADED SECTIONS INDICATE DESIGN AND/OR CONSTRUCTION ACTIVITY, NUMBER REFERS TO SECTION NUMBER

KEY PLAN

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SITE LAYOUT

CHECKED:	J. GERRETT	04.06.01	FIGURE NUMBER
DESIGNED:	S. LABB	04.06.01	10-1
FILE NAME:	FIG-1	XX.XX.XX	

G:\PROJECTS\0297-0207\FIG-1.DWG

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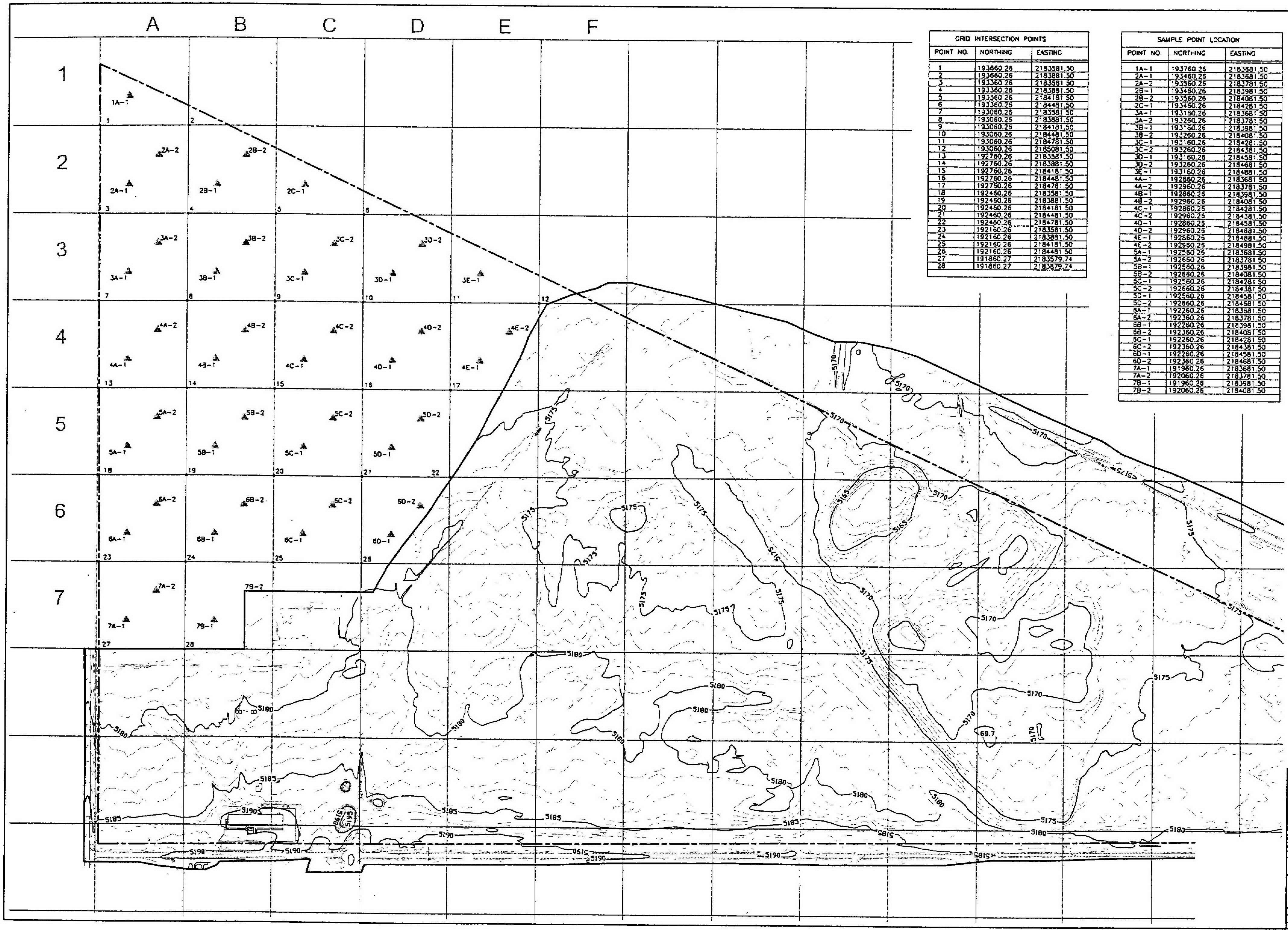


GRID INTERSECTION POINTS		
POINT NO.	NORTHING	EASTING
1	193660.26	2183581.50
2	193660.26	2183881.50
3	193360.26	2183581.50
4	193360.26	2183881.50
5	193360.26	2184181.50
6	193360.26	2184481.50
7	193060.26	2183581.50
8	193060.26	2183881.50
9	193060.26	2184181.50
10	193060.26	2184481.50
11	193060.26	2184781.50
12	193060.26	2185081.50
13	192760.26	2183581.50
14	192760.26	2183881.50
15	192760.26	2184181.50
16	192760.26	2184481.50
17	192760.26	2184781.50
18	192460.26	2183581.50
19	192460.26	2183881.50
20	192460.26	2184181.50
21	192460.26	2184481.50
22	192460.26	2184781.50
23	192160.26	2183581.50
24	192160.26	2183881.50
25	192160.26	2184181.50
26	192160.26	2184481.50
27	191860.27	2183579.74
28	191860.27	2183879.74

SAMPLE POINT LOCATION		
POINT NO.	NORTHING	EASTING
1A-1	193760.26	2183681.50
2A-1	193460.26	2183681.50
2A-2	193560.26	2183781.50
2B-1	193460.26	2183981.50
2B-2	193560.26	2184081.50
2C-1	193460.26	2184281.50
3A-1	193160.26	2183681.50
3A-2	193260.26	2183781.50
3B-1	193160.26	2183981.50
3B-2	193260.26	2184081.50
3C-1	193160.26	2184281.50
3C-2	193260.26	2184381.50
3D-1	193160.26	2184581.50
3D-2	193260.26	2184681.50
3E-1	193160.26	2184881.50
4A-1	192860.26	2183681.50
4A-2	192960.26	2183781.50
4B-1	192860.26	2183981.50
4B-2	192960.26	2184081.50
4C-1	192860.26	2184281.50
4C-2	192960.26	2184381.50
4D-1	192860.26	2184581.50
4D-2	192960.26	2184681.50
4E-1	192860.26	2184881.50
4E-2	192960.26	2184981.50
5A-1	192560.26	2183681.50
5A-2	192660.26	2183781.50
5B-1	192560.26	2183981.50
5B-2	192660.26	2184081.50
5C-1	192560.26	2184281.50
5C-2	192660.26	2184381.50
5D-1	192560.26	2184581.50
5D-2	192660.26	2184681.50
6A-1	192260.26	2183681.50
6A-2	192360.26	2183781.50
6B-1	192260.26	2183981.50
6B-2	192360.26	2184081.50
6C-1	192260.26	2184281.50
6C-2	192360.26	2184381.50
6D-1	192260.26	2184581.50
6D-2	192360.26	2184681.50
7A-1	191960.26	2183681.50
7A-2	192060.26	2183781.50
7B-1	191960.26	2183981.50
7B-2	192060.26	2184081.50

NOTES:

1. THE DIGITAL BASE MAP UTILIZED HEREIN WAS PROVIDED BY MERRICK & COMPANY, AND IS REPRESENTATIVE OF CONDITIONS IN APRIL '97
2. THE COORDINATE SYSTEM SHOWN IS THE COLORADO STATE PLANE, NORTH ZONE. NAD27 HORIZONTAL DATUM.
3. ELEVATIONS SHOWN ARE BASED ON THE NGVD29 VERTICAL DATUM.

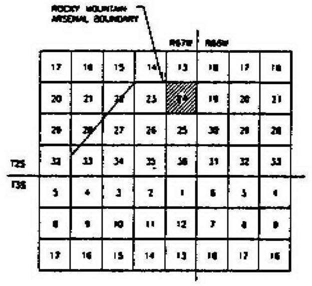
LEGEND:

▲ 1A-1	TEST PIT
┼ 16	GRID INTERSECTION

COLORADO STATE PLANE

0 75 150 225 300

SCALE IN FEET



▨ SHADED SECTIONS INDICATE DESIGN AND/OR CONSTRUCTION ACTIVITY, NUMBER REFERS TO SECTION NUMBER

KEY PLAN

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME

BORROW AREA 5 + ELF
GEOTECHNICAL STUDY

TITLE

BORROW AREA 5 TEST PITS AND GRID LOCATIONS

CHECKED:	J. BERRETZ	04.06.01	FIGURE NUMBER
DESIGNED:	S. [illegible]	04.06.01	2.2 1-1
FILE NAME:	BASE.dwg	XX.XX.XX	

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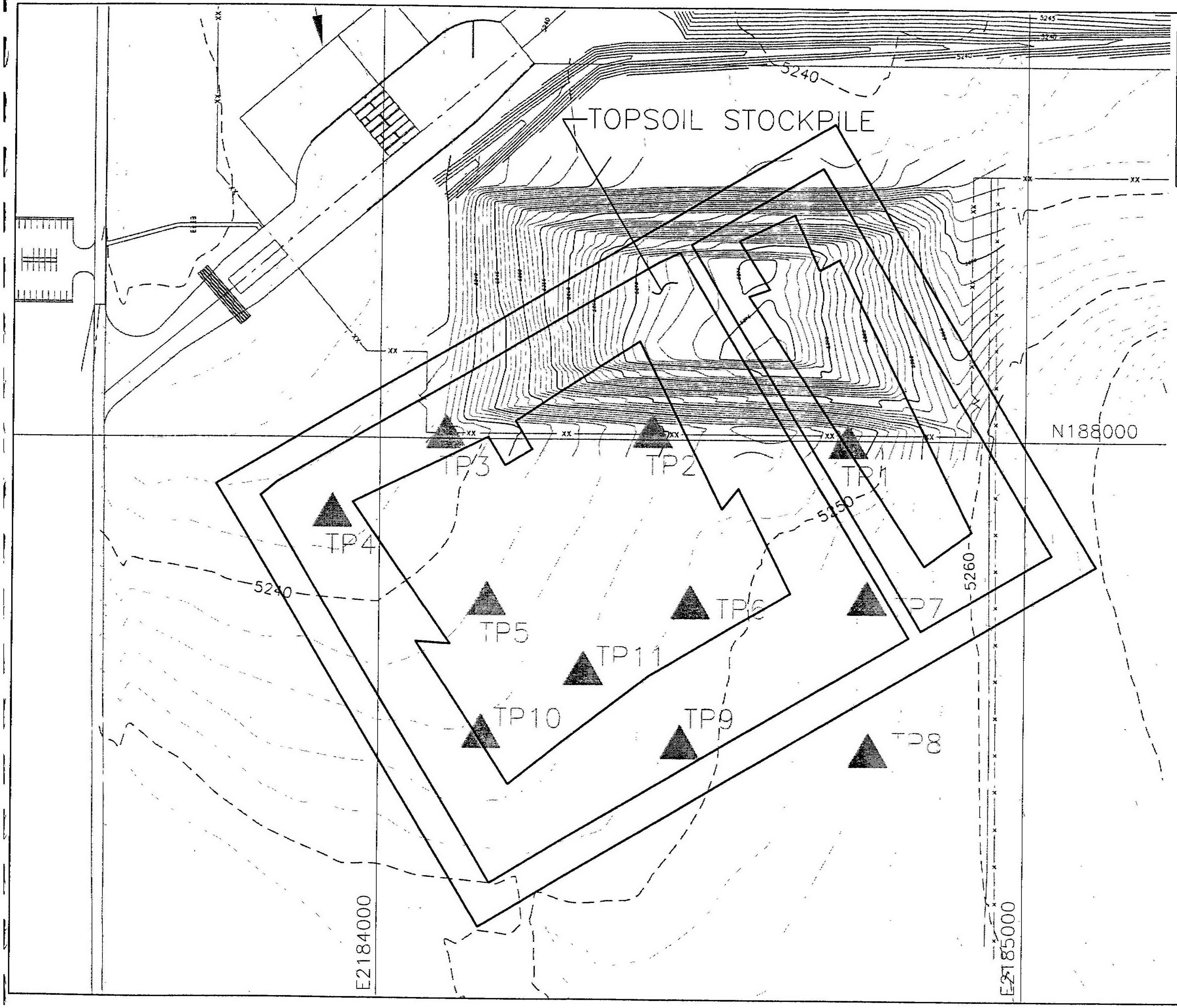


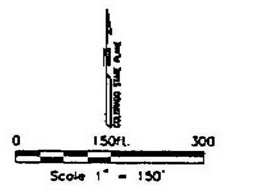
COORDINATE TABLE		
ID NUMBER	NORTHING	EASTING
TP1	187990.80	2184724 70
TP2	188005.80	2184422 20
TP3	188001 80	2184100 70
TP4	187877 30	2183926 70
TP5	187741 30	2184165.20
TP6	187737.30	2184482 70
TP7	187744.80	2184755 20
TP8	187506.80	2184758 70
TP9	187518 30	2184467 70
TP10	187533.30	2184157.70
TP11	187632 60	2184318 40

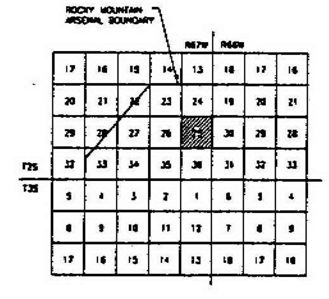
NOTES:

1. THE DIGITAL BASE MAP UTILIZED HEREIN WAS PROVIDED BY MERRICK & COMPANY, AND IS REPRESENTATIVE OF CONDITIONS IN APRIL '97
2. THE COORDINATE SYSTEM SHOWN IS THE COLORADO STATE PLANE, NORTH ZONE, NAD27 HORIZONTAL DATUM.
3. ELEVATIONS SHOWN ARE BASED ON THE NGVD29 VERTICAL DATUM.

LEGEND:

▲ TP3 TEST PIT LOCATION





▨ SHADED SECTIONS INDICATE DESIGN AND/OR CONSTRUCTION ACTIVITY, NUMBER REFERS TO SECTION NUMBER

KEY PLAN

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
BAS-ELF
GEOTECHNICAL STUDY

TITLE
ELF
TEST PIT LOCATIONS

			FIGURE NUMBER
CHECKED:	J. BERRETZ	04.06.01	2.2.2-1
DESIGNED:	S. LABB	04.06.01	
FILE NAME:	FIG-1-1	XX.XX.XX	

G:\PROJECTS\0297-0207\FIG1-1.DWG

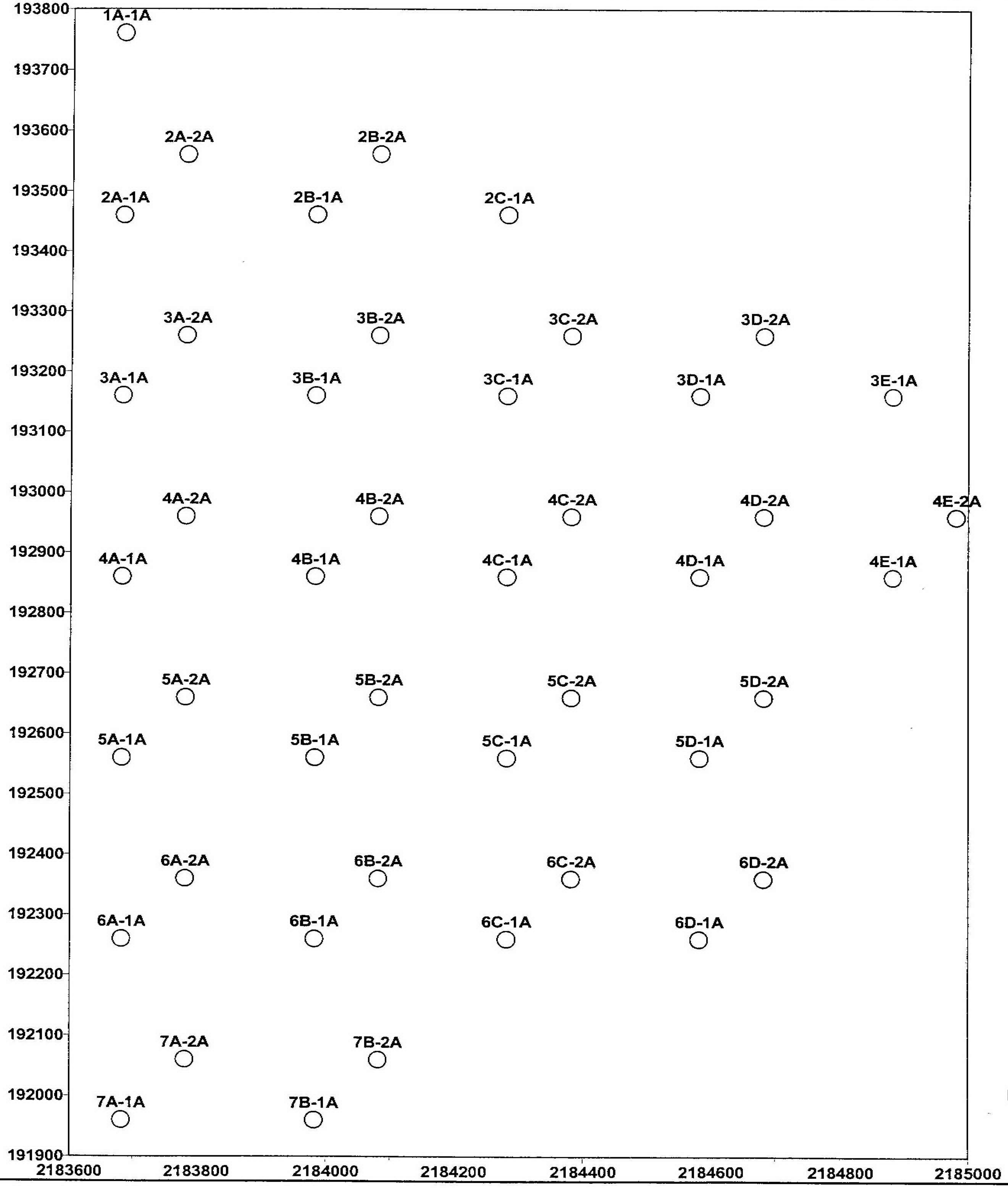


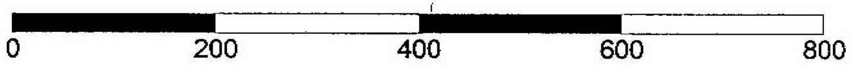
Figure 2.5.1A

BA5 Material Color Layer A (1.0 to 2.5 ft. below surface)

Legend

☐ **Color Type 1 - Dark Yellowish Brown to Light Yellowish Brown**

○ **= Test Pit Location**



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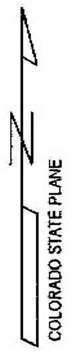

Note: Refer to Figure 2.2.1-1 for survey locations

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PROJECT NAME

ELF TEST PAD PROGRAM

TITLE

Borrow Area 5 Color Layer A

CHECKED	J. Berretz	01.02.02	FIGURE NUMBER
DESIGNED	R. Bennmark	01.02.02	2.5.1A
FILE NAME			

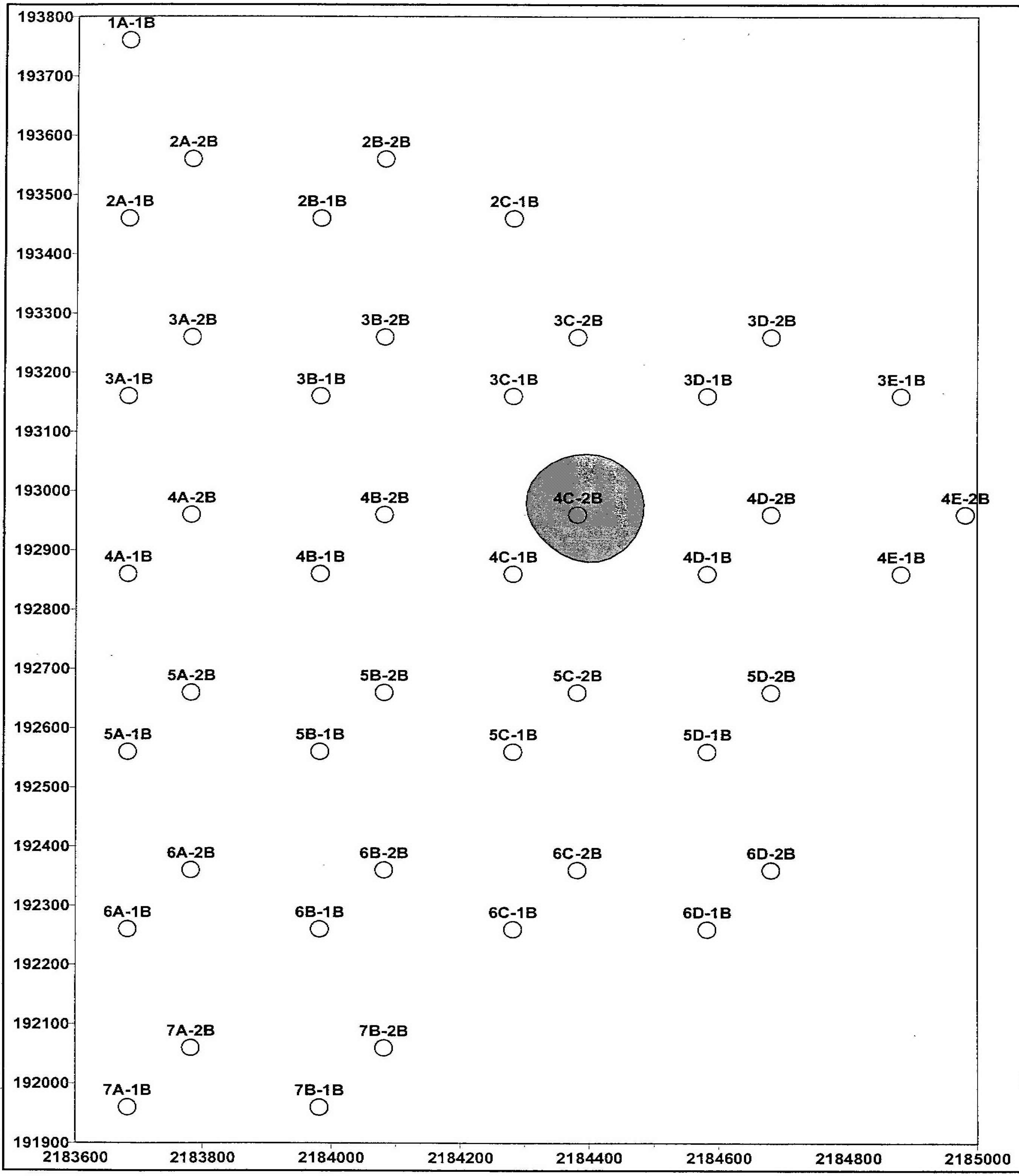


Figure 2.5.1B

BA5 Material Color Layer B (2.5 to 4.0 ft. below surface)

Legend

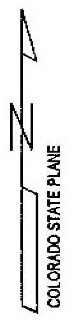
☐ Color Type 1 - Dark Yellowish Brown to Light Yellowish Brown

▨ Color Type 2 - Pale Brown to Very Pale Brown

○ = Test Pit Location

0 200 400 600 800

Scale



Note: Refer to Figure 2.2.1-1 for survey locations

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PROJECT NAME

ELF TEST PAD PROGRAM

TITLE

Borrow Area 5 Color Layer B

CHECKED J. Berretz 01.02.02

R. Benmark 01.02.02

FIGURE NUMBER

2.5.1B

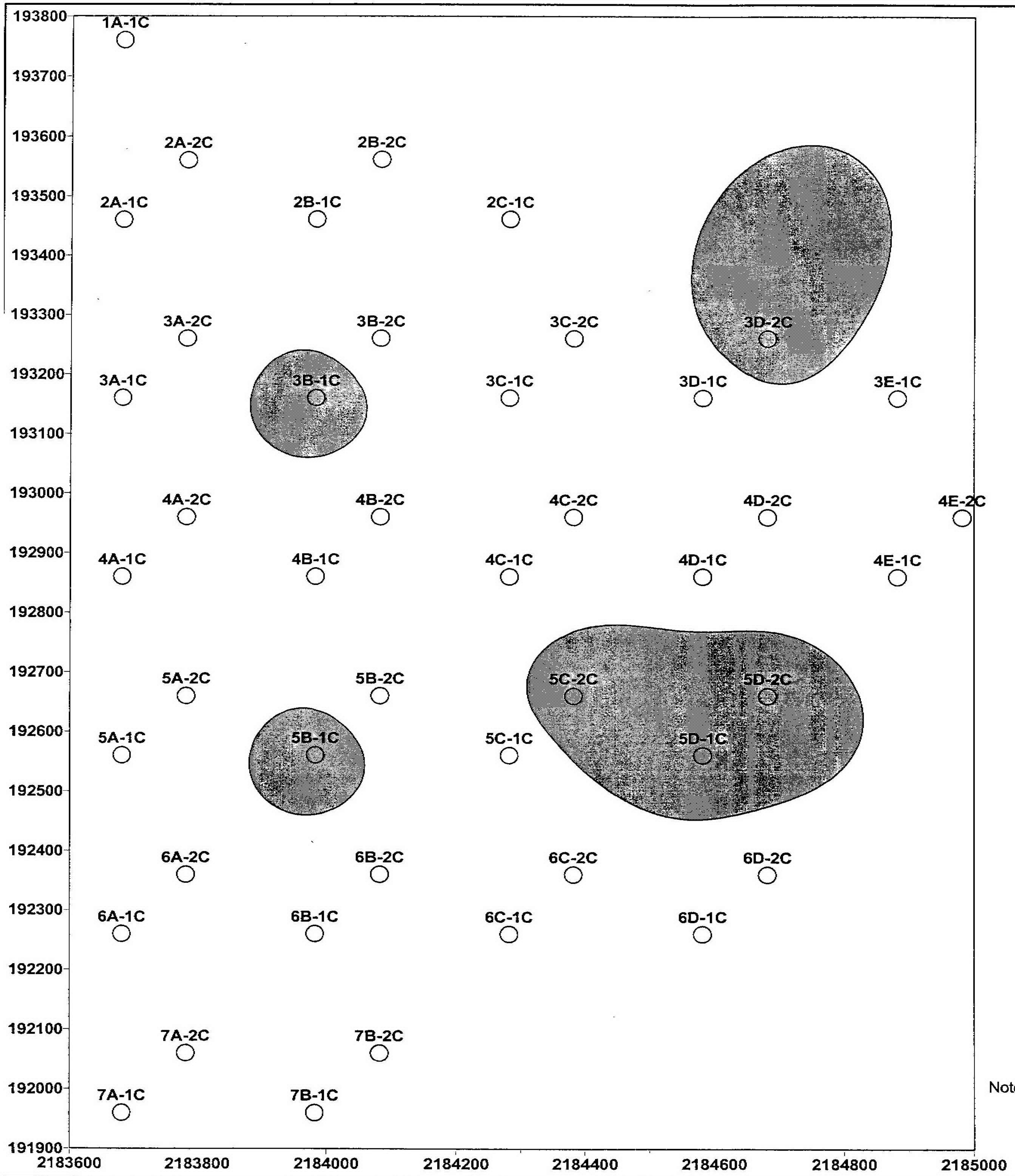
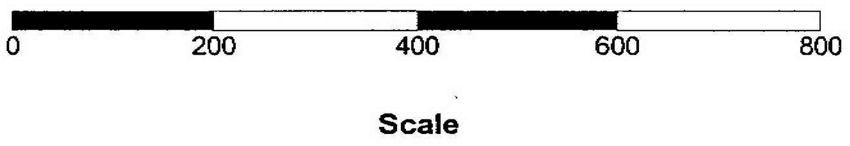


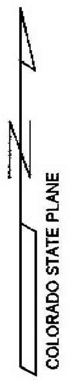
Figure 2.5.1C

BA5 Material Color Layer C (4.0 to 5.5 ft. below surface)

Legend

☐	**Color Type 1 - Dark Yellowish Brown to Light Yellowish Brown**
▨	**Color Type 2 - Pale Brown to Very Pale Brown**
○	**= Test Pit Location**





Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD PROGRAM

TITLE
Borrow Area 5 Color Layer C

CHECKED	J. Sorretz	01.02.02	FIGURE NUMBER
DESIGNED	R. Benmark	01.02.02	2.5.1C
FILE NAME			

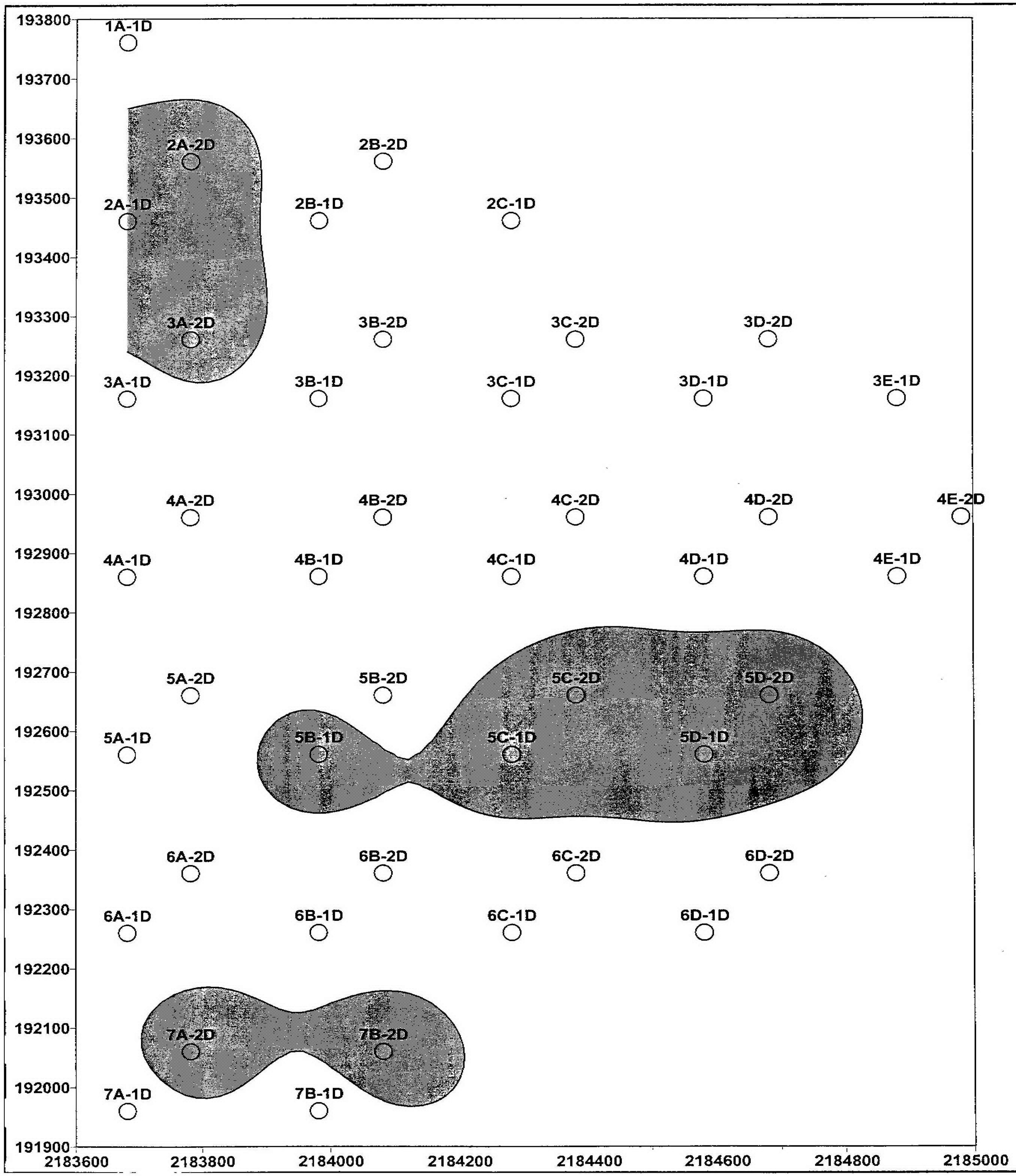


Figure 2.5.1D

BA5 Material Color Layer D (5.5 to 7.0 ft. below surface)

Legend

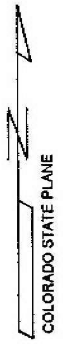
☐ Color Type 1 - Dark Yellowish Brown to Light Yellowish Brown

▨ Color Type 2 - Pale Brown to Very Pale Brown

○ = Test Pit Location

0 200 400 600 800

Scale



Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME

ELF TEST PAD PROGRAM

Borrow Area 5 Color Layer D

CHECKED J. Berretz 01.02.02
DESIGNED R. Benmark 01.02.02
FILE NAME

FIGURE NUMBER
2.5.1D

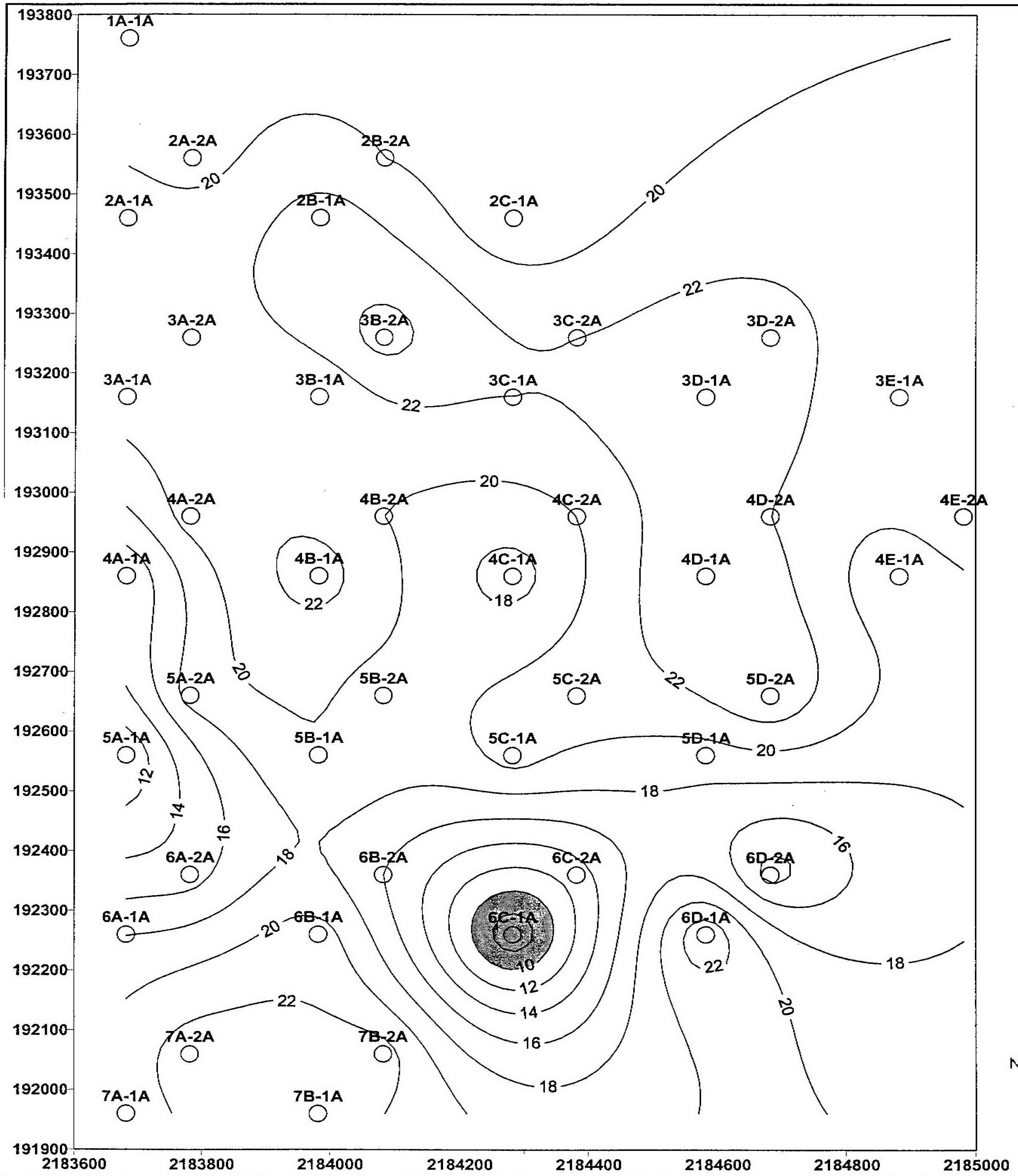


Figure 2.5.2A

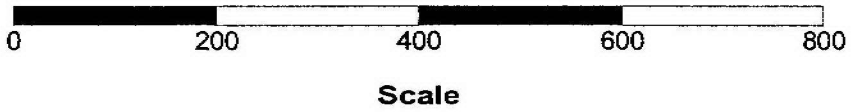
BA5 Plasticity Index Distribution Layer A (1.0 to 2.5 ft. below surface)

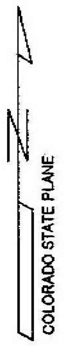
Legend

Contours at Two Percent Interval

▨ **Plasticity Index < 10**

○ **= Test Pit Location**





Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME

ELF TEST PAD PROGRAM

TITLE

Borrow Area 5 Plasticity Index Distribution Layer A

	J. Berretz	01.02.02	FIGURE NUMBER
	R. Benmark	01.02.02	2.5.2A

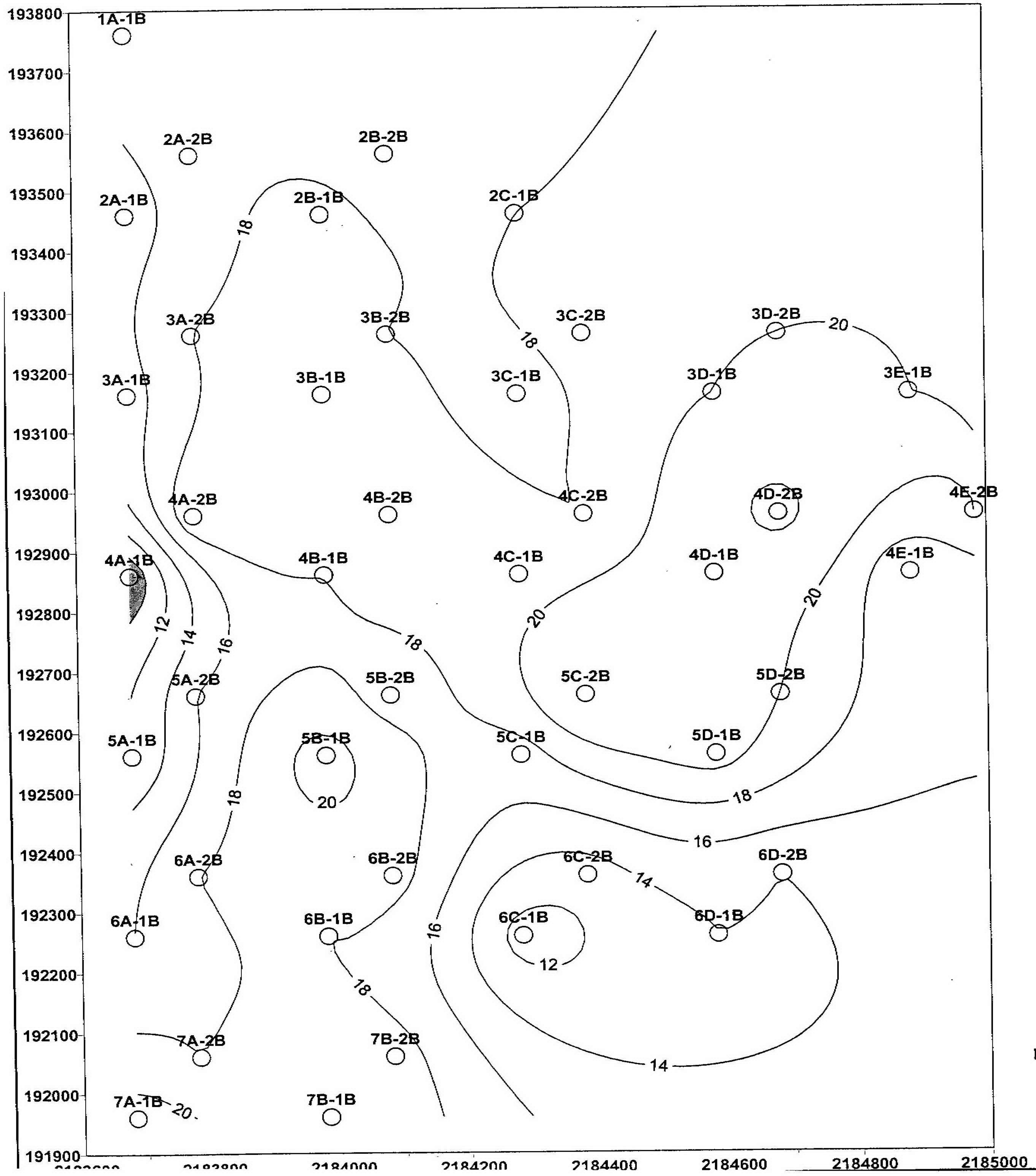


Figure 2.5.2B

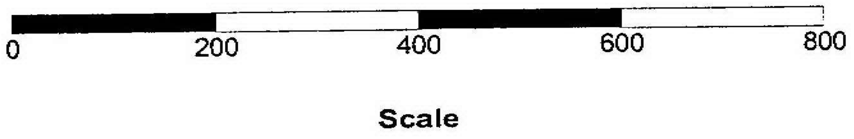
BA5 Plasticity Index Distribution Layer B (2.5 to 4.0 ft. below surface)

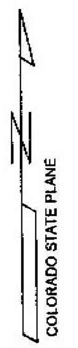
Legend

Contours at Two Percent Interval

▨ **Plasticity Index < 10**

○ **= Test Pit Location**





Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME

ELF TEST PAD PROGRAM

TITLE

Borrow Area 5 Plasticity Index Distribution Layer B

CHECKED J. Berretz 01.02.02

DESIGNED R. Benmark 01.02.02

FIGURE NUMBER 2.5.2B

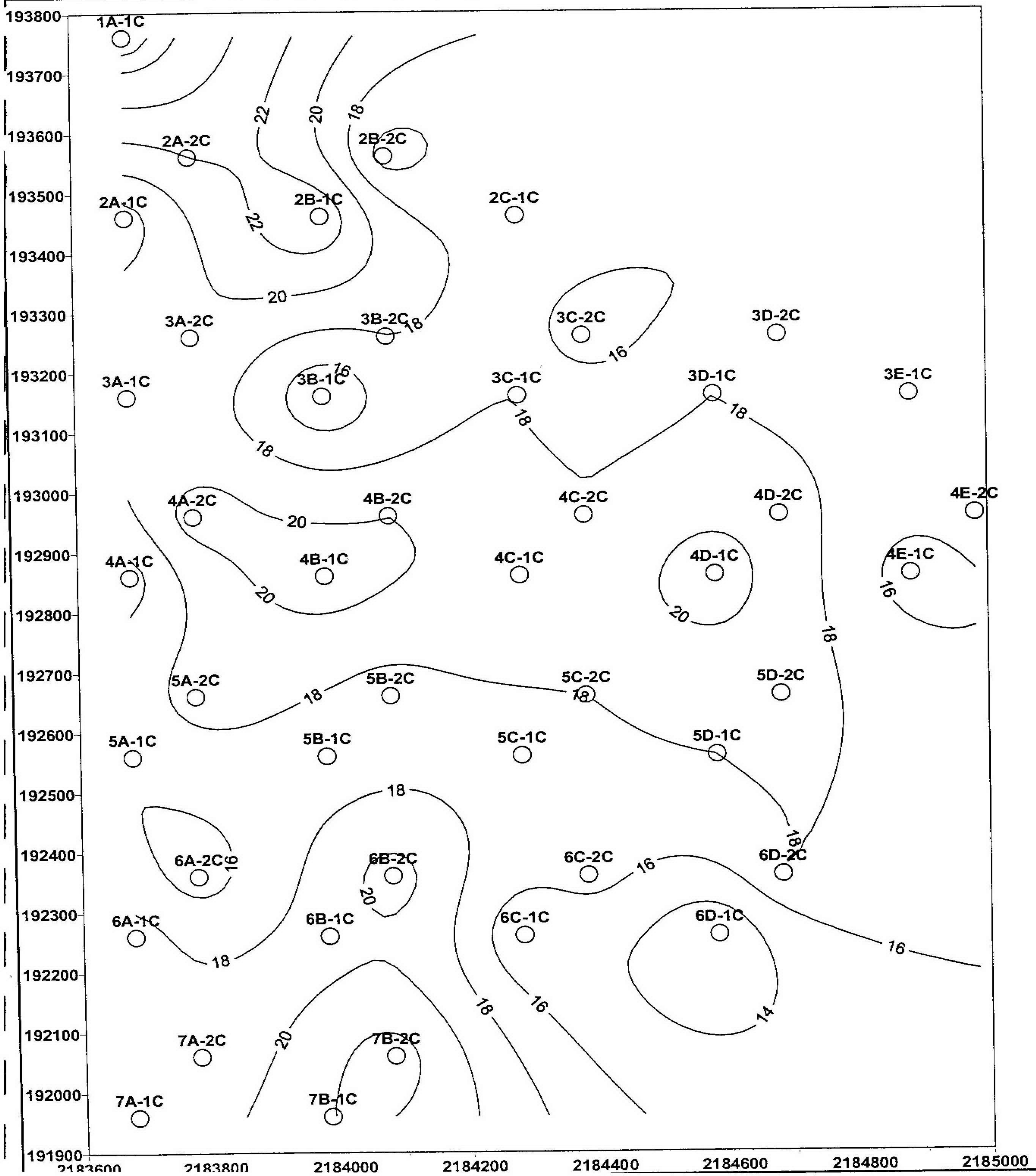


Figure 2.5.2C

BA5 Plasticity Index Distribution Layer C (4.0 to 5.5 ft. below surface)

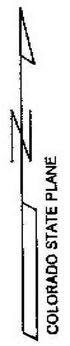
Legend

Contours at Two Percent Interval

○ = Test Pit Location

0 200 400 600 800

Scale



Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME

ELF TEST PAD PROGRAM

TITLE

Borrow Area 5 Plasticity Index Distribution Layer C

CHECKED J. Barretz 01.02.02
DESIGNED R. Benmark 01.02.02
FILE NAME XX.XX.XX

FIGURE NUMBER
2.5.2C

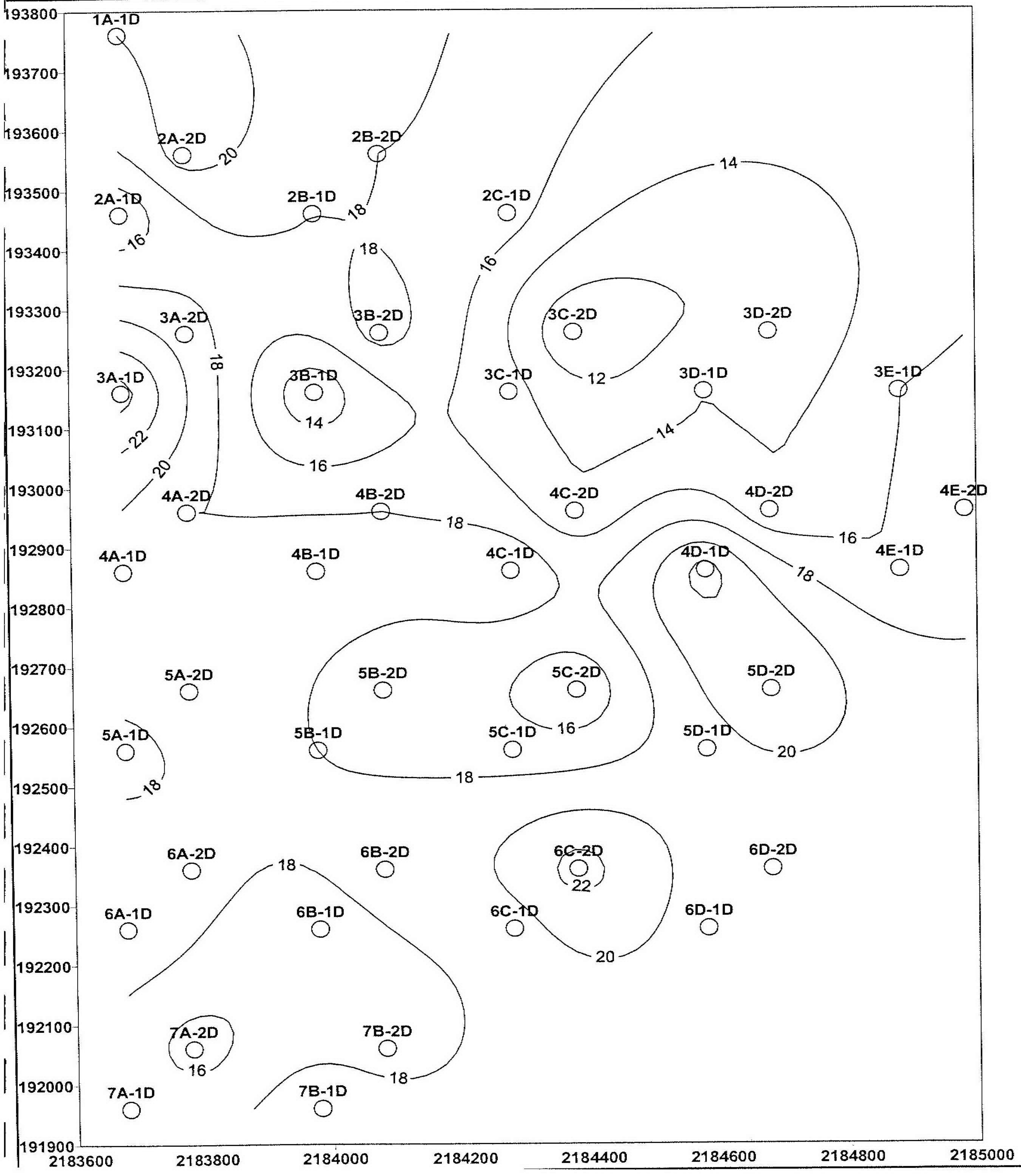


Figure 2.5.2D

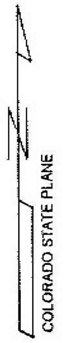
BA5 Plasticity Index Distribution Layer D (5.5 to 7.0 ft. below surface)

Legend

Contours at Two Percent Interval

○ **= Test Pit Location**

Scale



Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

POCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

ELF TEST PAD PROGRAM

Borrow Area 5 Plasticity Index Distribution Layer D

CHECKED	J. Barretz	01.02.02	
DESIGNED	R. Bersmark	01.02.02	2.5.2D

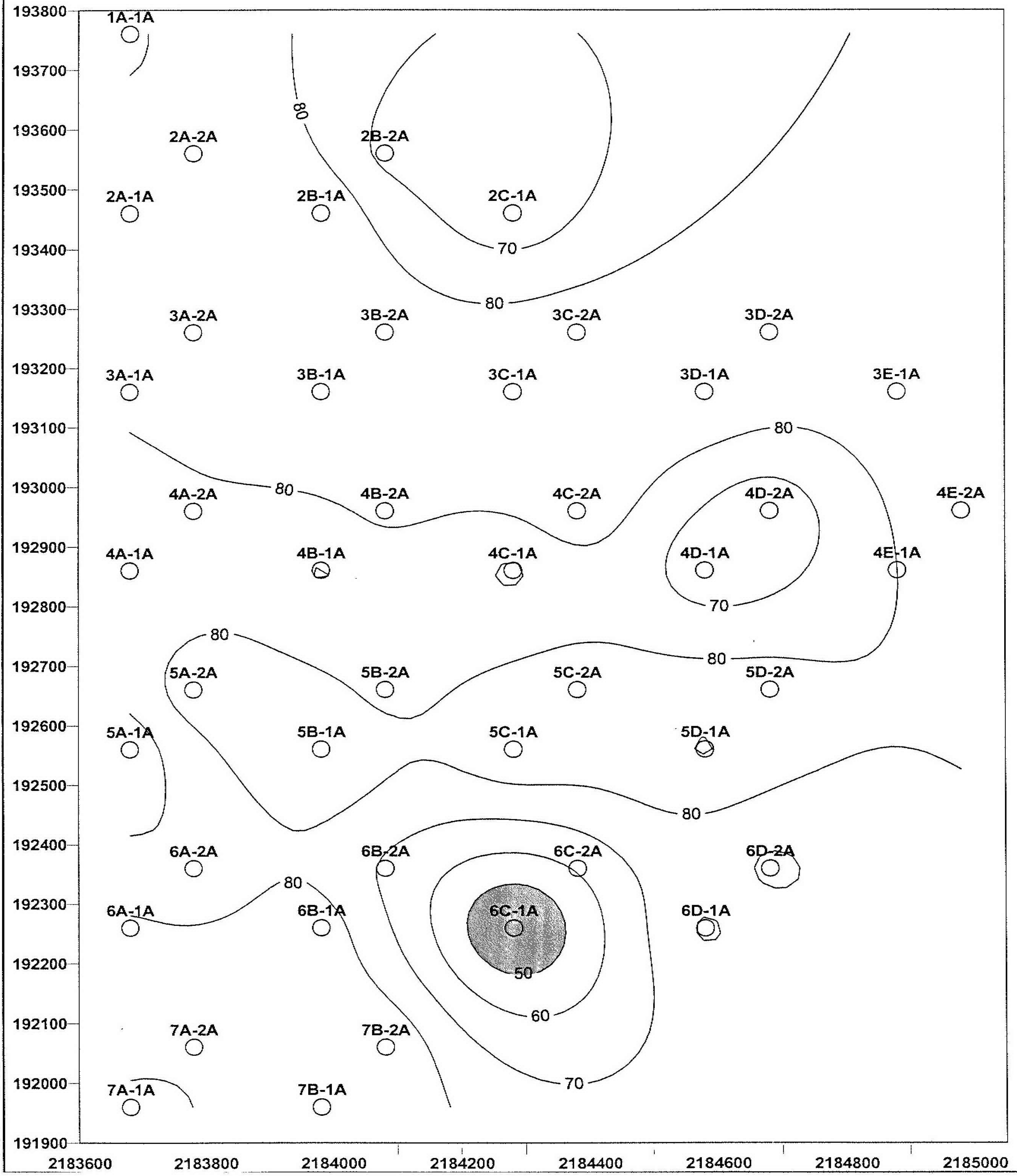


Figure 2.5.3A

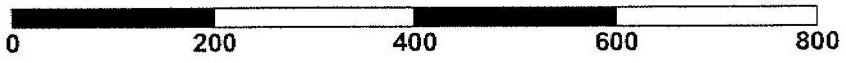
BA5 Percent 200 Distribution Layer A (1.0 to 2.5 ft. below surface)

Legend

Contours at ten percent Interval

▨ Less Than 50% Passing 200 Sieve

○ = Test Pit Location



Scale

Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

ELF TEST PAD PROGRAM

Borrow Area 5 Percent 200 Distribution Layer A

J. Berretz 01.02.02
R. Benmark 01.02.02
2.5.3A

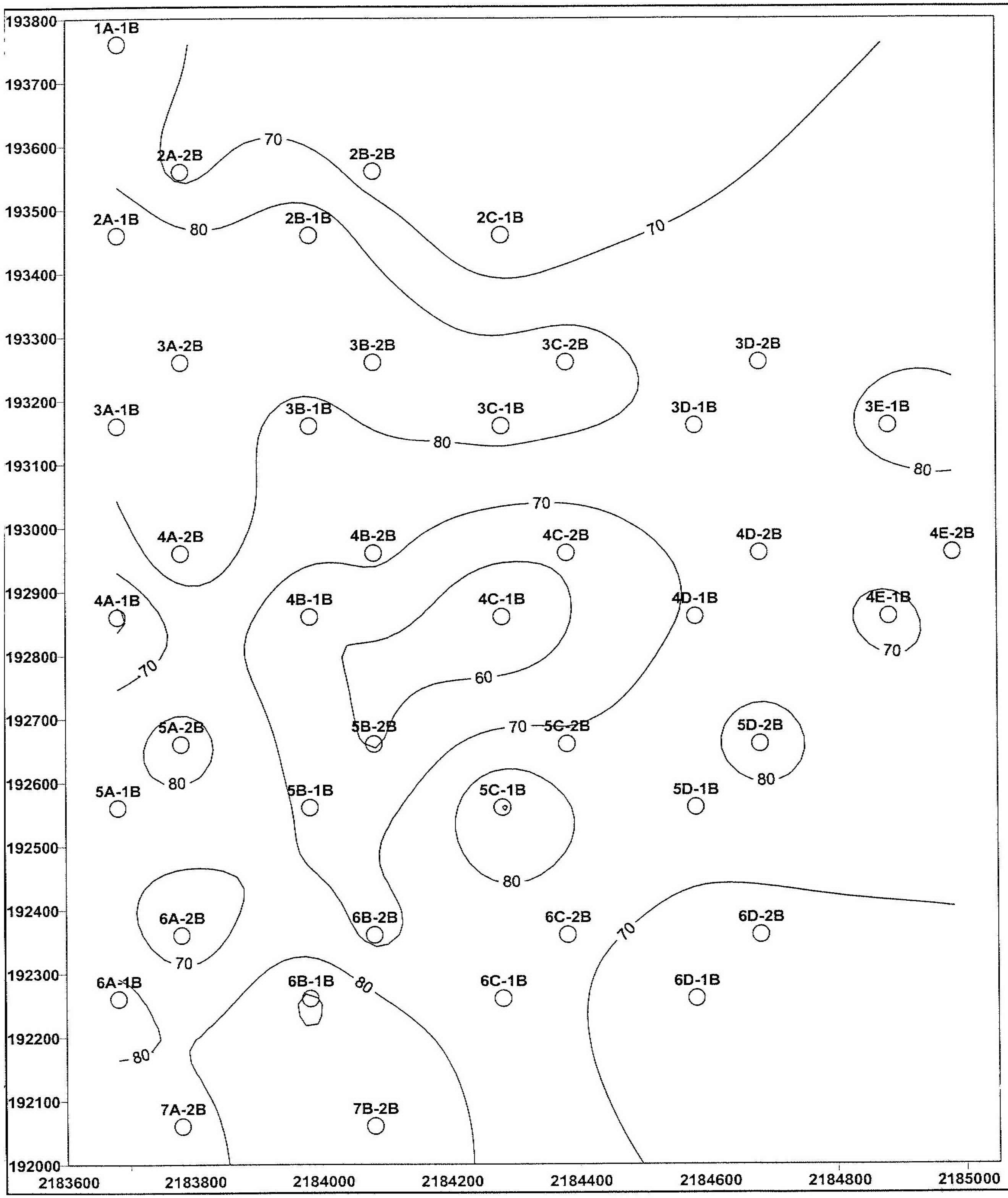


Figure 2.5.3B

BA5 Percent 200 Distribution Layer B (2.5 to 4.0 ft. below surface)

Legend

Contours at ten percent Interval

○ **= Test Pit Location**

0 200 400 600 800

Scale

COLORADO STATE PLANE

Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME

ELF TEST PAD PROGRAM

TITLE

Borrow Area 5 Percent 200 Distribution Layer B

	J. Berrelz	01.02.02	
	R. Benmark	01.02.02	2.5.3B

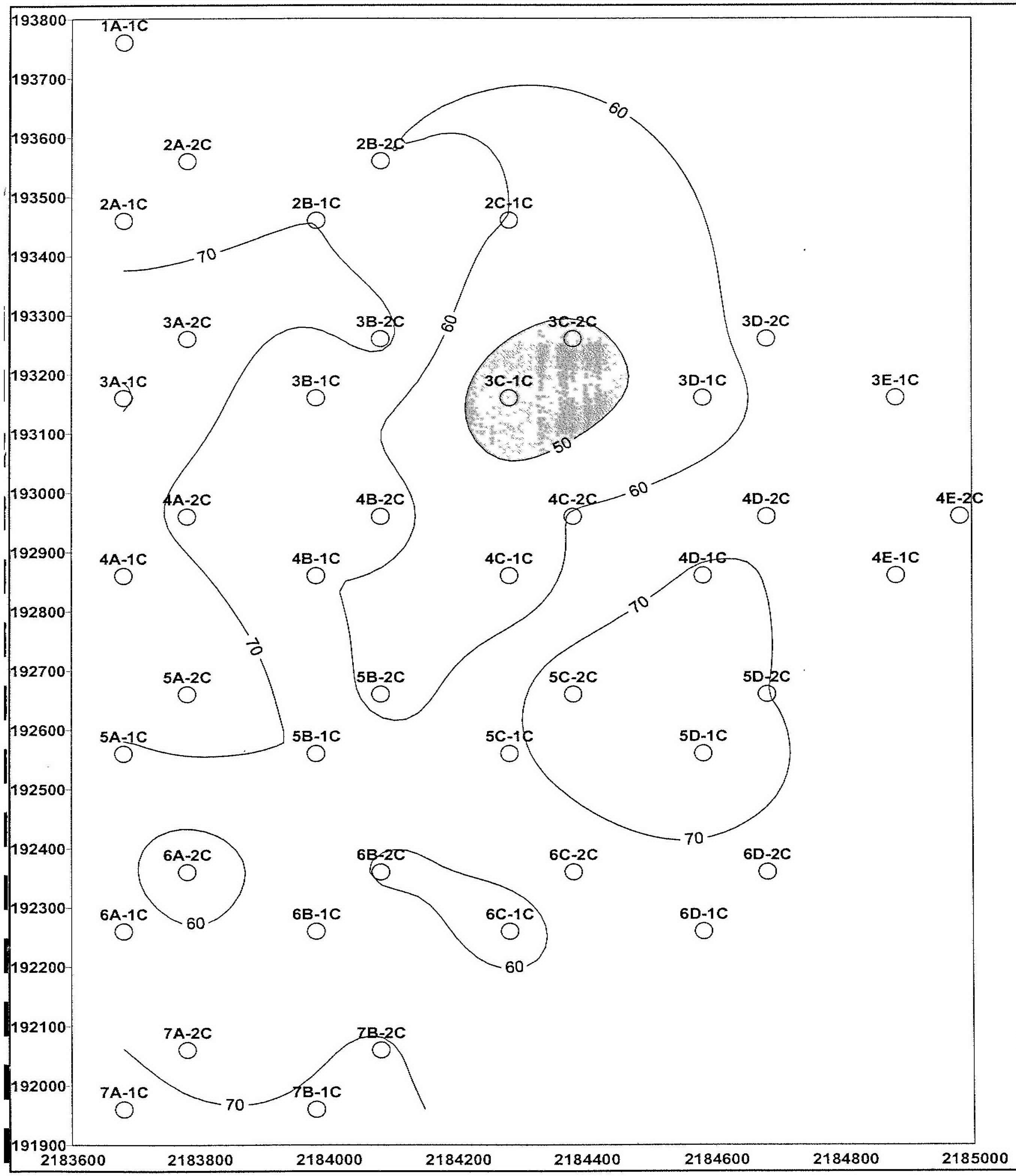


Figure 2.5.3C

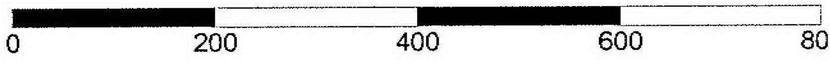
BA5 Percent 200 Distribution Layer C (4.0 to 5.5 ft. below surface)

Legend

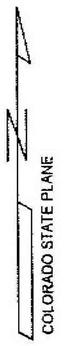
Contours at ten percent Interval

▨ **Less Than 50% Passing 200 Sieve**

○ **= Test Pit Location**



Scale



Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

ELF TEST PAD PROGRAM

Borrow Area 5 Percent 200 Distribution Layer C

J Barretz 01.02.02
R. Benmark 01.02.02
2.5.3C

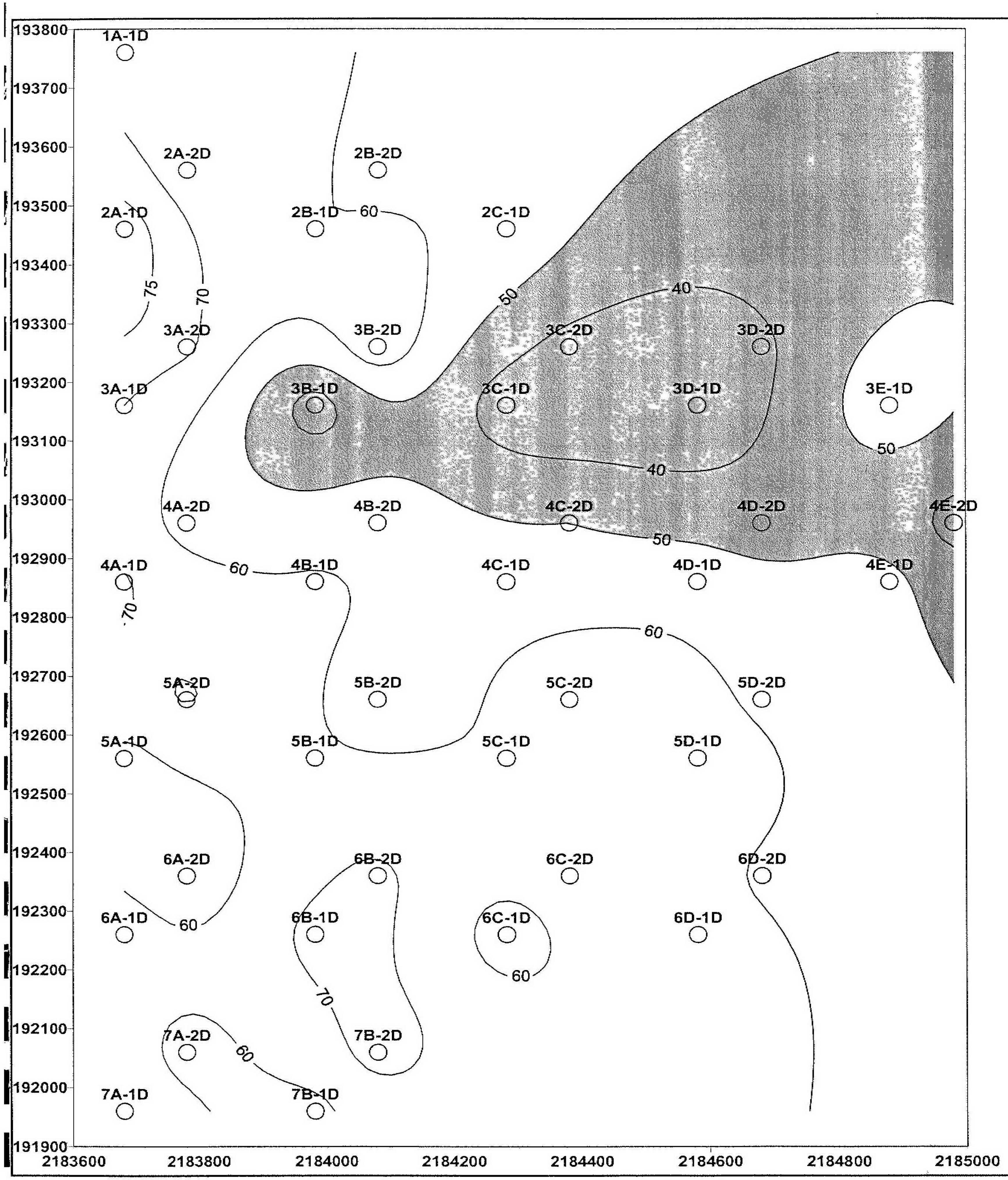


Figure 2.5.3D

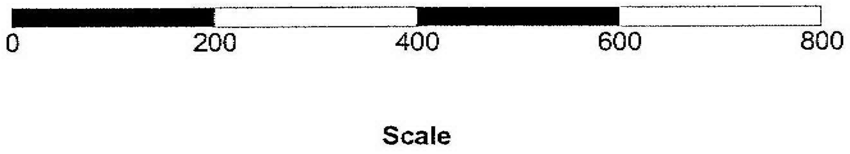
BA5 Percent 200 Distribution Layer D (5.5 to 7.0 ft. below surface)

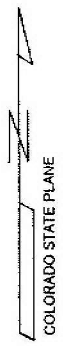
Legend

Contours at ten percent Interval

▨ **Less Than 50% Passing 200 Sieve**

○ **= Test Pit Location**





Note: Refer to Figure 2.2.1-1 for survey locations

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

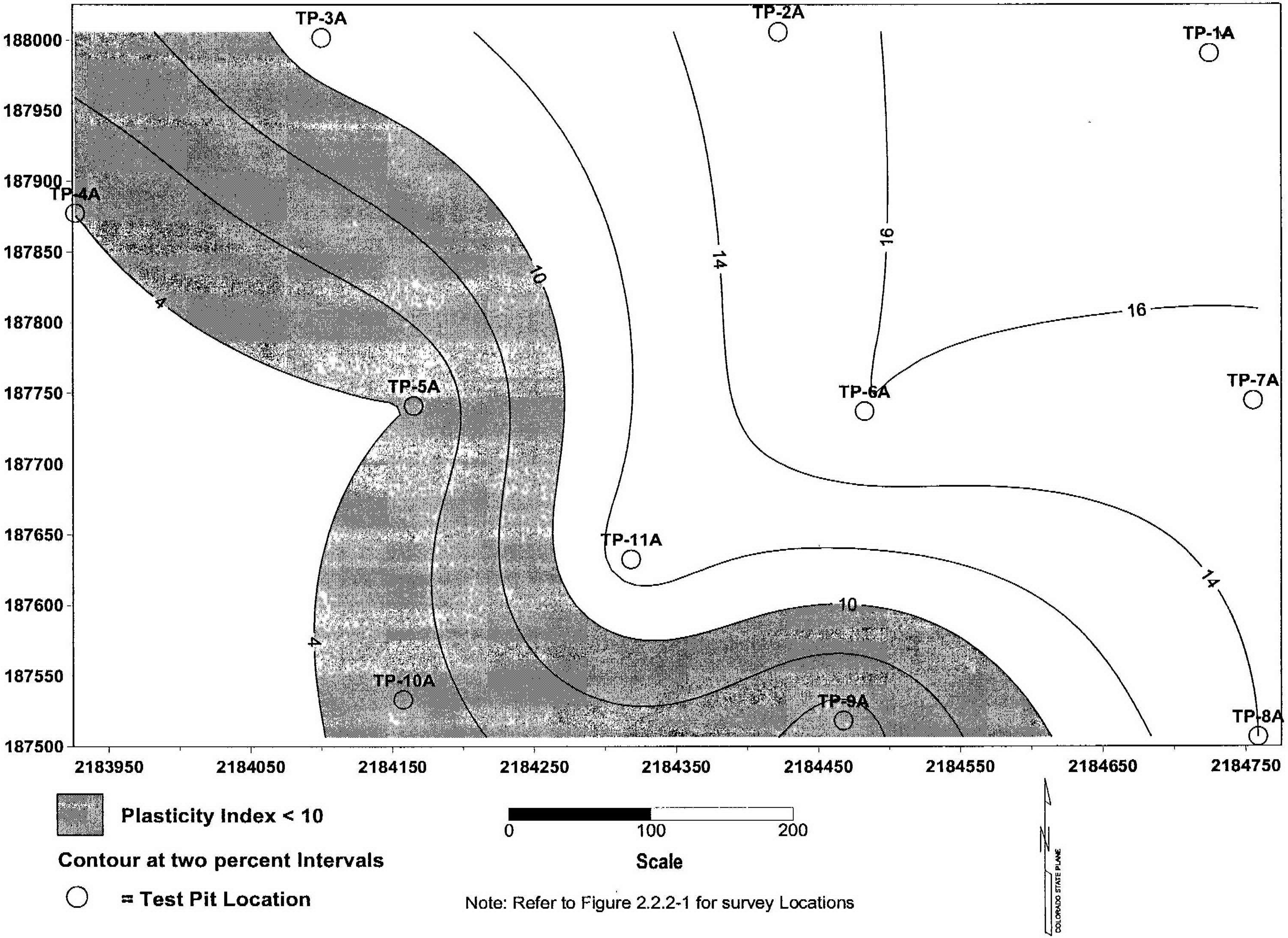
FOSTER WHEELER ENVIRONMENTAL CORPORATION

ELF TEST PAD PROGRAM

Borrow Area 5 Percent 200 Distribution Layer D

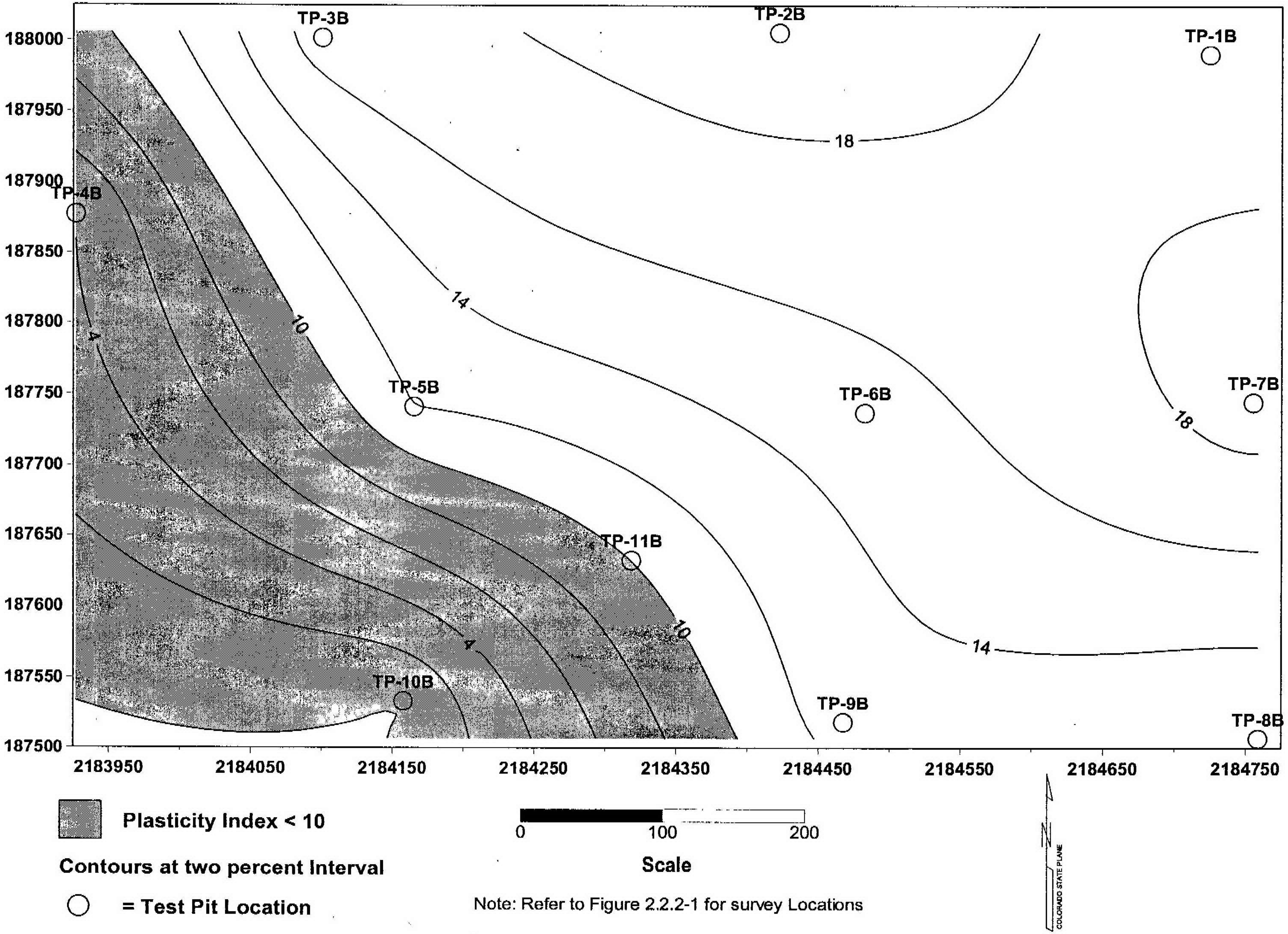
CHECKED	J Berretz	01.02.02	2.5.3D
DESIGNED	R Benmark	01.02.02	

Figure 2.6.1A - ELF Footprint Plasticity Index Distribution Layer A (1.0 to 3.5 ft. below surface)



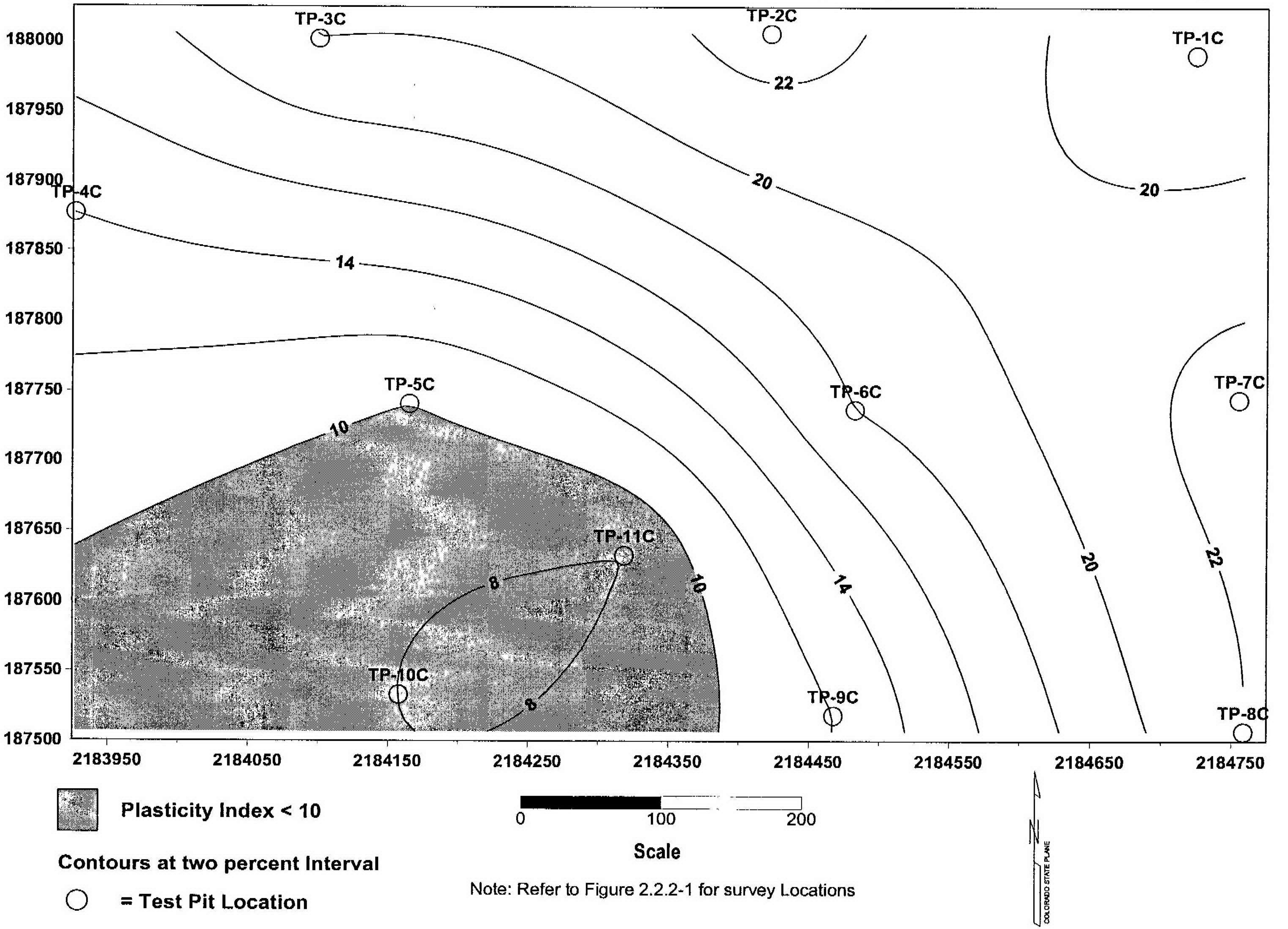
Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.1B - ELF Footprint Plasticity Index Distribution Layer B (3.5 to 6.0 ft. below surface)



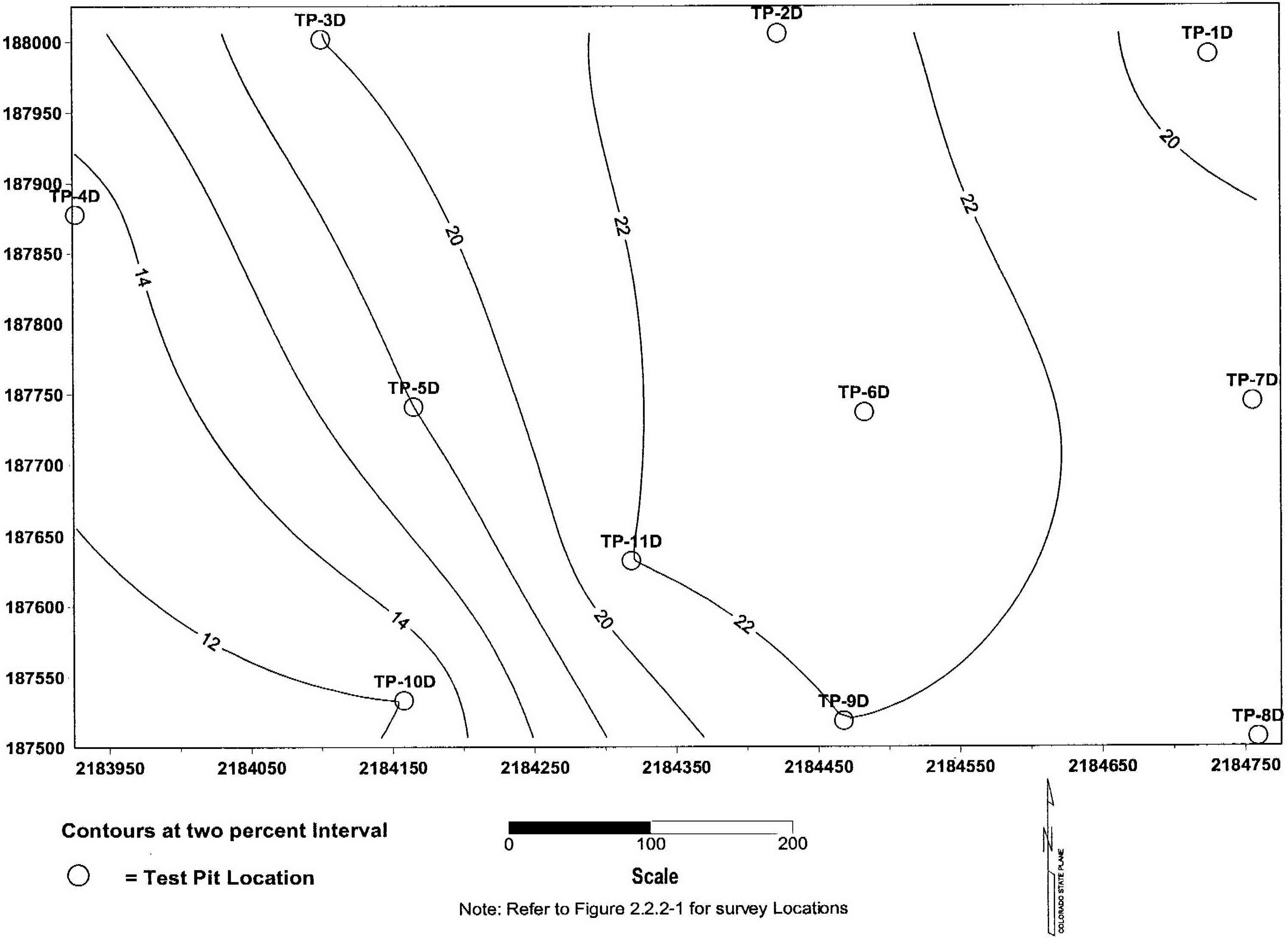
Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.1C - ELF Footprint Plasticity Index Distribution Layer C (6.0 to 8.5 ft. below surface)



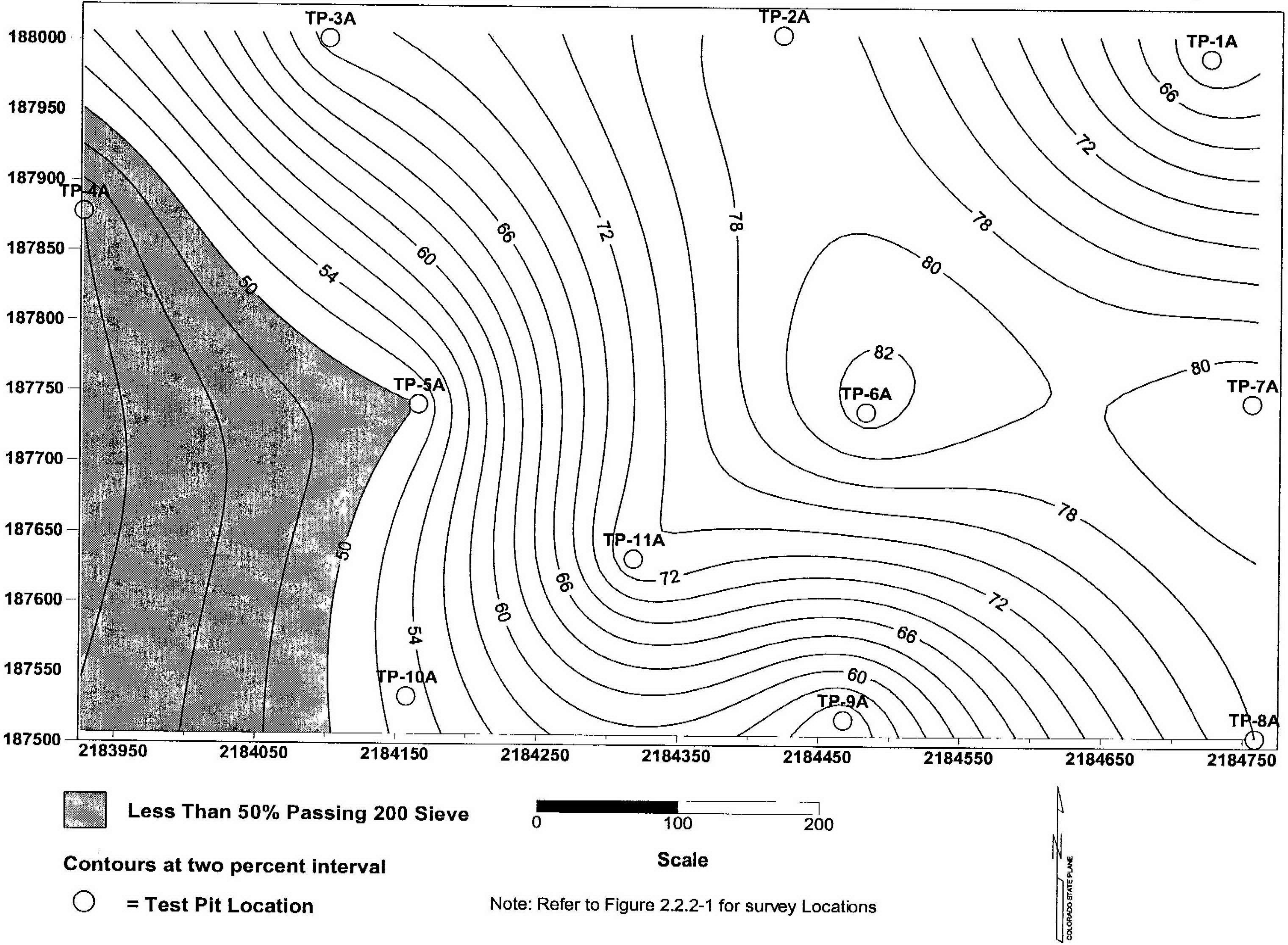
Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.1D - ELF Footprint Plasticity Index Distribution Layer D (8.5 to 11.0 ft. below surface)



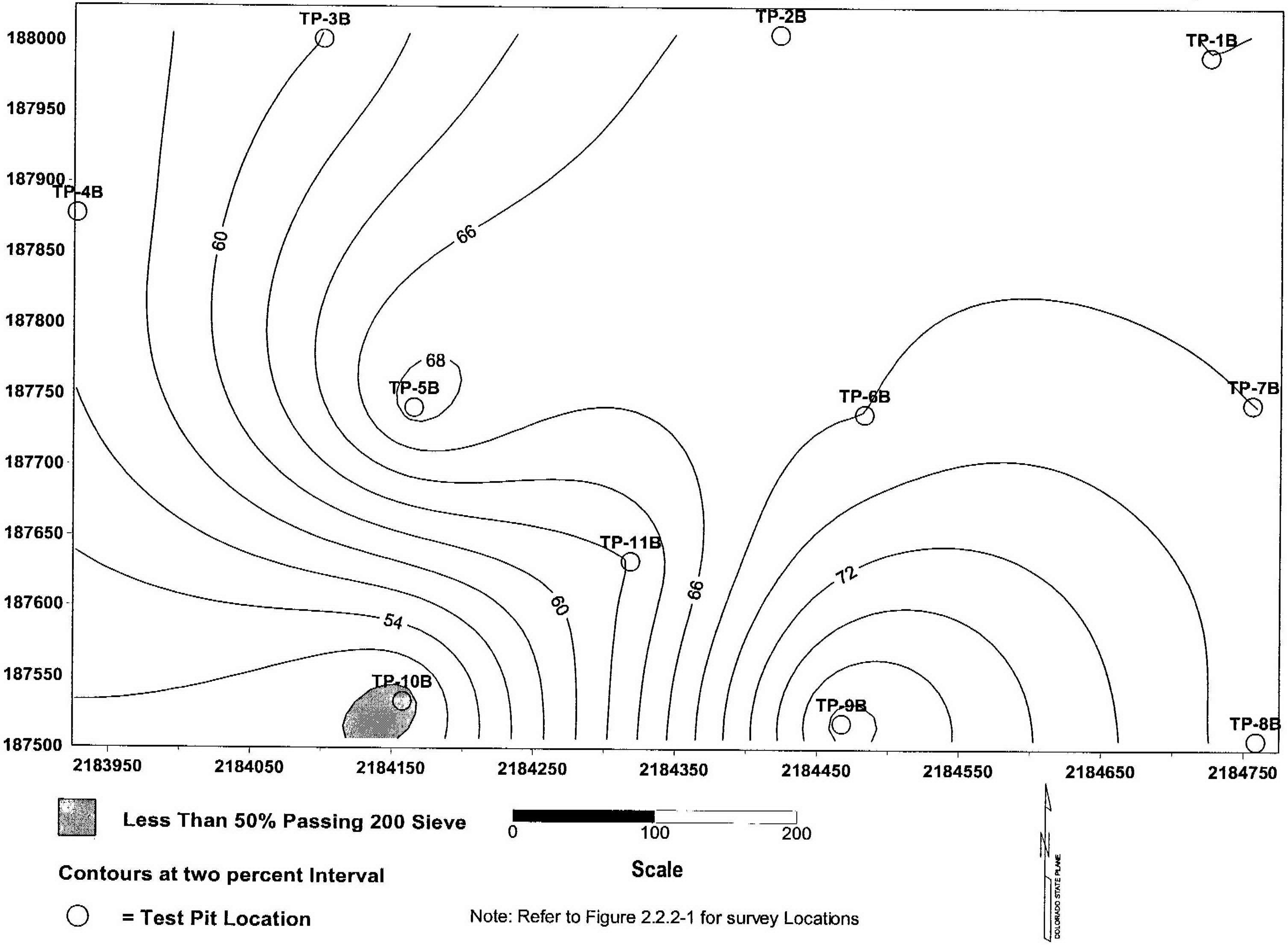
Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.2A - ELF Footprint Percent 200 Distribution Layer A (1.0 to 3.5 ft. below surface)



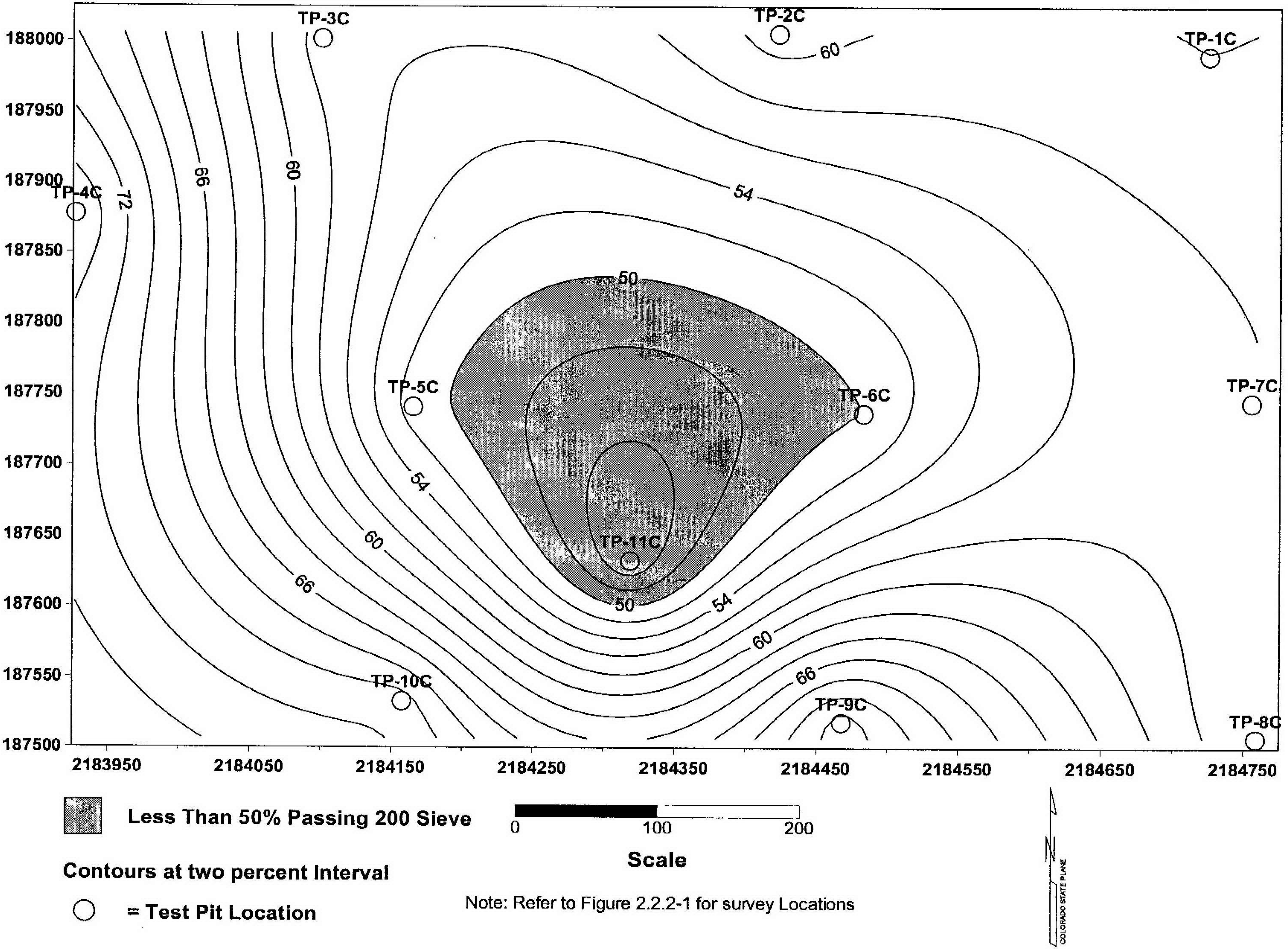
Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.2B - ELF Footprint Percent 200 Distribution Layer A (3.5 to 6.0 ft. below surface)



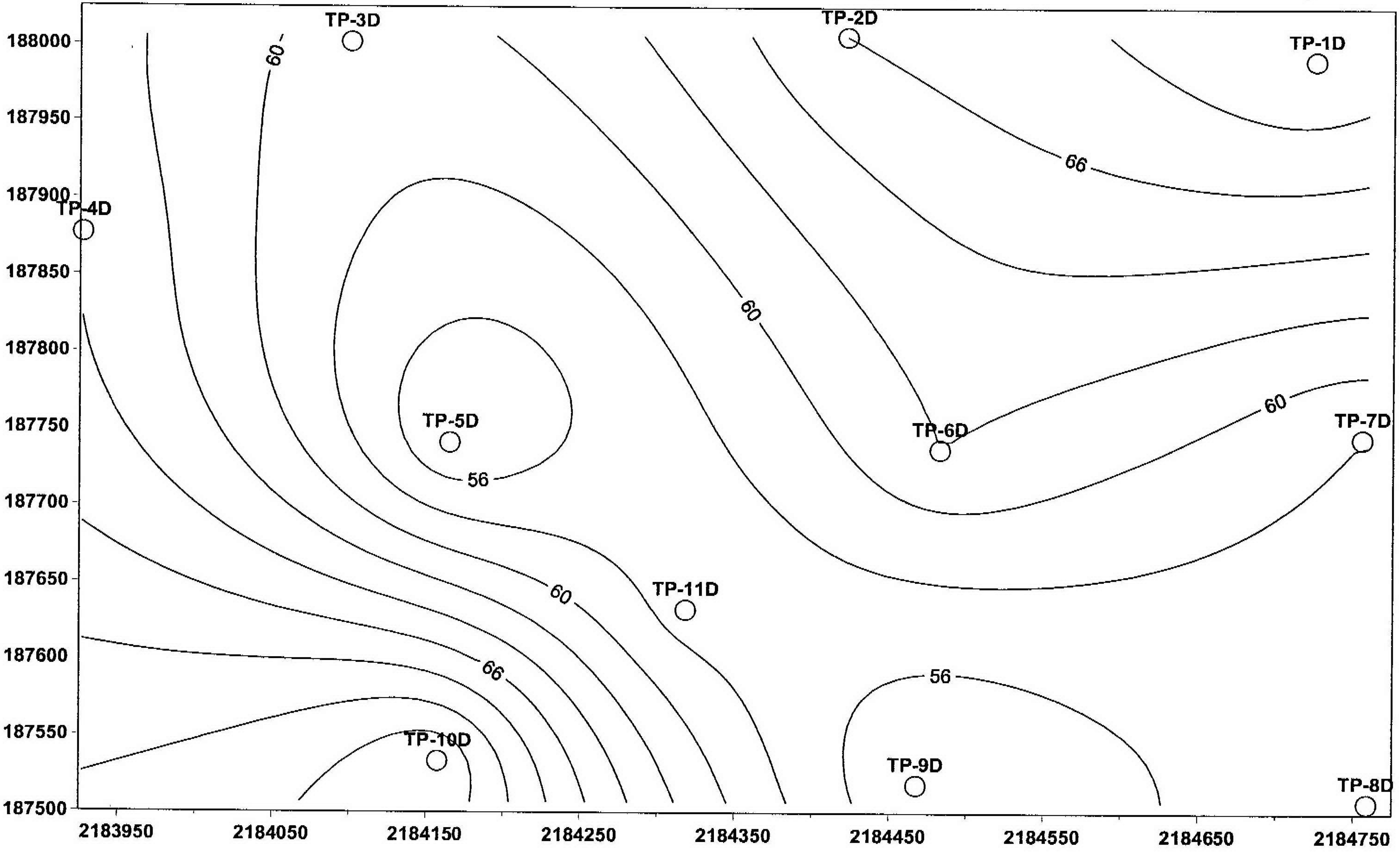
Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.2C - ELF Footprint Percent 200 Distribution Layer C (6.0 to 8.5 ft. below surface)



Note: Refer to Figure 2.2.2-1 for survey Locations

Figure 2.6.2D - ELF Footprint Percent 200 Distribution Layer D (8.5 to 11.0 ft. below surface)



Contours at two percent interval

○ = **Test Pit Location**

0 100 200

Scale

Note: Refer to Figure 2.2.2-1 for survey Locations

N COLORADO STATE PLANE

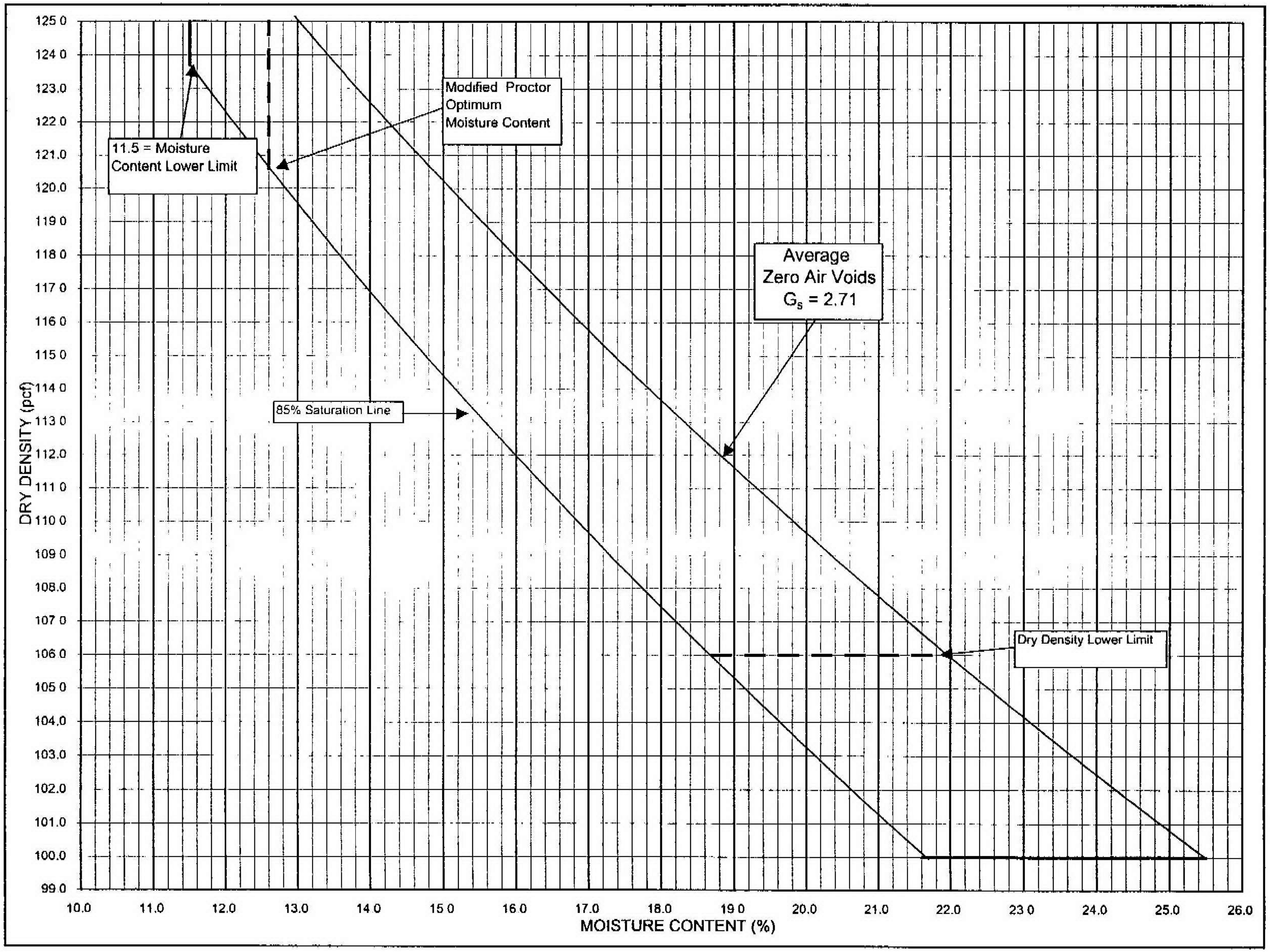
Figure 2.7-1
ELF TEST PADS ACCEPTABILITY ZONE EXAMPLE

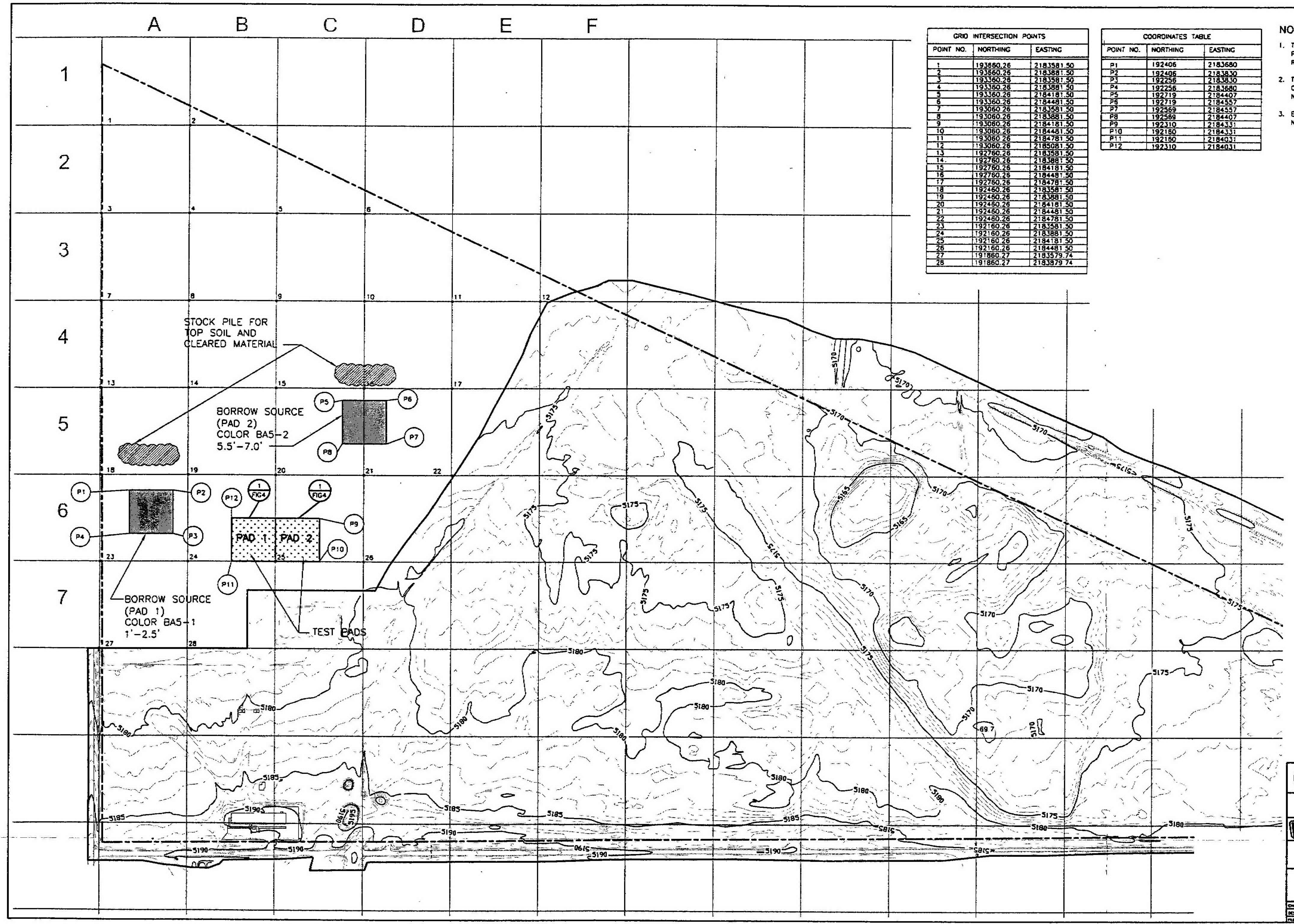
Test Pad: N/A

Lane Number: ANY

Lift Number: ANY

Compaction Equip: ANY



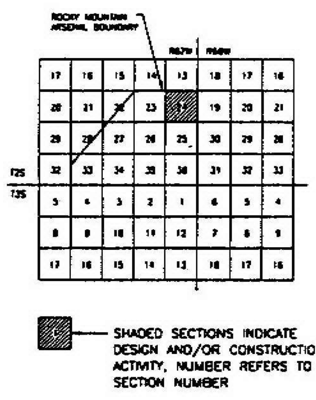


GRID INTERSECTION POINTS		
POINT NO.	NORTHING	EASTING
1	193660.26	2183581.50
2	193660.26	2183881.50
3	193360.26	2183581.50
4	193360.26	2183881.50
5	193360.26	2184181.50
6	193360.26	2184481.50
7	193060.26	2183581.50
8	193060.26	2183881.50
9	193060.26	2184181.50
10	193060.26	2184481.50
11	193060.26	2184781.50
12	193060.26	2185081.50
13	192760.26	2183581.50
14.	192760.26	2183881.50
15	192760.26	2184181.50
16	192760.26	2184481.50
17	192760.26	2184781.50
18	192460.26	2183581.50
19	192460.26	2183881.50
20	192460.26	2184181.50
21	192460.26	2184481.50
22	192460.26	2184781.50
23	192160.26	2183581.50
24	192160.26	2183881.50
25	192160.26	2184181.50
26	192160.26	2184481.50
27	191860.27	2183579.74
28	191860.27	2183879 74

COORDINATES TABLE		
POINT NO.	NORTHING	EASTING
P1	192406	2183680
P2	192406	2183830
P3	192256	2183830
P4	192256	2183680
P5	192719	2184407
P6	192719	2184557
P7	192569	2184557
P8	192569	2184407
P9	192310	2184331
P10	192160	2184331
P11	192160	2184031
P12	192310	2184031

NOTES:

1. THE DIGITAL BASE MAP UTILIZED HEREIN WAS PROVIDED BY MERRICK & COMPANY, AND IS REPRESENTATIVE OF CONDITIONS IN APRIL '97
2. THE COORDINATE SYSTEM SHOWN IS THE COLORADO STATE PLANE, NORTH ZONE, NAD27 HORIZONTAL DATUM.
3. ELEVATIONS SHOWN ARE BASED ON THE NGVD29 VERTICAL DATUM.



▨ SHADED SECTIONS INDICATE DESIGN AND/OR CONSTRUCTION ACTIVITY, NUMBER REFERS TO SECTION NUMBER

KEY PLAN

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

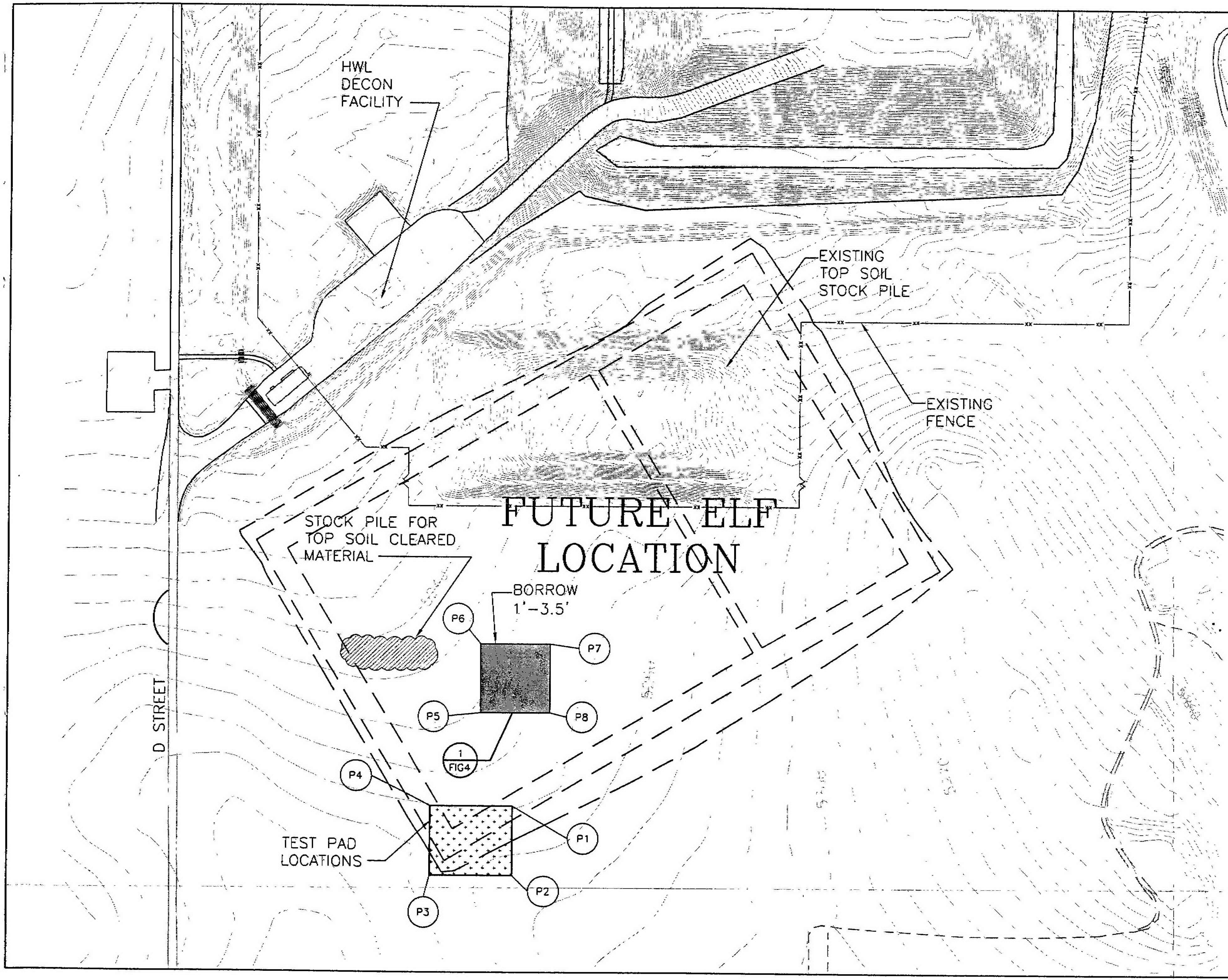
PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
BORROW AREA 5
BORROW MATERIAL AND
TEST PAD LOCATION

CHECKED:	J. BORRETZ	04.06.01	FIGURE NUMBER
DESIGNED	S. LABIB	04.06.01	3.0-1
FILE NAME:	FIG-3-0-1	[illegible]	

G:\PROJECTS\0297-0207\FIG-3-0-1.DWG

THIS DRAWING WAS CREATED USING AUTOCAD, DO NOT REVISE MANUALLY



COORDINATES TABLE		
POINT NO.	NORTHING	EASTING
P1	187355	2184302
P2	187205	2184302
P3	187205	2184122
P4	187355	2184122
P5	187557	2184231
P6	187707	2184231
P7	187707	2184381
P8	187557	2184381

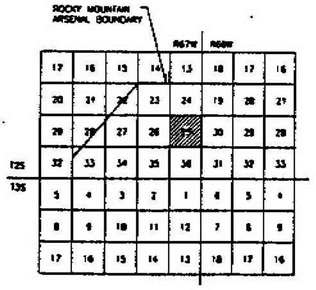
NOTES:

1. THE DIGITAL BASE MAP UTILIZED HEREIN WAS PROVIDED BY MERRICK & COMPANY, AND IS REPRESENTATIVE OF CONDITIONS IN APRIL '97
2. THE COORDINATE SYSTEM SHOWN IS THE COLORADO STATE PLANE, NORTH ZONE, NAD27 HORIZONTAL DATUM.
3. ELEVATIONS SHOWN ARE BASED ON THE NGVD29 VERTICAL DATUM.

COLORADO STATE PLANE

0 100 200

Scale 1" = 100'



▨ SHADED SECTIONS INDICATE DESIGN AND/OR CONSTRUCTION ACTIVITY, NUMBER REFERS TO SECTION NUMBER

KEY PLAN

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
BORROW MATERIAL
TEST PAD LOCATIONS
IN ELF AREA

CHECKED:	J. BORNETZ	04.08.01	FIGURE NUMBER
DESIGNED:	S. LAING	04.08.01	3.0–2
FILE NAME:	FIG-3-0-2	XX.XX.XX	

G:\PROJECTS\0297-0207\FIG-3-0-2.DWG

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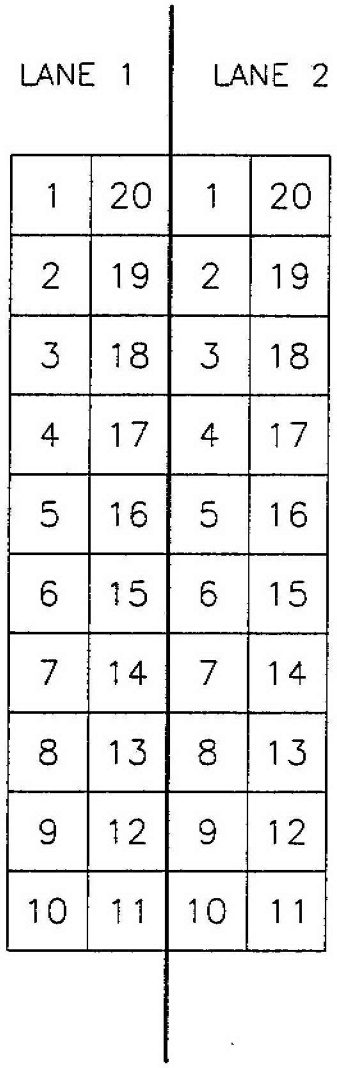


LANE 1		LANE 2	
1	20	1	20
2	19	2	19
3	18	3	18
4	17	4	17
5	16	5	16
6	15	6	15
7	14	7	14
8	13	8	13
9	12	9	12
10	11	10	11

GRID SYSTEM

N.T.S.

OVERLAY 150'x64'
TEST PAD WITH
A 15'x15' GRID SECTION
LABEL EACH GRID AS SHOWN

PROGRAM MANAGER
ROCKY MOUNTAIN ARSENAL

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
GRID SYSTEM

CHECKED: J. BERRETZ	04.10.01	FIGURE NUMBER
DESIGNED: S. LABB	04.10.01	Figure 4.0-1
FILE NAME: FIO-7	XX.XX.XX	

THIS DRAWING WAS CREATED USING AUTOCAD. DO NOT REVISE MANUALLY

G:\PROJECTS\0297-0207\

Figure 4.1.2-1

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVIY TESTS-TEST PAD 1, LANE 1, LIFT 2

Test Pad: 1 **Lane Number:** 1

Hydration 2 days **Lift Number:** 2 **Compaction Equip:** 815-F Compactor

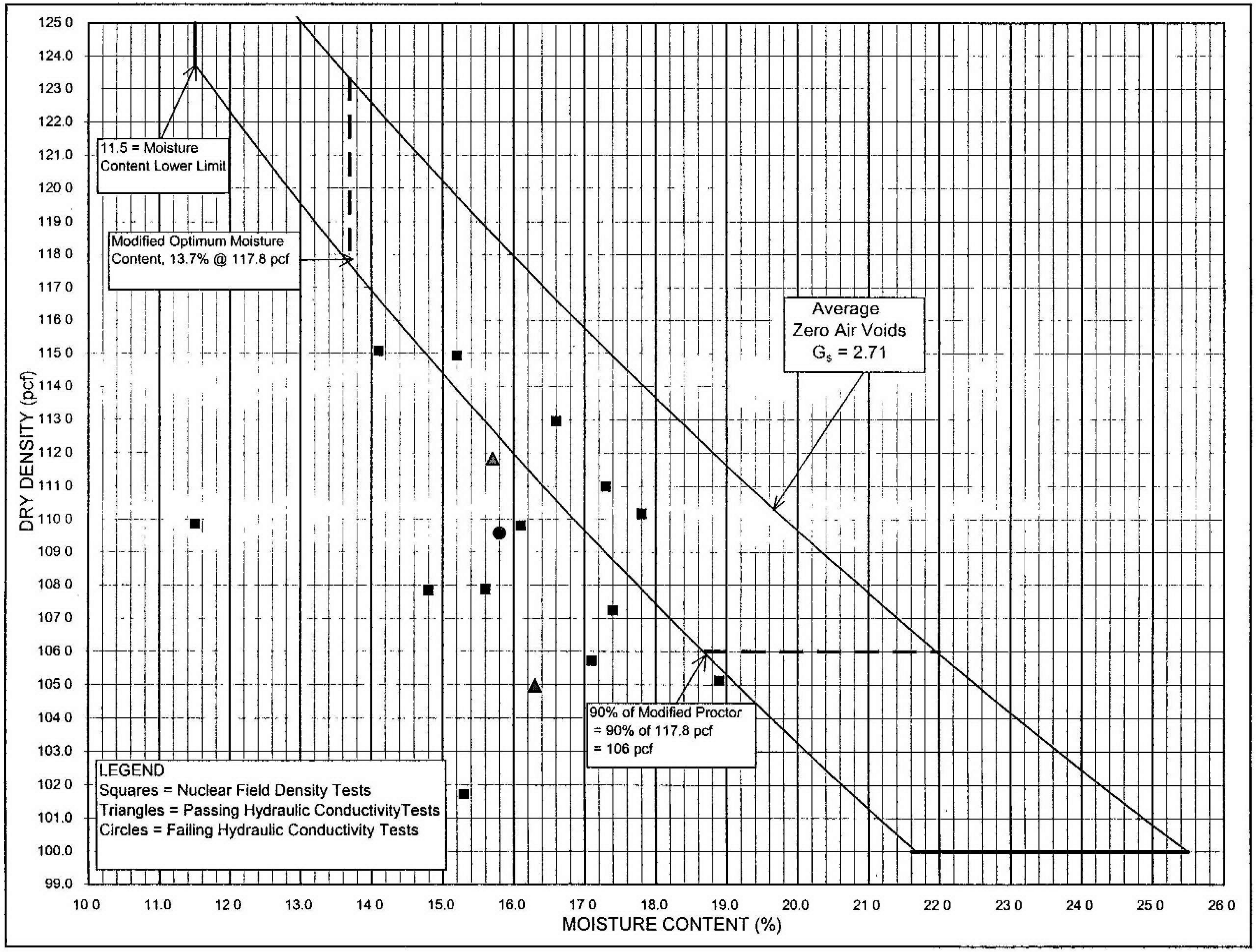


Figure 4.1.2-2

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 1, LIFT 3

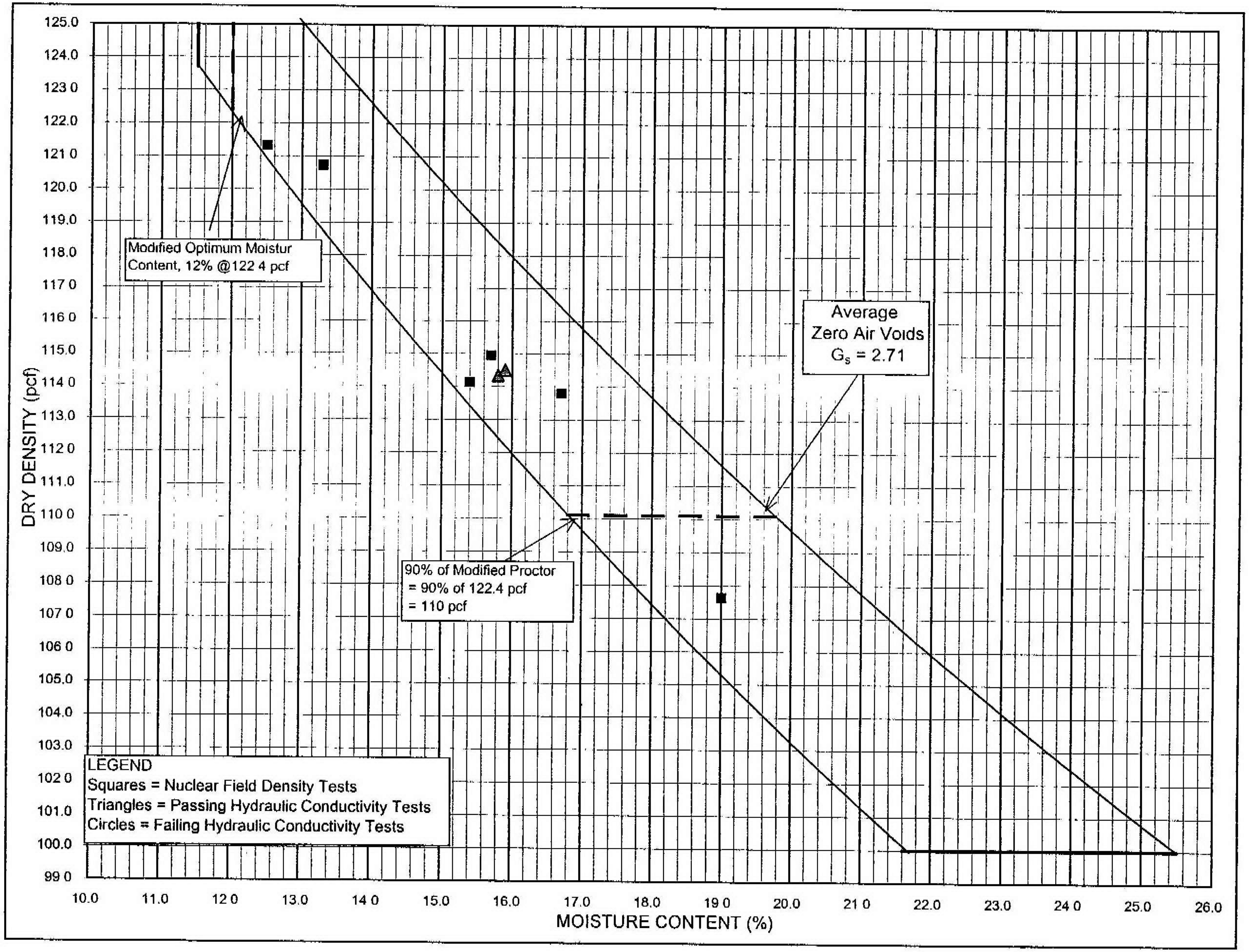
Test Pad: 1

Hydration 4 days

Lane Number: 1

Lift Number: 3

Compaction Equip: 815-F Compactor



Modified Optimum Moistur Content, 12% @122 4 pcf

Average Zero Air Voids G_s = 2.71

90% of Modified Proctor
= 90% of 122.4 pcf
= 110 pcf

Figure 4.1.2-3

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 1, LIFT 4

Test Pad: 1
Hydration 4 days
Lane Number: 1
Lift Number: 4
Compaction Equip: 815-F Compactor

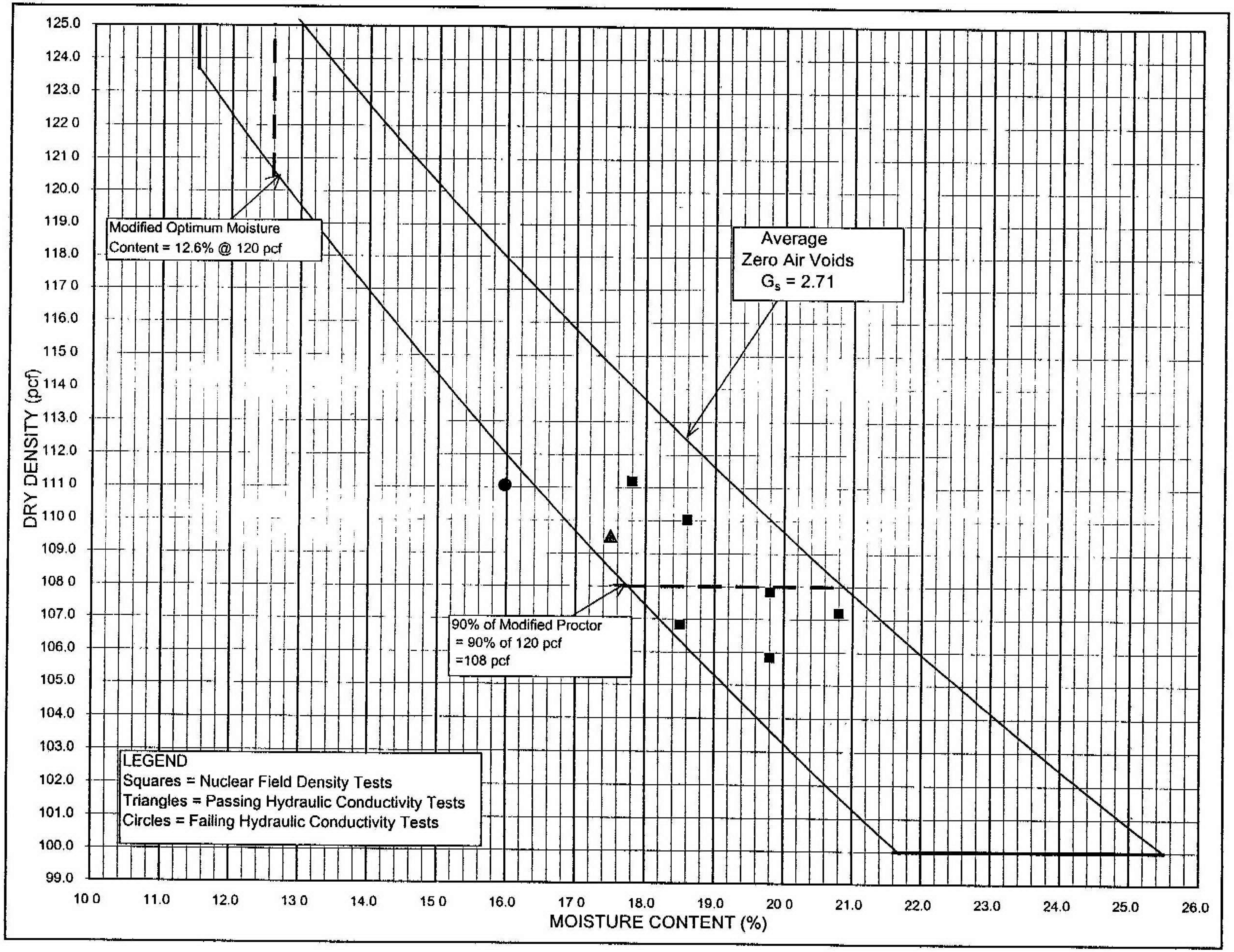


Figure 4.1.2-4

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 1, LIFT 5

Test Pad: 1
Hydration 4 days
Lane Number: 1
Lift Number: 5
Compaction Equip: 815-F Compactor

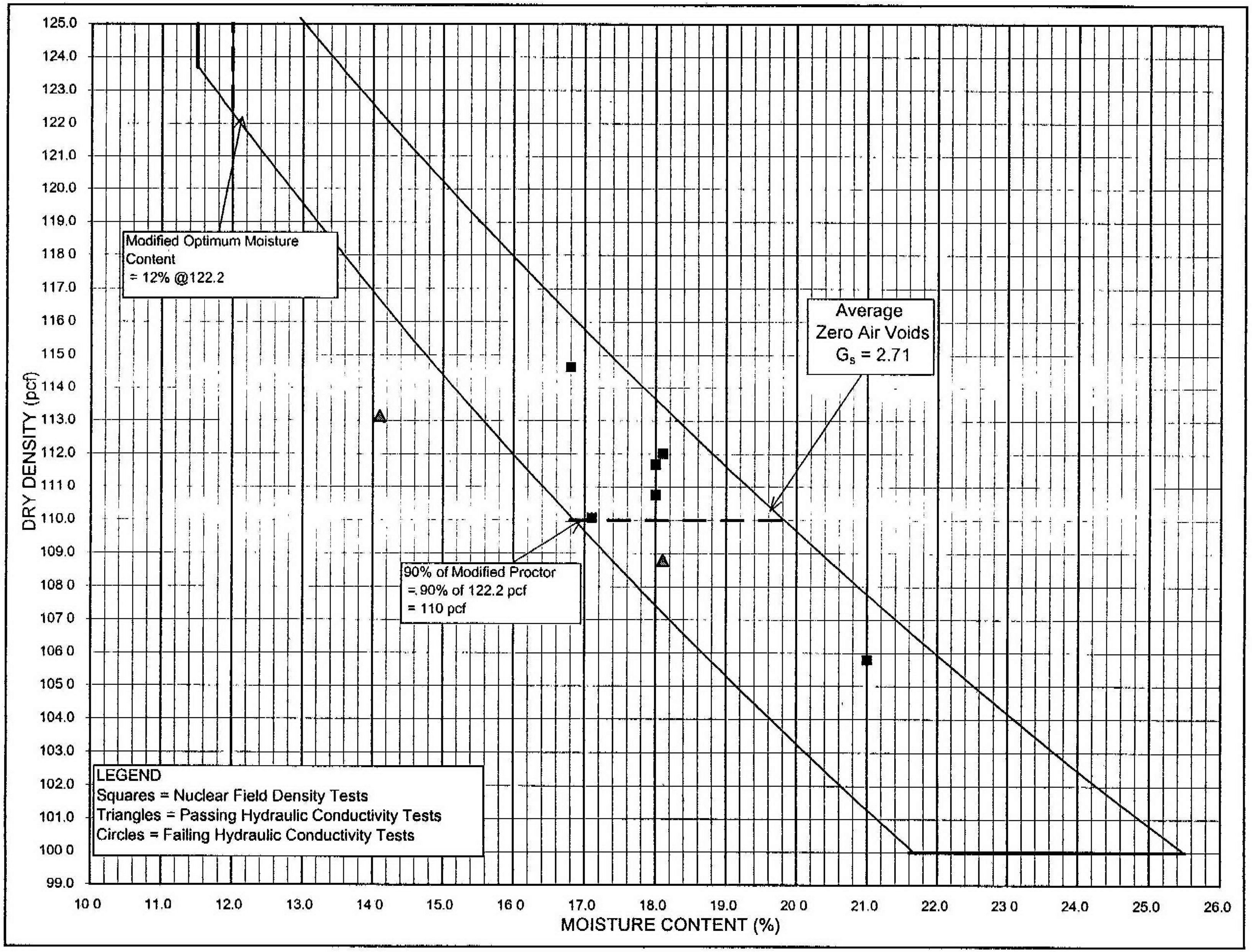


Figure 4.1.2-5A

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 2, LIFT 2

Test Pad: 1
Hydration 2 days
Lane Number: 2
Lift Number: 2
Compaction Equip: 825-G Compactor

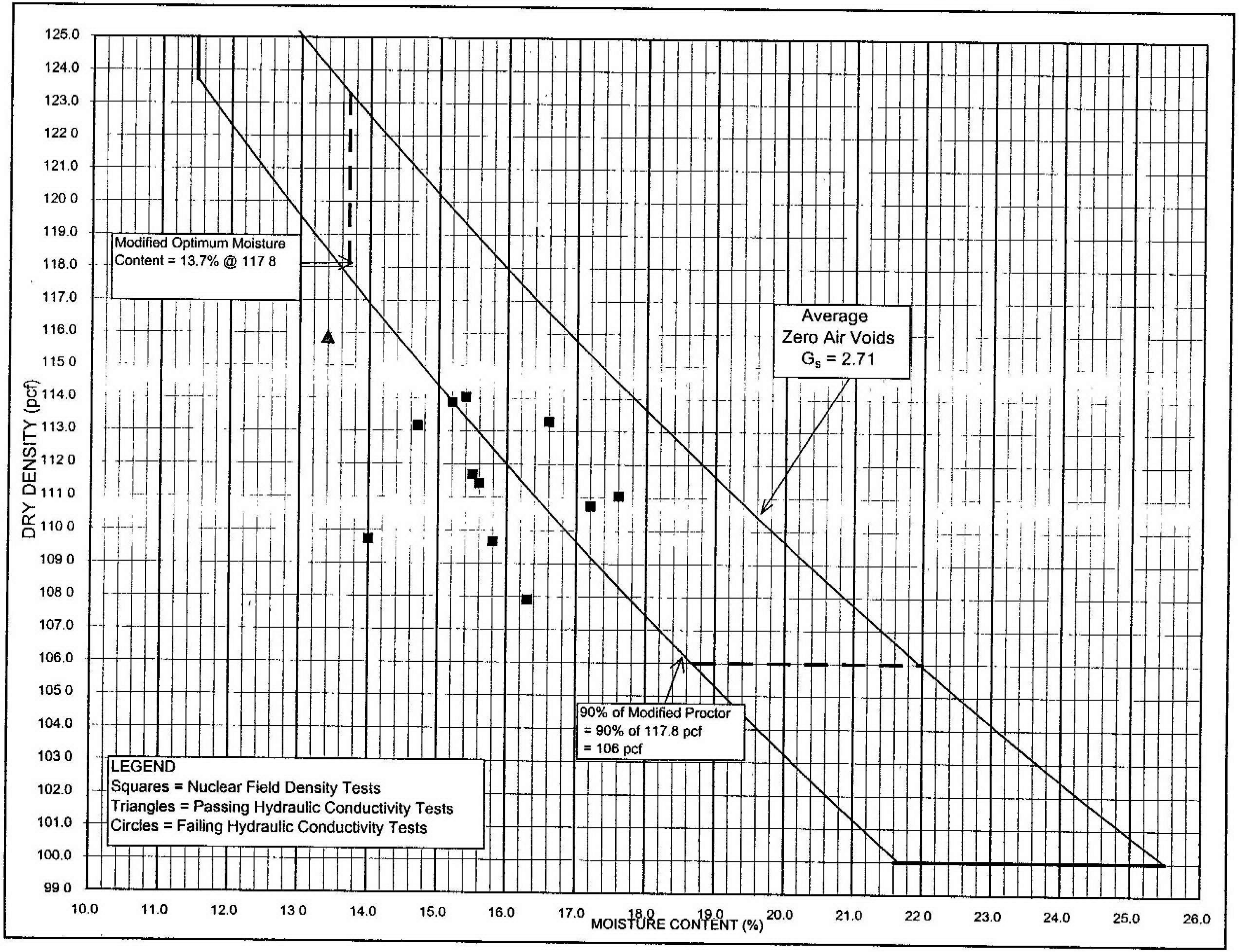


Figure 4.1.2-5B

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 2, LIFT 2

Test Pad: 1
Hydration 2 days
Lane Number: 2
Lift Number: 2
Compaction Equip: 825-G Compactor

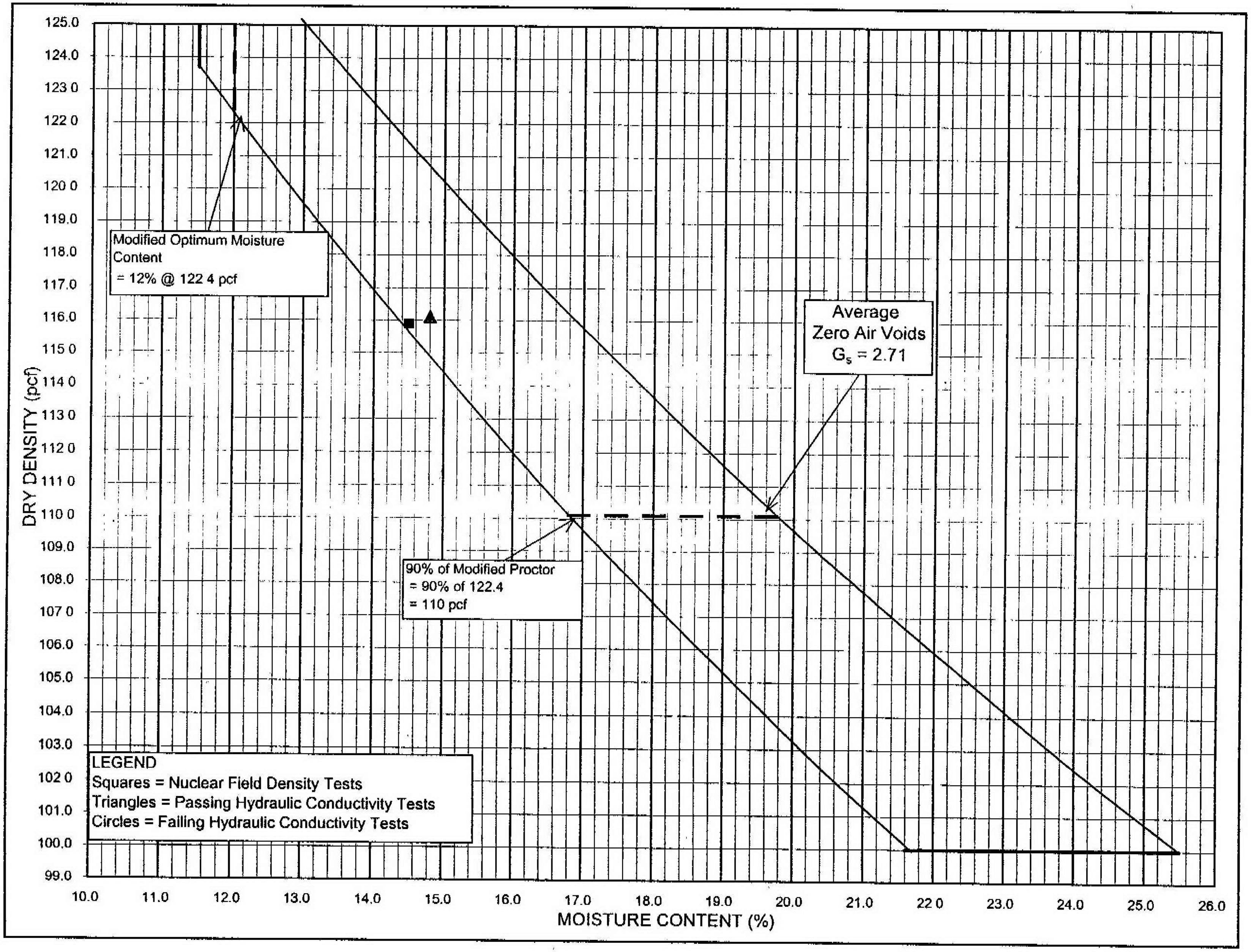


Figure 4.1.2-6

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 2, LIFT 3

Test Pad: 1
Hydration 4 days
Lane Number: 2
Lift Number: 3
Compaction Equip: 825-G Compactor

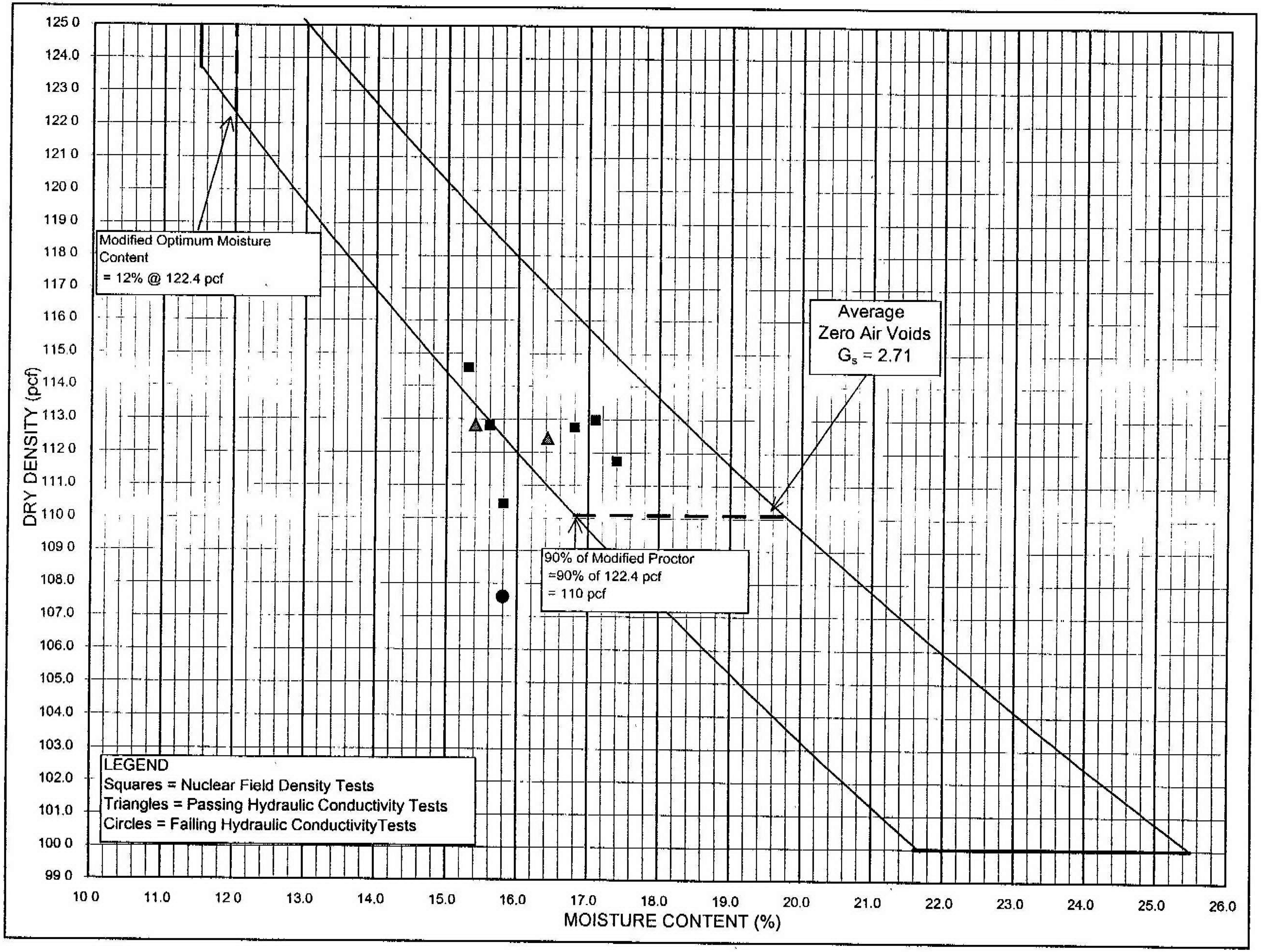


Figure 4.1.2-7

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 2, LIFT 4

Test Pad: 1
Hydration 4 days
Lane Number: 2
Lift Number: 4
Compaction Equip: 825-G Compactor

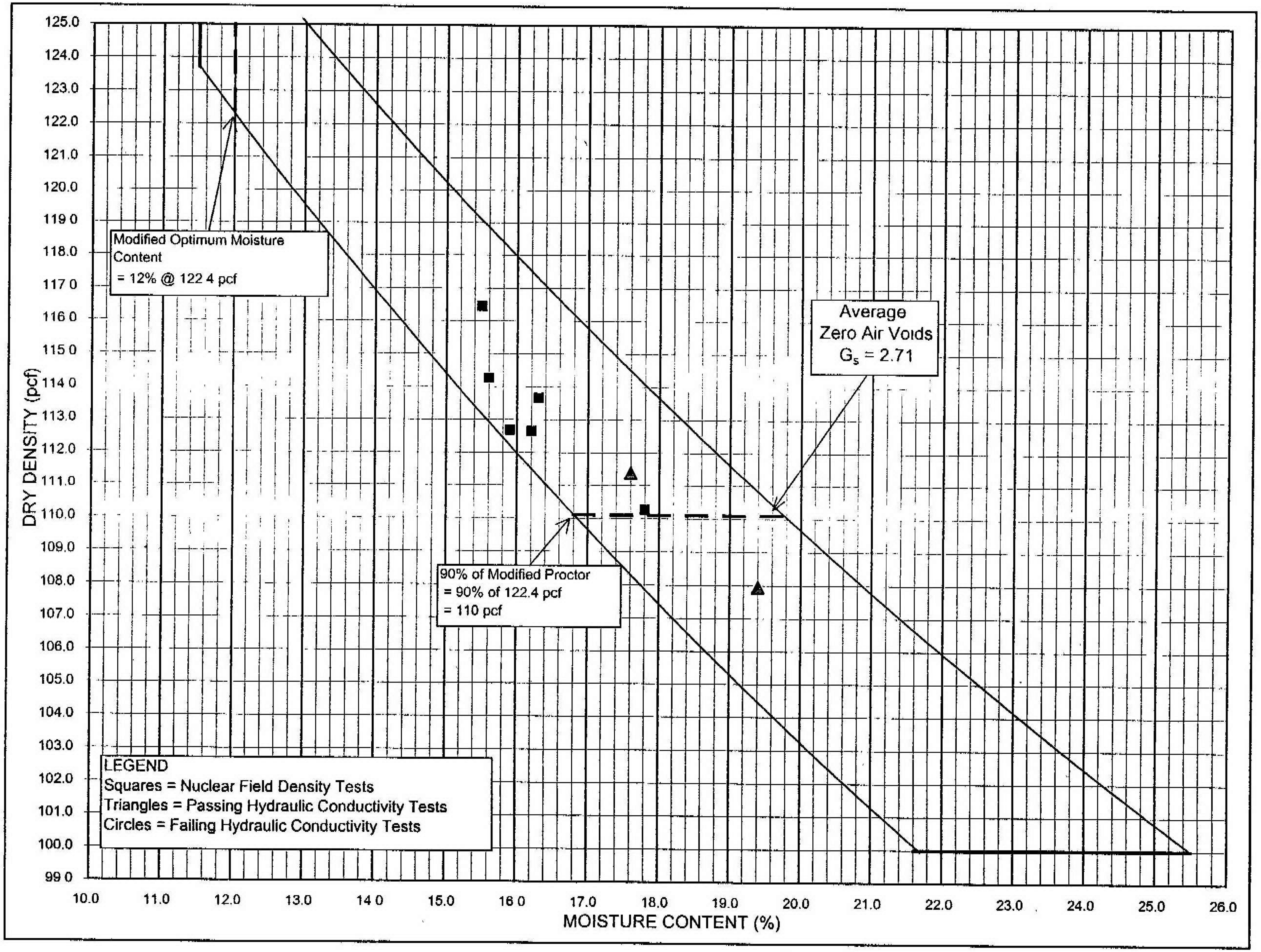


Figure 4.1.2-8

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 1, LANE 2, LIFT 5

Test Pad: 1

Hydration: 4 days

Lane Number: 2

Lift Number: 5

Compaction Equip: 825-G Compactor

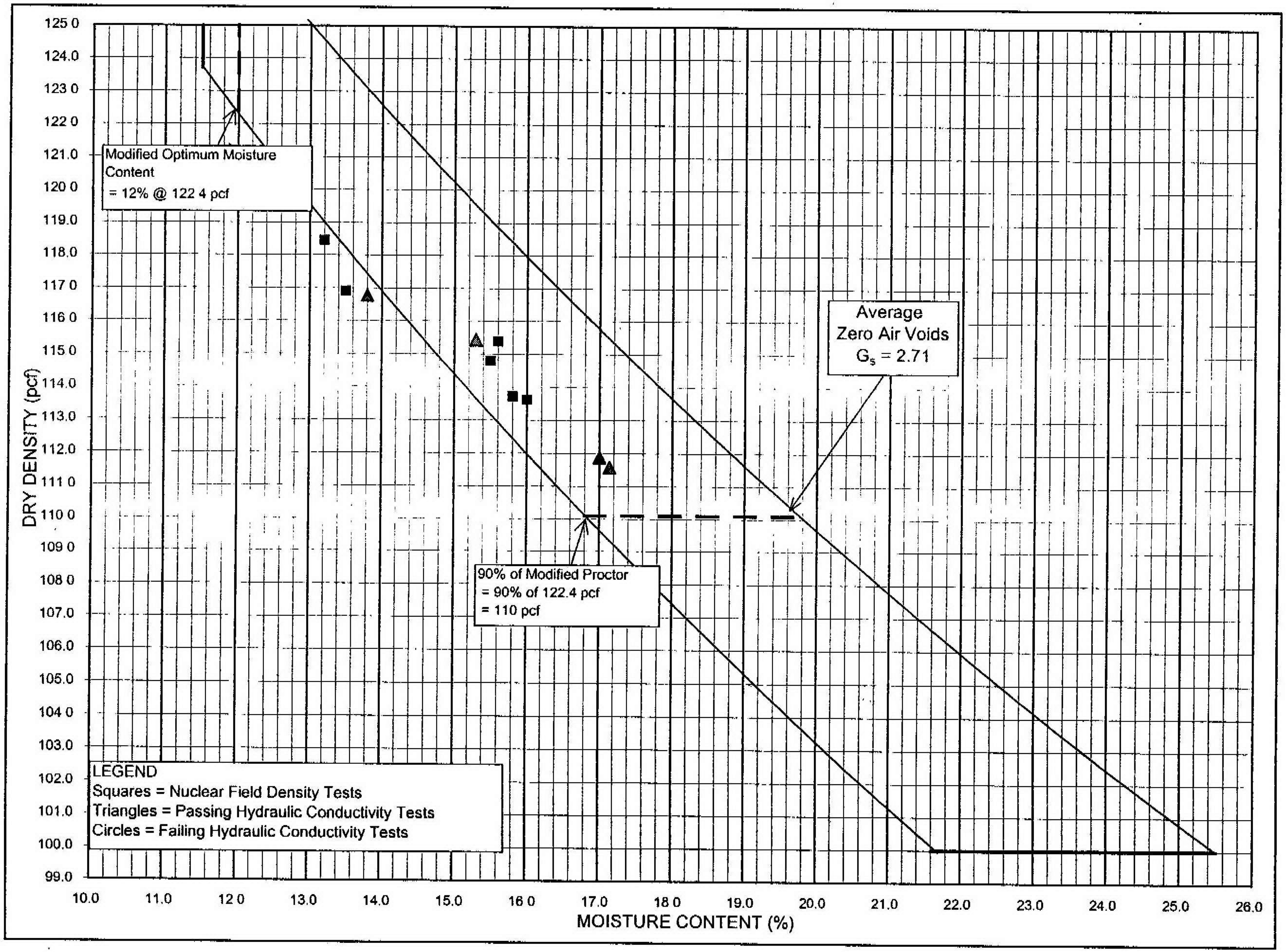


Figure 4.2.2-1

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 1, LIFT 2

Test Pad: 2
Hydration 4 days
Lane Number: 1
Lift Number: 2
Compaction Equip: 815-F Compactor

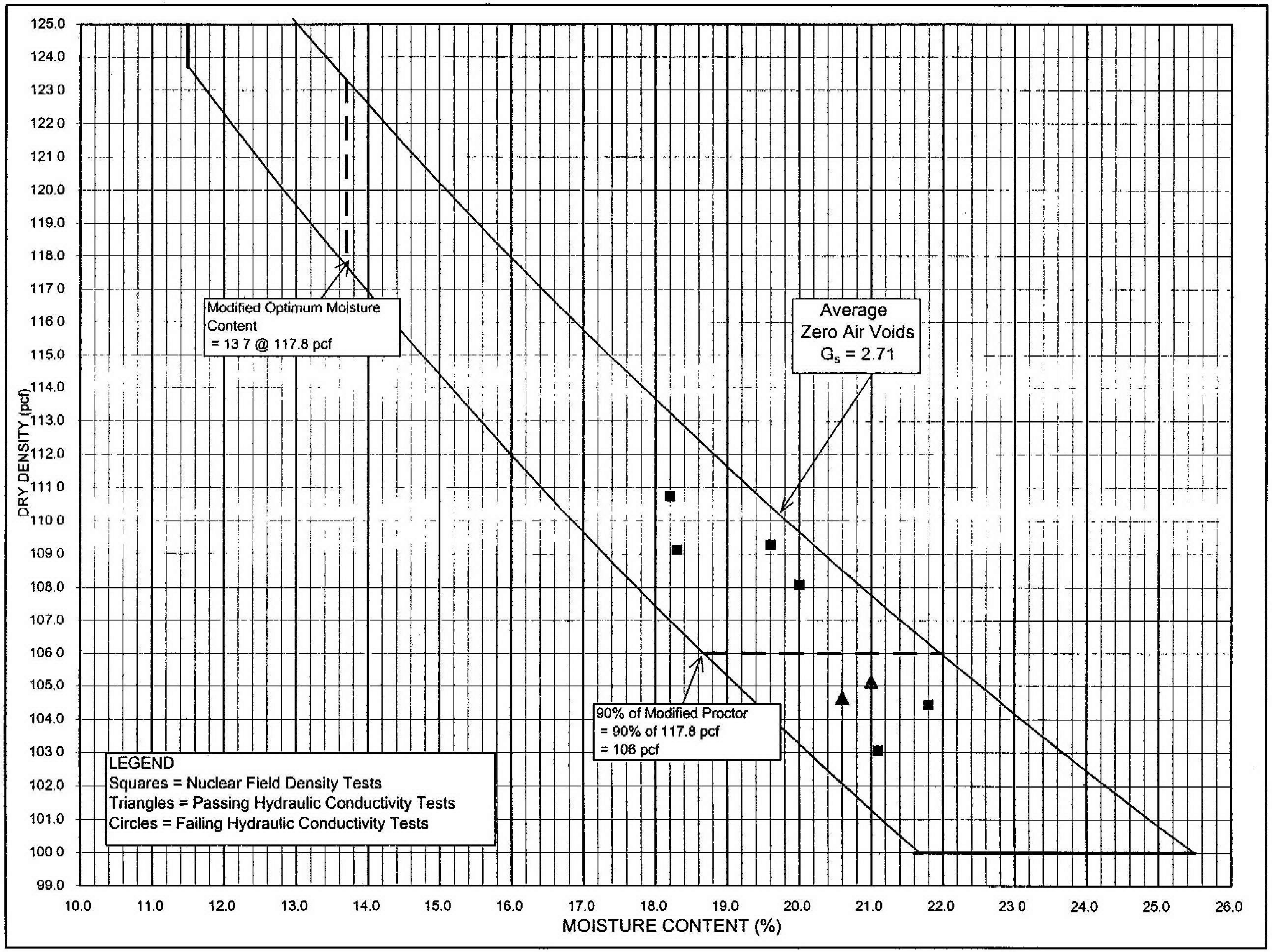


Figure 4.2.2-2A

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 1, LIFT 3

Test Pad: 2 **Lane Number:** 1

Hydration 4 days **Lift Number:** 3 **Compaction Equip:** 815-F Compactor

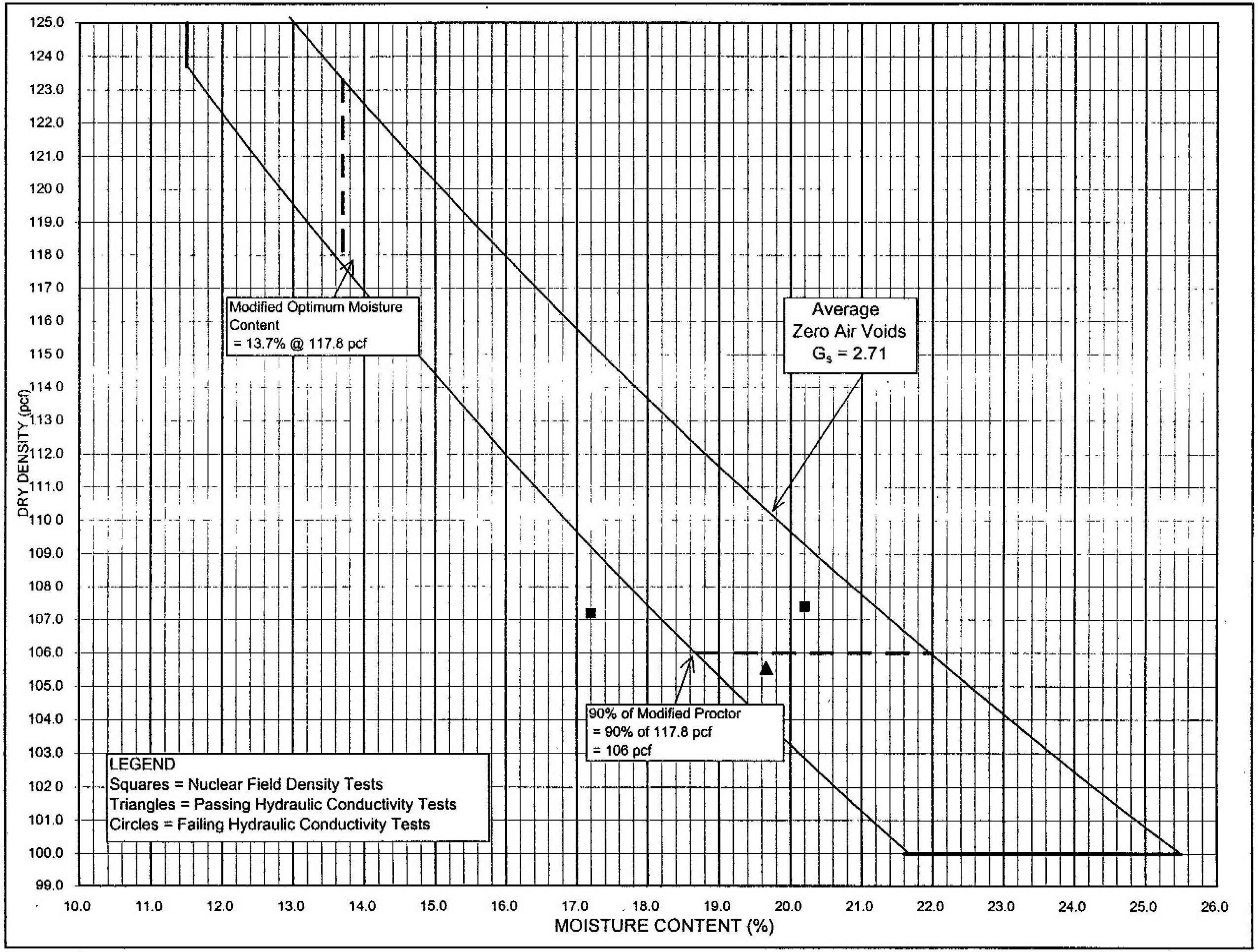


Figure 4.2.2-2B

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 1, LIFT 3

Test Pad: 2
Hydration 4 days
Lane Number: 1
Lift Number: 3
Compaction Equip: 815-F Compactor

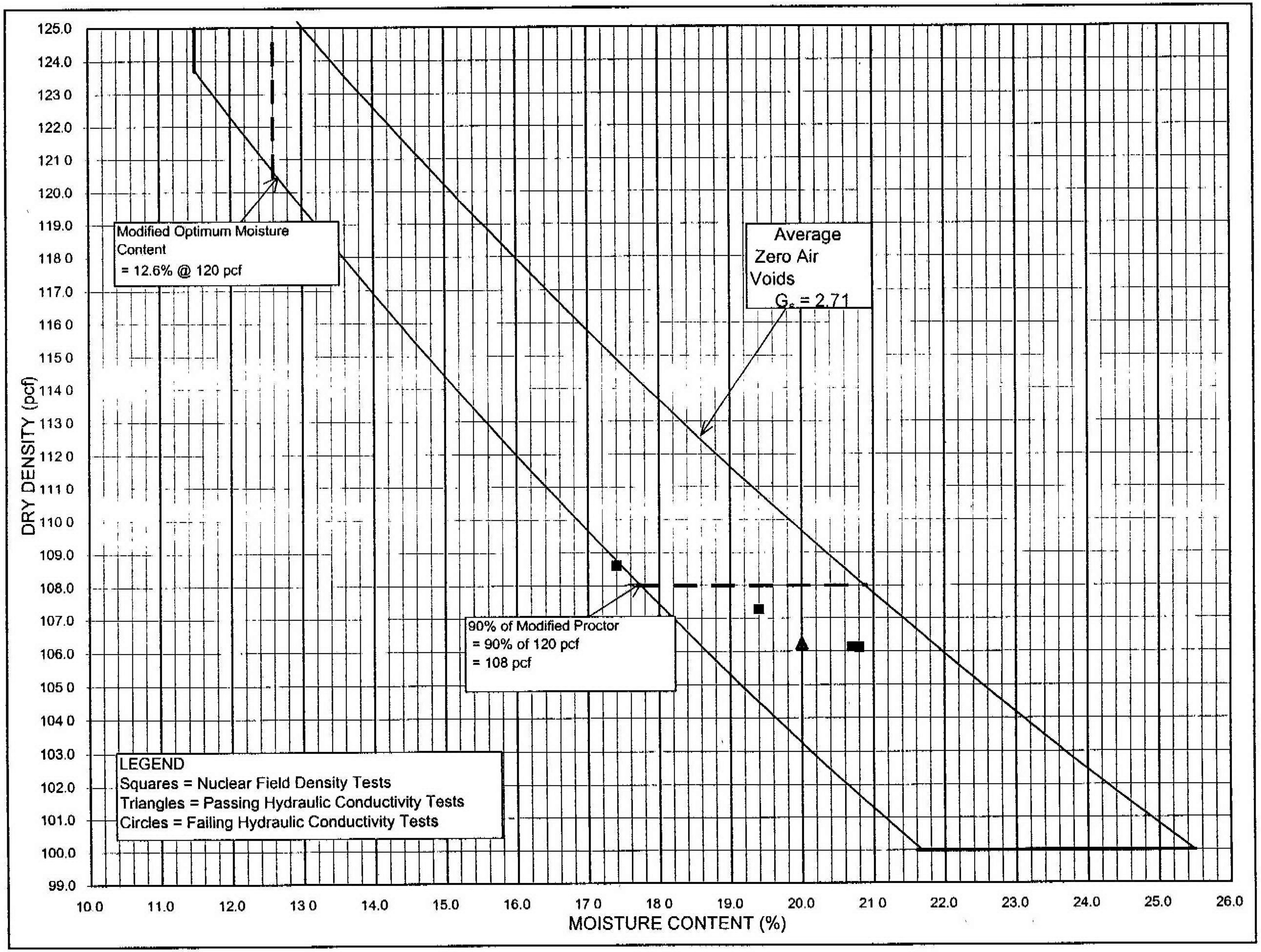


Figure 4.2.2-3

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 1, LIFT 4

Test Pad: 2
Hydration 4 days
Lane Number: 1
Lift Number: 4
Compaction Equip: 815-F Compactor

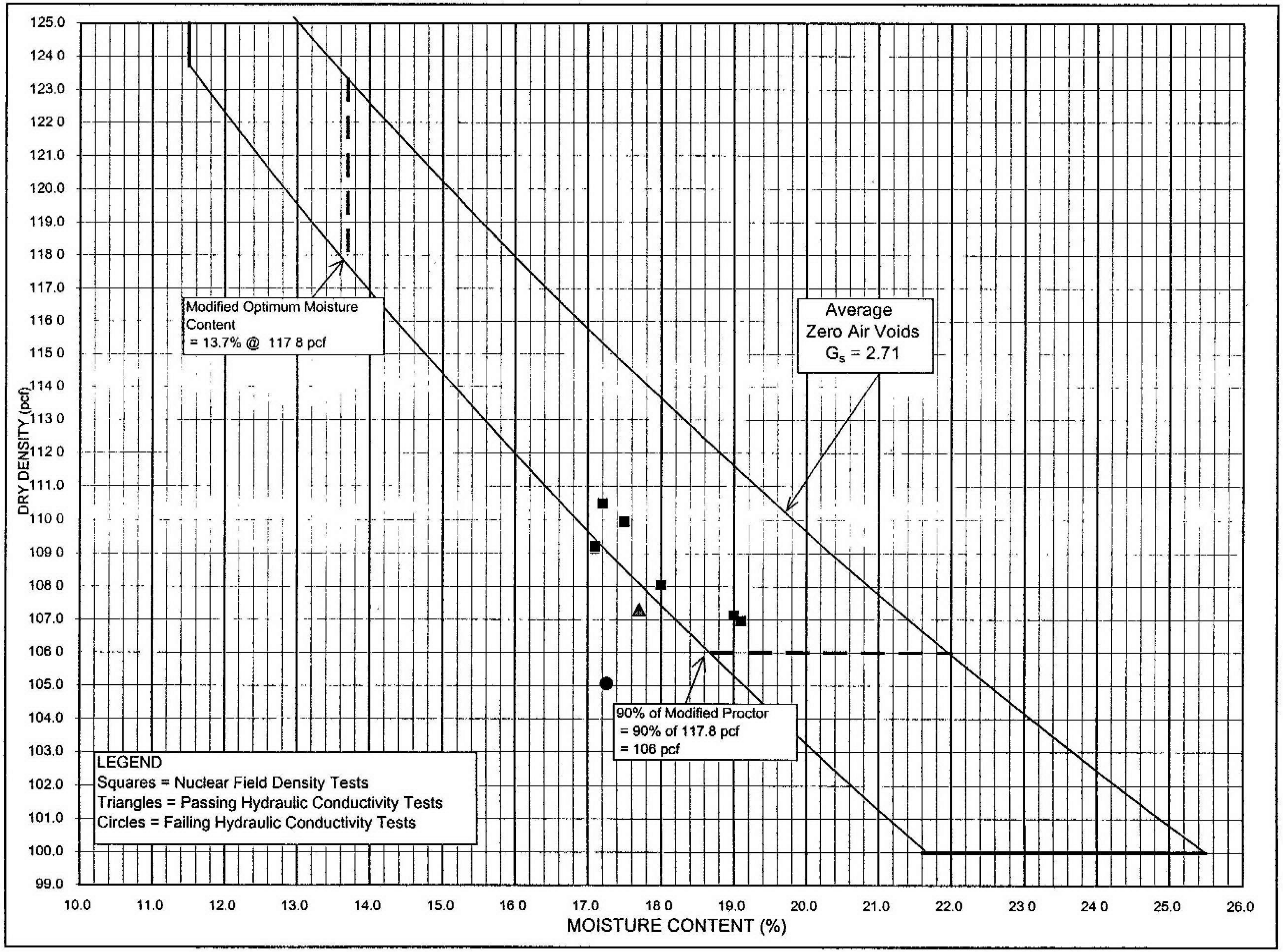


Figure 4.2.2-4

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 1, LIFT 5

Test Pad: 2

Hydration 4 days

Lane Number: 1

Lift Number: 5

Compaction Equip: 815-F Compactor

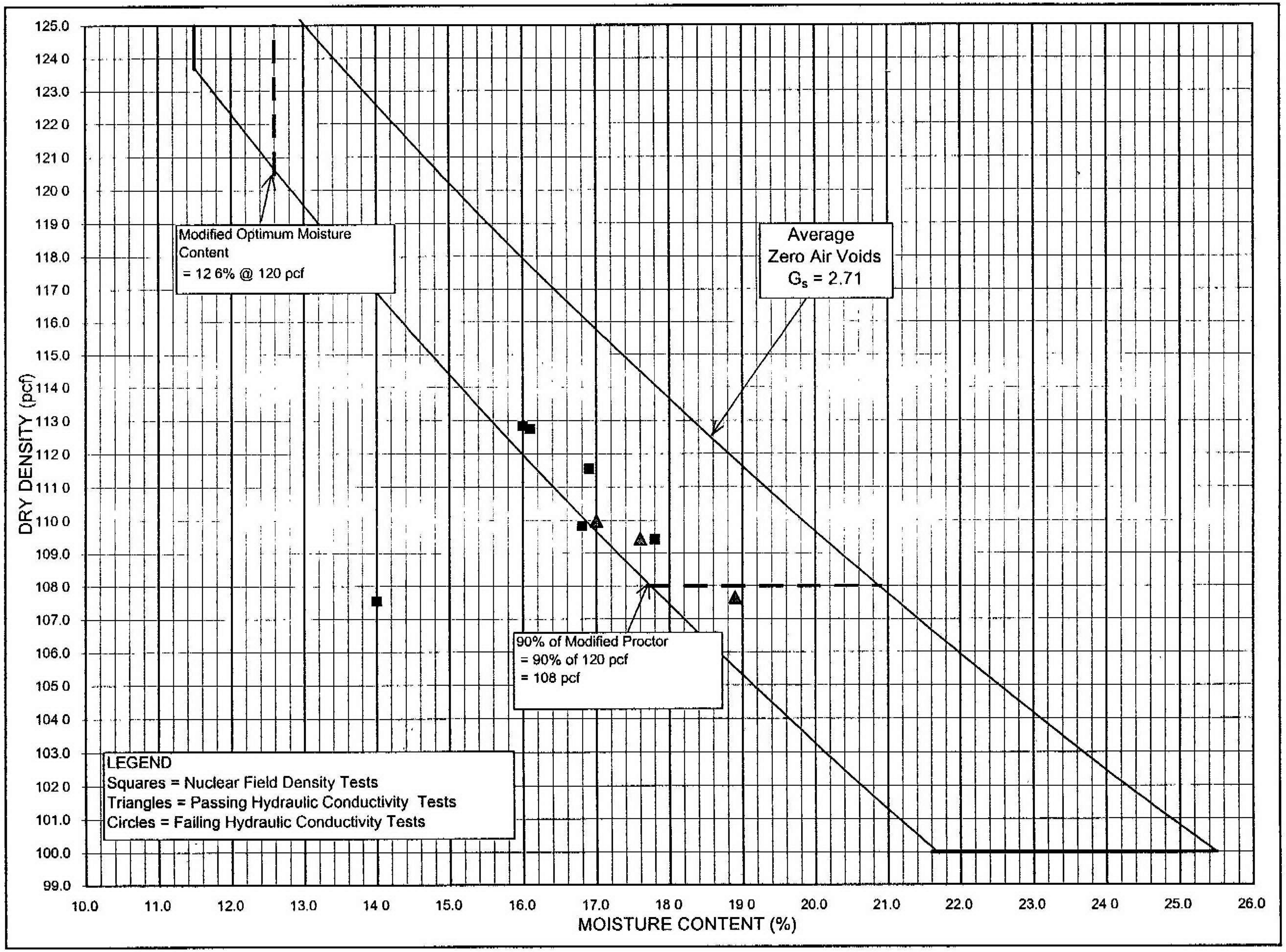


Figure 4.2.2-5

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 1, LIFT 6

Test Pad:	2	**Lane Number:**	1		
Hydration	2 days	**Lift Number:**	6	**Compaction Equip:**	815-F Compactor

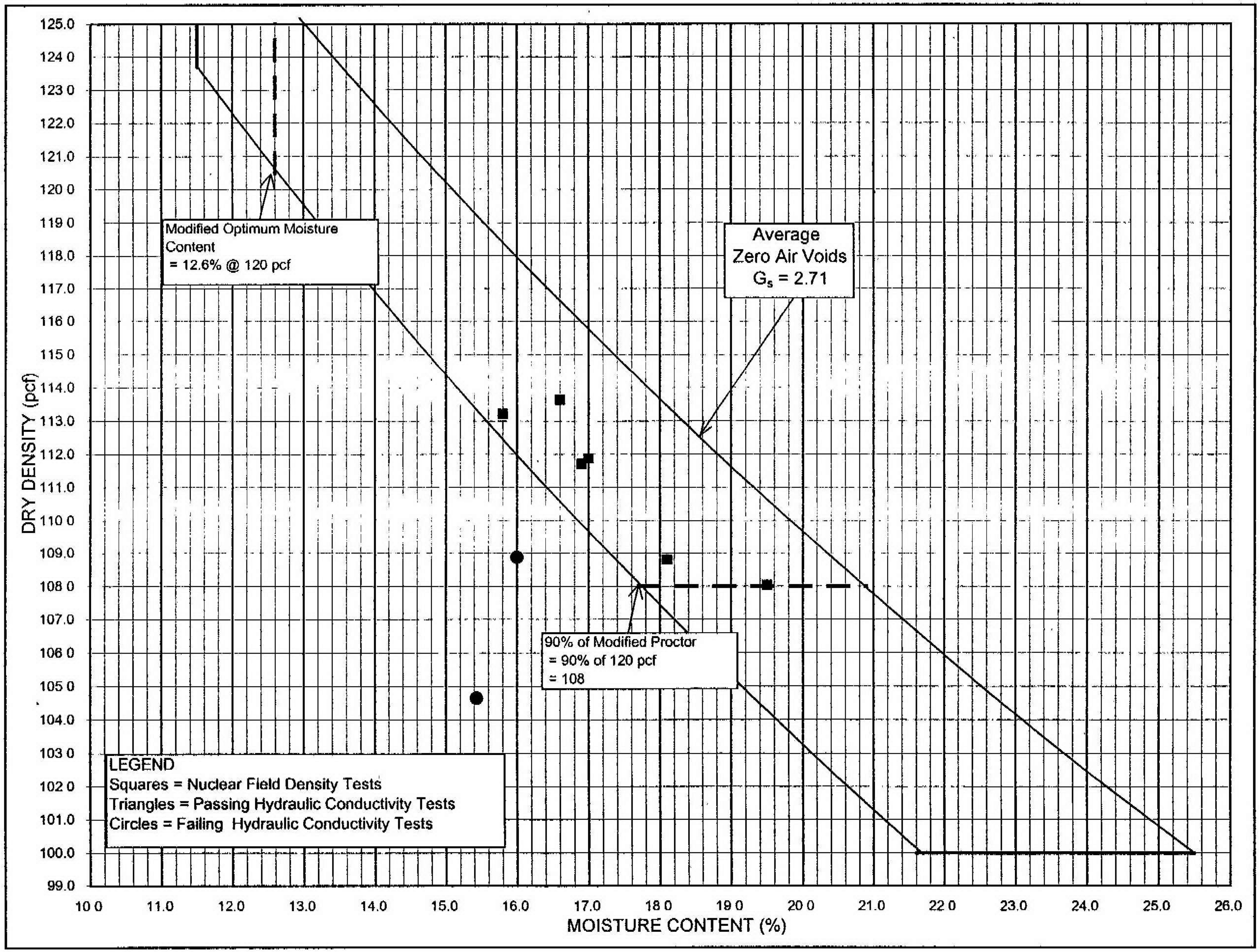


Figure 4.2.2-6

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 2

Test Pad: 2
Lane Number: 2
Hydration 4 days
Lift Number: 2
Compaction Equip: 825-G Compactor

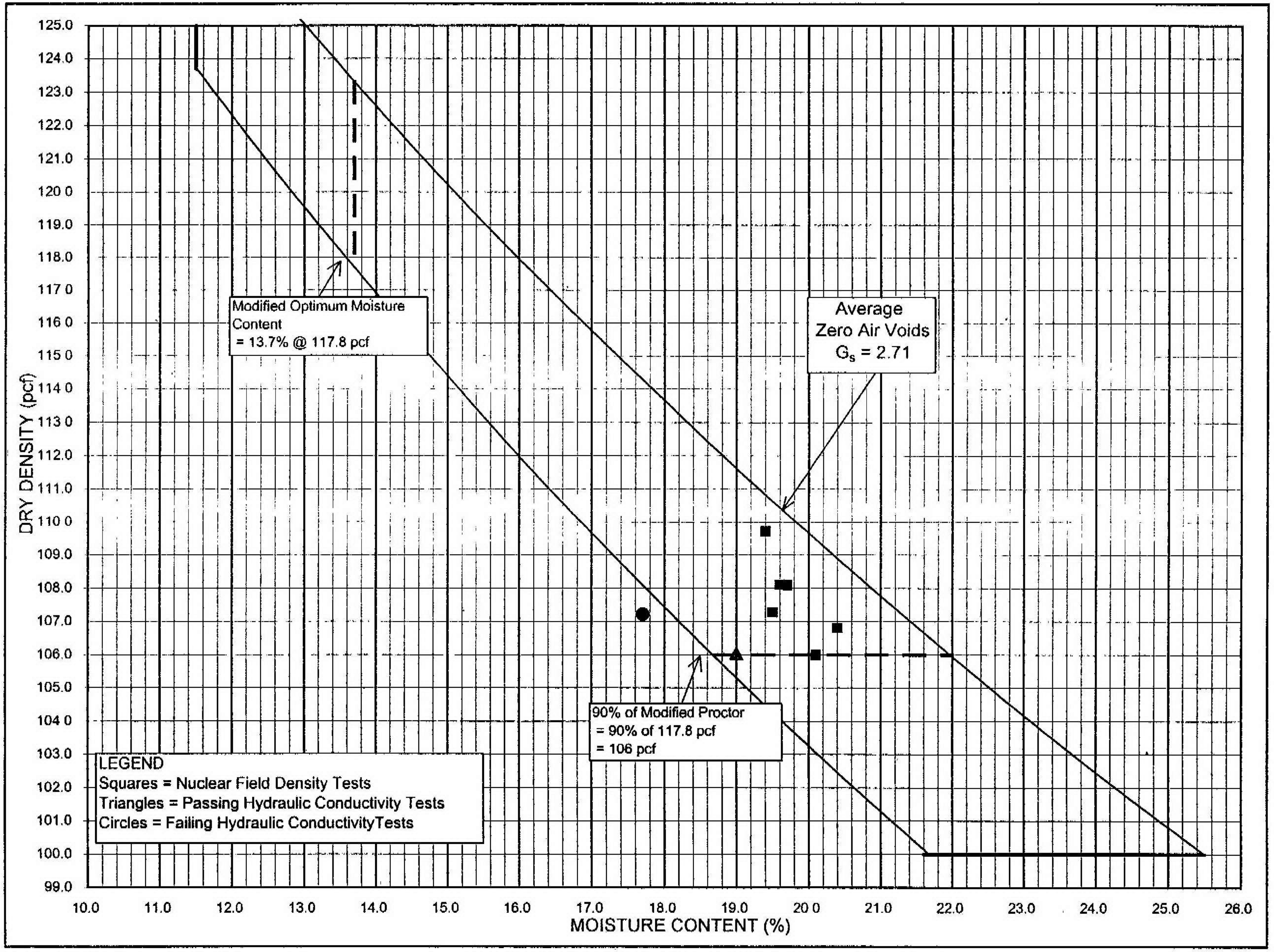


Figure 4.2.2-7A

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 3

Test Pad: 2

Hydration 4 days

Lane Number: 2

Lift Number: 3

Compaction Equip: 825-G Compactor

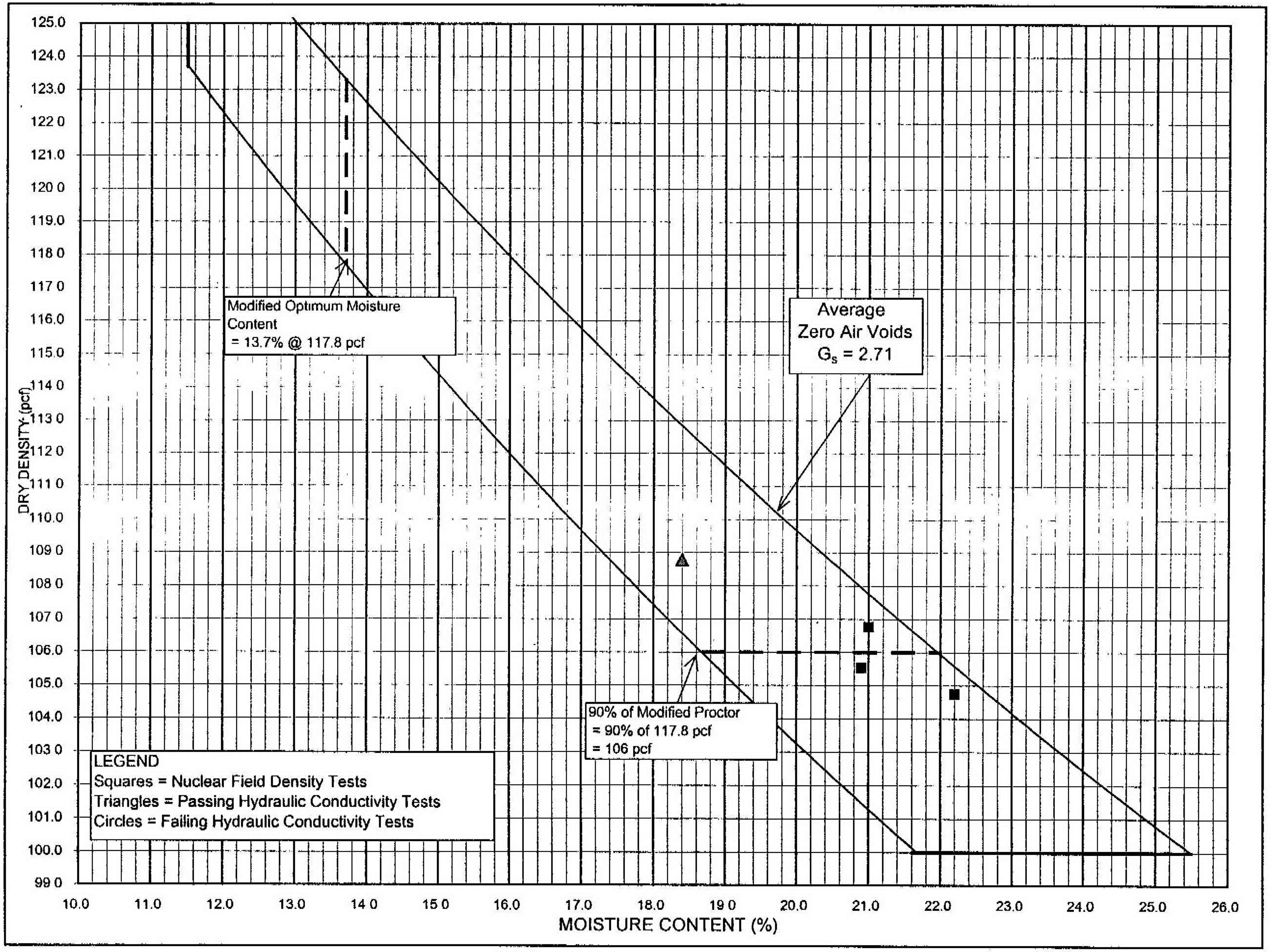


Figure 4.2.2-7B

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 3

Test Pad: 2
Hydration 4 days
Lane Number: 2
Lift Number: 3
Compaction Equip: 825-G Compactor

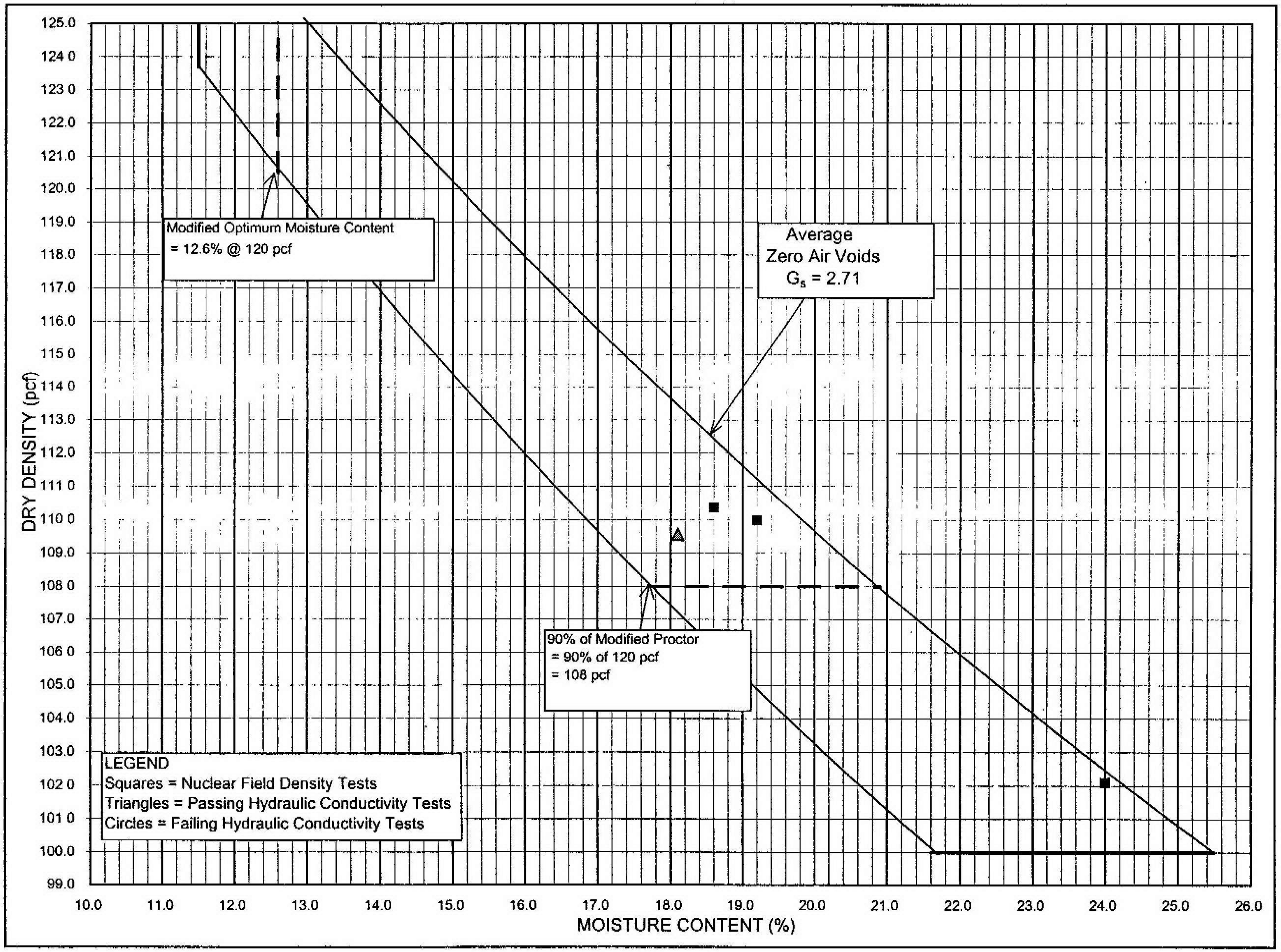


Figure 4.2.2-8A

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 4

Test Pad: 2
Hydration 4 days
Lane Number: 2
Lift Number: 4
Compaction Equip: 825-G Compactor

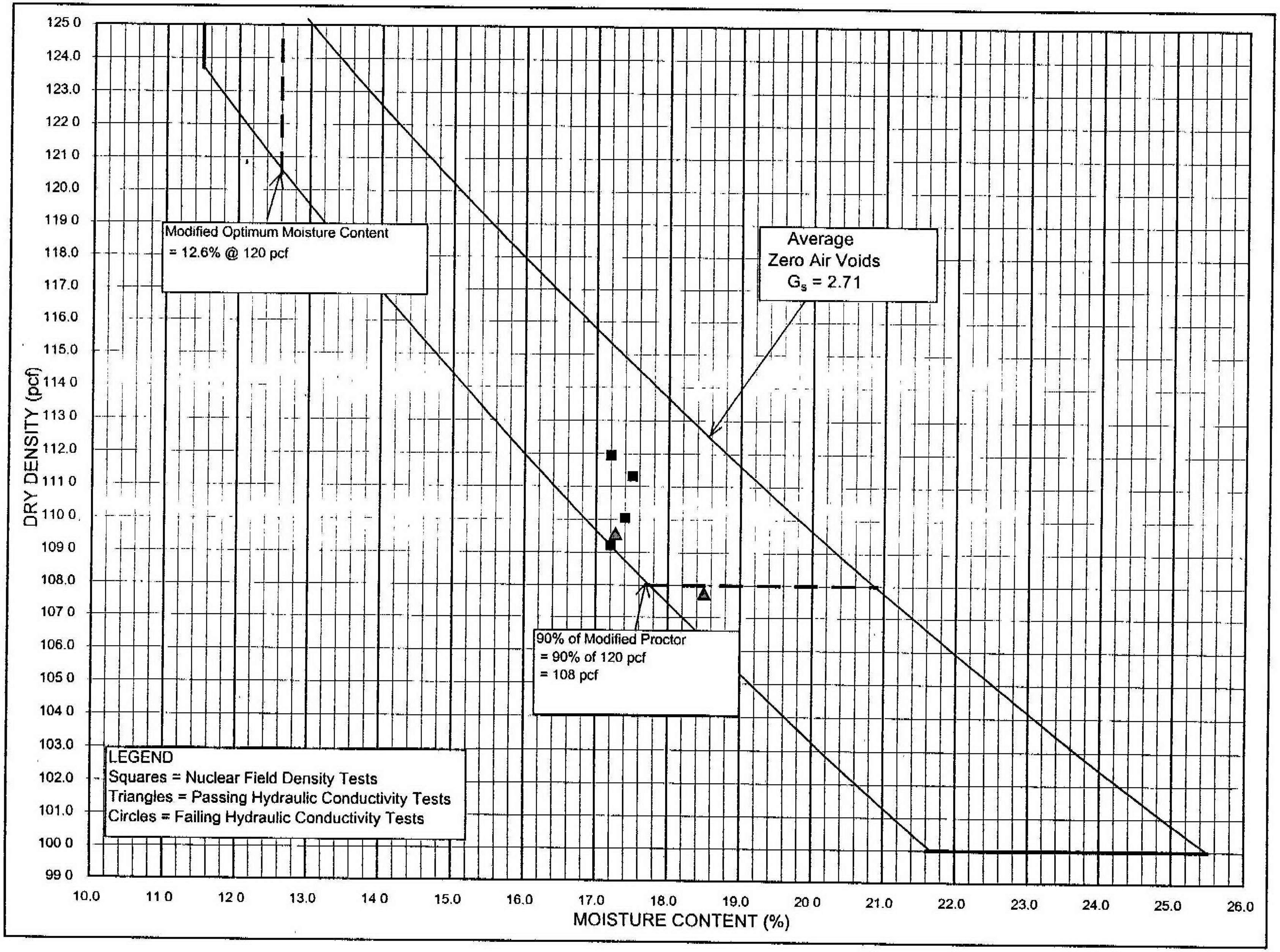


Figure 4.2.2-8B

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 4

Test Pad: 2 **Lane Number:** 2

Hydration 4 days **Lift Number:** 4 **Compaction Equip:** 825-G Compactor

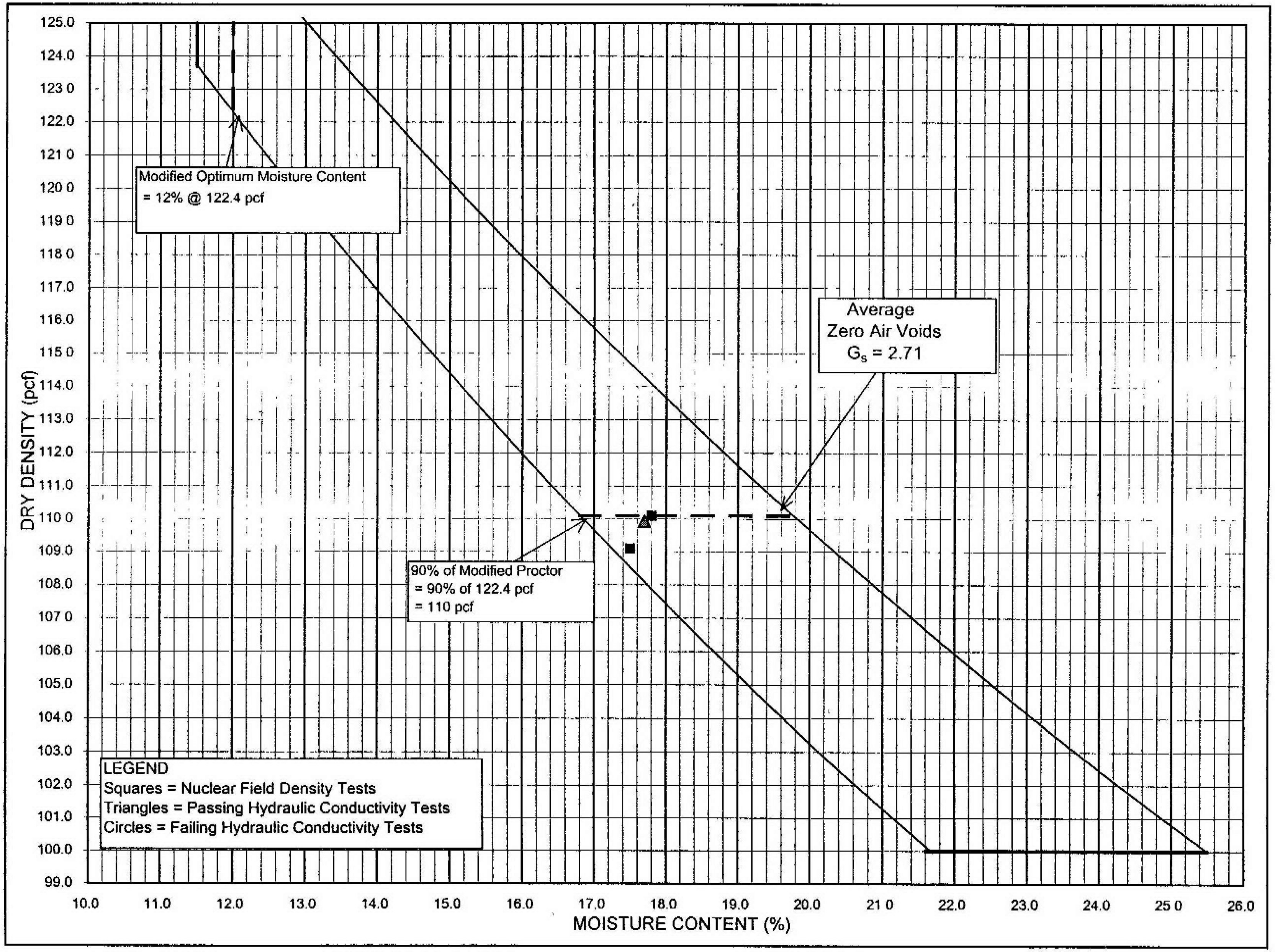


Figure 4.2.2-9

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 5

Test Pad: 2
Hydration 4 days
Lane Number: 2
Lift Number: 5
Compaction Equip: 825-G Compactor

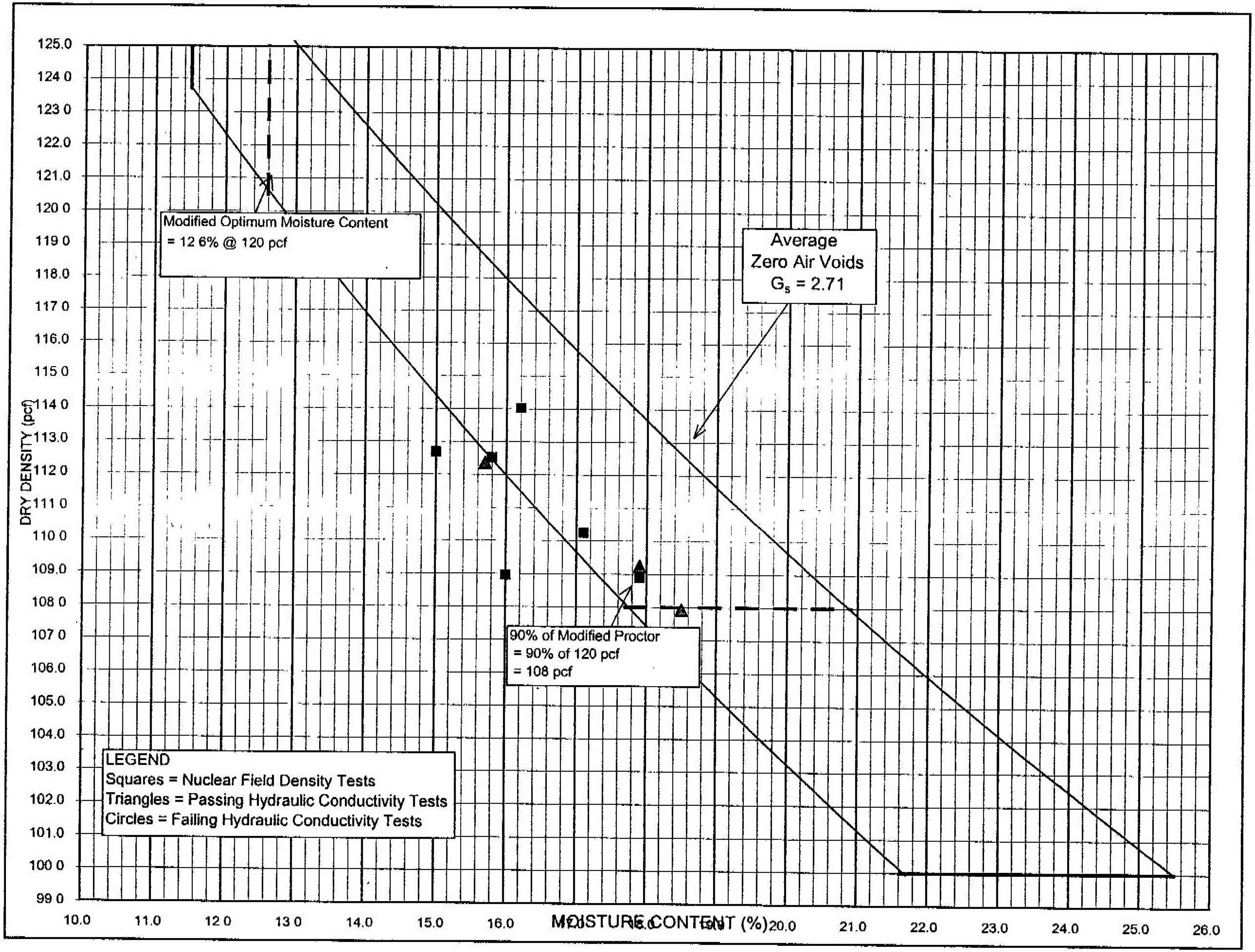


Figure 4.2.2-10

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 2, LANE 2, LIFT 6

Test Pad: 2
Hydration 2 days
Lane Number: 2
Lift Number: 6
Compaction Equip: 825-G Compactor

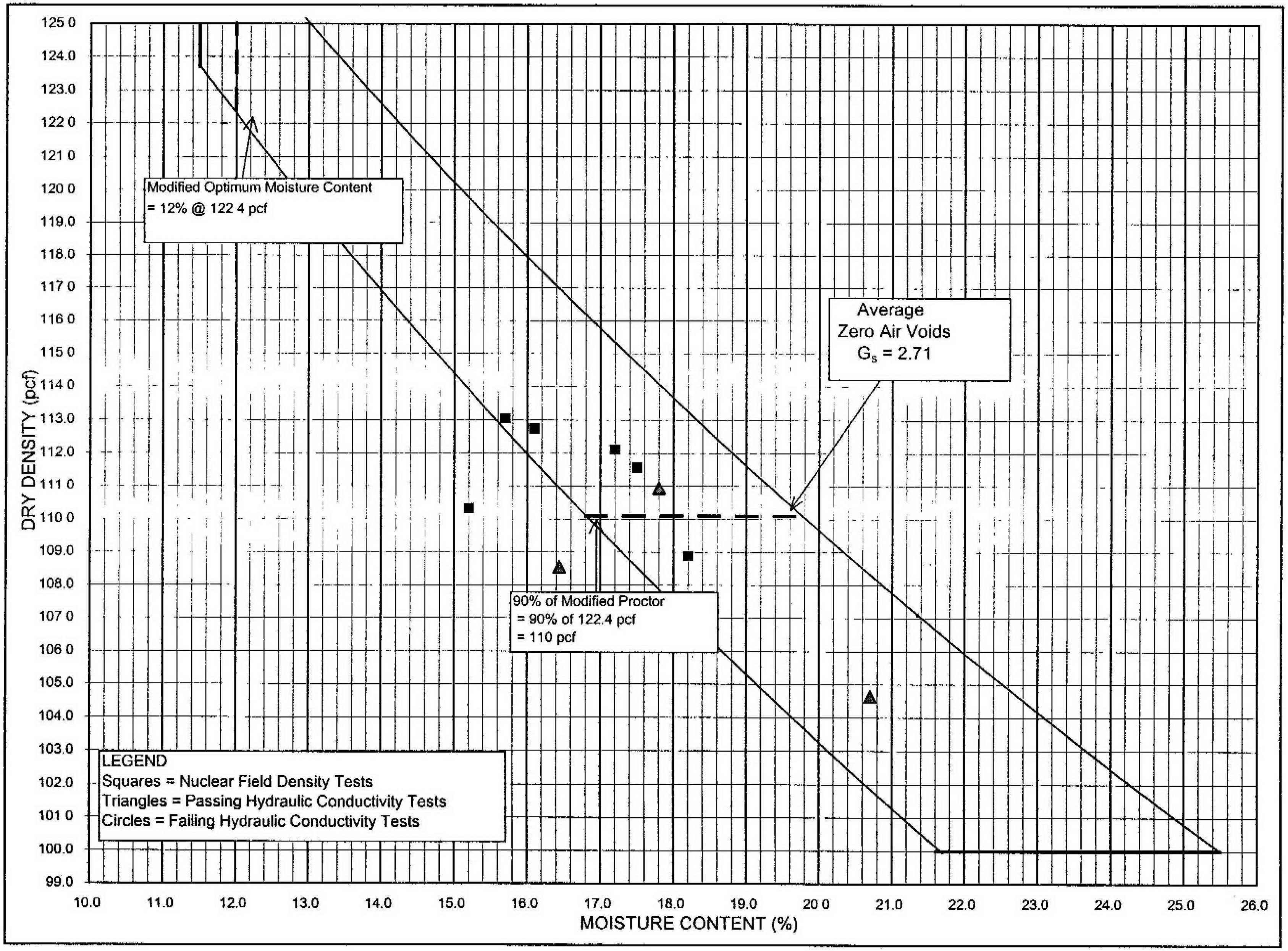


Figure 4.3.2-1

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 1, LIFT 2

Test Pad: 3
Hydration: 4 days
Lane Number: 1
Lift Number: 2
Compaction Equip: 815F Compactor

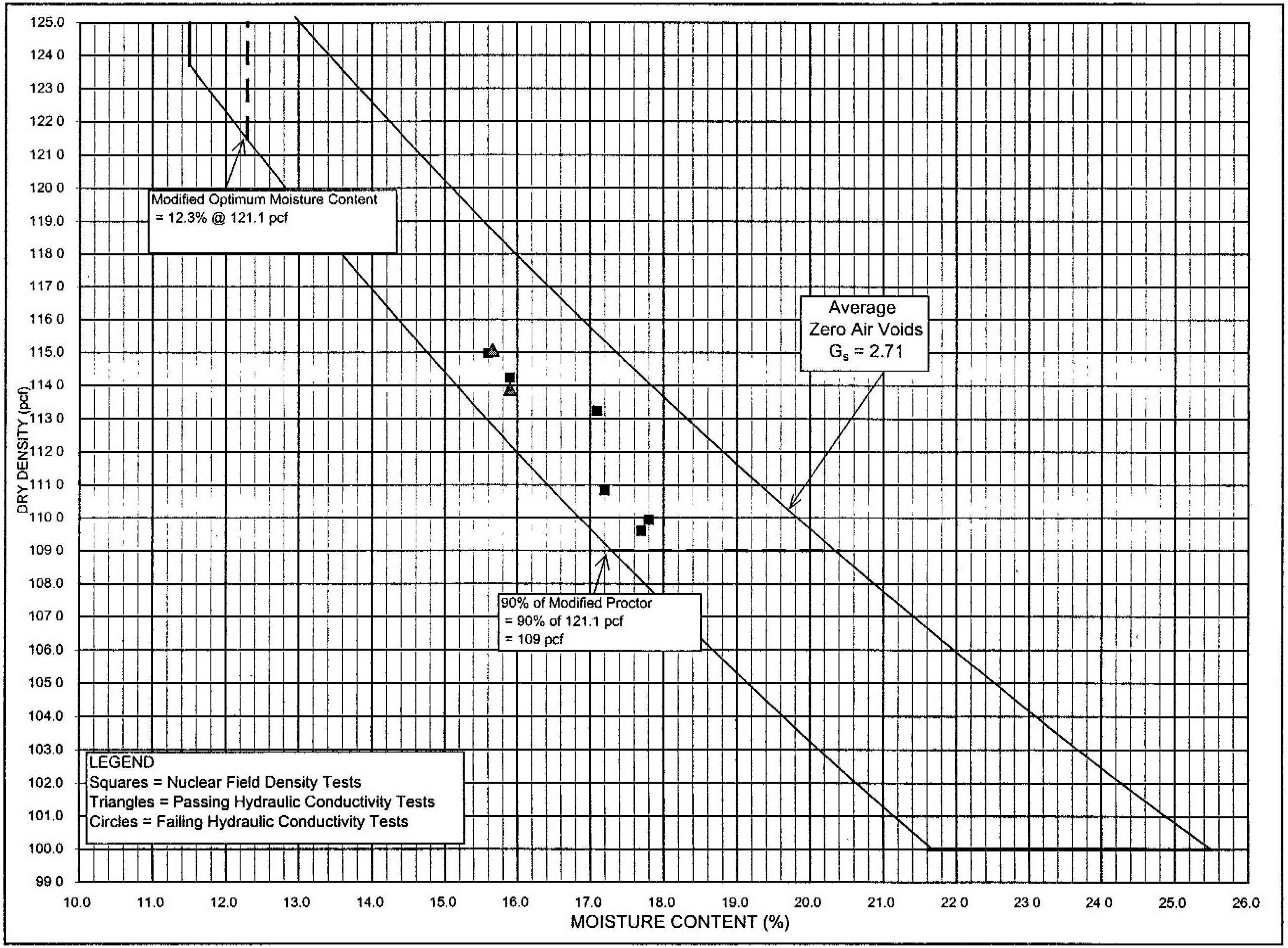


Figure 4.3.2-2

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 1, LIFT 3

Test Pad: 3
Hydration: 4 days
Lane Number: 1
Lift Number: 3
Compaction Equip: 815-F Compactor

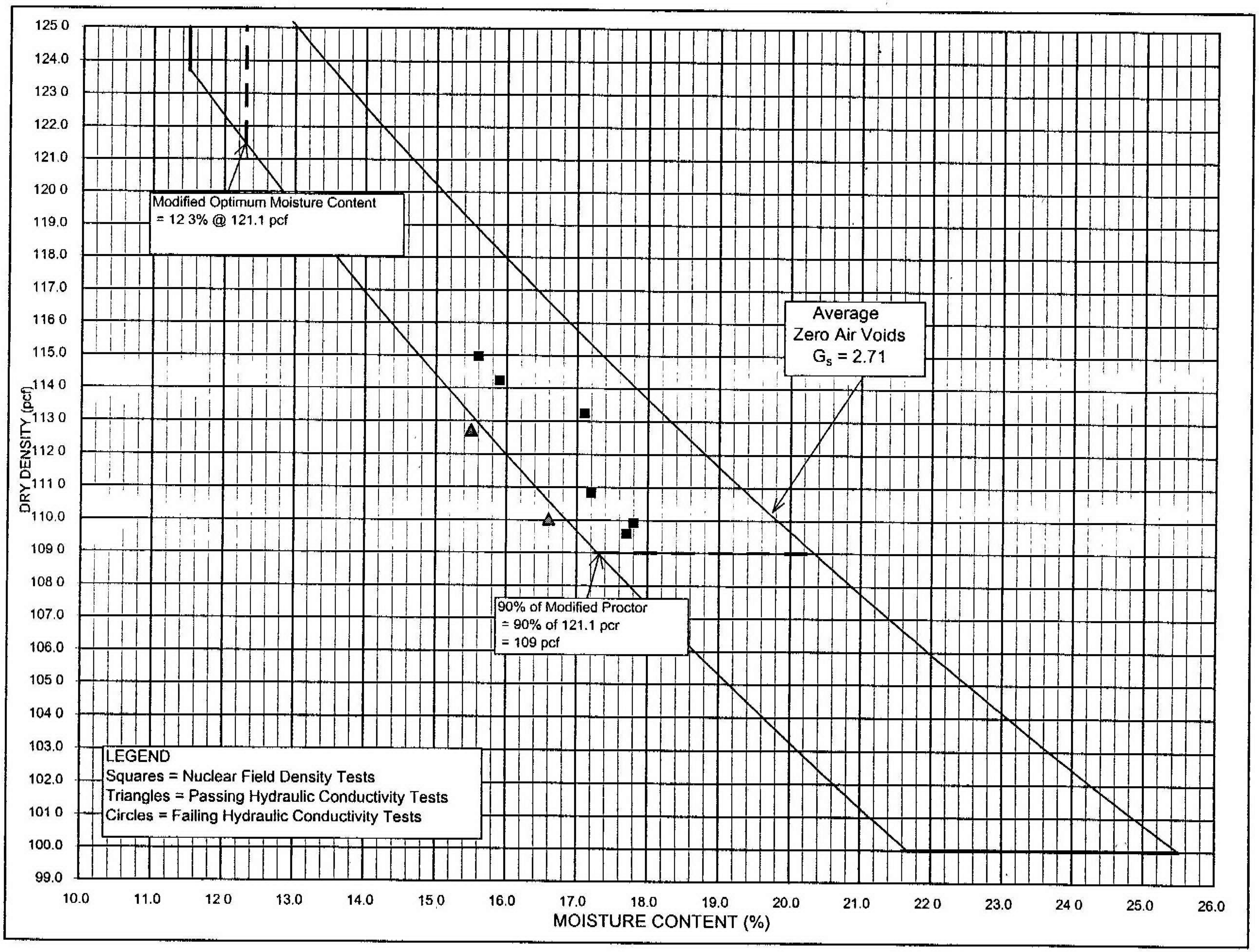


Figure 4.3.2-3

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 1, LIFT 4

Test Pad: 3
Hydration: 4 days
Lane Number: 1
Lift Number: 4
Compaction Equip: 815-F Compactor

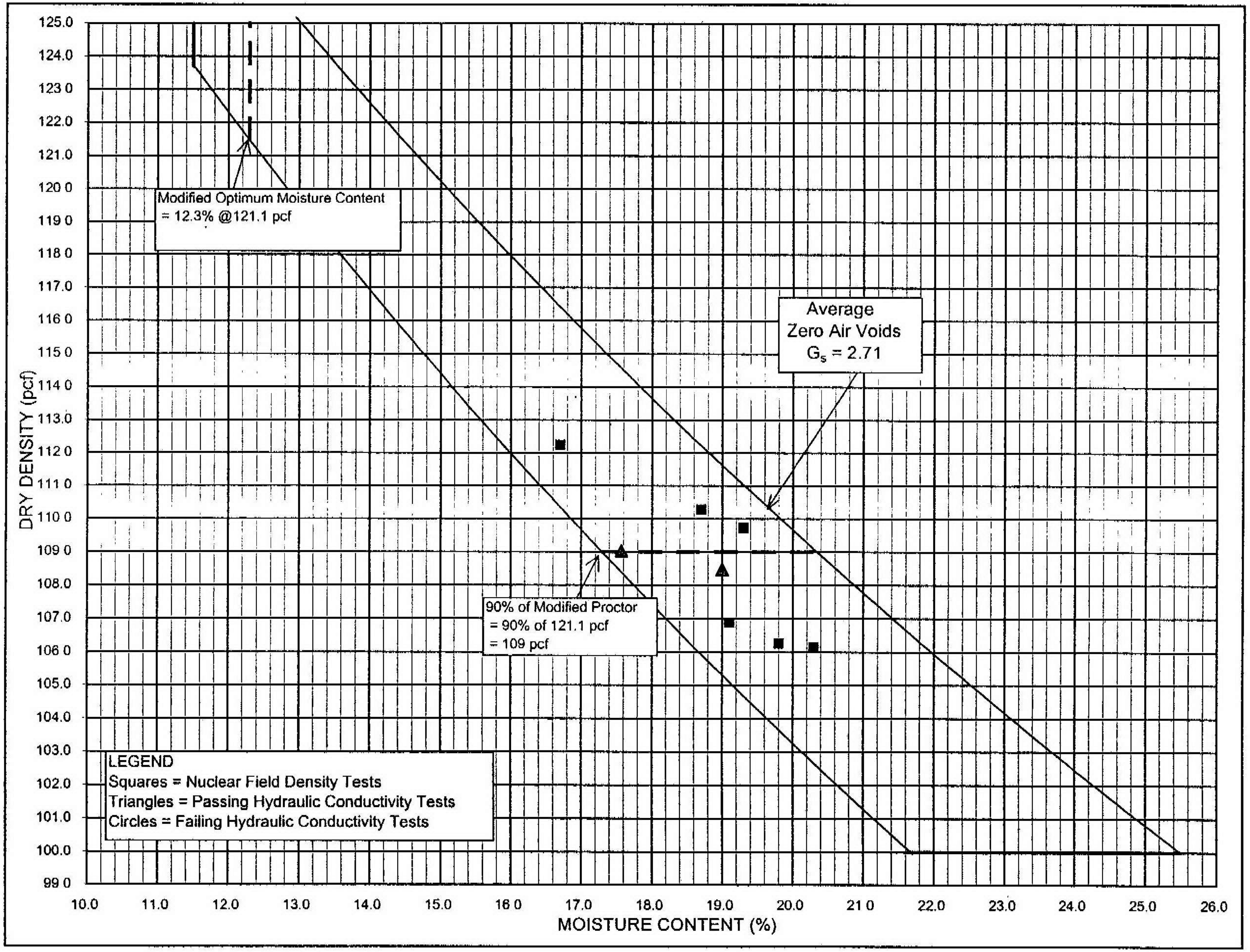


Figure 4.3.2-4

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 1, LIFT 5

Test Pad: 3
Hydration: 4 days
Lane Number: 1
Lift Number: 5
Compaction Equip: 815-F Compactor

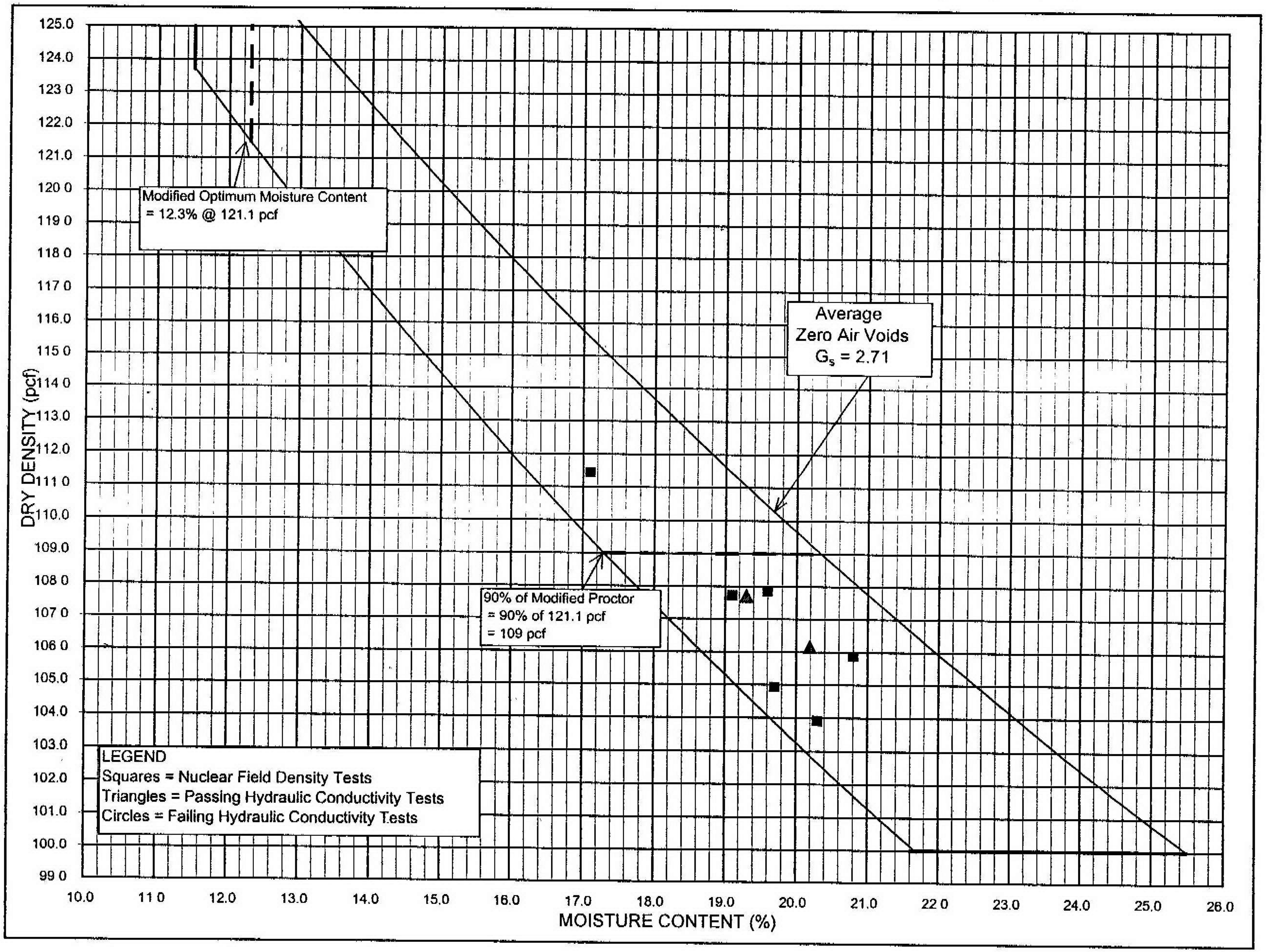
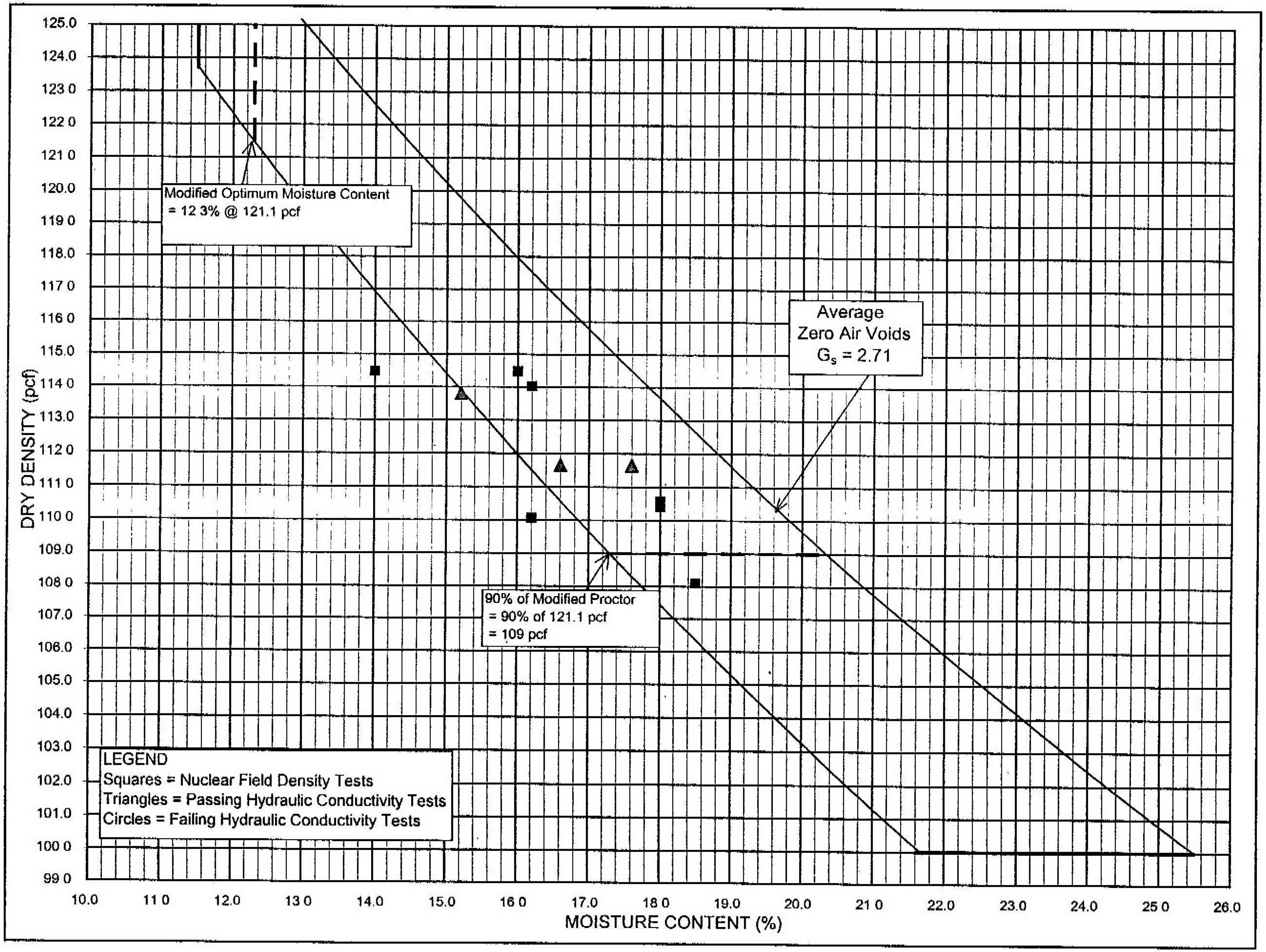


Figure 4.3.2-5

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 2, LIFT 2

Test Pad: 3 **Lane Number:** 2

Hydration: 4 days **Lift Number:** 2 **Compaction Equip:** 825-G Compactor



Modified Optimum Moisture Content
= 12 3% @ 121.1 pcf

Average
Zero Air Voids
G_s = 2.71

90% of Modified Proctor
= 90% of 121.1 pcf
= 109 pcf

LEGEND
Squares = Nuclear Field Density Tests
Triangles = Passing Hydraulic Conductivity Tests
Circles = Failing Hydraulic Conductivity Tests

Figure 4.3.2-6

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 2, LIFT 3

Test Pad: 3
Hydration: 4 days
Lane Number: 2
Lift Number: 3
Compaction Equip: 825-G Compactor

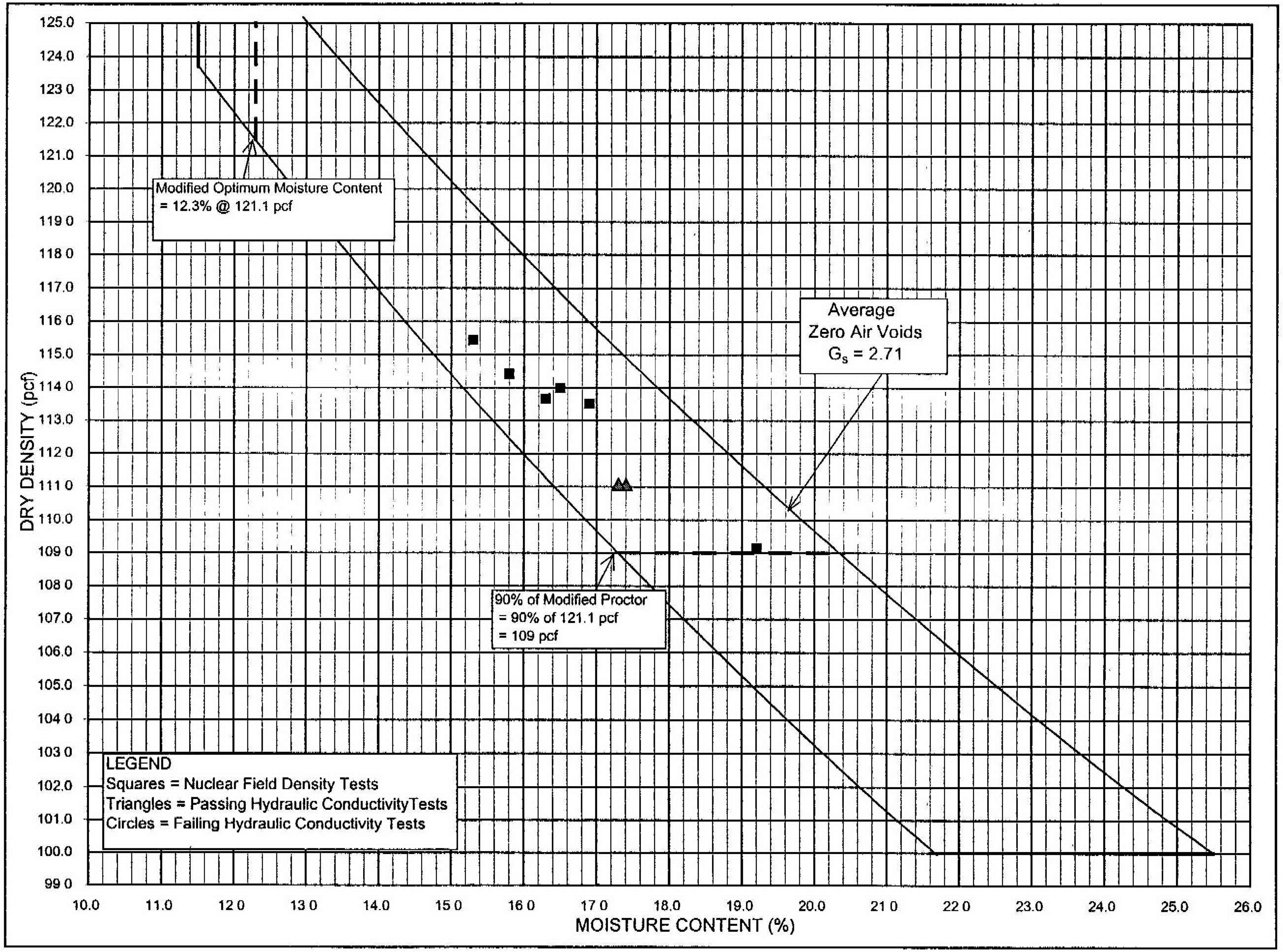


Figure 4.3.2-7

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 2, LIFT 4

Test Pad: 3 **Lane Number:** 2

Hydration: 4 days **Lift Number:** 4 **Compaction Equip:** 825-G Compactor

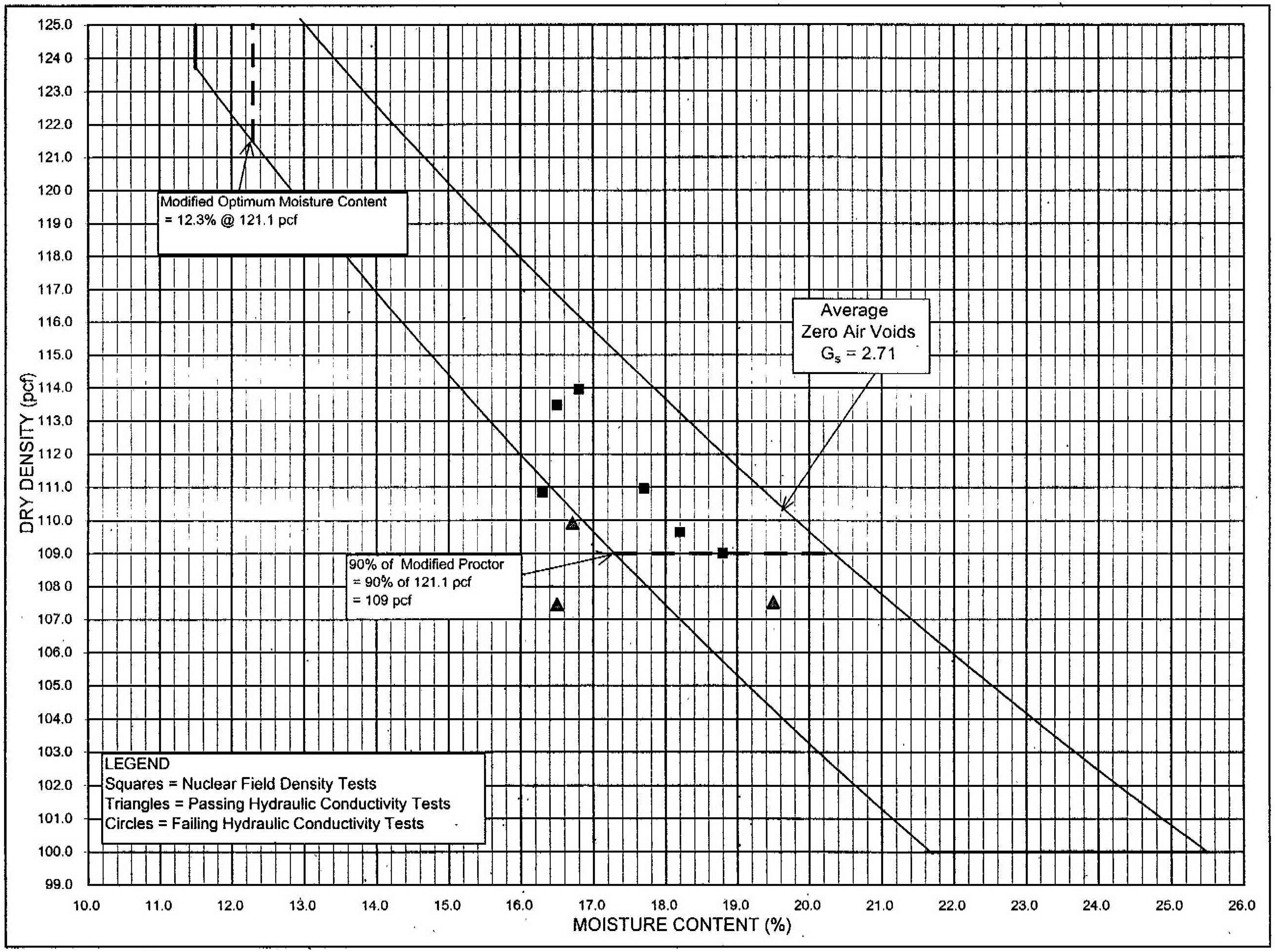
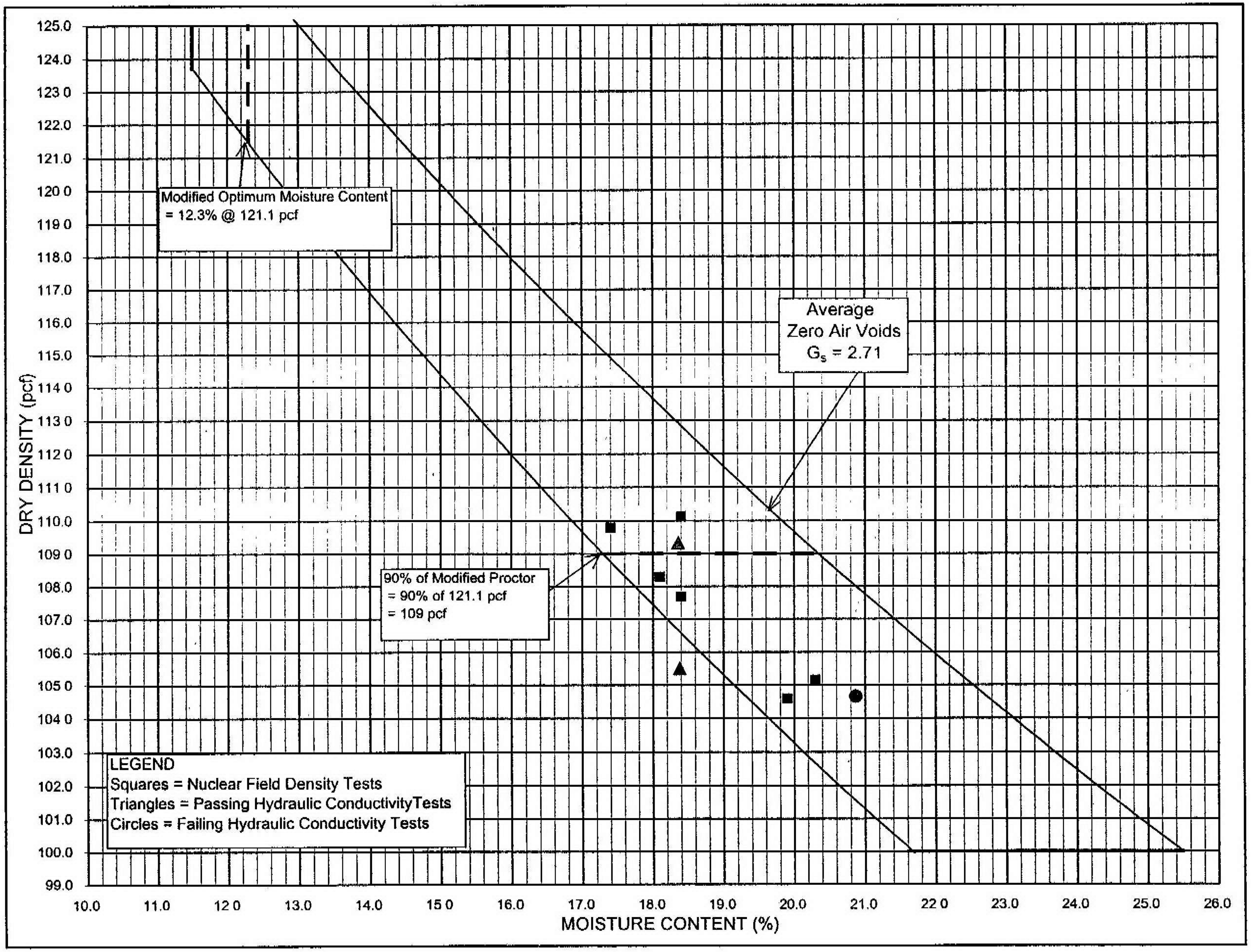
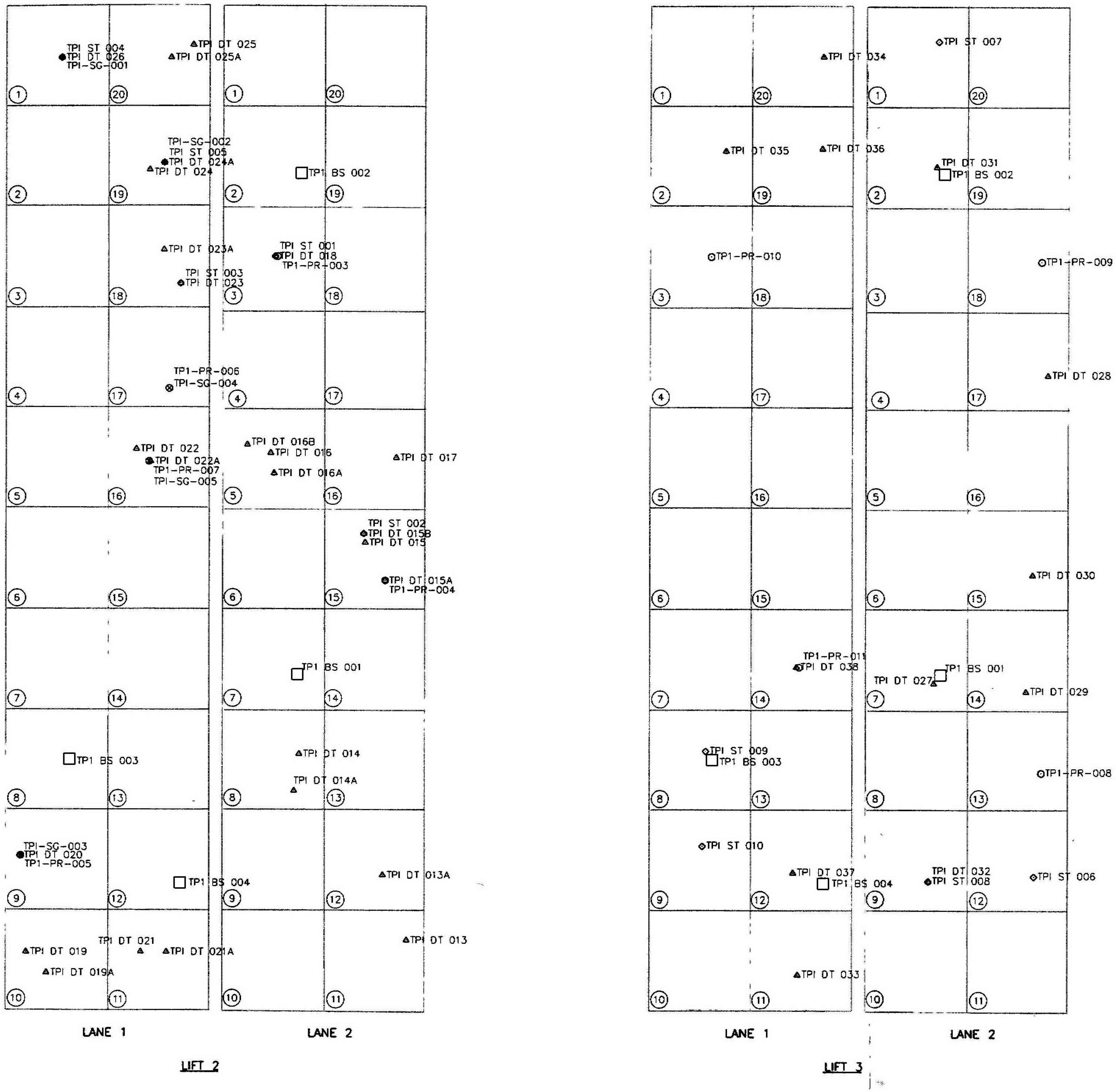


Figure 4.3.2-8

ELF TEST PADS NUCLEAR MOISTURE-DENSITY/HYDRAULIC CONDUCTIVITY TEST RESULTS - TEST PAD 3, LANE 2, LIFT 5

Test Pad: 3 **Lane Number:** 2
Hydration: 4 days **Lift Number:** 5 **Compaction Equip:** 825-G Compactor





LEGEND

△ TP1 DT XXXX	NUCLEAR DENSITY TEST POINT
× TP1-SG-XXX	SPECIFIC GRAVITY SAMPLE LOCATION
◇ TP1 ST XXX	SHELBY TUBE SAMPLE LOCATION
○ TP1-PR-XXX	MODIFIED PROCTOR SAMPLE LOCATION
☐ TP1 BS XXX	BLOCK SAMPLE LOCATION

COLORADO STATE PLANE

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SAMPLE LOCATIONS
TEST PAD 1 (SH. 1 OF 2)

CHECKED:	J. BORNETZ	12.03.01	FIGURE NUMBER 4.4-1
DESIGNED:	S. LABB	12.03.01	
FILE NAME:	TP-1.dwg	[illegible]	

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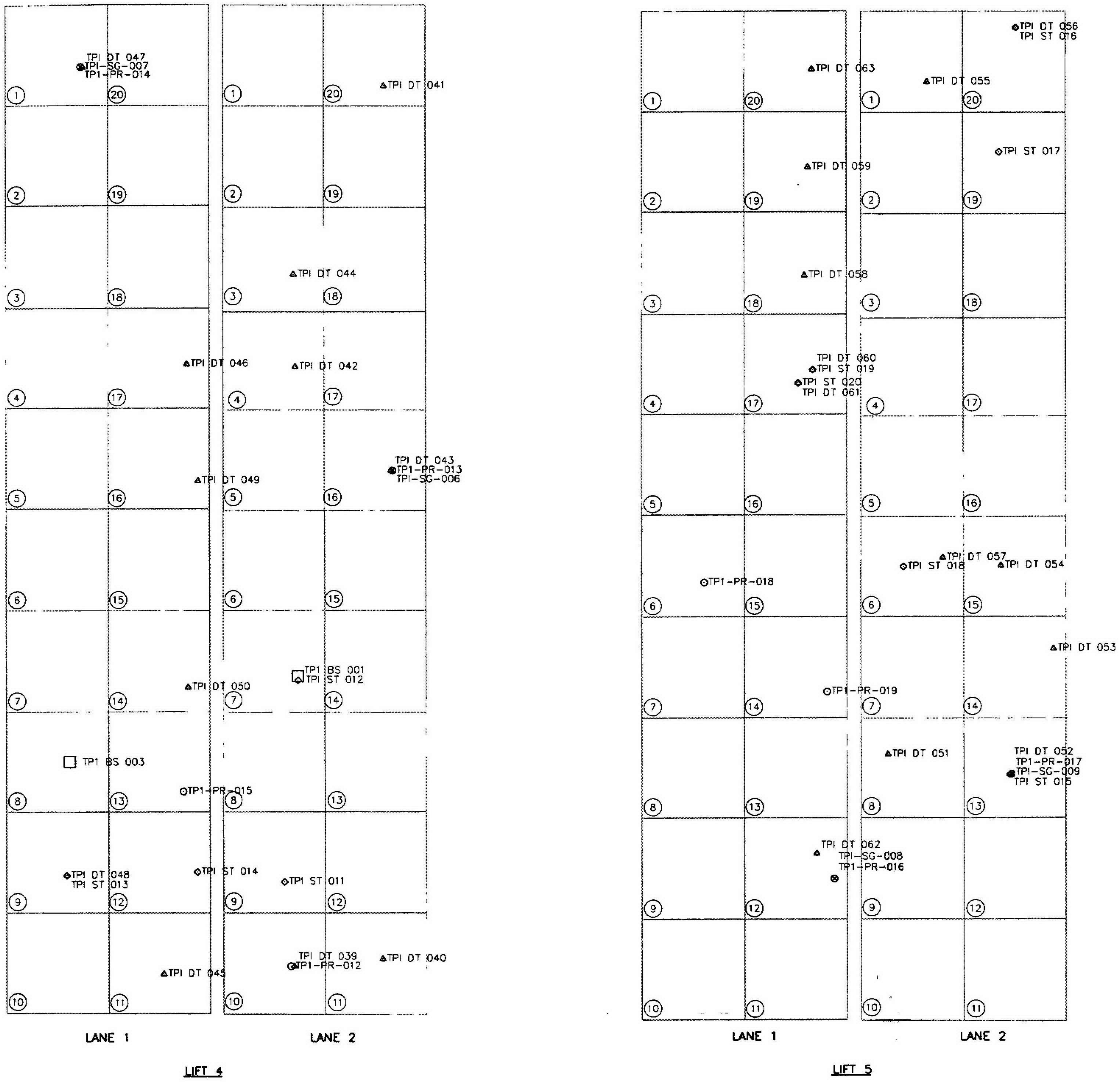
THIS DRAWING WAS CREATED USING AUTOCAD, DO NOT REVISE MANUALLY



LEGEND

△ TP1 DT XXXX	NUCLEAR DENSITY TEST POINT
× TP1-SG-XXX	SPECIFIC GRAVITY SAMPLE LOCATION
◇ TP1 ST XXX	SHELBY TUBE SAMPLE LOCATION
○ TP1-PR-XXX	MODIFIED PROCTOR SAMPLE LOCATION
☐ TP1 BS XXX	BLOCK SAMPLE LOCATION

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SAMPLE LOCATIONS
TEST PAD 1 (SH. 2 OF 2)

CHECKED:	J. BORRETZ	12.03.01
DESIGNED:	S. LANG	12.03.01
FILE NAME:	TP-2.dwg	XX.XX.XX

FIGURE NUMBER
4.4-2

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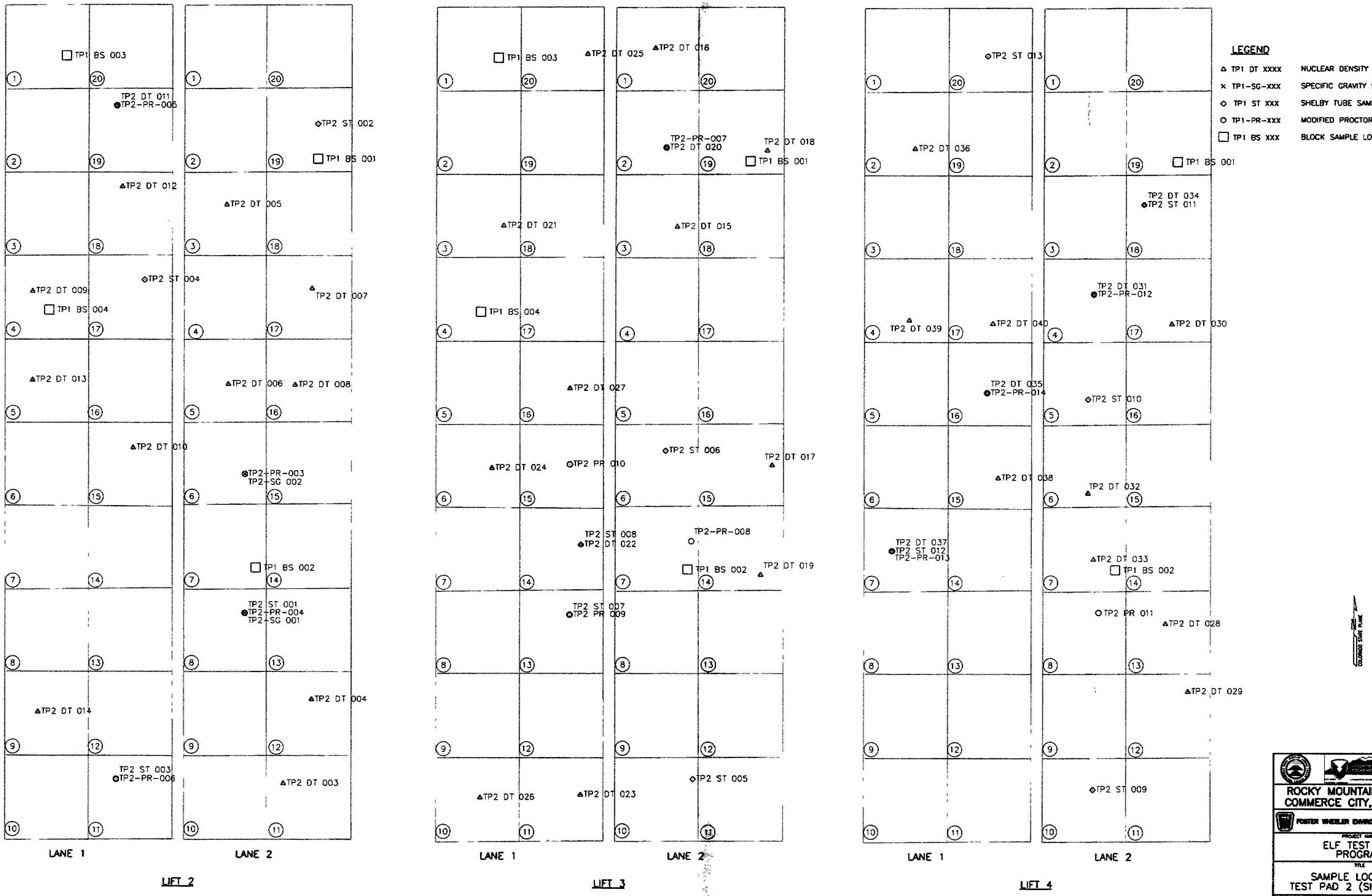

LEGEND

△ TP1 DT XXXX	NUCLEAR DENSITY TEST POINT
× TP1-SG-XXX	SPECIFIC GRAVITY SAMPLE LOCATION
◇ TP1 ST XXX	SHELBY TUBE SAMPLE LOCATION
○ TP1-PR-XXX	MODIFIED PROCTOR SAMPLE LOCATION
☐ TP1 BS XXX	BLOCK SAMPLE LOCATION

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SAMPLE LOCATIONS
TEST PAD 2 (SH. 1 OF 2)

CHECKED:	J. BENRETZ	12.03.01	FIGURE NUMBER
DESIGNED:	S. LAING	12.03.01	4.4-3
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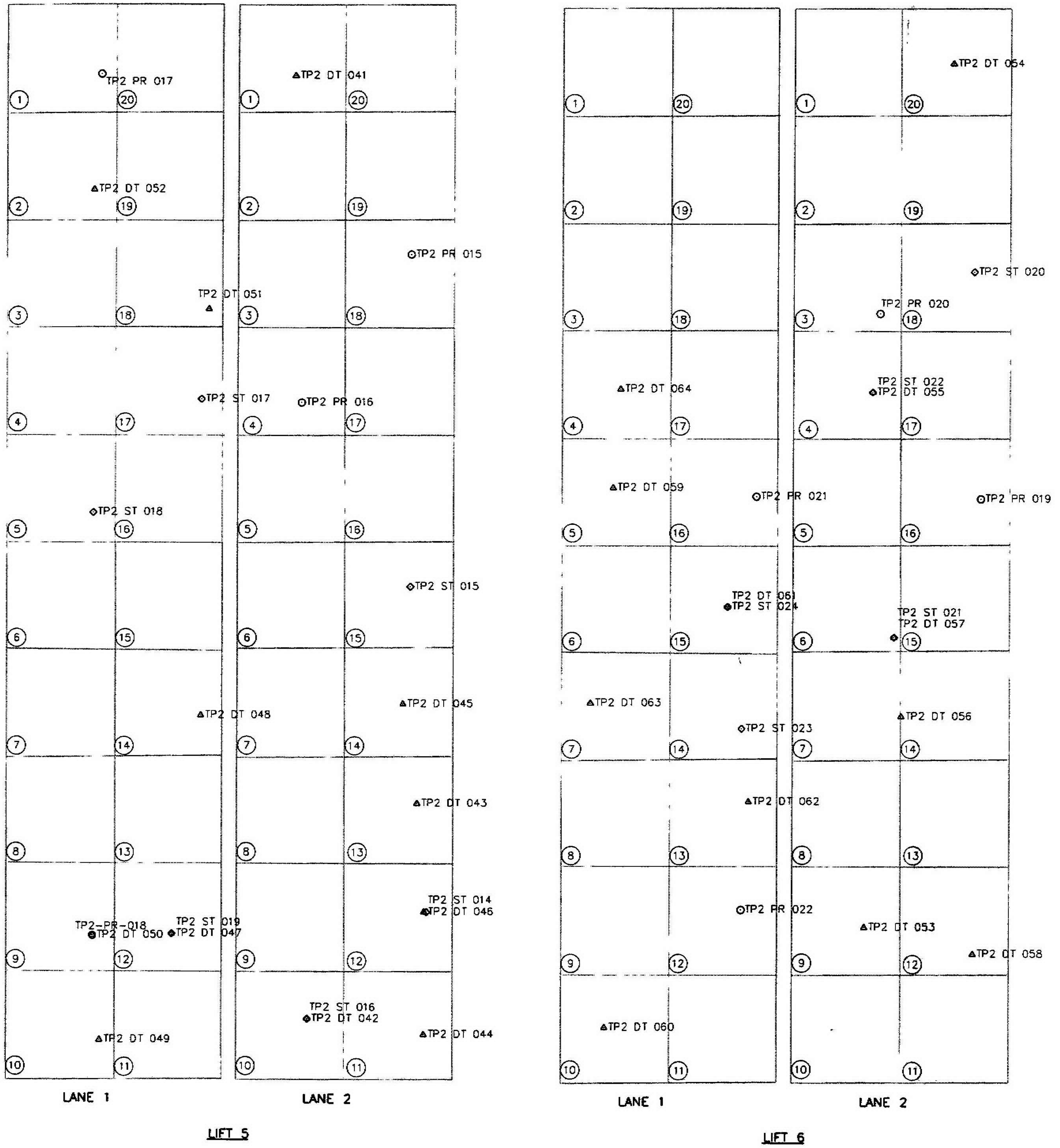

LEGEND

△ TP1 DT XXXX	NUCLEAR DENSITY TEST POINT
× TP1-SG-XXX	SPECIFIC GRAVITY SAMPLE LOCATION
◇ TP1 ST XXX	SHELBY TUBE SAMPLE LOCATION
○ TP1-PR-XXX	MODIFIED PROCTOR SAMPLE LOCATION

COLORADO STATE PLANE

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SAMPLE LOCATIONS
TEST PAD 2 (SH. 2 OF 2)

CHECKED:	J. BORRETZ	12.03.01	FIGURE NUMBER
DESIGNED:	S. LANG	12.03.01	4.4-4
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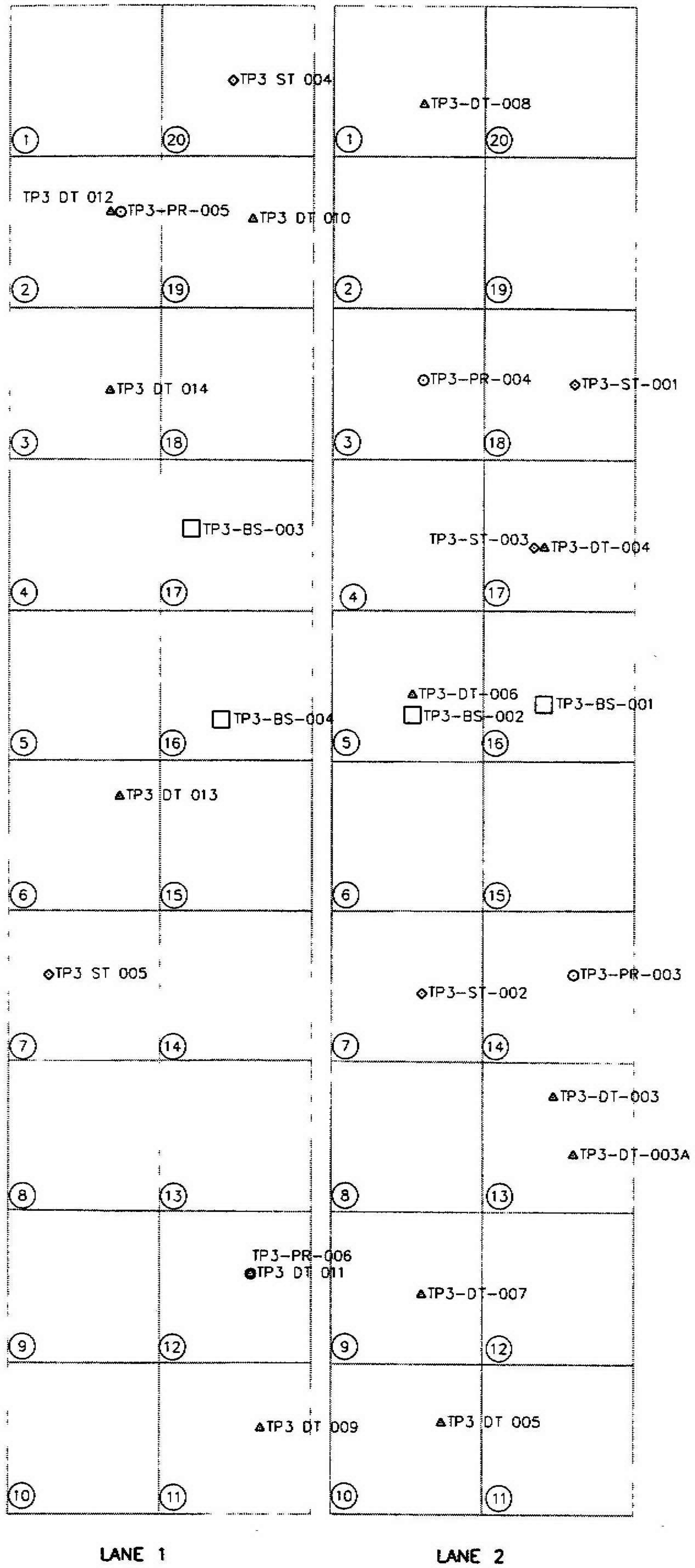
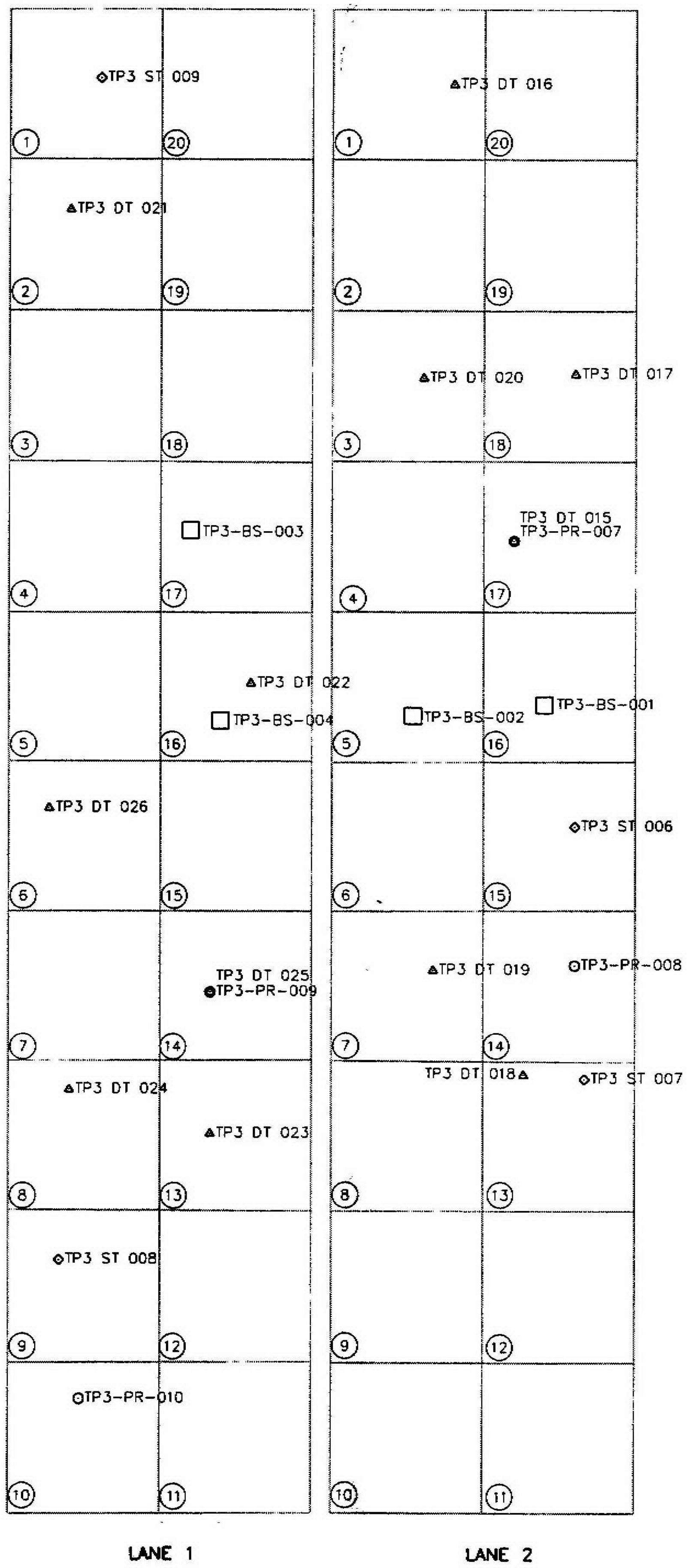


LIFT 2



LIFT 3

LEGEND

△ TP1 DT XXXX	NUCLEAR DENSITY TEST POINT
× TP1-SG-XXX	SPECIFIC GRAVITY SAMPLE LOCATION
◇ TP1 ST XXX	SHELBY TUBE SAMPLE LOCATION
○ TP1-PR-XXX	MODIFIED PROCTOR SAMPLE LOCATION
☐ TP1 BS XXX	BLOCK SAMPLE LOCATION

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SAMPLE LOCATIONS
TEST PAD 3 (SH. 1 OF 2)

CHECKED:	J. BORRETZ	12.03.01	FIGURE NUMBER
DESIGNED	S. LANG	12.03.01	4.4-5
FILE NAME:	TP-3.dwg	XX.XX.XX	

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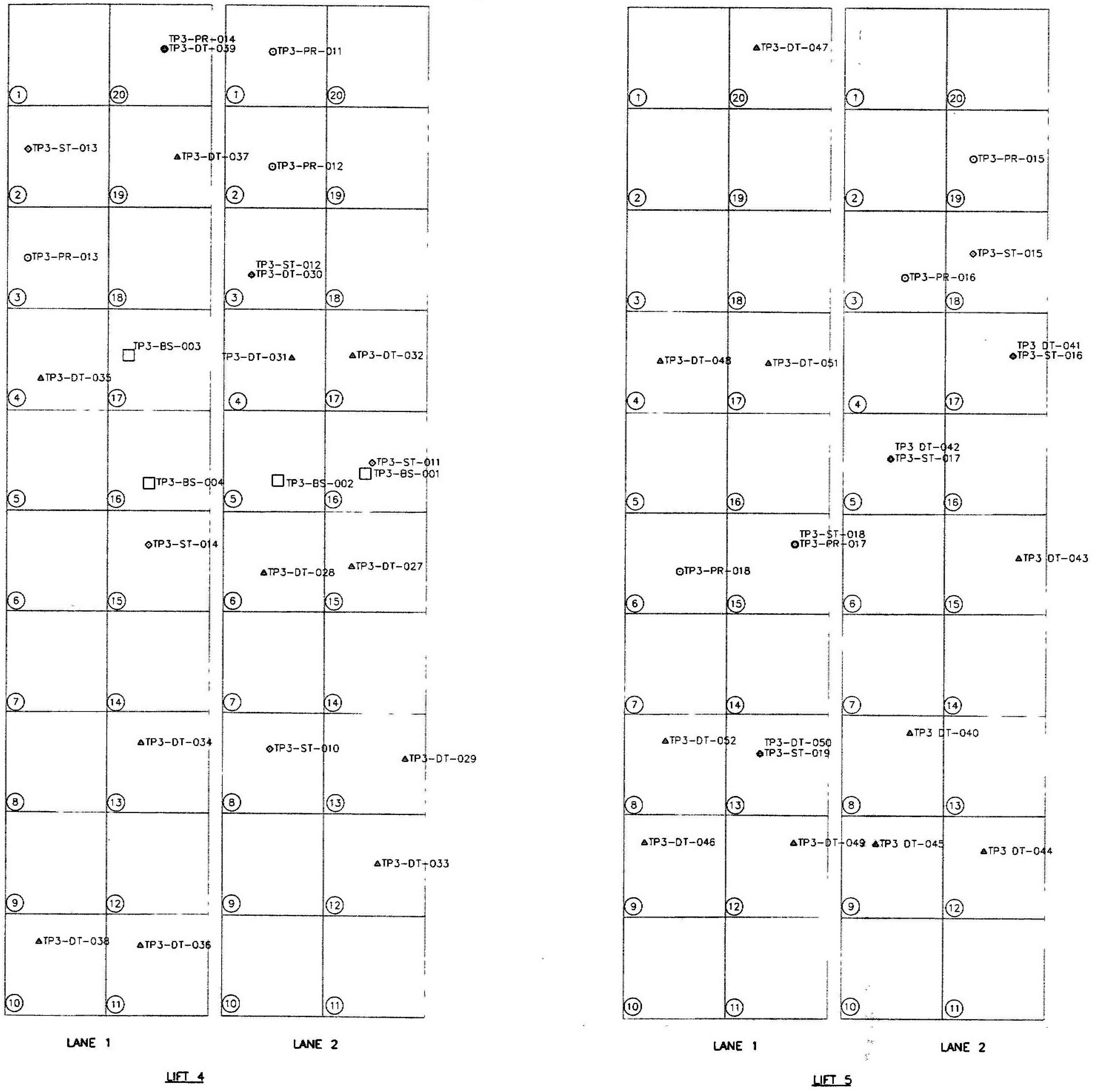
THIS DRAWING WAS CREATED USING AUTOCAD. DO NOT REVISE MANUALLY



LEGEND

△	TP1 DT XXXX	NUCLEAR DENSITY TEST POINT
×	TP1-SG-XXX	SPECIFIC GRAVITY SAMPLE LOCATION
◇	TP1 ST XXX	SHELBY TUBE SAMPLE LOCATION
○	TP1-PR-XXX	MODIFIED PROCTOR SAMPLE LOCATION
☐	TP1 BS XXX	BLOCK SAMPLE LOCATION

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PROJECT NAME
ELF TEST PAD
PROGRAM

TITLE
SAMPLE LOCATIONS
TEST PAD 3 (SH. 2 OF 2)

CHECKED:	J. BORRETZ	12.03.01	FIGURE NUMBER
DESIGNED	S. LAIRD	12.03.01	4.4-6
FILE NAME:	TP-3-2.dwg	XX.XX.XX	

G:\PROJECTS\0297-0207\TP-3-2.DWG

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Figure 4.5.4-1

ELF TEST PADS NUCLEAR DENSITY TEST RESULTS - OVERALL

Test Pad: Overall
Lift Number: All
Lane Number: All
Compaction Equip: All

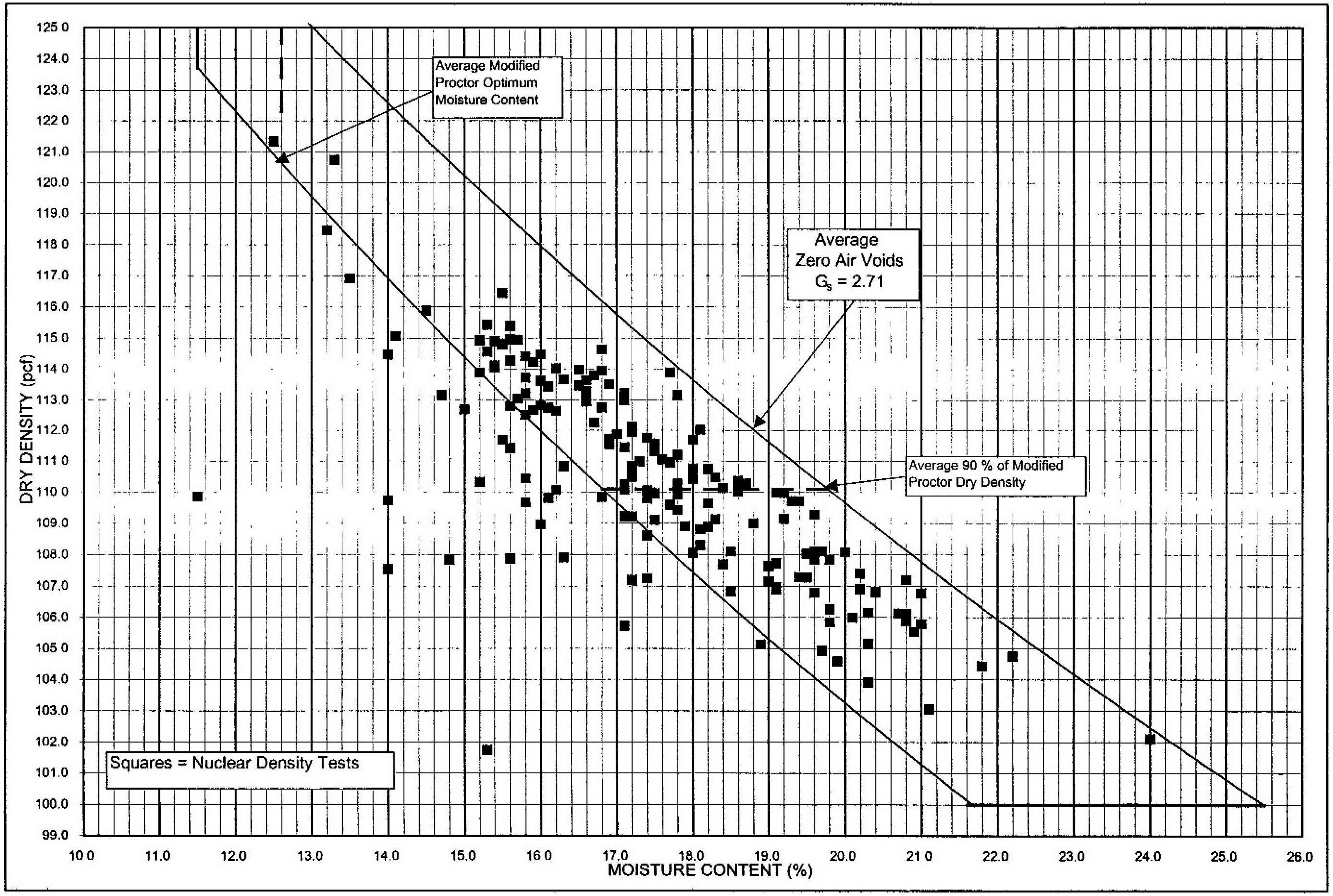


Figure 4.5.5-1

ELF TEST PADS SHELBY TUBE PASSING HYDRAULIC CONDUCTIVITY TEST RESULTS - OVERALL

Test Pad: Overall
Lane Number: All
Lift Number: All
Compaction Equip: All

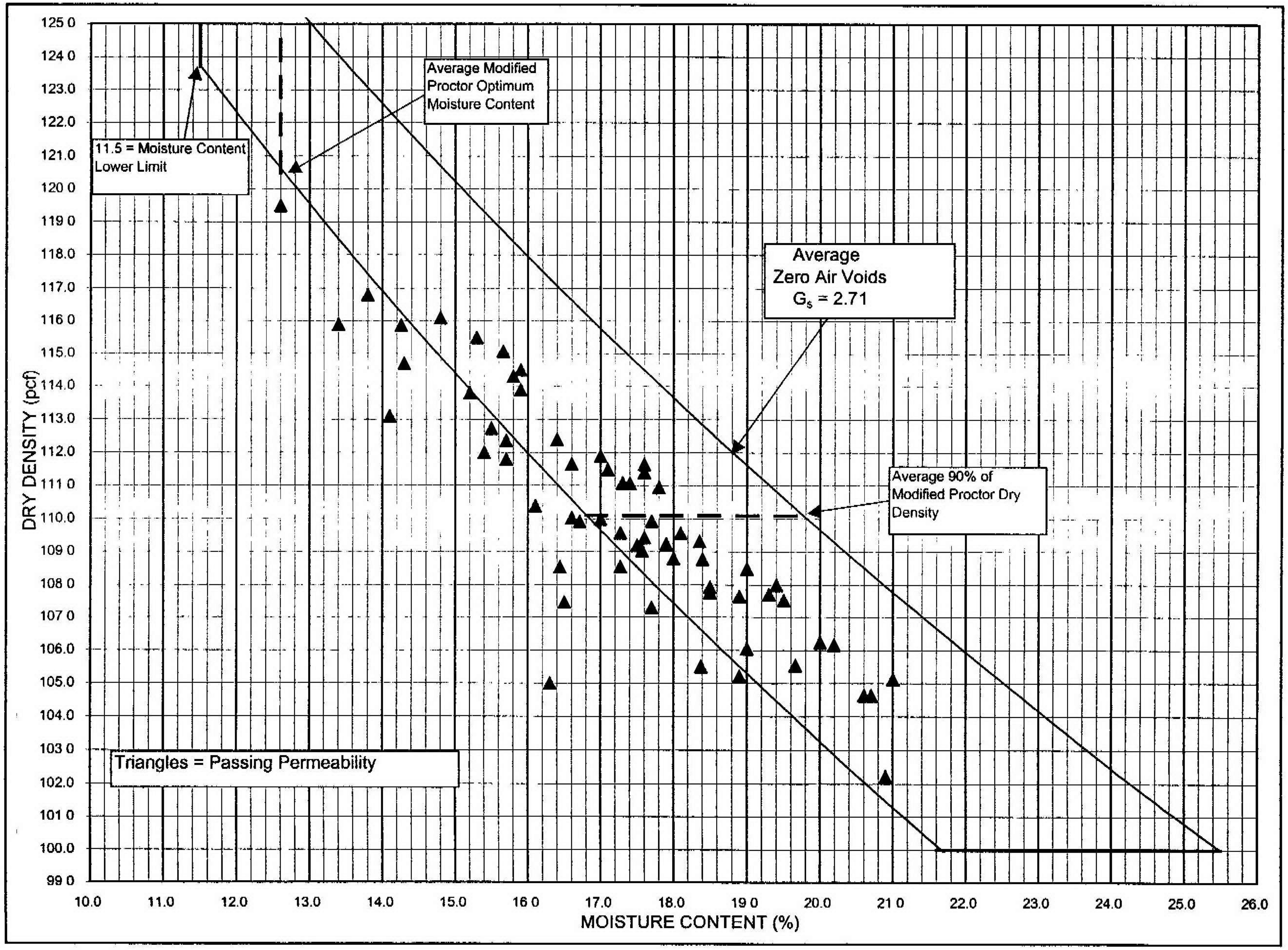


Figure 4.5.5-2

ELF TEST PADS SHELBY TUBE FAILING HYDRAULIC CONDUCTIVITY TEST RESULTS - OVERALL

Test Pad: Overall
Lane Number: All
Lift Number: All
Compaction Equip: All

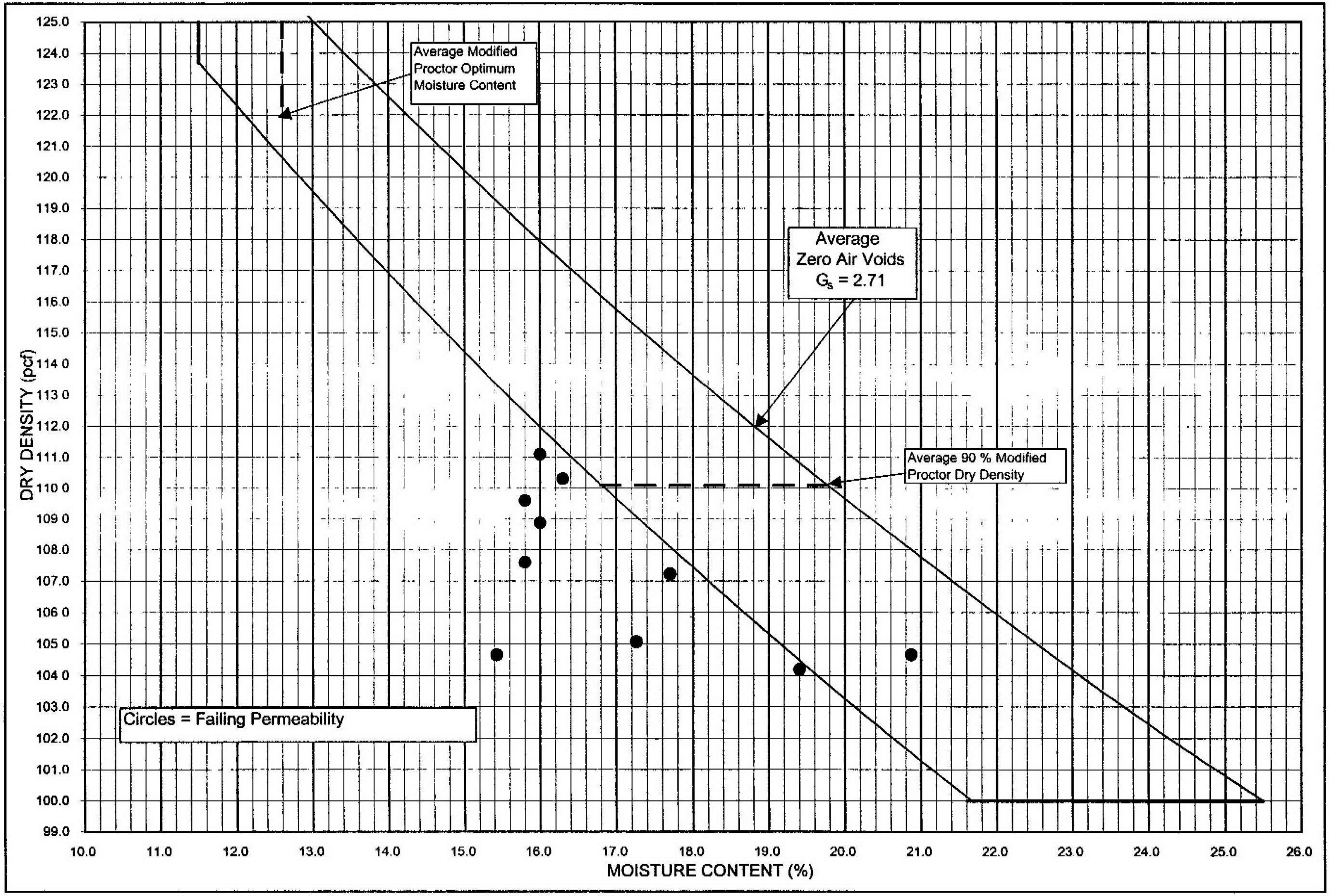
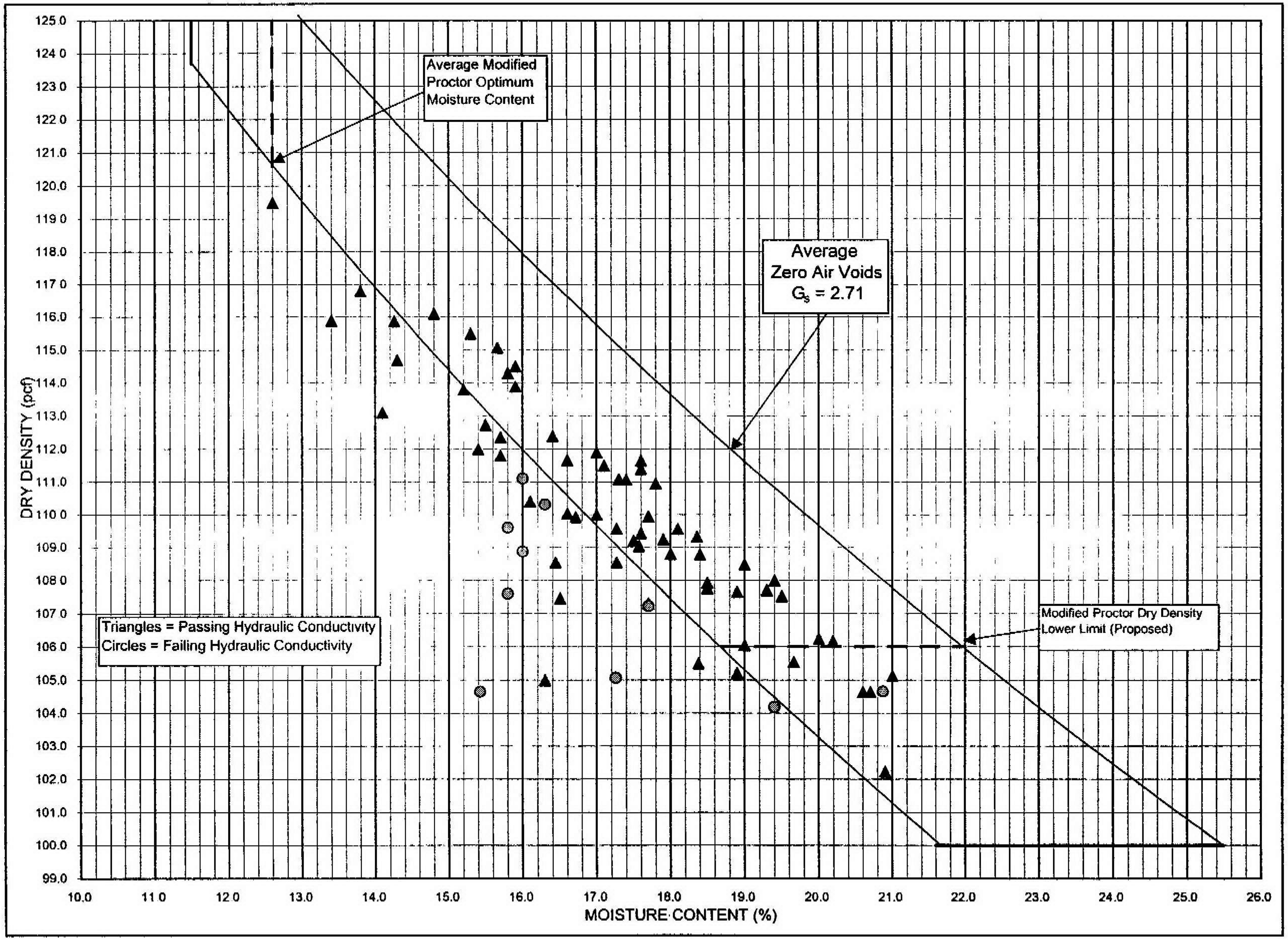


Figure 5.2-1

ELF TEST PADS SHELBY TUBE HYDRAULIC CONDUCTIVITY TEST RESULTS - OVERALL

Test Pad: Overall
Lane Number: All
Lift Number: All
Compaction Equip: All



TABLES

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP1A-1A	193760.26	2183681.50	5166.0-5164.5	1A-1-AS	1.0'-2.5'	100	91	39	19	20	104.5	18.0		CL	CL	15.8	10YR4/6	Moist, dark yellowish brown lean clay
TP1A-1A	193760.26	2183681.50	5166.0-5164.5	1A-1-AM	1.0'-2.5'									CL				
TP1A-1A	193760.26	2183681.50	5166.0-5164.5	1A-1-AR	1.0'-2.5'									CL				
TP1A-1B	193760.26	2183681.50	5164 5-5163.0	1A-1-BS	2 5'-4 0'	100	75	35	18	17	108.0	17.0		CL	CL	14.4	10YR5/6	Moist, yellowish brown lean clay with sand
TP1A-1B	193760.26	2183681.50	5164.5-5163.0	1A-1-BM	2 5'-4 0'									CL				
TP1A-1B	193760.26	2183681.50	5164.5-5163.0	1A-1-BR	2.5'-4.0'									CL				
TP1A-1C	193760.26	2183681.50	5163.0-5161.5	1A-1-CS	4.0'-5.5'	100	66	47	19	28	102.6	21.0		CL	CL	14.5	10YR6/4	Moist, light yellowish brown lean clay
TP1A-1C	193760.26	2183681.50	5163.0-5161.5	1A-1-CM	4.0'-5.5'									CL				
TP1A-1C	193760.26	2183681.50	5163.0-5161.5	1A-1-CR	4.0'-5.5'									CL				
TP1A-1D	193760.26	2183681.50	5161.5-5160.0	1A-1-DS	5 5'-7 0'	100	67	36	16	20	108 5	18 5		CL	CL	12.6	10YR7/4	Moist, very pale brown sandy lean clay
TP1A-1D	193760.26	2183681.50	5161.5-5160.0	1A-1-DM	5.5'-7 0'									CL				
TP1A-1D	193760.26	2183681.50	5161.5-5160.0	1A-1-DR	5.5'-7.0'									CL				
TP2A-1A	193460.26	2183681.40	5167.1-5165.6	2A-1-AS	1.0'-2.5'	100	86	39	18	21	102.5	20.5		CL	CL	14.2	10YR4/6	Moist, dark yellowish brown lean clay
TP2A-1A	193460.26	2183681.40	5167.1-5165.6	2A-1-AM	1.0'-2.5'									CL				
TP2A-1A	193460.26	2183681.40	5167.1-5165.6	2A-1-AR	1.0'-2.5'									CL				
TP2A-1B	193460.26	2183681.40	5165 6-5164 1	2A-1-BS	2 5'-4 0'	100	89	34	19	15	106.0	16.5		CL	CL	9 8	10YR5/6	Moist, yellowish brown lean clay
TP2A-1B	193460 26	2183681 40	5165.6-5164 1	2A-1-BM	2 5'-4 0'									CL				
TP2A-1B	193460.26	2183681.40	5165 6-5164 1	2A-1-BR	2 5'-4 0'									CL				
TP2A-1C	193460.26	2183681.40	5164.1-5162.6	2A-1-CS	4.0'-5.5'	100	64	34	17	17	110.0	16.5		CL	CL	10.8	10YR5/6	Moist, yellowish brown sandy lean clay
TP2A-1C	193460.26	2183681.40	5164.1-5162.6	2A-1-CM	4 0'-5 5'									CL				
TP2A-1C	193460.26	2183681.40	5164.1-5162.6	2A-1-CR	4.0'-5 5'									CL				
TP2A-1D	193460.26	2183681.40	5162.6-5161.1	2A-1-DS	5.5'-7 0'	100	78	40	26	14	92.5	26.5		CL	ML	11 2	10YR8/3	Moist, very pale brown silt with sand
TP2A-1D	193460 26	2183681 40	5162.6-5161.1	2A-1-DM	5 5'-7.0'									CL				
TP2A-1D	193460 26	2183681 40	5162 6-5161 1	2A-1-DR	5 5'-7 0'									CL				
TP2A-2A	193560.26	2183781.40	5167.3-5165.8	2A-2-AS	1.0'-2.5'	100	89	37	18	19	105.0	18.0	2.70	CL	CL	11.4	10YR5/4	Moist, yellowish brown lean clay
TP2A-2A	193560.26	2183781.40	5167.3-5165.8	2A-2-AM	1.0'-2.5'									CL				
TP2A-2A	193560.26	2183781.40	5167.3-5165.8	2A-2-AR	1.0'-2.5'									CL				
TP2A-2B	193560.26	2183781.40	5165.8-5164.3	2A-2-BS	2 5'-4 0'	100	67	34	17	17	108 5	16.5	2 70	CL	CL	9 7	10YR7/3	Moist, very pale brown sandy lean clay
TP2A-2B	193560.26	2183781 40	5165 8-5164 3	2A-2-BM	2 5'-4 0'						118.0	13.0		CL				
TP2A-2B	193560.26	2183781.40	5165 8-5164 3	2A-2-BR	2.5'-4.0'						105.5	18.0		CL				
TP2A-2C	193560.26	2183781.40	5164.3-5162.8	2A-2-CS	4.0'-5.5'	100	66	41	19	22	104 0	18.5	2.70	CL	CL	11.4	10YR5/4	Moist, yellowish brown sandy lean clay
TP2A-2C	193560.26	2183781.40	5164.3-5162.8	2A-2-CM	4.0'-5.5'									CL				
TP2A-2C	193560.26	2183781.40	5164.3-5162.8	2A-2-CR	4.0'-5.5'									CL				
TP2A-2D	193560.26	2183781.40	5162.8-5161.3	2A-2-DS	5.5'-7.0'	100	66	38	17	21	107.5	17 5	2 71	CL	CL	9.6	10YR7/3	Moist, very pale brown sandy lean clay
TP2A-2D	193560 26	2183781.40	5162.8-5161.3	2A-2-DM	5.5'-7.0'									CL				
TP2A-2D	193560.26	2183781.40	5162.8-5161.3	2A-2-DR	5 5'-7 0'									CL				
TP2B-1A	193460.26	2183981.60	5168.1-5166.6	2B-1-AS	1.0'-2.5'	100	69	41	18	23	103.5	19.5		CL	CL	13.7	10YR4/4	Moist, dark yellowish brown lean clay
TP2B-1A	193460.26	2183981.60	5168.1-5166.6	2B-1-AM	1.0'-2.5'									CL				
TP2B-1A	193460.26	2183981.60	5168.1-5166.6	2B-1-AR	1.0'-2.5'									CL				
TP2B-1B	193460.26	2183981.60	5166.6-5165 1	2B-1-BS	2 5'-4.0'	100	88	38	19	19	104.5	19.0		CL	CL	10 8	10YR5/6	Moist, yellowish brown lean clay
TP2B-1B	193460.26	2183981.60	5166.6-5165.1	2B-1-BM	2.5'-4.0'									CL				
TP2B-1B	193460 26	2183981.60	5166.6-5165.1	2B-1-BR	2 5'-4.0'									CL				
TP2B-1C	193460.26	2183981.60	5166.1-5163.6	2B-1-CS	4.0'-5.5'	100	70	44	20	24	97.5	23.0		CL	CL	12.8	10YR5/6	Moist, yellowish brown sandy lean clay
TP2B-1C	193460.26	2183981.60	5165.1-5163.6	2B-1-CM	4.0'-5.5'									CL				
TP2B-1C	193460.26	2183981.60	5165.1-5163.6	2B-1-CR	4.0'-5.5'									CL				
TP2B-1D	193460.26	2183981.60	5163 6-5162.1	2B-1-DS	5.5'-7.0'	100	60	35	17	18	109.5	17.0		CL	CL	8.2		

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP2B-1D	193460.26	2183981.60	5163.6-5162.1	2B-1-DM	5.5'-7 0'									CL			10YR6/4	Moist, light yellowish brown sandy lean clay
TP2B-1D	193460.26	2183981.60	5163.6-5162.1	2B-1-DR	5.5'-7.0'									CL				
TP2B-2A	193560.26	2184081.50	5168.0-5166.5	2B-2-AS	1.0'-2.5'	100	67	37	17	20	109.5	16.0		CL	CL	10.0	10YR5/4	Moist, yellowish brown sandy lean clay
TP2B-2A	193560.26	2184081.50	5168.0-5166.5	2B-2-AM	1.0'-2.5'									CL				
TP2B-2A	193560.26	2184081.50	5168.0-5166.5	2B-2-AR	1.0'-2.5'									CL				
TP2B-2B	193560.26	2184081.50	5166.5-5165.0	2B-2-BS	2.5'-4.0'	100	65	33	17	16	113.0	14 5		CL	CL	8.5	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP2B-2B	193560.26	2184081.50	5166.5-5165.0	2B-2-BM	2.5'-4 0'									CL				
TP2B-2B	193560.26	2184081.50	5166.5-5165 0	2B-2-BR	2.5'-4.0'									CL				
TP2B-2C	193560.26	2184081.50	5165.0-5163.5	2B-2-CS	4.0'-5.5'	100	60	31	16	15	114.0	14.0		CL	CL	8.2	10YR5/6	Moist, dark yellowish brown sandy lean clay
TP2B-2C	193560.26	2184081.50	5165.0-5163.5	2B-2-CM	4.0'-5.5'									CL				
TP2B-2C	193560.26	2184081.50	5165.0-5163.5	2B-2-CR	4.0'-5.5'									CL				
TP2B-2D	193560 26	2184081.50	5163.5-5162.0	2B-2-DS	5.5'-7.0'	100	59	34	16	18	109.0	17.0		CL	CL	8.1	10YR6/4	Moist, light yellowish brown sandy lean clay
TP2B-2D	193560.26	2184081.50	5163.5-5162.0	2B-2-DM	5.5'-7.0'									CL				
TP2B-2D	193560.26	2184081.50	5163.5-5162.0	2B-2-DR	5.5'-7.0'									CL				
TP2C-1A	193460.26	2184281.50	5167.4-5165.9	2C-1-AS	1.0'-2.5'	100	62	35	17	18	110.0	16.0		CL	CL	9.5	10YR5/6	Moist, yellowish brown sandy lean clay
TP2C-1A	193460.26	2184281.50	5167.4-5165.9	2C-1-AM	1.0'-2.5'									CL				
TP2C-1A	193460.26	2184281.50	5167.4-5165.9	2C-1-AR	1.0'-2.5'									CL				
TP2C-1B	193460.26	2184281.50	5165.9-5164.4	2C-1-BS	2.5'-4.0'	100	60	35	17	18	109 0	15.5		CL	CL	8.7	10YR5/8	Moist, yellowish brown sandy lean clay
TP2C-1B	193460.26	2184281.50	5165.9-5164.4	2C-1-BM	2.5'-4.0'									CL				
TP2C-1B	193460.26	2184281.50	5165.9-5164.4	2C-1-BR	2.5'-4 0'									CL				
TP2C-1C	193460.26	2184281.50	5164.4-5162.9	2C-1-CS	4.0'-5.5'	100	60	35	17	18	108 0	17.0		CL	CL	9.2	10YR5/8	Moist, yellowish brown sandy lean clay
TP2C-1C	193460.26	2184281.50	5164.4-5162.9	2C-1-CM	4.0'-5.5'									CL				
TP2C-1C	193460.26	2184281.50	5164.4-5162.9	2C-1-CR	4.0'-5.5'									CL				
TP2C-1D	193460.26	2184281.50	5162.9-5161.4	2C-1-DS	5.5'-7.0'	100	58	34	17	17	109 5	16.5		CL	CL	9.3	10YR5/6	Moist, yellowish brown sandy lean clay
TP2C-1D	193460.26	2184281.50	5162.9-5161.4	2C-1-DM	5.5'-7 0'									CL				
TP2C-1D	193460 26	2184281 50	5162 9-5161 4	2C-1-DR	5 5'-7 0'									CL				
TP3A-1A	193160 26	2183681.50	5169 3-5167.8	3A-1-AS	1.0'-2.5'	100	82	39	18	21	106.5	17.5		CL	CL	11.2	2.5YR5/4	Moist, light olive brown lean clay with sand
TP3A-1A	193160.26	2183681 50	5169.3-5167.8	3A-1-AM	1 0'-2 5'									CL				
TP3A-1A	193160.26	2183681.50	5169.3-5167.8	3A-1-AR	1 0'-2.5'									CL				
TP3A-1B	193160.26	2183681.50	5167 8-5166 3	3A-1-BS	2 5'-4.0'	100	82	34	19	15	109.0	16.5		CL	CL	9.9	10YR5/6	Moist, yellowish brown lean clay with sand
TP3A-1B	193160 26	2183681 50	5167 8-5166 3	3A-1-BM	2 5'-4.0'									CL				
TP3A-1B	193160.26	2183681.50	5167.8-5166 3	3A-1-BR	2 5'-4.0'									CL				
TP3A-1C	193160.26	2183681.50	5166.3-5164.8	3A-1-CS	4.0'-5.5'	100	81	36	18	18	106.0	18.0		CL	CL	10.6	10YR5/6	Moist, yellowish brown lean clay with sand
TP3A-1C	193160.26	2183681.50	5166.3-5164.8	3A-1-CM	4.0'-5.5'									CL				
TP3A-1C	193160.26	2183681.50	5166.3-5164.8	3A-1-CR	4.0'-5.5'									CL				
TP3A-1D	193160.26	2183681.50	5164 8-5163.3	3A-1-DS	5 5'-7.0'	100	70	43	18	25	103.5	20.5		CL	CL	13.1	10YR5/6	Moist, Yellowish brown sandy lean clay
TP3A-1D	193160.26	2183681.50	5164.8-5163.3	3A-1-DM	5.5'-7.0'									CL				
TP3A-1D	193160.26	2183681.50	5164.8-5163.3	3A-1-DR	5.5'-7 0'									CL				
TP3A-2A	193260.26	2183781.60	5168.9-5167.4	3A-2-AS	1.0'-2.5'	100	87	39	18	21	105.0	19.0		CL	CL	11.6	10YR4/4	Moist, dark yellowish brown lean clay
TP3A-2A	193260.26	2183781.60	5168.9-5167.4	3A-2-AM	1.0'-2.5'									CL				
TP3A-2A	193260.26	2183781.60	5168.9-5167.4	3A-2-AR	1.0'-2.5'									CL				
TP3A-2B	193260.26	2183781.60	5167.4-5165.9	3A-2-BS	2 5'-4 0'	100	87	36	18	18	106.5	18.5		CL	CL	10 1	10YR5/6	Moist, yellowish brown lean clay
TP3A-2B	193260.26	2183781.60	5167.4-5165.9	3A-2-BM	2 5'-4 0'									CL				
TP3A-2B	193260.26	2183781.60	5167.4-5165.9	3A-2-BR	2.5'-4.0'									CL				
TP3A-2C	193260.26	2183781.60	5165.9-5164.4	3A-2-CS	4.0'-5.5'	100	76	38	18	20	108.5	16.0		CL	CL	11.3	10YR4/6	Moist, dark yellowish brown lean clay with sand
TP3A-2C	193260.26	2183781.60	5165.9-5164.4	3A-2-CM	4.0'-5.5'									CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP3A-2C	193260.26	2183781.60	5165.9-5164.4	3A-2-CR	4.0'-5 5'									CL				
TP3A-2D	193260.26	2183781 60	5164 4-5162 9	3A-2-DS	5.5'-7.0'	100	72	39	20	19	99.0	22.5		CL	CL	10 5	10YR7/4	Moist, very pale brown lean clay with sand
TP3A-2D	193260.26	2183781.60	5164.4-5162.9	3A-2-DM	5.5'-7.0'									CL				
TP3A-2D	193260.26	2183781.60	5164 4-5162 9	3A-2-DR	5.5'-7.0'									CL				
TP3B-1A	193160.26	2183981.50	5168.4-5166.9	3B-1-AS	1.0'-2.5'	100	89	40	20	20	105.0	18.5		CL	CL	12.8	10YR5/6	Moist, yellowish brown lean clay
TP3B-1A	193160.26	2183981.50	5168.4-5166.9	3B-1-AM	1.0'-2.5'									CL				
TP3B-1A	193160.26	2183981.50	5168.4-5166.9	3B-1-AR	1.0'-2.5'									CL				
TP3B-1B	193160.26	2183981 50	5166.9-5165.4	3B-1-BS	2 5'-4 0'	100	75	39	20	19	104.0	18 0		CL	CL	10 3	10YR7/4	Moist, very pale brown lean clay with sand
TP3B-1B	193160.26	2183981 50	5166 9-5165.4	3B-1-BM	2.5'-4.0'									CL				
TP3B-1B	193160.26	2183981.50	5166 9-5165 4	3B-1-BR	2.5'-4.0'									CL				
TP3B-1C	193160.26	2183981.50	5165.4-5163.9	3B-1-CS	4.0'-5.5'	100	60	33	19	14	107.0	18.0		CL	CL	7.1	10YR7/4	Moist, very pale brown sandy lean clay
TP3B-1C	193160.26	2183981.50	5165.4-5163.9	3B-1-CM	4.0'-5 5'									CL				
TP3B-1C	193160.26	2183981.50	5165 4-5163.9	3B-1-CR	4.0'-5.5'									CL				
TP3B-1D	193160.26	2183981 50	5163 9-5162 4	3B-1-DS	5.5'-7.0'	100	34	29	17	12	120 0	12.0		SC	SC	5.7	10YR5/6	Moist, yellowish brown clayey sand
TP3B-1D	193160.26	2183981 50	5163 9-5162 4	3B-1-DM	5.5'-7.0'									SC				
TP3B-1D	193160.26	2183981 50	5163 9-5162 4	3B-1-DR	5 5'-7.0'									SC				
TP3B-2A	193260.26	2184081.40	5168.1-5166.6	3B-2-AS	1.0'-2.5'	100	86	43	18	25	101.0	19.5		CL	CL	12.9	10YR4/6	Moist, dark yellowish brown lean clay
TP3B-2A	193260.26	2184081.40	5168.1-5166.6	3B-2-AM	1.0'-2.5'									CL				
TP3B-2A	193260.26	2184081.40	5168 1-5166.6	3B-2-AR	1.0'-2.5'									CL				
TP3B-2B	193260.26	2184081 40	5166 6-5165 1	3B-2-BS	2 5'-4.0'	100	88	37	19	18	107 5	17.0		CL	CL	10 5	10YR4/6	Moist, dark yellowish brown lean clay
TP3B-2B	193260.26	2184081 40	5166 6-5165 1	3B-2-BM	2.5'-4 0'									CL				
TP3B-2B	193260.26	2184081 40	5166 6-5165 1	3B-2-BR	2 5'-4 0'									CL				
TP3B-2C	193260.26	2184081.40	5165.1-5163 6	3B-2-CS	4.0'-5.5'	100	73	36	18	18	108.0	17.5		CL	CL	9.5	10YR6/6	Moist, brownish yellow lean clay with sand
TP3B-2C	193260.26	2184081.40	5165.1-5163.6	3B-2-CM	4 0'-5.5'									CL				
TP3B-2C	193260 26	2184081.40	5165.1-5163.6	3B-2-CR	4 0'-5.5'									CL				
TP3B-2D	193260 26	2184081.40	5163.6-5162.1	3B-2-DS	5 5'-7 0'	100	68	37	18	19	109.5	17 5		CL	CL	9 7	10YR6/4	Moist, light yellowish brown sandy lean clay
TP3B-2D	193260 26	2184081 40	5163.6-5162.1	3B-2-DM	5 5'-7 0'									CL				
TP3B-2D	193260 26	2184081 40	5163 6-5162.1	3B-2-DR	5.5'-7.0'									CL				
TP3C-1A	193160.26	2184281 50	5168 2-5166 7	3C-1-AS	1.0'-2.5'	100	90	42	20	22	105.5	17.0		CL	CL	13.3	10YR4/4	Moist, dark yellowish brown lean clay
TP3C-1A	193160.26	2184281.50	5168.2-5166.7	3C-1-AM	1 0'-2.5'									CL				
TP3C-1A	193160.26	2184281.50	5168.2-5166.7	3C-1-AR	1.0'-2.5'									CL				
TP3C-1B	193160.26	2184281 50	5166.7-5165.2	3C-1-BS	2.5'-4 0'	100	83	37	20	17	106.5	18.0		CL	CL	10 1	2.5YR6/4	Moist, light yellowish brown lean clay with sand
TP3C-1B	193160.26	2184281.50	5166.7-5165 2	3C-1-BM	2 5'-4 0'									CL				
TP3C-1B	193160.26	2184281.50	5166.7-5165.2	3C-1-BR	2 5'-4 0'									CL				
TP3C-1C	193160.26	2184281.50	5165 2-5163.7	3C-1-CS	4.0'-5.5'	100	41	34	16	18	115.5	14.5		SC	SC	6.5	10YR8/3	Moist, very pale brown clayey sand
TP3C-1C	193160.26	2184281.50	5165 2-5163.7	3C-1-CM	4.0'-5.5'									SC				
TP3C-1C	193160.26	2184281.50	5165.2-5163.7	3C-1-CR	4.0'-5.5'									SC				
TP3C-1D	193160.26	2184281 50	5163.7-5162.2	3C-1-DS	5.5'-7 0'	100	34	31	16	15	120.5	11.5		SC	SC	6 1	10YR7/4	Moist, very pale brown clayey sand
TP3C-1D	193160.26	2184281 50	5163.7-5162.2	3C-1-DM	5.5'-7.0'									SC				
TP3C-1D	193160.26	2184281.50	5163.7-5162 2	3C-1-DR	5 5'-7.0'									SC				
TP3C-2A	193260.26	2184381.50	5168.1-5166.6	3C-2-AS	1.0'-2 5'	100	87	41	19	22	103.0	18.5		CL	CL	12.0	10YR4/4	Moist, dark yellowish brown lean clay
TP3C-2A	193260.26	2184381.50	5168.1-5166.6	3C-2-AM	1.0'-2.5'									CL				
TP3C-2A	193260.26	2184381.50	5168.1-5166.6	3C-2-AR	1.0'-2.5'									CL				
TP3C-2B	193260.26	2184381.50	5166 5-5165.1	3C-2-BS	2.5'-4.0'	100	86	38	19	19	108.0	17.0		CL	CL	9.5	2.5YR5/4	Moist, light olive brown lean clay
TP3C-2B	193260.26	2184381.50	5166.5-5165 1	3C-2-BM	2.5'-4.0'									CL				
TP3C-2B	193260.26	2184381.50	5166.5-5165.1	3C-2-BR	2.5'-4.0'									CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP3C-2C	193260.26	2184381.50	5165.1-5163.6	3C-2-CS	4.0'-5 5'	100	48	31	16	15	114.5	14.5		CL	SC	6.5	10YR6/4	Moist, light yellowish brown clayey sand
TP3C-2C	193260.26	2184381.50	5165.1-5163.6	3C-2-CM	4 0'-5.5'									CL				
TP3C-2C	193260.26	2184381.50	5165.1-5163.6	3C-2-CR	4.0'-5.5'									CL				
TP3C-2D	193260 26	2184381 50	5163 6-5162.1	3C-2-DS	5.5'-7.0'	100	37	28	18	10	118 0	12 5		SC	SC	6 3	10YR5/6	Moist, yellowish brown clayey sand
TP3C-2D	193260 26	2184381 50	5163 6-5162 1	3C-2-DM	5 5'-7 0'									SC				
TP3C-2D	193260.26	2184381 50	5163 6-5162 1	3C-2-DR	5 5'-7 0'									SC				
TP3D-1A	193160.26	2184581.60	5168.9-5167.4	3D-1-AS	1.0'-2.5'	100	90	42	18	24	101.5	20.5	2.70	CL	CL	15.1	10YR4/4	Moist, dark yellowish brown lean clay
TP3D-1A	193160.26	2184581.60	5168 9-5167.4	3D-1-AM	1.0'-2.5'						113.0	16.0		CL				
TP3D-1A	193160.26	2184581 60	5168.9-5167 4	3D-1-AR	1.0'-2.5'						98 5	21.5		CL				
TP3D-1B	193160 26	2184581 60	5167 4-5165 9	3D-1-BS	2 5'-4 0'	100	78	40	20	20	102.0	19 0	2 71	CL	CL	11 4	10YR6/4	Moist, light yellowish brown lean clay with sand
TP3D-1B	193160 26	2184581 60	5167 4-5165 9	3D-1-BM	2 5'-4 0'									CL				
TP3D-1B	193160 26	2184581 60	5167 4-5165 9	3D-1-BR	2 5'-4 0'									CL				
TP3D-1C	193160.26	2184581.60	5165.9-5164.4	3D-1-CS	4 0'-5.5'	100	53	36	18	18	110.5	15.0	2.70	CL	CL	7.9	10YR6/4	Moist, light yellowish brown sandy lean clay
TP3D-1C	193160.26	2184581 60	5165.9-5164.4	3D-1-CM	4 0'-5.5'									CL				
TP3D-1C	193160.26	2184581.60	5165.9-5164 4	3D-1-CR	4 0'-5.5'									CL				
TP3D-1D	193160.26	2184581.60	5164.4-5162 9	3D-1-DS	5 5'-7 0'	100	32	30	16	14	121 0	12 0	2.71	SC	SC	5 9	10YR6/4	Moist, light yellowish brown clayey sand
TP3D-1D	193160 26	2184581.60	5164.4-5162.9	3D-1-DM	5.5'-7 0'									SC				
TP3D-1D	193160 26	2184581 60	5164 4-5162 9	3D-1-DR	5 5'-7.0'									SC				
TP3D-2A	193260 26	2184681.40	5169 0-5167.5	3D-2-AS	1.0'-2.5'	100	88	40	17	23	103 5	19 5		CL	CL	11 4	10YR4/6	Moist, dark yellowish brown lean clay
TP3D-2A	193260.26	2184681 40	5169.0-5167 5	3D-2-AM	1 0'-2 5'									CL				
TP3D-2A	193260 26	2184681 40	5169 0-5167 5	3D-2-AR	1 0'-2 5'									CL				
TP3D-2B	193260.26	2184681.40	5167 5-5166 0	3D-2-BS	2 5'-4 0'	100	75	39	19	20	102 5	19 0		CL	CL	9 9	10YR6/4	Moist, light yellowish brown lean clay with sand
TP3D-2B	193260 26	2184681 40	5167 5-5166 0	3D-2-BM	2 5'-4.0'									CL				
TP3D-2B	193260 26	2184681 40	5167 5-5166 0	3D-2-BR	2 5'-4 0'									CL				
TP3D-2C	193260.26	2184681.40	5166.0-5164 5	3D-2-CS	4 0'-5 5'	100	65	35	19	16	109.5	17.5		CL	CL	7.5	10YR7/4	Moist, very pale brown sandy lean clay
TP3D-2C	193260.26	2184681 40	5166.0-5164 5	3D-2-CM	4.0'-5 5'									CL				
TP3D-2C	193260 26	2184681 40	5166 0-5164 5	3D-2-CR	4.0'-5.5'									CL				
TP3D-2D	193260 26	2184681 40	5164 5-5163 0	3D-2-DS	5 5'-7.0'	100	38	29	17	12	116 5	13 0		SC	SC	5 9	10YR5/6	Moist, yellowish brown clayey sand
TP3D-2D	193260 26	2184681 40	5164 5-5163 0	3D-2-DM	5 5'-7.0'									SC				
TP3D-2D	193260.26	2184681.40	5164.5-5163 0	3D-2-DR	5 5'-7 0'									SC				
TP3E-1A	193160.26	2184881.50	5169.9-5168.4	3E-1-AS	1.0'-2.5'	100	88	40	20	20	103.0	20.5		CL	CL	12.3	10YR4/4	Moist, dark yellowish brown lean clay
TP3E-1A	193160 26	2184881.50	5169.9-5168.4	3E-1-AM	1.0'-2.5'									CL				
TP3E-1A	193160.26	2184881.50	5169.9-5168 4	3E-1-AR	1.0'-2.5'									CL				
TP3E-1B	193160.26	2184881 50	5168 4-5166 9	3E-1-BS	2.5'-4.0'	100	82	38	18	20	107 0	17.0		CL	CL	10 2	10YR5/6	Moist, yellowish brown lean clay with sand
TP3E-1B	193160.26	2184881.50	5168.4-5166.9	3E-1-BM	2 5'-4 0'									CL				
TP3E-1B	193160 26	2184881 50	5168 4-5166 9	3E-1-BR	2.5'-4.0'									CL				
TP3E-1C	193160.26	2184881.50	5166.9-5165.4	3E-1-CS	4 0'-5 5'	100	68	36	19	17	109.5	17.5		CL	CL	9.2	10YR6/4	Moist, light yellowish brown sandy lean clay
TP3E-1C	193160.26	2184881.50	5166.9-5165.4	3E-1-CM	4.0'-5.5'									CL				
TP3E-1C	193160.26	2184881.50	5166.9-5165 4	3E-1-CR	4.0'-5.5'									CL				
TP3E-1D	193160 26	2184881 50	5165,4-5163 9	3E-1-DS	5.5'-7.0'	100	57	33	17	16	108.0	17.5		CL	CL	7.8	10YR6/4	Most, light yellowish brown sandy lean clay
TP3E-1D	193160.26	2184881.50	5165.4-5163.9	3E-1-DM	5 5'-7 0'									CL				
TP3E-1D	193160.26	2184881.50	5165.4-5163 9	3E-1-DR	5 5'-7 0'									CL				
TP4A-1A	192860.26	2183681.50	5169.8-5168.3	4A-1-AS	1.0'-2.5'	100	71	31	17	14	111.0	16.0	2.72	CL	CL	11.0	10YR5/4	Moist, yellowish brown lean clay with sand
TP4A-1A	192860.26	2183681.50	5169.8-5168.3	4A-1-AM	1.0'-2.5'									CL				
TP4A-1A	192860.26	2183681.50	5169.8-5168.3	4A-1-AR	1.0'-2.5'									CL				
TP4A-1B	192860 26	2183681 50	5168 3-5166 8	4A-1-BS	2 5'-4.0'	100	57	27	19	8	117.0	13.0	2.71	CL	CL	7.1		

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP4A-1B	192860.26	2183681 50	5168 3-5166 8	4A-1-BM	2 5'-4 0'									CL			10YR5/6	Moist, yellowish brown sandy lean clay
TP4A-1B	192860 26	2183681.50	5168 3-5166 8	4A-1-BR	2 5'-4.0'									CL				
TP4A-1C	192860 26	2183681.50	5166.8-5165.3	4A-1-CS	4.0'-5.5'	100	80	33	18	15	110.5	15.0	2.72	CL	CL	9.6	10YR5/6	Moist, yellowish brown lean clay with sand
TP4A-1C	192860.26	2183681.50	5166.8-5165.3	4A-1-CM	4.0'-5.5'									CL				
TP4A-1C	192860.26	2183681.50	5166.8-5165 3	4A-1-CR	4.0'-5.5'									CL				
TP4A-1D	192860 26	2183681.50	5165.3-5163 8	4A-1-DS	5 5'-7 0'	100	71	36	17	19	107 5	18 0	2.72	CL	CL	11 7	10YR4/6	Moist, dark yellowish brown lean clay with sand
TP4A-1D	192860 26	2183681 50	5165 3-5163.8	4A-1-DM	5 5'-7 0'						116 0	14 0		CL				
TP4A-1D	192860.26	2183681.50	5165 3-5163 8	4A-1-DR	5 5'-7.0'						103.5	19.5		CL				
TP4A-2A	192960 26	2183781.50	5170.3-5168.8	4A-2-AS	1 0'-2.5'	100	78	39	18	21	108 5	16 0		CL	CL	13.0	10YR3/6	Moist, dark yellowish brown lean clay with sand
TP4A-2A	192960.26	2183781.50	5170.3-5168 8	4A-2-AM	1 0'-2.5'									CL				
TP4A-2A	192960.26	2183781.50	5170.3-5168 8	4A-2-AR	1.0'-2.5'									CL				
TP4A-2B	192960 26	2183781.50	5168.8-5167 3	4A-2-BS	2 5'-4 0'	100	90	38	18	20	106 5	18 0		CL	CL	11 0	10YR4/6	Moist, dark yellowish brown lean clay
TP4A-2B	192960 26	2183781.50	5168.8-5167 3	4A-2-BM	2 5'-4 0'									CL				
TP4A-2B	192960 26	2183781.50	5168 8-5167 3	4A-2-BR	2 5'-4 0'									CL				
TP4A-2C	192960.26	2183781.50	5167.3-5165 8	4A-2-CS	4.0'-5.5'	100	66	38	17	21	109.0	16.5		CL	CL	10.0	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP4A-2C	192960 26	2183781.50	5167.3-5165.8	4A-2-CM	4 0'-5.5'									CL				
TP4A-2C	192960.26	2183781.50	5167.3-5165.8	4A-2-CR	4 0'-5 5'									CL				
TP4A-2D	192960 26	2183781 50	5165 8-5164 3	4A-2-DS	5 5'-7 0'	100	56	37	19	18	105.0	18.5		CL	CL	8 1	10YR6/4	Moist, light yellowish brown sandy lean clay
TP4A-2D	192960 26	2183781 50	5165 8-5164 3	4A-2-DM	5.5'-7 0'									CL				
TP4A-2D	192960 26	2183781 50	5165 8-5164 3	4A-2-DR	5 5'-7 0'									CL				
TP4B-1A	192860 26	2183981 50	5169 8-5168 3	4B-1-AS	1 0'-2 5'	100	69	41	18	23	105.0	18.5		CL	CL	11 6	2 5YR4/4	Moist, olive brown sandy lean clay
TP4B-1A	192860.26	2183981.50	5169 8-5168 3	4B-1-AM	1.0'-2.5'									CL				
TP4B-1A	192860.26	2183981.50	5169.8-5168 3	4B-1-AR	1.0'-2.5'									CL				
TP4B-1B	192860 26	2183981 50	5168.3-5166 8	4B-1-BS	2 5'-4 0'	100	60	35	17	18	111 5	15 5		CL	CL	9.4	10YR5/8	Most, yellowish brown sandy lean clay
TP4B-1B	192860 26	2183981 50	5168.3-5166.8	4B-1-BM	2 5'-4 0'									CL				
TP4B-1B	192860 26	2183981 50	5168 3-5166 8	4B-1-BR	2 5'-4 0'									CL				
TP4B-1C	192860 26	2183981.50	5166 8-5165 3	4B-1-CS	4 0'-5.5'	100	60	38	17	21	112 0	16.0		CL	CL	9 8	10YR5/6	Moist, yellowish brown sandy lean clay
TP4B-1C	192860 26	2183981.50	5166 8-5165 3	4B-1-CM	4 0'-5 5'									CL				
TP4B-1C	192860 26	2183981.50	5166.8-5165 3	4B-1-CR	4 0'-5 5'									CL				
TP4B-1D	192860 26	2183981.50	5165.3-5163 8	4B-1-DS	5 5'-7 0'	100	61	37	17	20	111 0	16 0		CL	CL	8.5	10YR5/6	Moist, yellowish brown sandy lean clay
TP4B-1D	192860.26	2183981 50	5165.3-5163.8	4B-1-DM	5 5'-7 0'									CL				
TP4B-1D	192860.26	2183981.50	5165.3-5163.8	4B-1-DR	5 5'-7 0'									CL				
TP4B-2A	192960.26	2184081.50	5169.5-5168 0	4B-2-AS	1.0'-2.5'	100	83	38	18	20	105.0	19.0		CL	CL	11 6	10YR 4/6	Moist, dark yellowish brown lean clay with sand
TP4B-2A	192960.26	2184081.50	5169.5-5168.0	4B-2-AM	1.0'-2 5'									CL				
TP4B-2A	192960.26	2184081.50	5169.5-5168.0	4B-2-AR	1.0'-2.5'									CL				
TP4B-2B	192960 26	2184081.50	5168.0-5166.5	4B-2-BS	2.5'-4 0'	100	73	37	17	20	108 5	16 5		CL	CL	9.5	10YR 5/6	Moist, yellowish brown lean clay with sand
TP4B-2B	192960.26	2184081.50	5168.0-5166 5	4B-2-BM	2.5'-4.0'									CL				
TP4B-2B	192960 26	2184081.50	5168 0-5166 5	4B-2-BR	2.5'-4 0'									CL				
TP4B-2C	192960.26	2184081.50	5166.5-5165.0	4B-2-CS	4.0'-5 5'	100	65	36	16	20	106.0	18.0		CL	CL	9.3	10YR 5/6	Moist, yellowish brown sandy lean clay
TP4B-2C	192960.26	2184081.50	5166.5-5165.0	4B-2-CM	4.0'-5.5'									CL				
TP4B-2C	192960.26	2184081.50	5166.5-5165.0	4B-2-CR	4.0'-5.5'									CL				
TP4B-2D	192960 26	2184081.50	5165 0-5163 5	4B-2-DS	5 5'-7.0'	100	58	34	16	18	109.0	16.5		CL	CL	8.1	10YR 6/4	Moist, light yellowish brown sandy lean clay
TP4B-2D	192960 26	2184081.50	5165.0-5163 5	4B-2-DM	5 5'-7 0'									CL				
TP4B-2D	192960.26	2184081 50	5165.0-5163.5	4B-2-DR	5 5'-7 0'									CL				
TP4C-1A	192860.26	2184281.50	5170.8-5169.3	4C-1-AS	1.0'-2.5'	100	68	36	19	17	109.5	17.5		CL	CL	9.5	10YR6/4	Moist, light yellowish brown sandy lean clay
TP4C-1A	192860.26	2184281.50	5170.8-5169.3	4C-1-AM	1.0'-2.5'									CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5

LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP4C-1A	192860 26	2184281.50	5170.8-5169.3	4C-1-AR	1.0'-2 5'									CL				
TP4C-1B	192860 26	2184281 50	5169 3-5167.8	4C-1-BS	2.5'-4 0'	100	51	35	16	19	112 0	14 0		CL	CL	7 6	10YR6/4	Moist, light yellowish brown sandy lean clay
TP4C-1B	192860.26	2184281.50	5169 3-5167 8	4C-1-BM	2 5'-4 0'									CL				
TP4C-1B	192860 26	2184281.50	5169.3-5167.8	4C-1-BR	2 5'-4 0'									CL				
TP4C-1C	192860 26	2184281.50	5167.8-5166.3	4C-1-CS	4.0'-5.5'	100	51	36	16	20	113.5	13 5		CL	CL	7 8	10YR5/6	Moist, yellowish brown sandy lean clay
TP4C-1C	192860 26	2184281.50	5167 8-5166.3	4C-1-CM	4.0'-5.5'									CL				
TP4C-1C	192860.26	2184281.50	5167 8-5166.3	4C-1-CR	4.0'-5.5'									CL				
TP4C-1D	192860 26	2184281 50	5166.3-5164.8	4C-1-DS	5 5'-7 0'	100	56	35	15	20	115 0	14 0		CL	CL	7.8	10YR5/6	Moist, yellowish brown sandy lean clay
TP4C-1D	192860 26	2184281 50	5166 3-5164.8	4C-1-DM	5 5'-7 0'									CL				
TP4C-1D	192860 26	2184281 50	5166 3-5164 8	4C-1-DR	5 5'-7 0'									CL				
TP4C-2A	192960 26	2184381.50	5170 2-5168.7	4C-2-AS	1.0'-2 5'	100	88	40	20	20	104 5	18 5		CL	CL	11.4	10YR 5/6	Moist, yellowish brown lean clay
TP4C-2A	192960.26	2184381.50	5170.2-5168.7	4C-2-AM	1.0'-2.5'									CL				
TP4C-2A	192960 26	2184381.50	5170.2-5168.7	4C-2-AR	1.0'-2.5'									CL				
TP4C-2B	192960 26	2184381 50	5168 7-5167.2	4C-2-BS	2.5'-4.0'	100	62	38	20	18	100.5	20 5		CL	CL	10 9	10YR 7/4	Moist, very pale brown sandy lean clay
TP4C-2B	192960.26	2184381 50	5168 7-5167 2	4C-2-BM	2 5'-4.0'									CL				
TP4C-2B	192960.26	2184381.50	5168 7-5167 2	4C-2-BR	2 5'-4 0'									CL				
TP4C-2C	192960 26	2184381 50	5167.2-5165.7	4C-2-CS	4 0'-5 5'	100	61	36	18	18	104.0	19 5		CL	CL	8 5	10YR 6/4	Moist, light yellowish brown sandy lean clay
TP4C-2C	192960 26	2184381.50	5167.2-5165.7	4C-2-CM	4.0'-5 5'									CL				
TP4C-2C	192960 26	2184381.50	5167 2-5165.7	4C-2-CR	4.0'-5.5'									CL				
TP4C-2D	192960 26	2184381 50	5165 7-5164 2	4C-2-DS	5 5'-7.0'	100	50	31	17	14	115 5	14 5		CL	CL	6.8	10YR 6/4	Moist, light yellowish brown sandy lean clay
TP4C-2D	192960 26	2184381.50	5165 7-5164 2	4C-2-DM	5 5'-7 0'									CL				
TP4C-2D	192960 26	2184381.50	5165.7-5164 2	4C-2-DR	5 5'-7 0'									CL				
TP4D-1A	192860.26	2184581.50	5171.5-5170 0	4D-1-AS	1.0'-2 5'	100	63	42	18	24	109 0	16.5		CL	CL	11.1	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP4D-1A	192860 26	2184581 50	5171.5-5170.0	4D-1-AM	1 0'-2.5'									CL				
TP4D-1A	192860 26	2184581.50	5171.5-5170 0	4D-1-AR	1 0'-2 5'									CL				
TP4D-1B	192860.26	2184581 50	5170 0-5168 5	4D-1-BS	2 5'-4.0'	100	71	42	21	21	98 5	22 0		CL	CL	12 5	10YR6/6	Moist, brownish yellow lean clay with sand
TP4D-1B	192860.26	2184581 50	5170 0-5168 5	4D-1-BM	2 5'-4 0'									CL				
TP4D-1B	192860 26	2184581 50	5170 0-5168.5	4D-1-BR	2 5'-4 0'									CL				
TP4D-1C	192860 26	2184581 50	5168.5-5167 0	4D-1-CS	4.0'-5 5'	100	71	42	21	21	100.0	21.5		CL	CL	10 7	10YR6/4	Moist, light yellowish brown sandy lean clay
TP4D-1C	192860.26	2184581.50	5168 5-5167 0	4D-1-CM	4.0'-5.5'									CL				
TP4D-1C	192860.26	2184581.50	5168.5-5167.0	4D-1-CR	4.0'-5 5'									CL				
TP4D-1D	192860.26	2184581 50	5167 0-5165 5	4D-1-DS	5 5'-7 0'	100	56	40	17	23	113.5	16.0		CL	CL	9 4	10YR5/6	Moist, yellowish brown sandy lean clay
TP4D-1D	192860 26	2184581.50	5167.0-5165 5	4D-1-DM	5 5'-7 0'									CL				
TP4D-1D	192860 26	2184581 50	5167 0-5165.5	4D-1-DR	5 5'-7 0'									CL				
TP4D-2A	192960.26	2184681.50	5171 0-5169 5	4D-2-AS	1.0'-2.5'	100	62	39	17	22	108.0	18.0		CL	CL	9.8	10YR5/6	Moist, yellowish brown sandy lean clay
TP4D-2A	192960.26	2184681.50	5171.0-5169.5	4D-2-AM	1.0'-2.6'									CL				
TP4D-2A	192960.26	2184681.50	5171.0-5169.5	4D-2-AR	1.0'-2.5'									CL				
TP4D-2B	192960 26	2184681.50	5169.5-5168 0	4D-2-BS	2 5'-4 0'	100	73	45	21	24	100 0	22 0		CL	CL	10.6	10YR8/3	Moist, very pale brown lean clay with sand
TP4D-2B	192960.26	2184681.50	5169.5-5168.0	4D-2-BM	2 5'-4 0'									CL				
TP4D-2B	192960.26	2184681.50	5169 5-5168 0	4D-2-BR	2.5'-4.0'									CL				
TP4D-2C	192960.26	2184681.50	5168.0-5166.5	4D-2-CS	4 0'-5.5'	100	69	38	19	19	99.0	22.0		CL	CL	8.5	10YR8/3	Moist, very pale brown sandy lean clay
TP4D-2C	192960.26	2184681.50	5168.0-5166.5	4D-2-CM	4.0'-5.5'									CL				
TP4D-2C	192960.26	2184681.50	5168.0-5166.5	4D-2-CR	4.0'-5.5'									CL				
TP4D-2D	192960.26	2184681.50	5166 5-5165 0	4D-2-DS	5.5'-7.0'	100	45	29	15	14	115.0	14.5		CL	SC	7 7	10YR8/3	Moist, very pale brown clayey sand
TP4D-2D	192960.26	2184681.50	5166.5-5165 0	4D-2-DM	5.5'-7.0'									CL				
TP4D-2D	192960 26	2184681 50	5166.5-5165.0	4D-2-DR	5 5'-7 0'									CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5

LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP4E-1A	192860.26	2184881.50	5172.5-5171 0	4E-1-AS	1 0'-2.5'	100	80	36	18	18	106.5	18.0		CL	CL	10.9	10YR4/4	Moist, dark yellowish brown lean clay with sand
TP4E-1A	192860.26	2184881.50	5172.5-5171 0	4E-1-AM	1 0'-2 5'									CL				
TP4E-1A	192860.26	2184881.50	5172 5-5171 0	4E-1-AR	1.0'-2.5'									CL				
TP4E-1B	192860.26	2184881 50	5171 0-5169 5	4E-1-BS	2 5'-4.0'	100	67	33	17	16	110.5	15.5		CL	CL	8 9	10YR5/8	Moist, yellowish brown sandy lean clay
TP4E-1B	192860 26	2184881.50	5171 0-5169 5	4E-1-BM	2 5'-4 0'									CL				
TP4E-1B	192860 26	2184881 50	5171.0-5169.5	4E-1-BR	2 5'-4 0'									CL				
TP4E-1C	192860.26	2184881 50	5169.5-5168.0	4E-1-CS	4.0'-5 5'	100	63	33	18	15	106.0	18.5		CL	CL	8 3	10YR7/4	Moist, very pale brown sandy lean clay
TP4E-1C	192860 26	2184881.50	5169 5-5168.0	4E-1-CM	4.0'-5.5'									CL				
TP4E-1C	192860 26	2184881 50	5169.5-5168.0	4E-1-CR	4.0'-5.5'									CL				
TP4E-1D	192860 26	2184881 50	5168 0-5166 5	4E-1-DS	5 5'-7 0'	100	53	33	17	16	111 0	15 0		CL	CL	7 8	10YR6/4	Dry, light yellowish brown sandy lean clay
TP4E-1D	192860 26	2184881.50	5168.0-5166 5	4E-1-DM	5 5'-7 0'									CL				
TP4E-1D	192860 26	2184881.50	5168.0-5166 5	4E-1-DR	5 5'-7 0'									CL				
TP4E-2A	192960 26	2184981.50	5171 3-5169.8	4E-2-AS	1.0'-2 5'	100	88	41	19	22	103.5	19 5		CL	CL	12 9	10YR4/6	Moist, dark yellowish brown lean clay
TP4E-2A	192960 26	2184981.50	5171 3-5169.8	4E-2-AM	1.0'-2.5'									CL				
TP4E-2A	192960.26	2184981 50	5171.3-5169 8	4E-2-AR	1 0'-2.5'									CL				
TP4E-2B	192960 26	2184981.50	5169 8-5168 3	4E-2-BS	2 5'-4 0'	100	78	37	17	20	107 0	18 0		CL	CL	9 4	10YR4/4	Moist, dark yellowish brown lean clay with sand
TP4E-2B	192960 26	2184981 50	5169 8-5168 3	4E-2-BM	2 5'-4 0'									CL				
TP4E-2B	192960 26	2184981 50	5169 8-5168 3	4L-2-BR	2 5'-4.0'									CL				
TP4E-2C	192960.26	2184981.50	5168 3-5166 8	4E-2 CS	4 0'-5 5'	100	60	37	20	17	104 5	19 0		CL	CL	8.9	10YR7/4	Moist, very pale brown sandy lean clay
TP4E-2C	192960 26	2184981.50	5168.3-5166 8	4E-2-CM	4 0'-5 5'									CL				
TP4E-2C	192960 26	2184981.50	5168.3-5166.8	4E-2-CR	4 0' 5 5'									CL				
TP4E-2D	192960 26	2184981 50	5166 8-5165 3	4L-2-DS	5 5'-7.0'	100	36	33	15	18	119.5	12 5		SC	CL	6 4	10YR5/6	Moist, yellowish brown clayey sand
TP4E-2D	192960 26	2184981 50	5166 8-5165 3	4E-2-DM	5.5'-7.0'									SC				
TP4E-2D	192960 26	2184981 50	5166 8-5165 3	4E-2-DR	5 5'-7.0'									SC				
TP5A-1A	192560.26	2183681 50	5171 3-5169 8	5A-1-AS	1 0'-2 5'	100	63	28	18	10	113.0	15.0		CL	CL	9.0	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP5A-1A	192560 26	2183681 50	5171 3-5169 8	5A-1-AM	1 0'-2 5'									CL				
TP5A-1A	192560 26	2183681 50	5171 3-5169 8	5A-1-AR	1 0'-2.5'									CL				
TP5A-1B	192560.26	2183681 50	5169 8-5168 3	5A-1-BS	2 5'-4 0'	100	76	30	18	12	110 0	15 0		CL	CL	9 3	10YR4/6	Moist, dark yellowish brown lean clay with sand
TP5A-1B	192560 26	2183681.50	5169 8-5168 3	5A-1-BM	2 5'-4 0'									CL				
TP5A-1B	192560 26	2183681 50	5169.8-5168 3	5A-1-BR	2 5'-4 0'									CL				
TP5A-1C	192560.26	2183681.50	5168.3-5166 8	5A-1-CS	4.0'-5.5'	100	68	33	17	16	112.0	15.0		CL	CL	9.7	10YR5/6	Moist, yellowish brown sandy lean clay
TP5A-1C	192560.26	2183681.50	5168 3-5166 8	5A-1-CM	4 0'-5.5'									CL				
TP5A-1C	192560.26	2183681.50	5168.3-5166 8	5A-1-CR	4 0'-5 5'									CL				
TP5A-1D	192560 26	2183681 50	5166 8-5165 3	5A-1-DS	5.5'-7 0'	100	57	33	16	17	114 0	14 5		CL	CL	9 4	10YR5/8	Moist, yellowish brown sandy lean clay
TP5A-1D	192560.26	2183681 50	5166 8-5165 3	5A-1-DM	5 5'-7.0'									Cl				
TP5A-1D	192560.26	2183681 50	5166 8-5165 3	5A-1-DR	5 5'-7 0'									CL				
TP5A-2A	192660.26	2183781.50	5171 3-5169 8	5A-2-AS	1 0'-2 5'	100	87	38	19	19	106.0	18.0		CL	CL	13 3	10YR4/4	Moist, dark yellowish brown lean clay
TP5A-2A	192660.26	2183781.50	5171.3-5169.8	5A-2-AM	1.0'-2 5'									CL				
TP5A-2A	192660.26	2183781.50	5171.3-5169 8	5A-2-AR	1.0'-2 5'									CL				
TP5A-2B	192660.26	2183781.50	5169.8-5168 3	5A-2-BS	2 5'-4 0'	100	86	34	18	16	107 5	17.5		CL	CL	11.8	10YR5/6	Moist, dark yellowish brown lean clay
TP5A-2B	192660.26	2183781 50	5169 8-5168 3	5A-2-BM	2 5'-4 0'									CL				
TP5A-2B	192660.26	2183781 50	5169 8-5168 3	5A-2-BR	2 5'-4 0'									CL				
TP5A-2C	192660.26	2183781.50	5168.3-5166.8	5A-2-CS	4.0'-5.5'	100	80	37	18	19	104.5	19.5		CL	CL	12.9	10YR4/6	Moist, dark yellowish brown lean clay with sand
TP5A-2C	192660.26	2183781.50	5168.3-5166.8	5A-2-CM	4.0'-5.5'									CL				
TP5A-2C	192660.26	2183781.50	5168.3-5166.8	5A-2-CR	4 0'-5.5'									CL				
TP5A-2D	192660 26	2183781.50	5166.8-5165.3	5A-2-DS	5 5'-7 0'	100	71	39	19	20	101 5	20 5		CL	CL	14 5		

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP5A-2D	192660.26	2183781 50	5166 8-5165 3	5A-2-DM	5 5'-7 0'									CL			10YR6/4	Moist, yellowish brown lean clay with sand
TP5A-2D	192660 26	2183781 50	5166 8-5165 3	5A-2-DR	5 5'-7.0'									CL				
TP5B-1A	192560 26	2183981.50	5171.9-5170.4	5B-1-AS	1 0'-2.5'	100	90	39	19	20	104.5	18.5		CL	CL	12.9	10YR4/6	Moist, dark yellowish brown lean clay
TP5B-1A	192560.26	2183981.50	5171.9-5170.4	5B-1-AM	1.0'-2 5'									CL				
TP5B-1A	192560 26	2183981 50	5171.9-5170.4	5B-1-AR	1.0'-2.5'									CL				
TP5B-1B	192560.26	2183981 50	5170 4-5168 9	5B-1-BS	2 5'-4 0'	100	69	39	18	21	106 5	17 5		CL	CL	11 6	10YR5/6	Moist, yellowish brown sandy lean clay
TP5B-1B	192560.26	2183981 50	5170 4-5168 9	5B-1-BM	2.5'-4.0'									CL				
TP5B-1B	192560 26	2183981.50	5170 4-5168 9	5B-1-BR	2 5'-4.0'									CL				
TP5B-1C	192560.26	2183981.50	5168.9-5167.4	5B-1-CS	4 0'-5 5'	100	70	39	22	17	98.5	22 5		CL	CL	12.2	10YR7/4	Moist, very pale brown lean clay with sand
TP5B-1C	192560.26	2183981.50	5168.9-5167 4	5B-1-CM	4 0'-5.5'									CL				
TP5B-1C	192560 26	2183981.50	5168 9-5167.4	5B-1-CR	4.0'-5 5'									CL				
TP5B-1D	192560 26	2183981 50	5167 4-5165 9	5B-1-DS	5 5'-7 0'	100	61	36	18	18	105 5	18 5		CL		8 8	10YR7/4	Moist, very pale brown sandy lean clay
TP5B-1D	192560 26	2183981 50	5167 4-5165 9	5B-1-DM	5 5'-7 0'									CL	CL			
TP5B-1D	192560 26	2183981.50	5167 4-5165 9	5B-1-DR	5 5'-7 0'									CL				
TP5B-2A	192660.26	2184081.50	5172.5-5171.0	5B-2-AS	1.0'-2.5'	100	77	37	18	19	105.5	18.0	2.71	CL	CL	11 1	10YR5/4	Moist, yellowish brown lean clay with sand
TP5B-2A	192660 26	2184081 50	5172 5-5171.0	5B-2-AM	1.0'-2.5'									CL				
TP5B-2A	192660.26	2184081 50	5172.5-5171 0	5B-2-AR	1.0'-2.5'									CL				
TP5B-2B	192660 26	2184081 50	5171 0-5169 5	5B-2-BS	2 5'-4 0'	100	59	34	17	17	111 5	15 5	2 73	CL	CL	8 6	10YR5/6	Moist, yellowish brown sandy lean clay
TP5B-2B	192660 26	2184081 50	5171 0-5169 5	5B-2-BM	2 5'-4 0'						122 5	12 0		CL				
TP5B-2B	192660 26	2184081 50	5171 0-5169 5	5B-2-BR	2 5' 4 0'						110 0	16 0		CL				
TP5B-2C	192660 26	2184081 50	5169 5-5168 0	5B-2-CS	4 0'-5 5'	99	57	33	16	17	114 0	14 5	2 70	CL	CL	8.8	10YR5/6	Moist, yellowish brown sandy lean clay
TP5B-2C	192660 26	2184081.50	5169.5-5168.0	5B-2-CM	4 0'-5 5'									CL				
TP5B-2C	192660 26	2184081 50	5169.5-5168.0	5B-2-CR	4.0'-5 5'									CL				
TP5B-2D	192660 26	2184081 50	5168 0-5166 5	5B-2-DS	5 5'-7 0'	100	56	32	16	16	113.5	14.0	2 73	CL	CL	6 9	10YR5/4	Moist, yellowish brown sandy lean clay
TP5B-2D	192660 26	2184081 50	5168 0-5166 5	5B-2-DM	5 5'-7 0'									CL				
TP5B-2D	192660 26	2184081 50	5168 0-5166 5	5B-2-DR	5 5'-7 0'									CL				
TP5C-1A	192560 26	2184281 50	5173 6-5172.1	5C-1-AS	1 0' 2 5'	100	89	41	20	21	105 0	19 0		CL	CL	12 7	10YR4/4	Moist, dark yellowish brown lean clay
TP5C-1A	192560 26	2184281 50	5173 6-5172 1	5C-1-AM	1 0'-2 5'									CL				
TP5C-1A	192560 26	2184281.50	5173.6-5172 1	5C-1-AR	1 0'-2.5'									CL				
TP5C-1B	192560.26	2184281 50	5172 1-5170 6	5C-1-BS	2 5'-4 0'	100	91	36	19	17	105 5	18 0		CL	CL	10 2	2 5YR5/4	Moist, light olive brown lean clay with sand
TP5C-1B	192560.26	2184281 50	5172 1-5170 6	5C-1-BM	2 5'-4 0'									CL				
TP5C-1B	192560.26	2184281 50	5172 1-5170 6	5C-1-BR	2 5'-4 0'									CL				
TP5C-1C	192560.26	2184281,50	5170 6-5169 1	5C-1-CS	4.0'-5.5'	100	68	34	17	17	111.5	15.5		CL	CL	8.7	10YR7/4	Moist, very pale brown sandy lean clay
TP5C-1C	192560.26	2184281.50	5170.6-5169 1	5C-1-CM	4.0'-5.5'									CL				
TP5C-1C	192560.26	2184281.50	5170 6-5169.1	5C-1-CR	4.0'-5.5'									CL				
TP5C-1D	192560 26	2184281.50	5169.1-5167 6	5C-1-DS	5 5'-7.0'	100	61	34	17	17	109 0	17.0		CL	CL	7 5	10YR8/3	Moist, very pale brown sandy lean clay
TP5C-1D	192560.26	2184281 50	5169 1-5167 6	5C-1-DM	5.5'-7 0'									CL				
TP5C-1D	192560 26	2184281.50	5169.1-5167 6	5C-1-DR	5 5'-7.0'									CL				
TP5C-2A	192660.26	2184381.50	5173.9-5172.4	5C-2-AS	1.0'-2 5'	100	86	40	19	21	105.0	19.0		CL	CL	12.2	2.5YR4/4	Moist, olive brown lean clay
TP5C-2A	192660.26	2184381.50	5173.9-5172.4	5C-2-AM	1.0'-2.5'									CL				
TP5C-2A	192660.26	2184381.50	5173 9-5172.4	5C-2-AR	1.0'-2.5'									CL				
TP5C-2B	192660 26	2184381.50	5172.4-5170 9	5C-2-BS	2 5'-4.0'	100	72	41	18	23	101.5	18.0		CL	CL	10 8	10YR5/6	Moist, yellowish brown lean clay with sand
TP5C-2B	192660 26	2184381.50	5172.4-5170 9	5C-2-BM	2 5'-4 0'									CL				
TP5C-2B	192660 26	2184381 50	5172 4-5170.9	5C-2-BR	2 5'-4 0'									CL				
TP5C-2C	192660 26	2184381.50	5170.9-5169.4	5C-2-CS	4 0'-5 5'	100	78	40	22	18	96.5	23 0	2.71	CL	CL	8.8	10YR7/4	Moist, very pale brown lean clay with sand
TP5C-2C	192660.26	2184381.50	5170 9-5169.4	5C-2-CM	4 0'-5.5'						105.0	19.0		CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP5C-2C	192660.26	2184381 50	5170.9-5169.4	5C-2-CR	4.0'-5 5'						93.5	25.0		CL				
TP5C-2D	192660 26	2184381.50	5169.4-5167 9	5C-2-DS	5 5'-7 0'	100	65	33	19	14	106 5	18 0		CL	CL	8.0	10YR7/4	Moist, very pale brown sandy lean clay
TP5C-2D	192660 26	2184381.50	5169 4-5167 9	5C-2-DM	5 5'-7.0'									CL				
TP5C-2D	192660 26	2184381.50	5169.4-5167 9	5C-2-DR	5 5'-7 0'									CL				
TP5D-1A	192560 26	2184581 50	5174.5-5173.0	5D-1-AS	1.0'-2 5'	100	91	39	20	19	105.5	18.0		CL	CL	11 0	10YR6/4	Moist, light yellowish brown lean clay
TP5D-1A	192560.26	2184581.50	5174.5-5173 0	5D-1-AM	1 0'-2.5'									CL				
TP5D-1A	192560.26	2184581.50	5174.5-5173.0	5D-1-AR	1.0'-2 5'									CL				
TP5D-1B	192560 26	2184581 50	5173 0-5171.5	5D-1-BS	2 5'-4 0'	100	74	40	19	21	108.0	17 0		CL	CL	10 4	10YR5/8	Moist, yellowish brown lean clay with sand
TP5D-1B	192560 26	2184581 50	5173 0-5171 5	5D-1-BM	2 5'-4 0'									CL				
TP5D-1B	192560 26	2184581.50	5173 0-5171 5	5D-1-BR	2 5'-4 0'									CL				
TP5D-1C	192560 26	2184581 50	5171.5-5170.0	5D-1-CS	4 0'-5.5'	100	76	40	22	18	100.5	21.0		CL	CL	9.3	10YR8/3	Moist, very pale brown lean clay with sand
TP5D-1C	192560.26	2184581 50	5171 5-5170.0	5D-1-CM	4.0'-5.5'									CL				
TP5D-1C	192560.26	2184581 50	5171 5-5170 0	5D-1-CR	4.0'-5.5'									CL				
TP5D-1D	192560 26	2184581 50	5170 0-5168 5	5D-1-DS	5 5'-7 0'	100	70	38	19	19	107 0	19 0		CL	CL	8 9	10YR8/3	Moist, very pale brown sandy lean clay
TP5D-1D	192560 26	2184581.50	5170.0-5168 5	5D-1-DM	5 5'-7 0'									CL				
TP5D-1D	192560 26	2184581 50	5170 0-5168 5	5D-1-DR	5 5'-7 0'									CL				
TP5D-2A	192660 26	2184681.50	5173.6-5172.1	5D-2-AS	1 0'-2 5'	100	85	44	20	24	105.0	19.0		CL	CL	12 4	2.5YR4/4	Moist, olive brown lean clay with sand
TP5D-2A	192660 26	2184681 50	5173.6-5172.1	5D-2-AM	1 0' 2 5'									CL				
TP5D-2A	192660 26	2184681.50	5173 6-5172 1	5D-2-AR	1 0'-2 5'									CL				
TP5D-2B	192660 26	2184681 50	5172 1-5170 6	5D-2-BS	2 5'-4 0'	100	85	39	19	20	105 0	19 0		CL	CL	11 5	10YR5/6	Moist, yellowish brown lean clay with sand
TP5D-2B	192660 26	2184681 50	5172 1-5170 6	5D 2-BM	2 5'-4 0'									CL				
TP5D-2B	192660 26	2184681 50	5172 1-5170 6	5D-2-BR	2 5'-4 0'									CI				
TP5D-2C	192660.26	2184681 50	5170.6-5169.1	5D-2-CS	4.0'-5 5'	100	70	41	22	19	99.0	21.5		CL	CL	10.3	10YR7/4	Moist, very pale brown sandy lean clay with sand
TP5D-2C	192660 26	2184681 50	5170 6-5169 1	5D-2-CM	4 0'-5.5'									CL				
TP5D-2C	192660.26	2184681.50	5170 6-5169 1	5D-2-CR	4 0'-5 5'									CL				
TP5D-2D	192660 26	2184681 50	5169.1-5176 6	5D-2-DS	5 5'-7 0'	100	57	40	18	22	109.5	17.0		CL	CL	8 8	10YR8/3	Moist, very pale brown sandy lean clay
TP5D-2D	192660 26	2184681 50	5169 1-5176 6	5D-2-DM	5 5'-7 0'									CL				
TP5D-2D	192660.26	2184681 50	5169 1-5176 6	5D-2-DR	5 5'-7 0'									CL				
TP6A-1A	192260.26	2183681 50	5172 4-5170 9	6A-1-AS	1 0'-2 5'	100	82	35	17	18	108 5	16 5	2 72	CL	CL	11 6	10YR4/4	Moist, dark yellowish brown lean clay with sand
TP6A-1A	192260.26	2183681.50	5172 4-5170 9	6A-1 AM	1 0'-2 5'									CL				
TP6A-1A	192260.26	2183681.50	5172.4-5170 9	6A-1-AR	1 0'-2 5'									CL				
TP6A-1B	192260 26	2183681.50	5170 9-5169 4	6A-1-BS	2 5'-4 0'	100	84	33	17	16	108 5	16 5	2 71	CL	CL	10 5	10YR4/4	Moist, dark yellowish brown lean clay with sand
TP6A-1B	192260 26	2183681 50	5170.9-5169 4	6A-1-BM	2 5'-4 0'									CL				
TP6A-1B	192260.26	2183681 50	5170 9-5169 4	6A-1-BR	2 5'-4 0'									CL				
TP6A-1C	192260.26	2183681.50	5169 4-5167.9	6A-1-CS	4 0'-5.5'	100	65	36	17	19	110.0	16.5	2 71	CL	CL	10.5	10YR4/6	Moist, dark yellowish brown lean clay with sand
TP6A-1C	192260.26	2183681 50	5169.4-5167.9	6A-1-CM	4.0'-5 5'									CL				
TP6A-1C	192260 26	2183681 50	5169 4-5167.9	6A-1-CR	4.0'-5.5'									CL				
TP6A-1D	192260.26	2183681.50	5167 9-5166 4	6A-1-DS	5 5'-7 0'	100	65	38	18	20	109 5	17 0	2 72	CL	CL	9 8	10YR7/4	Moist, very pale brown sandy lean clay
TP6A-1D	192260 26	2183681 50	5167 9-5166 4	6A-1-DM	5.5'-7.0'									CL				
TP6A-1D	192260 26	2183681.50	5167.9-5166.4	6A-1-DR	5 5'-7 0'									CL				
TP6A-2A	192360.26	2183781 50	5172.7-5171 2	6A-2-AS	1 0'-2.5'	100	71	32	17	15	112.0	15.5		CL	CL	10.0	10YR4/6	Moist, dark yellowish brown lean clay with sand
TP6A-2A	192360.26	2183781.50	5172.7-5171 2	6A-2-AM	1.0'-2.5'									CL				
TP6A-2A	192360.26	2183781.50	5172.7-5171.2	6A-2-AR	1.0'-2.5'									CL				
TP6A-2B	192360 26	2183781.50	5171.2-5169 7	6A-2-BS	2 5'-4 0'	100	62	35	17	18	110 0	16 0		CL	CL	8 3	10YR5/6	Moist, yellowish brown sandy lean clay
TP6A-2B	192360 26	2183781.50	5171 2-5169 7	6A-2-BM	2 5'-4 0'									CL				
TP6A-2B	192360 26	2183781.50	5171.2-5169.7	6A-2-BR	2 5'-4 0'									CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5

LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP6A-2C	192360.26	2183781.50	5169.7-5168.2	6A-2-CS	4.0'-5.5'	100	54	31	16	15	115.0	13 0		CL	CL	7.6	10YR5/6	Moist, yellowish brown sandy lean clay
TP6A-2C	192360.26	2183781.50	5169.7-5168.2	6A-2-CM	4 0'-5.5'									CL				
TP6A-2C	192360 26	2183781.50	5169.7-5168.2	6A-2-CR	4 0'-5.5'									CL				
TP6A-2D	192360 26	2183781 50	5168 2-5166 7	6A-2-DS	5 5'-7 0'	100	53	35	16	19	115 0	13 0		CL	CL	8.6	10YR5/6	Moist, yellowish brown sandy lean clay
TP6A-2D	192360 26	2183781 50	5168 2-5166.7	6A-2-DM	5 5'-7 0'									CL				
TP6A-2D	192360.26	2183781.50	5168 2-5166.7	6A-2-DR	5 5'-7 0'									CL				
TP6B-1A	192260.26	2183981.50	5178.7-5177.4	6B-1-AS	1 0'-2.5'	100	85	39	18	21	106.0	17.0		CL	CL	11.6	10YR4/4	Moist, dark yellowish brown lean clay
TP6B-1A	192260 26	2183981.50	5178 7-5177.4	6B-1-AM	1 0'-2 5'									CL				
TP6B-1A	192260 26	2183981 50	5178.7-5177 4	6B-1-AR	1.0'-2 5'									CL				
TP6B-1B	192260 26	2183981 50	5177 4-5175 9	6B-1-BS	2 5'-4 0'	100	92	38	20	18	103 5	18.5		CL	CL	10 4	10YR6/4	Moist, light yellowish brown lean clay
TP6B-1B	192260 26	2183981 50	5177 4-5175 9	6B-1-BM	2 5'-4 0'									CL				
TP6B-1B	192260 26	2183981 50	5177 4-5175 9	6B-1-BR	2.5'-4.0'									CL				
TP6B-1C	192260 26	2183981 50	5175 9-5174 4	6B-1-CS	4 0'-5 5'	100	68	38	19	19	109 6	16.5		CL	CL	11 0	10YR5/6	Moist, yellowish brown sandy lean clay
TP6B-1C	192260 26	2183981 50	5175.9-5174 4	6B-1-CM	4 0'-5 5'									CL				
TP6B-1C	192260.26	2183981 50	5175.9-5174 4	6B-1-CR	4 0'-5 5'									CL				
TP6B-1D	192260 26	2183981 50	5174 4-5172 9	6B-1-DS	5 5'-7 0'	100	73	37	21	16	100 0	21 5		CL	CL	10 9	10YR7/4	Moist, very pale brown lean clay with sand
TP6B-1D	192260 26	2183981 50	5174 4-5172.9	6B-1-DM	5 5'-7.0'									CL				
TP6B-1D	192260 26	2183981 50	5174 4-5172 9	6B-1-DR	5 5'-7 0'									CL				
TP6B-2A	192360 26	2184081.50	5174 6-5173 1	6B-2-AS	1 0'-2 5'	100	68	33	17	16	105 0	18 5		CL	CL	8.2	2 5YR6/4	Moist, light yellowish brown sandy lean clay
TP6B-2A	192360 26	2184081 50	5174 6-5173 1	6B-2-AM	1 0'-2 5'									CL				
TP6B-2A	192360.26	2184081.50	5174.6-5173.1	6B-2-AR	1.0'-2.5'									CL				
TP6B-2B	192360 26	2184081 50	5173 1-5171 6	6B-2-BS	2 5'-4 0'	100	67	36	17	19	110 0	16 5		CL	CL	9 1	10YR5/6	Moist, yellowish brown sandy lean clay
TP6B-2B	192360 26	2184081 50	5173 1-5171 6	6B-2-BM	2 5'-4 0'									CL				
TP6B-2B	192360 26	2184081 50	5173 1-5171.6	6B-2-BR	2 5'-4 0'									CL				
TP6B-2C	192360.26	2184081.50	5171 6-5170.1	6B-2-CS	4.0'-5.5'	100	59	38	17	21	111.5	16 0		CL	CL	10 5	10YR 5/6	Moist, yellowish brown sandy lean clay
TP6B-2C	192360.26	2184081 50	5171.6-5170.1	6B-2-CM	4.0'-5 5'									CL				
TP6B-2C	192360 26	2184081 50	5171 6-5170.1	6B-2-CR	4 0'-5 5'									CL				
TP6B-2D	192360 26	2184081 50	5170 1-5168 6	6B-2-DS	5 5'-7 0'	100	72	39	19	20	99 5	22 0		CL	CL	11 2	10YR7/4	Moist, very pale brown clay with sand
TP6B-2D	192360 26	2184081 50	5170 1-5168 6	6B-2-DM	5 5'-7 0'									CL				
TP6B-2D	192360 26	2184081 50	5170 1-5168 6	6B-2-DR	5 5'-7 0'									CL				
TP6C-1A	192260.26	2184281.50	5176.9-5175.4	6C-1-AS	1 0'-2 5'	100	35	25	19	6	117.5	13.0		SC	SC-SM	5 5	10YR5/6	Moist, yellowish brown silty,clayey sand
TP6C-1A	192260 26	2184281 50	5176 9-5175 4	6C-1-AM	1.0'-2.5'									SC				
TP6C-1A	192260.26	2184281 50	5176.9-5175 4	6C-1-AR	1 0'-2 5'									SC				
TP6C-1B	192260.26	2184281.50	5175.4-5173 9	6C-1-BS	2 5'-4.0'	100	75	29	18	11	111 0	16 0		CL	CL	7 9	10YR6/6	Moist, brownish, yellow lean clay with sand
TP6C-1B	192260 26	2184281 50	5175 4-5173 9	6C-1-BM	2 5'-4 0'									CL				
TP6C-1B	192260 26	2184281 50	5175 4-5173 9	6C-1-BR	2 5'-4 0'									CL				
TP6C-1C	192260.26	2184281 50	5173.9-5172 4	6C-1-CS	4 0'-5.5'	100	57	32	18	14	109 5	16 5		CL	CL	7.7	10YR5/8	Moist, yellowish brown sandy lean clay
TP6C-1C	192260.26	2184281 50	5173.9-5172.4	6C-1-CM	4 0'-5 5'									CL				
TP6C-1C	192260.26	2184281.50	5173.9-5172.4	6C-1-CR	4.0'-5.5'									CL				
TP6C-1D	192260 26	2184281 50	5172 4-5170 9	6C-1-DS	5 5'-7.0'	100	55	36	17	19	114 0	14 0		CL	CL	8.3	10YR5/6	Moist, yellowish brown sandy lean clay
TP6C-1D	192260 26	2184281 50	5172 4-5170 9	6C-1-DM	5 5'-7 0'									CL				
TP6C-1D	192260 26	2184281.50	5172.4-5170.9	6C-1-DR	5.5'-7.0'									CL				
TP6C-2A	192360.26	2184381.50	5175.8-5174.3	6C-2-AS	1.0'-2.5'	100	61	30	17	13	109.5	16.5		CL	CL	9.9	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP6C-2A	192360.26	2184381.50	5175.8-5174.3	6C-2-AM	1.0'-2.5'									CL				
TP6C-2A	192360.26	2184381.50	5175.8-5174.3	6C-2-AR	1.0'-2.5'									CL				
TP6C-2B	192360 26	2184381 50	5174 3-5172 8	6C-2-BS	2 5'-4 0'	100	73	31	18	13	110 0	16.5		CL	CL	9.2		

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP6C-2B	192360 26	2184381 50	5174.3-5172 8	6C-2-BM	2 5'-4 0'									CL			10YR5/6	Moist, yellowish brown lean clay with sand
TP6C-2B	192360 26	2184381 50	5174 3-5172 8	6C-2-BR	2 5'-4.0'									CL				
TP6C-2C	192360.26	2184381.50	5172 8-5171.3	6C-2-CS	4 0'-5.5'	100	65	34	17	17	108 0	17.5		CL	CL	8 7	10YR7/4	Moist, very pale brown sandy lean clay
TP6C-2C	192360.26	2184381 50	5172.8-5171 3	6C-2-CM	4.0'-5 5'									CL				
TP6C-2C	192360.26	2184381.50	5172 8-5171 3	6C-2-CR	4 0'-5 5'									CL				
TP6C-2D	192360 26	2184381.50	5171.3-5169.8	6C-2-DS	5 5'-7 0'	100	67	41	18	23	106.5	18 5		CL	CL	9 2	10YR5/6	Moist, yellowish brown sandy lean clay
TP6C-2D	192360 26	2184381 50	5171.3-5169.8	6C-2-DM	5.5'-7 0'									CL				
TP6C-2D	192360 26	2184381 50	5171 3-5169 8	6C-2-DR	5 5'-7.0'									CL				
TP6D-1A	192260.26	2184581 40	5177.7-5176 2	6D-1-AS	1.0'-2.5'	100	82	42	18	24	104.0	19.5	2.71	CL	CL	12.2	10YR4/4	Moist, dark yellowish brown lean clay with sand
TP6D-1A	192260 26	2184581 40	5177.7-5176 2	6D-1-AM	1.0'-2.5'						113.0	14.5		CL				
TP6D-1A	192260 26	2184581.40	5177 7-5176 2	6D-1-AR	1.0'-2.5'						100 5	21.0		CL				
TP6D-1B	192260 26	2184581 40	5176 2-5174.7	6D-1-BS	2.5'-4 0'	100	61	30	16	14	113 5	14 5	2 70	CL	CL	8.2	10YR4/4	Moist, dark yellowish brown sandy lean clay
TP6D-1B	192260 26	2184581 40	5176 2-5174 7	6D-1-BM	2 5'-4.0'									CL				
TP6D-1B	192260.26	2184581 40	5176 2-5174 7	6D-1-BR	2 5'-4 0'									CL				
TP6D-1C	192260.26	2184581.40	5174 7-5173 2	6D-1-CS	4 0'-5 5'	100	66	29	17	12	114.0	14.0	2.71	CL	CL	8 0	10YR5/6	Moist, yellowish brown sandy lean clay
TP6D-1C	192260 26	2184581.40	5174.7-5173.2	6D-1-CM	4.0'-5.5'						120.5	11.0		CL				
TP6D-1C	192260.26	2184581 40	5174 7-5173 2	6D-1-CR	4 0'-5.5'						111 0	15 5		CL				
TP6D-1D	192260 26	2184581 40	5173 2-5171 7	6D-1-DS	5 5'-7 0'	100	67	35	16	19	110 0	16 0	2 71	CL	CL	10 3	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP6D-1D	192260 26	2184581 40	5173.2-5171 7	6D-1-DM	5 5'-7 0'									CL				
TP6D-1D	192260 26	2184581 40	5173 2-5171 7	6D-1-DR	5 5'-7 0'									CL				
TP6D-2A	192360.26	2184681 50	5176 4 5174 9	6D 2-AS	1 0' 2 5'	100	67	29	16	13	109 0	16 5		CL	CL	9 5	10YR3/6	Moist, dark yellowish brown sandy lean clay
TP6D-2A	192360 26	2184681 50	5176 4-5174 9	6D-2-AM	1 0'-2 5'									CL				
TP6D-2A	192360 26	2184681 50	5176.4-5174 9	6D-2-AR	1 0'-2 5'									CL				
TP6D-2B	192360 26	2184681 50	5174 9-5173 4	6D-2-BS	2 5'-4 0'	100	66	31	17	14	112 5	14 5		CL	CL	9 6	10YR4/6	Moist, dark yellowish brown sandy lean clay
TP6D-2B	192360 26	2184681 50	5174 9-5173 4	6D-2-BM	2 5'-4 0'									CL				
TP6D-2B	192360 26	2184681 50	5174 9-5173 4	6D-2-BR	2 5'-4 0'									CL				
TP6D-2C	192360 26	2184681 50	5173 4-5171 9	6D-2-CS	4 0'-5 5'	100	67	35	17	18	110 0	16.5		CL	CL	9 3	10YR5/6	Moist, yellowish brown sandy lean clay
TP6D-2C	192360 26	2184681 50	5173.4-5171.9	6D-2-CM	4.0'-5 5'									CL				
TP6D-2C	192360 26	2184681 50	5173 4-5171 9	6D-2-CR	4.0'-5.5'									CL				
TP6D-2D	192360 26	2184681 50	5171 9-5170 4	6D-2-DS	5 5'-7 0'	100	58	35	17	18	110 5	16 0		CL	CL	7 6	10YR5/6	Moist, yellowish brown sandy lean clay
TP6D-2D	192360 26	2184681.50	5171.9-5170.4	6D-2-DM	5 5'-7 0'									CL				
TP6D-2D	192360 26	2184681 50	5171 9-5170 4	6D-2-DR	5 5'-7 0'									CL				
TP7A-1A	191960 26	2183681.50	5175.1-5173.6	7A-1-AS	1.0'-2 5'	100	91	41	20	21	102.0	19.5		CL	CL	11.2	10YR5/6	Moist, yellowish brown lean clay
TP7A-1A	191960.26	2183681.50	5175.1-5173.6	7A-1-AM	1.0'-2 5'									CL				
TP7A-1A	191960.26	2183681.50	5175 1-5173.6	7A-1-AR	1.0'-2.5'									CL				
TP7A-1B	191960.26	2183681 50	5173 6-5172 1	7A-1-BS	2 5'-4 0'	100	72	40	19	21	103 0	18 0		CL	CL	10 3	10YR5/6	Moist, yellowish brown lean clay with sand
TP7A-1B	191960 26	2183681 50	5173 6-5172 1	7A-1-BM	2 5'-4 0'									CL				
TP7A-1B	191960 26	2183681 50	5173 6-5172 1	7A-1-BR	2 5'-4 0'									CL				
TP7A-1C	191960.26	2183681.50	5172.1-5170.6	7A-1-CS	4.0'-5 5'	100	77	40	21	19	101.0	21.5		CL	CL	9 6	10YR8/3	Moist, very pale brown lean clay with sand
TP7A-1C	191960 26	2183681.50	5172.1-5170.6	7A-1-CM	4.0'-5.5'									CL				
TP7A-1C	191960.26	2183681.50	5172.1-5170 6	7A-1-CR	4.0'-5.5'									CL				
TP7A-1D	191960.26	2183681 50	5170 6-5169 1	7A-1-DS	5 5'-7 0'	100	68	37	19	18	106 0	18 0		CL	CL	8 0	10YR8/3	Moist, very pale brown sandy lean clay
TP7A-1D	191960.26	2183681 50	5170 6-5169 1	7A-1-DM	5 5'-7.0'									CL				
TP7A-1D	191960.26	2183681 50	5170 6-5169 1	7A-1-DR	5.5'-7.0'									CL				
TP7A-2A	192060.26	2183781 50	5175 1-5173 6	7A-2-AS	1.0'-2.5'	100	89	42	19	23	105.0	18.0		CL	CL	12 8	10YR4/4	Moist, dark yellowish brown lean clay
TP7A-2A	192060.26	2183781.50	5175.1-5173.6	7A-2-AM	1.0'-2.5'									CL				

TABLE 2.4.1-1 BORROW AREA 5 TEST RESULTS

BORROW AREA 5																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DESCRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP7A-2A	192060 26	2183781 50	5175.1-5173 6	7A-2-AR	1.0'-2.5'									CL				
TP7A-2B	192060 26	2183781.50	5173 6-5172 1	7A-2-BS	2 5'-4 0'	100	76	35	17	18	108.0	17 0		CL	CL	8.8	10YR5/6	Moist, yellowish brown lean clay with sand
TP7A-2B	192060.26	2183781.50	5173.6-5172 1	7A-2-BM	2.5'-4 0'									CL				
TP7A-2B	192060 26	2183781 50	5173 6-5172.1	7A-2-BR	2.5'-4 0'									CL				
TP7A-2C	192060 26	2183781.50	5172.1-5170 6	7A-2-CS	4 0'-5.5'	100	64	37	19	18	103 0	19 0		CL	CL	9 5	10YR6/4	Moist, light yellowish brown sandy lean clay
TP7A-2C	192060.26	2183781.50	5172 1-5170 6	7A-2-CM	4 0'-5.5'									CL				
TP7A-2C	192060.26	2183781.50	5172.1-5170.6	7A-2-CR	4.0'-5 5'									CL				
TP7A-2D	192060.26	2183781.50	5170.6-5169.1	7A-2-DS	5.5'-7 0'	100	57	34	19	15	106 0	18 0		CL	CL	7 2	10YR7/4	Moist, very pale brown sandy lean clay
TP7A-2D	192060 26	2183781 50	5170 6-5169 1	7A-2-DM	5 5'-7 0'									CL				
TP7A-2D	192060 26	2183781 50	5170 6-5169 1	7A-2-DR	5 5'-7 0'									CL				
TP7B-1A	191960.26	2183981.50	5175.8-5174.3	7B-1-AS	1.0'-2.5'	100	86	42	20	22	102 0	19.5		CL	CL	11 8	10YR4/4	Moist, dark yellowish brown lean clay
TP7B-1A	191960.26	2183981 50	5175.8-5174.3	7B-1-AM	1.0'-2 5'									CL				
TP7B-1A	191960.26	2183981.50	5175.8-5174 3	7B-1-AR	1.0'-2.5'									CL				
TP7B-1B	191960 26	2183981.50	5174 3-5172 8	7B-1-BS	2 5'-4 0'	100	86	39	19	20	106 0	17 5		CL	CL	9 2	10YR5/4	Moist, yellowish brown lean clay
TP7B-1B	191960 26	2183981 50	5174 3-5172 8	7B-1-BM	2 5'-4 0'									CL				
TP7B-1B	191960 26	2183981 50	5174 3-5172 8	7B-1-BR	2 5'-4 0'									CL				
TP7B-1C	191960.26	2183981.50	5172.8-5171.3	7B-1-CS	4.0'-5.5'	100	71	40	18	22	103 5	18 5		CL	CL	9 6	10YR6/4	Moist, light yellowish brown lean clay with sand
TP7B-1C	191960.26	2183981 50	5172.8-5171 3	7B-1-CM	4.0'-5 5'									CL				
TP7B-1C	191960 26	2183981 50	5172 8-5171 3	7B-1-CR	4 0'-5 5'									CL				
TP7B-1D	191960 26	2183981 50	5169 8-5168 3	7B-1-DS	5 5'-7 0'	100	57	37	17	20	110 0	17 0		CL	CL	7 9	10YR8/3	Moist, very pale brown sandy lean clay
TP7B-1D	191960 26	2183981 50	5169 8-5168 3	7B-1-DM	5 5'-7 0'									CI				
TP7B-1D	191960 26	2183981 50	5169 8-5168 3	7B-1-DR	5 5'-7 0'									CI				
TP7B-2A	192060.26	2184081.50	5175.9-5174 4	7B-2-AS	1 0'-2 5'	100	90	42	19	23	106.0	19 0		CL	CL	14.7	10YR4/4	Moist, dark yellowish brown lean clay
TP7B-2A	192060 26	2184081 50	5175 9-5174 4	7B-2-AM	1.0'-2 5'									CL				
TP7B-2A	192060.26	2184081.50	5175.9-5174.4	7B-2-AR	1 0'-2.5'									CL				
TP7B-2B	192060 26	2184081.50	5174 4-5172 9	7B-2-BS	2.5'-4.0'	100	87	39	20	19	107 5	17 5		CL	CL	9 4	10YR5/4	Moist, dark yellowish brown lean clay
TP7B-2B	192060 26	2184081.50	5174 4-5172 9	7B-2-BM	2 5'-4 0'									CL				
TP7B-2B	192060 26	2184081 50	5174 4-5172 9	7B-2-BR	2 5'-4 0'									CL				
TP7B-2C	192060 26	2184081 50	5172 9-5171 4	7B-2-CS	4 0'-5 5'	100	71	42	19	23	103 0	19 5		CL	CL	10.3	10YR7/4	Moist, very pale brown lean clay with sand
TP7B-2C	192060.26	2184081 50	5172 9-5171 4	7B-2-CM	4 0'-5 5'									CL				
TP7B-2C	192060.26	2184081.50	5172.9-5171.4	7B-2-CR	4.0'-5 5'									CL				
TP7B-2D	192060.26	2184081.50	5171.4-5169.9	7B-2-DS	5 5'-7.0'	100	74	37	20	17	103 0	20 0		CL	CL	8 5	10YR8/3	Moist, very pale brown lean clay with sand
TP7B-2D	192060 26	2184081 50	5171 4-5169 9	7B-2-DM	5 5'-7 0'									CL				
TP7B-2D	192060 26	2184081.50	5171.4-5169 9	7B-2-DR	5.5'-7.0'									CL				
				Average		100.0	69.8	36.5	18.1	18.4	107.7	17.4	2.71			9.9		
				Minimum		100.0	32	25	15	6	92.5	11.5	2.70			5.5		
				Maximum		100.0	92	47	26	28	120.5	23.0	2.73			15.8		

TABLE 2.4.2-1 ELF FOOTPRINT TEST RESULTS

Sheet 1 of 3

ELF FOOTPRINT																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DECRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP-1-A	187990 70	2184724.70	5249 60	TP-1-AS	1 0'-3 5'	100	62	35	17	18	109.0	16.5		CL	CL	14.6	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-1-A	187991 70	2184725 70	5249 60	TP-1-AM	1 0'-3 5'													
TP-1-A	187992.70	2184726.70	5249.60	TP-1-AR	1.0'-3.5'													
TP-1-B	187993 70	2184727 70	5247 10	TP-1-BS	3 5'-6 0'	100	66	35	18	17	105.0	19 0		CL	CL	14 6	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-1-B	187994 70	2184728 70	5247 10	TP-1-BM	3 5'-6 0'													
TP-1-B	187995 70	2184729 70	5247 10	TP-1-BR	3 5'-6 0'													
TP-1-C	187990 70	2184724 70	5244 60	TP-1-CS	6,0'-8 5'	99	60	32	14	18	111.0	16.0		CL	CL	10.5	10 YR 5/6	Moist, yellowish brown sandy lean clay
TP-1-C	187991.70	2184725 70	5244 60	TP-1-CM	6 0'-8 5'													
TP-1-C	187992 70	2184726 70	5244 60	TP-1-CR	6 0'-8 5'													
TP-1-D	187993 70	2184727 70	5242 10	TP-1-DS	8 5'-11 0'	100	70	34	15	19	111 0	16 0		CL	CL	10 8	10YR 6/4	Moist, light yellowish brown sandy lean clay
TP-1-D	187994 70	2184728 70	5242 10	TP-1-DM	8 5'-11 0'													
TP-1-D	187995 70	2184729 70	5242 10	TP-1-DR	8 5'-11 0'													
TP-2-A	188005 80	2184422 20	5244 80	TP-2-AS	1 0' - 3 5'	100	80	33	18	15	105 5	15 5		CL	CL	8 4	10YR 6/4	Moist, light yellowish brown lean clay with sand
TP-2-A	188005 80	2184422 20	5244 80	TP-2-AM	1 0' - 3 5'													
TP-2-A	188005 80	2184422 20	5244 80	TP-2-AR	1 0' - 3 5'													
TP-2-B	188005 80	2184422 20	5244 80	TP-2-BS	3 5'-6 0'	100	67	36	17	19	108 5	17 0		CL	CL	9 9	10YR 5/6	Moist, Yellowish brown sandy lean clay
TP-2-B	188005 80	2184422 20	5244 80	TP-2-BM	3 5'-6 0'													
TP 2 B	188005 80	2184422 20	5244 80	TP-2-BR	3 5'-6 0'													
TP-2-C	188005 80	2184422 20	5244 80	TP-2-CS	6 0'-8 5'	100	61	40	17	23	106.5	19 0		CL	CL	10 8	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-2-C	188005 80	2184422 20	5244 80	TP-2 CM	6 0'-8 5'													
TP-2-C	188005 80	2184422 20	5244 80	TP-2-CR	6.0'-8 5'													
TP-2-D	188005 80	2184422 20	8244 80	TP-2-DS	8 5' 11 0	100	66	38	15	23	103 5	18 5	2 72	CL	CL	10 5	10YR 6/4	Moist, light yellowish brown sandy lean clay
TP-2-D	188005 80	2184422 20	8244 80	TP-2-DM	8 5'-11 1						112 0	14 5						
TP-2-D	188005 80	2184422 20	8244 80	TP-2-DR	8 5'-11 2						100 5	19 5						
TP-3-A	188001 80	2184100 70	5237 60	TP 3 AS	1 0' 3 5'	100	69	29	18	12	112 5	15 0		CL	CL	10 5	10 YR 4/6	Moist, dark yellowish brown sandy lean clay
TP-3-A	188001 80	2184100 70	5237 60	TP-3-AM	1 0' - 3 5'													
TP-3-A	188001.80	2184100.70	5237.60	TP-S-AR	1 0' - 3 5'													
TP-3-B	188001 80	2184100 70	5237 60	TP-3 BS	3 5' - 6 0'	99	60	33	16	16	111 5	16 5	2 71	CL	CL	12 5	10YR 4/6	Moist, dark yellowish brown sandy lean clay
TP 3 B	188001 80	2184100 70	5237 60	TP-3-BM	3 5' - 6 0'													
TP-3-B	188001 80	2184100 70	5237 60	TP-3-BR	3 5' - 6 0'													
TP-3-C	188002 80	2184101 70	5237 60	TP-3-CS	6 0'-8 5'	99	57	36	16	20	111 5	16 5		CL	CL	14 4	10YR 4/6	Moist, dark yellowish brown sandy lean clay
TP-3-C	188003 80	2184102 70	5237 60	TP-3-CM	6 0'-8 5'													
TP-3-C	188004 80	2184103.70	5237.60	TP-3-CR	6 0'-8 5'													
TP-3-D	188001 80	2184100 70	5237 60	TP-3-DS	8 5'-11 0'	99	59	35	15	20	109 5	18 0		CL	CL	15 9	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-3-D	188001 80	2184100 70	5237 60	TP-3-DM	8 5'-11 0'													
TP-3-D	188001 80	2184100 70	5237 60	TP-3-DR	8 5'-11 0'													
TP-4-A	187877 30	2183926 70	5236 60	TP-4-AS	1 0'-3.5'	100	44	26	22	4	113.0	14 5		CL	SC-SM	6.8	10YR 5/6	Moist, yellowish brown silty clayey sand
TP-4-A	187877 30	2183926 70	5236.60	TP-4-AM	1 0'-3.5'													
TP-4-A	187877.30	2183926 70	5236 60	TP-4-AR	1 0'-3 5'													
TP-4-B	187877 30	2183926 70	5236 60	TP-4-BS	3 5'-6 0'	100	56	26	22	4	113 5	14 0		CL	CL-ML	7 8	10YR 5/6	Moist, yellowish brown sandy silty clay
TP-4-B	187877 30	2183926.70	5236 60	TP-4-BM	3 5'-6 0'													
TP-4-B	187877 30	2183926 70	5236 60	TP-4-BR	3 5'-6 0'													
TP-4-C	187877.30	2183926.70	5236.60	TP-4-CS	6.0'-8.5'	100	76	32	18	14	109.0	17.5		CL	CL	14.3	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-4-C	187877.30	2183926 70	5236 60	TP-4-CM	6 0'-8 5'													
TP-4-C	187877.30	2183926 70	5236.60	TP-4-CR	6 0'-8 5'													
TP-4-D	187877 30	2183926 70	5236 60	TP-4-DS	8 5'-11 0'	100	64	31	18	13	111 5	16 0		CL	CL	13 1	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-4-D	187877.30	2183926 70	5236 60	TP-4-DM	8 5'-11 0'													
TP-4-D	187877 30	2183926 70	5236 60	TP-4-DR	8.5'-11.0'													
TP-5-A	187741.30	2184165.20	5241 50	TP-5-AS	1 0'-3 5'	100	50	26	22	4	115 0	12.5						

TABLE 2.4.2-1 ELF FOOTPRINT TEST RESULTS

ELF FOOTPRINT																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DECRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP-5-A	187741.30	2184165 20	5241 50	TP-5-AM	1 0'-3 5'									SC	SM	8 8	10YR 5/6	Moist, yellowish brown silty clay
TP-5-A	187741 30	2184165 20	5241 50	TP-5-AR	1 0'-3 5'													
TP-5-B	187741 30	2184165 20	5241 50	TP 5 BS	3 5' -6 0'	100	69	30	18	12	112 5	15 5		CL	CL	10 9	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-5-B	187741 30	2184165 20	5241 50	TP-5-BM	3 5' -6 0'													
TP-5-B	187741 30	2184165,20	5241 50	TP-5-BR	3 5' -6,0'													
TP-5-C	187741.30	2184165.20	5241.50	TP-5-CS	6.0' - 8.5'	100	51	29	19	10	116.5	13.5		CL	CL	8 3	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-5-C	187742 30	2184166 20	5241.50	TP-5-CM	6 0' - 8 5'													
TP-5-C	187743.30	2184167.20	5241.50	TP-5-CR	6.0' - 8.5'													
TP-5-D	187743 30	2184167 20	5241 50	TP-5-DS	8 5' - 11 0'	100	54	35	17	18	110 0	16 5		CL	CL	10 6	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-5-D	187743 30	2184167 20	5241 50	TP-5-DM	8 5' - 11 0'													
TP-5-D	187743 30	2184167 20	5241 50	TP-5-DR	8 5' - 11 0'													
TP-6-A	187737 30	2184482 70	5248 00	TP-6-AS	1 0'-3 5'	100	83	34	18	16	108 0	17 0	2.72	CL	CL	10.1	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-6-A	187737 30	2184483 70	5248 00	TP-6-AM	1 0'-3 5'						116 0	14 0						
TP-6-A	187737 30	2184484 70	5248.00	TP-6-AR	1.0'-3 5'						105.0	18 5						
TP-6 B	187738 30	2184485 70	5248 00	TP-6-BS	3 5'-6 0'	100	68	30	15	15	110 5	15 5		CL	CL	8 2	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-6-B	187739 30	2184486 70	5248 00	TP 6-BM	3 5'-6 0'													
TP-6 B	187740 30	2184487 70	5248 00	TP-6-BR	3 5'-6 0'													
TP-6-C	187740 30	2184487 70	5248 00	TP-6 CS	6 0'-8 5'	99	50	34	16	18	113 0	15 5		CL	CL	9 2	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-6-C	187740,30	2184487,70	5248,00	TP-6-CM	6 0'-8 5'													
TP-6-C	187740 30	2184487 70	5248 00	TP-6-CR	6.0'-8 5'													
TP-6-D	187740 30	2184487 70	5248 00	TP-6-DS	8 5'-11 0'	100	62	39	16	23	105 0	19 5		CL	CL	10 1	10YR 6/4	Most, light yellowish brown sandy lean clay
TP-6 D	187740 30	2184487 70	5248 00	TP-6-DM	8 5'-11 0'													
TP-6-D	187740 30	2184487 70	5248 00	TP 6 DR	8 5' 11 0'													
TP-7-A	187744 80	2184755 20	5253,90	TP-7-AS	1 0'-3 5'	100	82	33	18	15	105 5	16 5		CL	CL	10 3	10YR 6/4	Moist, light yellowish brown lean clay with sand
TP-7-A	187745 80	2184756,20	5253 90	TP-7-AM	1.0'-3 5'													
TP-7-A	187746 80	2184757 20	5253 90	TP-7-AR	1 0'-3 5'													
TP-7-B	187747 80	2184758 20	5253 90	TP-7-BS	3 5'-6 0'	100	68	36	17	19	105 0	18 0		CL	CL	CL	10YR 5/8	Moist, yellowish brown sandy lean clay
TP-7-B	187748 80	2184759 20	5253 90	TP-7-BM	3 5'-6 0'													
TP-7-B	187749 80	2184760 20	5253 90	TP 7-BR	3 5'-6 0'													
TP-7-C	187744 80	2184755 20	5253 90	TP-7-CS	6 0'-8 5'	100	58	38	15	23	106.5	18 0		CL	CL	9 6	10YR 6/6	Moist, brownish yellow sandy lean clay
TP-7-C	187744 80	2184755 20	5253 90	TP-7-CM	6 0'-8 5'													
TP-7-C	187744 80	2184755 20	5253 90	TP-7-CR	6 0'-8 5'													
TP-7-D	187744 80	2184755 20	5253 90	TP 7 DS	8 5'-11 0'	99	58	36	15	21	113 0	15 0	2 71	CL	CL	8 7	10YR 6/6	Moist, brownish yellow sandy lean clay
TP-7-D	187744 80	2184755 20	5253 90	TP-7-DM	8 5'-11 0'						121.5	11 6						
TP-7-D	187744 80	2184755 20	5253 90	TP-7-DR	8 5'-11 0'						108 5	17.0						
TP-8-A	187506 80	2184758 70	5254.50	TP-8-AS	1 0' - 3 5'	100	78	32	18	14	110.0	16.0	2.71	CL	CL	8 6	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-8-A	187507 80	2184759 70	5254.50	TP-8-AM	1 0' - 3 5'													
TP-8-A	187508 80	2184760.70	5254.50	TP-8-AR	1.0' - 3.5'													
TP-8-B	187506 80	2184758 70	5254 50	TP-8-BS	3.5'-6 0'	100	69	30	18	12	111 0	16 0		CL	CL	9 1	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-8-B	187507 80	2184759 70	5254 50	TP-8-BM	3 5'-6 0'													
TP-8-B	187508 80	2184760 70	5254 50	TP-8-BR	3 5'-6 0'													
TP-8-C	187509.80	2184761 70	5254.50	TP-8-CS	6.0'-8.5'	100	56	39	17	22	106 5	19 0	2 71	CL	CL	11.1	10YR 6/6	Moist, brownish yellow sandy lean clay
TP-8-C	187510.80	2184762.70	5254.50	TP-8-CM	6.0'-8.5'													
TP-8-C	187511.80	2184763.70	5254.50	TP-8-CR	6.0'-8.5'													
TP-8-D	187512 80	2184764 70	5254 50	TP-8-DS	8 5'-11 0'	99	57	35	15	20	110 5	15 5		CL	CL	9 9	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-8-D	187513 80	2184765 70	5254 50	TP-8-DM	8 5'-11 0'													
TP-8-D	187514 80	2184766 70	5254 50	TP-8-DR	8 5'-11 0'													
TP-9-A	187518.30	2184467.70	5248 80	TP-9-AS	1.0' -3.5'	100	54	27	22	5	113.5	14.0		ML	ML	6.7	10YR 5/6	Moist, yellowish brown sandy silt
TP-9-A	187519.30	2184468.70	5248 80	TP-9-AM	1.0' -3.5'													

TABLE 2.4.2-1 ELF FOOTPRINT TEST RESULTS

Sheet 3 of 3

ELF FOOTPRINT																		
LOCATION						GRAIN SIZE DISTRIBUTION		ATTERBERG LIMITS			Max Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification		% MC	In Situ Munsell Hue	LABORATORY VISUAL SOIL DECRIPTION
TEST PIT NUMBER	NORTHING	EASTING	ELEVATION	SAMPLE NUMBER	DEPTH	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI				Field	Lab			
TP-9-A	187520.30	2184469.70	5248.80	TP-9-AR	1 0' -3 5'													
TP-9-B	187521 30	2184470 70	5248 80	TP-9-BS	3 5' - 6 0'	100	79	31	18	13	106 0	18.0		CL	CL	9	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-9-B	187522 30	2184471 70	5248 80	TP-9-BM	3 5' - 6 0'													
TP-9-B	187523 30	2184472 70	5248 80	TP-9-BR	3 5' - 6 0'													
TP-9-C	187524 30	2184473 70	5248 80	TP-9-CS	6 0'-8.5'	100	73	29	17	12	112.5	15.5		CL	CL	8.7	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-9-C	187525.30	2184474.70	5248 80	TP-9-CM	6 0'-8 5'													
TP-9-C	187526 30	2184475 70	5248.80	TP-9-CR	6.0'-8 5'													
TP-9-D	187526 30	2184475 70	5248 80	TP-9-DS	8 5'-11 0'	99	54	37	15	22	108 0	18 0		CL	CL	11 1	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-9-D	187526 30	2184475 70	5248 80	TP-9-DM	8 5'-11 0'													
TP-9-D	187526 30	2184475 70	5248 80	TP-9-DR	8 5'-11 0'													
TP-10-A	187533.30	2184157.70	5243 90	TP-10-AS	1 0'-3 5'	100	53	27	22	5	114.5	14.0		SC	CL-ML	7 7	10YR 5/6	Moist, yellowish brown sandy silty clay
TP-10-A	187534 30	2184158 70	5243 90	TP-10-AM	1 0'-3.5'													
TP-10-A	187535.30	2184159.70	5243 90	TP-10-AR	1 0'-3 5'													
TP-10-B	187536 30	2184160 70	5243 90	TP-10-BS	3 5'-6 0'	100	49	Non-Plastic			115 0	12 5		ML	SM	6 1	10 YR 5/6	Moist, yellowish brown silty sand
TP-10-B	187537 30	2184161 70	5243 90	TP-10-BM	3 5'-6 0'													
TP-10-B	187538 30	2184162 70	5243 90	PT-10-BR	3 5'-6 0'													
TP-10-C	187539 30	2184163.70	5243 90	TP-10-CS	6 0' 8 5'	100	71	28	20	9	107.0	16 0		CL	CL	9.1	10YR 5/6	Moist, yellowish brown lean clay with sand
TP-10-C	187540 30	2184164 70	5243.90	TP-10-CM	6 0'-8 5'													
TP-10-C	187541.30	2184165 70	5243.90	TP-10-CR	6 0'-8 5'													
TP-10-D	187542 30	2184166 70	5243 90	TP-10-DS	8 5'-11 0'	100	74	31	19	12	109 5	16 0		CL	CL	10 5	10YR 5/8	Moist, yellowish brown lean clay with sand
TP-10-D	187543 30	2184167 70	5243 90	TP 10-DM	8 5'-11 0'													
TP-10-D	187544 30	2184168 70	5243 90	TP-10 DR	8 5' 11 0'													
TP-11-A	187632 60	2184318 40	5245 60	TP-11-AS	1 0'-3 5'	100	74	31	18	13	108 0	16 5		CL	CL	10 7	10YR 6/4	Moist, light yellowish brown lean clay with sand
TP-11-A	187632.60	2184318 40	5245 60	TP-11-AM	1 0'-3 5'													
TP-11-A	187632 60	2184318 40	5245 60	TP-11-AR	1 0'-3 5'													
TP-11-B	187632 60	2184318 40	5245 60	TP-11-BS	3 5'-6 0'	100	62	29	19	10	112 0	14 5		CL	CL	8 2	10YR 5/6	Moist, yellowish brown sandy lean clay
TP-11-B	187632 60	2184318 40	5245 60	TP-11-BM	3 5'-6 0'													
TP-11-B	187632 60	2184318 40	5245 60	TP 11-BR	3 5' 6 0'													
TP-11-C	187632 60	2184318 40	5245 60	TP-11-CS	6 0'-8 5'	100	44	27	19	8	115 0	14 0		CL	SC	6 9	10YR 5/6	Moist, yellowish brown clayey sand
TP-11-C	187632 60	2184318 40	5245 60	TP 11-CM	6 0'-8 5'													
TP-11-C	187632 60	2184318 40	5245 60	TP-11-CR	6 0'-8 5'													
TP-11-D	187632 60	2184318 40	5245 60	TP-11-DS	8 5'-11 0	100	57	38	16	22	105 0	19 5		CL	CL	11 2	10YR 6/4	Moist, light yellowish brown sandy lean clay
TP-11-D	187632 60	2184318 40	5245 60	TP-11-DM	8 5'-11 1													
TP-11-D	187632 60	2184318 40	5245 60	TP 11 DR	8 5' 11 2													

TABLE 3.0-1 QA MATRIX

Quality Control Item	Test Procedure	Testing Frequency	Testing Performance Criteria
TEST PAD CONSTRUCTION ACTIVITIES			
Borrow Area and Test Pads Layout	Visual Inspection	As Needed	Not Applicable
Test pad survey	Visual Inspection	As Needed	Not Applicable
Survey of CCL Thickness	Review of Survey Data	After Survey Completed and Submitted	CCL thickness of 3 feet (-0.1 to +0.2 foot)
Subgrade Preparation	Section 5.1 of Test Pad Work Plan	Continuous during preparation	Verify that the subgrade is prepared in accordance with Section 5.1 of the Test Pads Work Plan
Number of compactor passes	Section 5.3 of Test Pad Work Plan	Continuous during compaction	Verify that the soil compactor makes the minimum number of passes required in Section 5.3 of the Test Pads Work Plan prior to nuclear density tests. Document the number of passes to obtain acceptable densities, after failing tests.
Nuclear density	ASTM D 2922 and 3017	6 tests per lift per lane	Verify that the moisture content and density are within the selected AZ.
Loose lift thickness	Section 5.3 of theTest Pad Work Plan	Continuous during placement	Verify that the loose lift thickness is not greater than 1/2 inch less than the length of the compactor's pad-foot.
Sample grid layout	Section 6.2.2 of the Test Pad Work Plan	Every test type per lift per lane	Verify that the sampling grids are layed out in 15-foot by 15-foot grid sections.
Sample location selection for the placed CCL material	Section 6.2.2 of the Test Pad Work Plan	Every time testing of the CCL material is required	Verify that random sample location selection has been done in accordance with Section 6.2.2 of the Test Pads Work Plan.
Laboratory moisture content	ASTM D 2216 or 4643	6 per lift per lane	Confirmation of nuclear moisture tests
Laboratory hydraulic conductivity tests	ASTM D1587/D5084	2 per lift per lane	Verify that the hydraulic conductivity is less than 1 x 10^{-7} cm/sec
Sand Cone Tests	ASTM D1556	1 per lift per lane	To calibrate nuclear density tests

Quality Control Item	Test Procedure	Testing Frequency	Testing Performance Criteria
			density tests
Large Scale Block Samples	ASTM D5084	1 per top 1foot per lane and 1 per middle 1foot per lane	Verify that hydraulic conductivity is less than 1 x 10^{-7} cm/sec
BORROW ACTIVITIES			
Borrow Area Preparation Activities	Section 5.2 of Test Pad Work Plan	Continuous during processing	Verify that the borrow material is processed in accordance with Section 5.2 of the Test Pads Work Plan.
Confirmatory index property testing	ASTM D422, ASTM D 4318, ASTM D4318	3 index property tests per test pad borrow source	Verify that material is within the soil index properties criteria listed in Section 4.2 of the Test Pad Work Plan.
Type of borrow material	Visual Inspection using Munsell color chart and index properties (ASTM D2488).	As Needed	Verify that the borrow material meets the soil group color designation. BA 5 Color Type 1 - 10YR7s and 10YR8s; BA 5 color Type 2 - 10YR 6s through 10YR3s; ELF all colors encountered and is visually classified to be within the range of index properties.
Distribution of process water	Visual Inspection	As Required	Not Applicable
Soil stabilizer passes	Section 5.2 of Test Pad Work Plan	Continuous during compaction	Verify that the soil stabilizer makes the minimum number of passes required in Section 5.3 of the Test Pads Work Plan prior to nuclear density tests. Verify processing depth and clod size.
In situ moisture content	ASTM D4643 and/or 2216	2 per day on material from proposed borrow source	To verify adequate hydration.

Quality Control Item	Test Procedure	Testing Frequency	Testing Performance Criteria
Remolded Triaxial Shear Strength Tests	ASTM D4767	1 per AZ developed during BA 5 - ELF Geotechnical Study	For use in Final Design/Specification
Remolded Hydraulic conductivity Test	ASTM D5084	3 per test pad borrow source	Verify that hydraulic conductivity is less than 1 x 10^{-7} cm/sec

ASTM= American Society for Testing and Materials
AZ= Acceptable Hydraulic Conductivity Zone
BA 5= Borrow Area 5
CCL= Compacted Clay Liner
ELF= Enhanced Hazardous Waste Landfill

TABLE 3.2.2-1 TESTS PER LIFT PER LANE

Lift	Minimum Number of Tests, Samples, and Observations per Lane (32-foot width)
Lift 1, 10-inch loose lift	Check for subgrade mixing, 1 laboratory moisture sample
Lifts 2 through 6, 8-inch loose lift	Per Lift: 6 nuclear density tests (ASTM D 2922 and 3017), 2 Standard Proctors (ASTM D 698), 6 laboratory moistures (ASTM D 2216 or 4643), 2 Shelby Tubes for 2 laboratory hydraulic conductivity tests (ASTM D 1587), 1 sand cone (ASTM D 1556).
Once graded to 3-foot thickness and smooth drum rolling	6 nuclear density tests (ASTM D 2922 and 3017), 2 Standard Proctors (ASTM D 698), 6 laboratory moistures (ASTM D 2216 or 4643), 2 Shelby Tubes for 2 laboratory hydraulic conductivity tests (ASTM D 1587), 1 sand cone (ASTM D 1556).
Upper 14 inches and Middle 14 inches	1 block sample taken from the upper foot and 1 block sample taken from the middle foot of each lane of each test pad

Note: One sand cone test was conducted per lane only for a total of 2 sand cone tests per test pad. Prior to construction of the test pads, 5 sand cone tests will be conducted for density correlation. The total number of sand cone tests for the test pad program was 11.

ASTM= American Society for Testing and Materials

TABLE 4.0-1 RANDOM SAMPLE SELECTION SHEET EXAMPLE

ELF Test Pads (Borrow Area 5) Color Type 1
Sampling Random Number Generation Sheet

	Lift		Lift	
Grids	**Lane 1**		**Lane 2**	
1	Test	Grid Location	Test	Grid Location
2	Density Test #1	13	Density Test #1	13
3	Density Test #2	4	Density Test #2	17
4	Density Test #3	4	Density Test #3	13
5	Density Test #4	13	Density Test #4	6
6	Density Test #5	18	Density Test #5	9
7	Density Test #6	20	Density Test #6	1
8				
9	Test	Grid Location	Test	Grid Location
10	Lab Moisture	11	Lab Moisture	2
11	Lab Moisture	8	Lab Moisture	14
12	Lab Moisture	18	Lab Moisture	2
13	Lab Moisture	7	Lab Moisture	18
14	Lab Moisture	7	Lab Moisture	4
15	Lab Moisture	7	Lab Moisture	10
16				
17	Test	Grid Location	Test	Grid Location
18	Proctor	2	Proctor	14
19	Proctor	12	Proctor	3
20				
	Test	Grid Location	Test	Grid Location
	Shelby Perm	20	Shelby Perm	18
	Shelby Perm	7	Shelby Perm	7
	Test	Grid Location	Test	Grid Location
	Block Perm	5	Block Perm	17
	Block Perm	14	Block Perm	12

Lift	Minimum Number of Tests, Samples and Observations per Lane (32 foot width)
Lift 1, 10-inch loose lift	Check for subgrade mixing, 1 laboratory moisture sample
Lift 2 through 7, 8-inch loose	Per lift: 6 nuclear density tests (ASTM D 2922 and 3017), 2 Modified Proctors (ASTM D 1557), 6 Laboratory moistures (ASTM D 2216 or 4643), 2 Shelby Tubes for 2 Laboratory permeability tests (ASTM D 5084), 1 Sand Cone (ASTM 1556)
Once graded to 3-foot thickness and smooth drum rolled	Per lift: 6 nuclear density tests (ASTM D 2922 and 3017), 2 Modified Proctors (ASTM D 1557), 6 Laboratory moistures (ASTM D 2216 or 4643), 2 Shelby Tubes for 2 Laboratory permeability tests (ASTM D 5084), 1 Sand Cone (ASTM 1556)
Top and Bottom 18 inches	1 block sample taken from the upper half and 1 block sample taken from the bottom half of each lane of each test pad

ASTM = American Society for Testing and Materials

TABLE 4.1.1-1 ELF TEST PAD 1 TEST DATA FOR SOIL CLASSIFICATION, MODIFIED PROCTOR AND SPECIFIC GRAVITY

ELF TEST PAD 1															
Location				Grain Size		Atterberg Limits			Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification	Sample Moisture Content (%)	Munsell Color	Laboratory Visual Soil Description
Sample Number	Northing	Easting	Elevation	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI							
*TP1-PR-001	192,288 30	2,183,801 18	5172 9	100	76	34	18	16	118.5	13 0		CL	7 4	10YR6/4	Dry, Light Yellowish Brown lean Clay with Sand
*TP1-CL-001	192,288 30	2,183,801 18	5172 9	100	76	34	18	16				CL	7 4	10YR6/4	Dry, Light Yellowish Brown lean Clay with Sand
*TP1-PR-002	192,391.41	2,183,700.81	5171.9	100	63	34	18	16	121.0	12.5		CL	9 9	10YR4/3	Moist, Dark Yellowish Brown sandy lean Clay
*TP1-CL-002	192,391 41	2,183,700 81	5171 9	100	63	34	18	16				CL	9.9	10YR4/3	Moist, Dark Yellowish Brown sandy lean Clay
*TP1-CL-003	192,339 27	2,183,756 23	5172 9	100	72	36	18	18				CL	10 8	10YR4/3	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-003	192,272 72	2,184,112 66	5177 2	100	74	38	17	21	121.5	12.5		CL	14 4	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-004	192,224.28	2,184,128.99	5178.0	100	85	40	17	23	120 0	13 9		CL	14 5	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-005	192,183 10	2,184,074 89	5176 5	100	85	42	18	24	121 5	13 5	2 71	CL	15.6	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-006	192,253.00	2,184,097 00	5176 5	100	79	41	17	24	121.0	13.0	2.70	CL	15 3	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-007	192,242.10	2,184,094 23	5177 4	100	83	42	18	24	121 0	13 5	2 70	CL	15.9	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-008	192,195 47	2,184,130 95	5178 8	100	69	37	16	21	123 5	12 0		CL	17 9	10YR4/4	Moist, Dark Yellowish Brown sandy lean Clay
TP1-PR-009	192,271.95	2,184,130.66	5178.3	100	73	38	16	22	125 5	11 5		CL	17.0	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-010	192,272 74	2,184,082 45	5177 6	100	77	38	18	20	123.0	12.5		CL	16 3	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-011	192,211.32	2,184,094.61	5177.9	100	63	33	17	16	125 0	10 5		CL	14.3	10YR4/4	Moist, Dark Yellowish Brown sandy lean Clay
TP1-PR-012	192,167 10	2,184,115 44	5179 0	100	80	39	17	22	124 0	12 0	2.70	CL	17 8	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-013	192,240 87	2,184,129 79	5179 4	100	77	38	18	20	123.0	12 5	2 72	CL	16 7	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-014	192,300.77	2,184,084 29	5177.5	100	83	41	18	23	122 5	12 5		CL	18.3	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-015	192,193 01	2,184,098 91	5178 3	100	72	38	17	21	124 5	11.5		CL	18 9	10YR4/4	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-016	192,181 04	2,184,100 99	5178 7	100	59	37	16	21	124 5	12 0	2 72	CL	15 6	10YR4/6	Moist, Dark Yellowish Brown sandy lean Clay
TP1-PR-017	192,196.45	2,184,126 73	5179 5	100	65	37	16	21	126 5	11 0	2 71	CL	13 3	10YR4/6	Moist, Dark Yellowish Brown sandy lean Clay
TP1-PR-018	192,225 10	2,184,082 14	5179 0	100	75	36	17	19	126.0	11.5		CL	13 7	10YR4/6	Moist, Dark Yellowish Brown lean Clay with Sand
TP1-PR-019	192,208 75	2,184,100 29	5179.1	100	63	39	17	22	126 5	11 5		CL	14.1	10YR4/6	Moist, Dark Yellowish Brown sandy lean Clay
TP1-SG-001											2.71				
TP1-SG-002											2 72				
* = Borrow Source location															

SG = Specific Gravity
CL = Classification
PR = Modified Proctor
USCS = Unified Soil Classification System

TABLE 4.1.2-1 NUCLEAR DENSITY TEST RESULTS FOR ELF TEST PAD 1, LANE 1 (815 COMPACTOR)

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)						
ELF-TP1-DT-002	8/16/01	0	3	NUCLEAR	13.3	114 7	97%	75 8%	NA	NA	NA	SUBGRADE
ELF-TP1-DT-019	8/21/01	2	10	NUCLEAR	14.1	115.1	98%	81 3%	2	4	N	
ELF-TP1-DT-019A	8/22/01	2	10	NUCLEAR	16.6	113.0	96%	90.4%	2	6	Y	
ELF-TP1-DT-020	8/21/01	2	9	NUCLEAR	15.2	114.9	98%	87.3%	2	4	Y	
ELF-TP1-DT-021	8/21/01	2	11	NUCLEAR	17.4	107.2	91%	81.6%	2	4	N	
ELF-TP1-DT-021A	8/22/01	2	11	NUCLEAR	11 5	109.9	93%	57 7%	2	6	N	
ELF-TP1-DT-022	8/21/01	2	16	NUCLEAR	15 3	101.7	86%	62.5%	2	4	N	
ELF-TP1-DT-022A	8/22/01	2	16	NUCLEAR	17.1	105.7	90%	77.2%	2	6	N	
ELF-TP1-DT-023	8/21/01	2	18	NUCLEAR	17.3	111.0	94%	89 4%	2	4	Y	
ELF-TP1-DT-024	8/21/01	2	19	NUCLEAR	16.1	109 8	93%	80.7%	2	4	N	
ELF-TP1-DT-024A	8/22/01	2	19	NUCLEAR	14 8	107.8	92%	70 5%	2	6	N	
ELF-TP1-DT-025	8/21/01	2	20	NUCLEAR	18.9	105.1	89%	84 1%	2	4	N	
ELF-TP1-DT-025A	8/22/01	2	20	NUCLEAR	17.8	110 2	94%	90.1%	2	6	Y	
ELF-TP1-DT-026	8/22/01	2	1	NUCLEAR	15.6	107 9	92%	74.4%	2	4	N	
ELF-TP1-DT-033	8/28/01	3	11	NUCLEAR	16 7	113 8	93%	93 0%	4	6	Y	
ELF-TP1-DT-034	8/28/01	3	20	NUCLEAR	15 4	114 1	93%	86 5%	4	6	Y	
ELF-TP1-DT-035	8/28/01	3	2	NUCLEAR	15 7	115 0	94%	90.2%	4	6	Y	
ELF-TP1-DT-036	8/28/01	3	19	NUCLEAR	19 0	107 6	88%	90.1%	4	6	N	
ELF-TP1-DT-037	8/28/01	3	12	NUCLEAR	13 3	120 7	99%	89 8%	4	6	Y	
ELF-TP1-DT-038	8/28/01	3	14	NUCLEAR	12 5	121 3	99%	85 9%	4	6	Y	
ELF-TP1-DT-045	8/29/01	4	11	NUCLEAR	18 6	110 0	90%	93 8%	4	6	N	
ELF-TP1-DT-046	8/29/01	4	17	NUCLEAR	17 8	111.2	91%	92 5%	4	6	Y	
ELF-TP1-DT-047	8/29/01	4	1	NUCLEAR	20 8	107.2	89%	97.5%	4	6	N	
ELF-TP1-DT-048	8/29/01	4	9	NUCLEAR	19 8	105.8	88%	89 7%	4	6	N	
ELF-TP1-DT-049	8/29/01	4	16	NUCLEAR	19.8	107.8	89%	94.3%	4	6	N	
ELF-TP1-DT-050	8/29/01	4	14	NUCLEAR	18.5	106.8	89%	85.9%	4	6	N	
ELF-TP1-DT-058	8/30/01	5	18	NUCLEAR	18 0	111 7	91%	94.8%	4	4	Y	
ELF-TP1-DT-059	8/30/01	5	19	NUCLEAR	18.1	112 0	91%	96.1%	4	4	Y	
ELF-TP1-DT-060	8/30/01	5	16	NUCLEAR	17.1	110 1	90%	86 3%	4	4	N	
ELF-TP1-DT-061	8/30/01	5	17	NUCLEAR	21 0	105.8	86%	95 0%	4	4	N	
ELF-TP1-DT-062	8/30/01	5	12	NUCLEAR	16 8	114 6	94%	95.7%	4	4	Y	
ELF-TP1-DT-063	8/30/01	5	20	NUCLEAR	18 0	110 8	90%	92.5%	4	4	Y	
Averages	--	--	--		**16.9**	**110.5**	**91.9%**	**86.3%**				

AZ = Acceptable Hydraulic Conductivity Zone

TABLE 4.1.2-2 NUCLEAR DENSITY TEST RESULTS FOR ELF TEST PAD 1, LANE 2 (825 COMPACTOR)

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)						
ELF-TP1-DT-001	8/16/01	0	11	NUCLEAR	13.9	106.5	90%	64.0%	N/A	NA	NA	SUBGRADE
ELF-TP1-DT-013	8/20/01	2	11	NUCLEAR	14.0	109.7	93%	70.0%	2	4	N	
ELF-TP1-DT-013A	8/20/01	2	11	NUCLEAR	17.2	110.8	94%	88.3%	2	6	Y	
ELF-TP1-DT-014	8/20/01	2	8	NUCLEAR	15.6	111.4	95%	81.5%	2	4	N	
ELF-TP1-DT-014A	8/20/01	2	8	NUCLEAR	15.2	113.9	97%	84.8%	2	6	N	
ELF-TP1-DT-015	8/20/01	2	15	NUCLEAR	15.8	109.7	93%	78.9%	2	4	N	
ELF-TP1-DT-015A	8/20/01	2	15	NUCLEAR	16.3	107.9	92%	77.8%	2	6	N	
ELF-TP1-DT-015B	8/20/01	2	15	NUCLEAR	17.6	111.1	94%	91.1%	2	8	Y	
ELF-TP1-DT-016	8/20/01	2	5	NUCLEAR	14.7	113.2	96%	80.5%	2	4	N	
ELF-TP1-DT-016A	8/20/01	2	5	NUCLEAR	15.5	111.7	95%	81.6%	2	6	N	
ELF-TP1-DT-016B	8/20/01	2	5	NUCLEAR	16.6	113.3	96%	91.2%	2	8	Y	
ELF-TP1-DT-017	8/20/01	2	16	NUCLEAR	15.4	114.0	97%	86.3%	2	4	Y	
ELF-TP1-DT-018	8/20/01	2	3	NUCLEAR	14.5	115.9	95%	85.5%	2	4	Y	
ELF-TP1-DT-027	8/27/01	3	7	NUCLEAR	15.6	112.8	92%	84.6%	4	6	N	
ELF-TP1-DT-028	8/27/01	3	17	NUCLEAR	15.3	114.6	94%	87.0%	4	6	Y	
ELF-TP1-DT-029	8/27/01	3	14	NUCLEAR	17.4	111.8	91%	91.8%	4	6	Y	
ELF-TP1-DT-030	8/27/01	3	15	NUCLEAR	17.1	113.0	92%	93.2%	4	6	Y	
ELF-TP1-DT-031	8/27/01	3	2	NUCLEAR	16.8	112.8	92%	91.0%	4	6	Y	
ELF-TP1-DT-032	8/27/01	3	9	NUCLEAR	15.8	110.4	90%	80.5%	4	6	N	
ELF-TP1-DT-039	8/28/01	4	10	NUCLEAR	17.8	110.3	90%	90.3%	4	4	Y	
ELF-TP1-DT-040	8/28/01	4	11	NUCLEAR	15.5	116.5	95%	92.8%	4	4	Y	
ELF-TP1-DT-041	8/28/01	4	20	NUCLEAR	15.9	112.7	92%	85.9%	4	4	Y	
ELF-TP1-DT-042	8/28/01	4	4	NUCLEAR	16.2	112.7	92%	87.5%	4	4	Y	
ELF-TP1-DT-043	8/28/01	4	16	NUCLEAR	16.3	113.7	93%	90.4%	4	4	Y	
ELF-TP1-DT-044	8/28/01	4	3	NUCLEAR	15.6	114.3	93%	88.0%	4	4	Y	
ELF-TP1-DT-051	8/29/01	5	8	NUCLEAR	15.6	115.4	94%	90.7%	4	4	Y	
ELF-TP1-DT-052	8/29/01	5	13	NUCLEAR	15.8	113.7	93%	87.8%	4	4	Y	
ELF-TP1-DT-053	8/29/01	5	14	NUCLEAR	13.5	116.9	95%	81.8%	4	4	N	
*ELF-TP1-ST-015	8/29/01	5	14	SHELBY	17.1	111.6	91%	90.0%	4	4	Y	
ELF-TP1-DT-054	8/29/01	5	15	NUCLEAR	15.5	114.8	94%	88.7%	4	4	Y	
ELF-TP1-DT-055	8/29/01	5	1	NUCLEAR	16.0	113.6	93%	88.7%	4	4	Y	
ELF-TP1-DT-056	8/29/01	5	20	NUCLEAR	13.2	118.5	97%	83.5%	4	4	N	
Averages	--	--	--		**15.8**	**113.0**	**93.5%**	**86.2%**				

AZ = Acceptable Hydraulic Conductivity Zone

TABLE 4.1.2-3 SHELBY TUBE HYDRAULIC CONDUCTIVITY TEST RESULTS FOR ELF TEST PAD 1

LANE 1, 815 COMPACTOR

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST			PERCENT COMPACTION	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	PERMEABILITY/ ASSOCIATED TESTING	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)							
* ELF-TP1-ST-003	8/21/01	2	18	SHELBY	15.7	111.8	95%	83.0%	2	4	N	K = 5.5 X 10^{-9}	
* ELF-TP1-ST-004	8/22/01	2	1	SHELBY	15.8	109.6	93%	78.7%	2	4	N	K = 3.5 X 10^{-7}	Low Moisture
* ELF-TP1-ST-005	8/22/01	2	19	SHELBY	16.3	105.0	89%	72.2%	2	6	N	K = 3.9 X 10^{-8}	
* ELF-TP1-ST-009	8/28/01	3	8	SHELBY	15.8	114.3	93%	89.3%	4	6	Y	K = 4.1 X 10^{-9}	
* ELF-TP1-ST-010	8/28/01	3	9	SHELBY	15.9	114 5	93%	90 2%	4	6	Y	K = 3.7 X 10^{-9}	
* ELF-TP1-ST-013	8/29/01	4	9	SHELBY	16 0	111 1	92%	82.7%	4	6	N	K = 1.6 X 10^{-6}	Poor Sample
* ELF-TP1-ST-014	8/29/01	4	12	SHELBY	17.5	109.5	91%	87.1%	4	6	Y	K = 5.2 X 10^{-9}	
* ELF-TP1-ST-019	8/30/01	5	16	SHELBY	14.1	113.1	92%	77.2%	4	4	N	K = 3.4 X 10^{-9}	
* ELF-TP1-ST-020	8/30/01	5	17	SHELBY	18.1	108.8	89%	88.4%	4	4	N	K = 1.9 X 10^{-9}	
* = Oven Moisture													
Averages	--	--	--		**16.1**	**110.9**	**92.0%**	**83.2%**					

LANE 2, 825 COMPACTOR

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST			PERCENT COMPACTION	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	PERMEABILITY/ ASSOCIATED TESTING	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)							
*ELF-TP1-ST-001	8/20/01	2	3	SHELBY	14.8	116.1	95%	87.8%	2	4	Y	K = 2.0 X 10^{-8}	
*ELF-TP1-ST-002	8/20/01	2	15	SHELBY	13.4	115.9	98%	78 9%	2	8	N	K = 5 5 X 10^{-8}	
*ELF-TP1-ST-006	8/27/01	3	12	SHELBY	15 8	107.6	88%	74.8%	4	6	N	K = 1.6 X 10^{-6}	Poor Sample
*ELF-TP1-ST-007	8/27/01	3	1	SHELBY	16.4	112.4	92%	88 2%	4	6	Y	K = 1 2 X 10^{-8}	
*ELF-TP1-ST-008	8/27/01	3	9	SHELBY	15.4	112.8	92%	83.5%	4	6	N	K = 3.3 X 10^{-8}	
*ELF-TP1-ST-011	8/28/01	4	9	SHELBY	19.4	108.0	88%	92.7%	4	4	N	K = 1.6 X 10^{-8}	
*ELF-TP1-ST-012	8/28/01	4	7	SHELBY	17.6	111.4	91%	91.9%	4	4	Y	K = 4.4 X 10^{-9}	
*ELF-TP1-ST-015	8/29/01	5	14	SHELBY	17.1	111.6	91%	90.0%	4	4	Y	K = 7.7 X 10^{-9}	
*ELF-TP1-ST-016	8/29/01	5	20	SHELBY	13.8	116.8	95%	83.3%	4	4	N	K = 2.8 X 10^{-8}	
*ELF-TP1-ST-017	8/29/01	5	19	SHELBY	17.0	111.9	91%	89.9%	4	4	Y	K = 2.4 X 10^{-8}	
*ELF-TP1-ST-018	8/29/01	5	6	SHELBY	15.3	115.4	94%	89.1%	4	4	Y	K = 3.7 X 10^{-8}	
* = Oven Moisture													
Averages	--	--	--		**16.1**	**112.4**	**92.1%**	**86.2%**					

AZ = Acceptable Hydraulic Conductivity Zone

Table 4.1.2-4
Summary of Nuclear Density and Hydraulic Conductivity Tests

				Summary of Nuclear Density Tests							
	Test Pad 1, Lane 1					Test Pad 1, Lane 2					
Lift #	2	3	4	5	All Lane 1	2	3	4	5	All Lane 2	All Test Pad 1
Range of moisture content (%)	11.5 - 18.9	12.5 - 19	17.8 - 20.8	16.8 - 21.0	11.5 - 21.0	14.0 - 17 6	15.3 - 17.1	15.5 - 17.8	13.2 - 16.0	13.2 - 17.8	11.6 - 21.0
Range of Dry Density (pcf)	101.7 - 115.1	107.6 - 121.3	106.8 - 111.2	110.1 - 114.6	101.7 - 121.3	107.9 - 115.9	110.4 - 114.6	110.3 - 116.5	113.6 - 118.5	107.9 - 118.5	101.7 - 121.3
Number of tests in AZ	4 (Figure 5.1.1-1)	5 (Figure 5.1 1-2	2 (Figure 5.1.1-3)	4 (Figure 5.1.1-4)	15	5 (Figure 5.1.1-5)	4 (Figure 5.1 1-6)	6 (Figure 5.1.1 - 7)	4 (Figure 5.1 1-8)	19	34
Number of tests out of AZ	9 (Figure 5.1 1-1)	1 (Figure 5.1.1-2)	4 (Figue 5.1.1 3)	2 (Figure 5.1.1-4)	16	7 (Figure 5.1.1-5)	2 (Figure 5.1.1-6)	0 (Figure 5 1.1 - 7)	2 (Figure 5.1.1-8)	11	27

				Summary of Shelby Tube Hydrualic ConductivityTests							
	Test Pad 1. Lane 1					Test Pad 1, Lane 2					
Lift #	2	3	4	5	All Lane 1	2	3	4	5	All Lane 2	All Test Pad 1
Range of moisture content (%)	15.7 - 16.3	15.8 - 15 9	16 0 - 17.5	14.1 - 18.1	14.1 - 18.1	13.4 - 14.8	15.4 - 16 4	17.6 - 19 4	13 8 - 17.0	13.4 - 19.4	13 4 - 19.4
Range of Dry Density (pcf)	105 0 - 111 8	114 3 - 114 5	109 5 - 111.1	108.8 - 113.1	105 0 - 113 1	115.9 - 116.1	107.6 - 112.8	108 0 - 111 4	111.9 - 116.8	107 6 - 116 8	105.0 - 116.8
Number of tests in AZ	0 (Figure 5.1.1-1)	2 (Figure 5.1.1-2)	1 (Figure 5 1 1-3)	0 (Figure 5.1.1-4)	3	1 (Figure 5 1.1-5)	1 (Figure 5.1.1-6)	1 (Figure 5.1.1-7)	2 (Figure 5.1.1-8)	5	8
Number of tests out of AZ	3 (Figure 5 1.1-1)	0 (Figure 5.1.1-2)	1(Figure 5.1.1-3)	2 (Figure 5 1 1-4)	6	1 (Figure 5.1.1-5)	2 (Figure 5.1.1-6)	1 (Figure 5 1.1-7)	1 (Figure 5.1 1-8)	5	11
Number of Passing Permeability Tests	2 (Figure 5 1.1-1)	2 (Figure 5.1 1-2)	1(Figure 5.1.1-3)	2 (Figure 5.1 1-4)	7	2 (Figure 5.1.1-5)	2 (Figure 5.1.1-6)	2 (Figure 5 1 1-7)	3 (Figure 5.1.1-8)	9	16

AZ = Acceptable Hydraulic Conductivity Zone

Table 4.1.3-1
Large Block Hydraulic Conductivity Data, Test Pad 1, TP1-BS-001

Sample No.: **ELF-TP1-BS-001**

Initial Conditions Prior to Permeation

Avg Length = 15 5 cm
Avg Diameter = 30.5 cm
Length/Diameter = 0.51
Area = 732.2 cm^2
Volume = 11368 cm^3

Initial Water Content, w = 15 9 %
B value = 0 95

Final Conditions After Permeation

Final Water Content, w = 16 6 %
Degree of Saturation, S = 100.0 % (Assumed)

Pore Volume, PV = 3559 cm^3
B value = 0 95

Test Specification

Cell Pressure = 85 psi
Inflow Pressure = 80 psi
Inflow Area = 4 35 cm^2
Outflow Pressure = 80 psi
Outflow Area = 4 38 cm^2
Pressure Difference = 0 psi
Inflow Burette area = 0 8744 cm^2
Inflow Anulus Factor = 3.972

Max Effective Stress = 5 psi
Min Effective Stress = 5 psi
Avg Effective Stress = 5 psi
Avg Gradient = 1.2
Outflow Burette Area = 0 8741 cm^2
Outflow Anulus Factor = 4 015

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	Σ Q_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
9/22/2001 21 33	9/23/2001 7 52	10 19 00	10 19 00	0 43	0 51	8 37	24 36	16 50	39 1	39 4	39 4	0 011	1 01	1,34E-06			
9/23/2001 7 55	9/23/2001 19.00	11 05 00	21 24 00	0 89	0.59	8 21	24 58	17 01	37 9	38 0	77 4	0 022	1 00	1 16E-06			
9/23/2001 19 02	9/24/2001 7 39	12 37 00	34 01 00	1 42	0 62	8 63	24 75	16 03	39 8	43 7	121 1	0 034	1 10	1 20E-06			
9/24/2001 7 42	9/24/2001 18 22	10 40 00	44 41 00	1 86	0 42	8 04	24 52	17 15	37 9	37 0	158 1	0 044	0 98	1 17E-06			
9/24/2001 18 24	9/25/2001 8 43	14 19 00	59 00 00	2 46	0 62	8 90	24 53	16 42	41 2	40 7	198 7	0 056	0 99	1 04E-06			
9/25/2001 8 45	9/25/2001 21 48	13 03 00	72 03 00	3 00	0 42	7 91	24 33	16 66	37 2	38 5	237 2	0 067	1 03	9 90E-07			
9/25/2001 21 52	9/26/2001 9 02	11 10 00	83 13 00	3 47	0 52	7 42	24 50	17 47	34 3	35 3	272 5	0 077	1 03	1 00E-06			
9/26/2001 9 03	9/26/2001 22 06	13 03 00	96 16 00	4 01	0 48	7 68	24 48	17 26	35 8	36 2	308 7	0 087	1 01	9 05E-07			
9/26/2001 22 08	9/27/2001 13 28	15 20 00	111 36 00	4 65	0 50	8 23	24 51	16 91	38 4	38 1	346 8	0 097	0 99	8 53E-07			
9/27/2001 13 32	9/28/2001 7 25	17 53 00	129 29 00	5 40	0 49	8 82	24 50	16 10	41 4	42 1	350 8	0 099	1 02	8 58E-07			
9/28/2001 7 27	9/28/2001 20 50	13 23 00	142 52 00	5 95	0 42	7 59	24 51	17 23	35 6	36 5	387 3	0 109	1 02	8 80E-07			
9/28/2001 20 52	9/29/2001 13 58	17 06 00	159 58 00	6 67	0 51	8 30	24 32	16 21	38 7	40 7	428 0	0 120	1 05	8 26E 07			
9/29/2001 14 01	9/30/2001 7 38	17 37 00	177 35 00	7 40	0 52	8 68	24 56	16 67	40 6	39 6	467 5	0 131	0 98	8 04E 07			
9/30/2001 7 40	9/30/2001 21 36	13 56 00	191 31 00	7 98	0 63	7 48	24 64	17 56	34 1	35 5	503 1	0 141	1 04	8 01E-07			
9/30/2001 21 37	10/1/2001 15 13	17 36 00	209 07 00	8 71	0 46	8 16	24 42	16 85	38 3	38 0	541 0	0 152	0 99	7 41E-07			
10/1/2001 15 16	10/2/2001 10 43	19.27 00	228 34 00	9 52	0 60	8 39	24 42	16 69	38 7	38 8	579 8	0 163	1 00	6 97E-07			
10/2/2001 10 45	10/3/2001 7 24	20 39 00	249 13 00	10 38	0 52	8 46	24 61	16 81	39 5	39 1	618 9	0 174	0 99	6 60E-07			
10/3/2001 7 26	10/4/2001 9 10	25 44 00	274 57 00	11 46	0 29	8 42	24 40	16 29	40 4	40.7	659 6	0.185	1 01	5 59E-07			
10/4/2001 9 12	10/5/2001 9 24	24 12 00	299 09 00	12 46	0 47	7 88	24 49	17 18	36 8	36 7	696 2	0.196	1 00	5 04E-07			
10/5/2001 9 26	10/6/2001 8 57	23 31 00	322 40 00	13 44	0 62	7 62	24 43	17 48	34 8	34 9	731 1	0 205	1 00	4 82E-07			
10/6/2001 8 59	10/7/2001 11 27	26 28 00	349 08 00	14 55	0 36	7 59	24 45	17 31	35 9	35 8	766 9	0 215	1 00	4 41E-07			
10/7/2001 11 29	10/8/2001 19 56	32 27 00	381 35 00	15 90	0 27	7 96	24 40	16 86	38 2	37 8	804 7	0 226	0 99	3 95E 07			
10/8/2001 19 58	10/10/2001 9 21	37 23 00	418 58 00	17 46	0 41	8 11	24 43	16 84	38 3	38 1	842 8	0 237	0 99	3 48E-07			
10/10/2001 9 23	10/12/2001 7 32	46 09 00	465 07 00	19 38	0 29	8 71	24 62	16 30	41 9	41 7	884 5	0 249	1 00	3 24E 07			
10/12/2001 7 34	10/14/2001 5 50	46 16 00	511 23 00	21 31	0 24	8 28	24 52	16 63	40 0	39 6	924 1	0 260	0 99	2 97E 07			
10/14/2001 5 52	10/15/2001 22 00	40 08 00	551 31 00	22 98	0 33	7 46	24 61	17 57	35 5	35 3	959 4	0 270	1 00	2 81E-07			
10/15/2001 22 01	10/17/2001 22 04	48 03 00	599 34 00	24.98	0 41	8.10	24 58	17 02	38 2	37 9	997 3	0 280	0 99	2 67E-07			
10/17/2001 22 06	10/19/2001 20 20	46 14 00	645 48 00	26 91	0 31	7 48	24 56	17 49	35 6	35 5	1032 7	0 290	0.99	2 46E-07			
10/19/2001 21 23	10/21/2001 21 21	47 58 00	693 46 00	28 91	0 15	7 14	24 52	17 48	34 8	35 3	1068 0	0 300	1 02	2 30E-07			
10/21/2001 21 23	10/24/2001 11 22	61.59 00	755 45 00	31 49	0 20	7 97	24 51	16 97	38 6	37 8	1105 9	0 311	0.98	2 06E-07			
10/24/2001 11 24	10/27/2001 8 23	68.59.00	824 44 00	34 36	0 37	8 02	24 46	16 86	38 0	38 1	1144 0	0 321	1 00	1 87E-07			
10/27/2001 8 25	10/30/2001 13 19	77 54 00	902 38.00	37 61	0.24	8 18	24 43	16 67	39 5	38 9	1182 9	0 332	0 99	1 73E-07	1 00	0 98	
10/31/2001 20 49	11/4/2001 9.05	84 16 00	986 54 00	41 12	0.27	8 04	24 38	16 68	38 6	38 5	1221 4	0 343	1 00	1 56E-07			
11/4/2001 9.07	11/7/2001 23 25	86 18 00	1073 12 00	44 72	0 22	8,02	24 54	16.77	38 8	39 0	1260.4	0 354	1 00	1.52E-07			
11/7/2001 21 38	11/10/2001 21 36	71 58 00	1145 10 00	47 72	0 38	7 04	24 39	17.71	33 1	33 5	1293 9	0 364	1 01	1 45E-07			
11/10/2001 21 38	11/14/2001 7 26	81,48 00	1226 58 00	51 12	0 20	7 49	24 62	17 32	36.2	36.6	1330.5	0 374	1 01	1,43E-07			
11/14/2001 7 28	11/17/2001 20 24	84 56 00	1311 54 00	54 66	0 37	7 51	24 60	17 48	35.5	35 7	1366.2	0.384	1 01	1 34E-07			
11/17/2001 20 26	11/21/2001 12 02	87 36 00	1399 30 00	58 31	0.32	7 38	24 57	17 36	35 1	36 2	1402 3	0 394	1 03	1 30E-07			
11/21/2001 12 03	11/25/2001 10 30	94.27 00	1493 57 00	62 25	0.35	7 38	24 30	17 30	35,0	35 1	1437.4	0.404	1 00	1 20E-07			
11/25/2001 10 31	11/28/2001 21 54	83.23.00	1577 20 00	65 72	0.40	6 57	24 39	18,20	30 7	31 0	1468 5	0.413	1 01	1 12E-07			
11/28/2001 21 56	12/2/2001 12 25	86 29 00	1663,49 00	69 33	0 21	6 47	24 67	18 41	31 1	31.4	1499.9	0.421	1 01	1,07E-07			
12/2/2001 12 26	12/6/2001 15 22	98 56 00	1762 45 00	73.45	0.42	6 70	24 40	18 00	31 2	32 1	1532 0	0 430	1 03	9.78E-08			
12/6/2001 15 24	12/10/2001 20 44	101 20 00	1864 05 00	77 67	0 20	6.55	24 60	18 11	31 6	32 5	1564 5	0.440	1.03	9 48E-08			
12/10/2001 20 46	12/15/2001 9 51	109 05 00	1973 10 00	82 22	0 20	6.74	24 45	17 77	32 5	33,5	1598 0	0 449	1 03	9.28E-08			
12/15/2001 9 54	12/19/2001 9 28	95 34 00	2068 44 00	86 20	0.17	6 32	24 52	18 40	30.6	30 7	1628,7	0 458	1.00	9 43E-08	1 00	0.95	Terminated
												Avg Last 4·		**9.49E-08**			
												Lower Limit:		**7.12E-08**	75%		
												Upper Limit.		**1 19E-07**	125%		

Table 4.1.3-2
Large Block Hydraulic Conductivity Data, Test Pad 1, TP1-BS-002

Sample No.: **ELF-TP1-BS-002**

Initial Conditions Prior to Permeation

Avg Length =	15 1	cm	Initial Water Content, w =	17 2	%
Avg Diameter =	30 4	cm			
Length/Diameter =	0.50				
Area =	725 8	cm²			
Volume =	10978	cm³	B value =	0 98	

Final Conditions After Permeation

Final Water Content, w =	18 95	%	Pore Volume, PV =	3835	cm³
Degree of Saturation, S =	100 0	% (Assumed)	B value =	0 99	

Test Specification

Cell Pressure =	85	psi	Max Effective Stress =	8	psi
Inflow Pressure =	83	psi	Min Effective Stress =	2	psi
Inflow Area =	4 87	cm²	**Avg Effective Stress =**	**5**	**psi**
Outflow Pressure =	77	psi	**Avg Gradient =**	**28.5**	
Outflow Area =	4 62	cm²			
Pressure Difference =	6	psi			
Inflow Burette area =	0 8775	cm²	Outflow Burette Area =	0 8606	cm²
Inflow Anulus Factor =	4 550		Outflow Anulus Factor =	4 364	

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	ΣQ_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm³)	(cm³)	(cm³)			(cm/s)	at HW	at TW	
9/22/2001 21 34	9/24/2001 7:43	34 09 00	34 09 00	1 42	0.50	16 39	24 33	8 47	88 2	85 1	85 1	0 022	0 96	3 40E-08			
9/24/2001 7 45	9/25/2001 21:48	38:03 00	72 12.00	3 01	0.90	17 19	24 61	8 28	90.4	87 6	172 7	0 045	0 97	3 14E-08			
9/25/2001 21.52	9/27/2001 13 28	39 36 00	111 48:00	4 66	0 48	16 43	24 38	8.29	88.5	86 3	259 0	0 068	0 97	2 96E-08			
9/27/2001 13 32	9/29/2001 13 58	48,26.00	160 14 00	6 68	0 49	18 82	24 55	5 87	101 7	100 2	359 2	0 094	0 98	2 81E-08			
9/29/2001 14,02	10/1/2001 15 13	49 11 00	209 25,00	8 73	0,49	18.02	24 30	6.52	97 3	95 4	454 6	0.119	0 98	2 64E-08			
10/1/2001 15 17	10/3/2001 19 42	52 25 00	261 50 00	10 91	0 77	18 55	24 52	6 39	98 7	97 2	551 8	0 144	0 99	2 52E-08			
10/3/2001 19 44	10/5/2001 22 55	51 11 00	313 01 00	13 04	0 51	17 27	24 52	7 38	93 0	91 9	643 8	0 168	0 99	2 43E-08			
10/5/2001 22 57	10/8/2001 7 23	56 26 00	369 27,00	15 39	0 68	18 31	24 51	6.58	97 8	96.2	739 9	0 193	0 98	2 32E-08			
10/8/2001 7 25	10/10/2001 20 25	61 00 00	430 27 00	17 94	0 63	18 52	24 57	6 32	99 3	97 9	837 8	0.218	0 99	2 18E-08			
10/10/2001 20 27	10/13/2001 9 10	60 43 00	491 10 00	20 47	0 49	17 43	24 52	7 17	94 0	93 1	930 9	0 243	0 99	2 07E-08			
10/13/2001 9 12	10/15/2001 22 02	60 50 00	552 00.00	23 00	0 52	16 78	24 51	7 89	90 2	89 1	1020 1	0 266	0 99	1 98E-08			
10/15/2001 22 03	10/18/2001 20 48	70 45 00	622 45 00	25 95	0 33	18 15	24 40	6 20	98 9	97 6	1117 7	0 291	0 99	1 87E-08			
10/18/2001 20 50	10/21/2001 21 18	72,28 00	695 13 00	28 97	0 48	18 01	24 32	6 39	97 3	96.2	1213 9	0 317	0 99	1 80E-08			
10/21/2001 21 20	10/24/2001 23 30	74 10 00	769 23 00	32 06	0 53	17 79	24 36	6 71	95 8	94 7	1308 5	0 341	0 99	1 73E-08			
10/24/2001 23 32	10/28/2001 8 14	81 42 00	851 05 00	35 46	0 32	18 48	24 40	5 84	100 8	99 6	1408 1	0 367	0 99	1 65E-08			
10/28/2001 8 16	10/31/2001 20 29	84 13 00	935 18 00	38 97	0 34	18 44	24 42	5 98	100 5	98 9	1507 0	0 393	0 98	1 60E-08	1 00	0 99	
10/31/2001 20.50	11/4/2001 9 05	84 15 00	1019 33 00	42 48	0 62	18 26	24 25	6 42	97.9	95 6	1602 6	0 418	0 98	1 55E-08			
11/4/2001 9 08	11/7/2001 23 27	86 19 00	1105 52 00	46 08	0 37	17 60	24 46	6 82	95 6	94 6	1697 3	0.443	0 99	1 48E-08			
11/7/2001 23 29	11/10/2001 21 38	70 09 00	1176 01 00	49 00	0 49	14 36	24 42	10.10	77 0	76 8	1774 1	0,463	1 00	1 46E 08			
11/10/2001 21 40	11/14/2001 7 26	81 46 00	1257 47 00	52 41	0 32	16 03	24 38	8.33	87 2	86.1	1860 2	0 485	0 99	1 42E-08			
11/14/2001 7 30	11/17/2001 20 26	84 56.00	1342 43 00	55 95	0 46	16 25	24 51	8 32	87 6	86 8	1947 0	0 508	0 99	1 38E-08			
11/17/2001 20 28	11/21/2001 12 05	87 37 00	1430 20 00	59 60	0 44	16 29	24 54	8.09	88.0	88.2	2035 2	0 531	1 00	1 35E-08			
11/21/2001 12 06	11/25/2001 10 32	94 26 00	1524 46 00	63 53	0 59	17 51	24 49	7 10	93 9	93 3	2128 5	0 555	0 99	1 33E-08			
11/25/2001 10 33	11/28/2001 21 56	83 23 00	1608 09 00	67 01	0 40	14 81	24 25	9 31	80 0	80.1	2208 7	0 576	1 00	1 28E-08			
11/28/2001 21 58	12/2/2001 12 28	86 30 00	1694 39 00	70 61	0 30	14 89	24 69	9 75	81 0	80 1	2288 8	0 597	0 99	1 24E-08			
12/2/2001 12 29	12/6/2001 15 24	98 55 00	1793 34 00	74 73	0 25	16 24	24 70	8 19	88 7	88 6	2377 4	0.620	1 00	1 20E-08			
12/6/2001 15 26	12/10/2001 20 44	101 18 00	1894 52 00	78 95	0 20	16 00	24 61	8 31	87 7	87 4	2464 8	0.643	1 00	1 16E-08			
12/10/2001 20 46	12/15/2001 9 51	109 05 00	2003 57 00	83 50	0 30	16,80	24 50	7 48	91 6	91 3	2556.1	0.666	1 00	1 12E-08			
12/15/2001 9 55	12/19/2001 9 28	95 33 00	2099 30 00	87 48	0 37	15 23	24 63	9 22	82 5	82 7	2638.7	0.688	1 00	1 15E-08	0 99	1 00	Terminated
												Avg Last 4:		**1 16E-08**			
												Lower Limit:		**8.69E-09**	75%		
												Upper Limit:		**1 45E-08**	125%		

Table 4.1.3-3
Large Block Hydraulic Conductivity Data, Test Pad 1, TP1-BS-003

Sample No : **ELF-TP1-BS-003**

Initial Conditions Prior to Permeation

Avg Length =	15 1	cm	Initial Water Content, w =	16.9	%
Avg Diameter =	30 4	cm			
Length/Diameter =	0 50				
Area =	725 8	cm^2			
Volume =	10960	cm^3	B value =	0 95	

Final Conditions After Permeation

Final Water Content, w =	19 8	%	Pore Volume, PV =	4004	cm^3
Degree of Saturation, S =	100 0	% (Assumed)	B value =	0 96	

Test Specification

Cell Pressure =	90	psi	Max Effective Stress =	8	psi
Inflow Pressure =	88	psi	Min Effective Stress =	2	psi
Inflow Area =	4 30	cm^2	**Avg Effective Stress =**	**5**	**psi**
Outflow Pressure =	82	psi	**Avg Gradient =**	**28.4**	
Outflow Area =	4 28	cm^2			
Pressure Difference =	6	psi			
Inflow Burette area =	0 8744	cm^2	Outflow Burette Area =	0.8744	cm^2
Inflow Anulus Factor =	3 920		Outflow Anulus Factor =	3 895	

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	ΣQ_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
9/29/2001 20 10	10/1/2001 15 18	43 08 00	43 08,00	1 80	0 46	19 37	24 52	5 06	93 0	95 3	95 3	0.024	1 02	2 95E-08			
10/1/2001 15 20	10/3/2001 11 28	44 08,00	87 16 00	3 64	0 61	18 22	24 34	7 57	86 6	82 1	177 3	0.044	0 95	2.57E 08			
10/3/2001 11 30	10/5/2001 9 26	45,56 00	133 12 00	5 55	0 52	18 09	24 40	6 99	86 4	85 2	262 6	0 066	0 99	2.52E-08			
10/5/2001 9.28	10/7/2001 11 29	50 01 00	183 13.00	7 63	0 38	18 73	24 34	6 18	90 3	88 9	351 5	0.088	0 98	2 42E-08			
10/7/2001 11 31	10/9/2001 12 46	49 15 00	232 28.00	9 69	0 55	18 11	24 33	7 07	86 4	84 5	435 9	0 109	0 98	2 34E-08			
10/9/2001 12 48	10/11/2001 15 34	50 46 00	283 14.00	11 80	0 40	17 86	24 47	7 20	85 9	84 5	520 5	0.130	0 98	2 26E-08			
10/11/2001 15 36	10/13/2001 22 21	54 45 00	337 59 00	14 08	0 51	18.87	24 45	6 46	90 3	88 1	608 5	0.152	0.97	2 20E-08			
10/13/2001 22 23	10/16/2001 8,25	58 02,00	396 01 00	16 50	0 50	19 37	24 50	5 90	92 8	91 0	699 6	0.175	0.98	2 14E-08			
10/17/2001 11 43	10/19/2001 20 18	58 35 00	452 36 00	18.66	0 40	18 33	24.19	6.60	88 2	86 1	785 7	0.196	0 98	2 08E-08			
10/19/2001 20 20	10/21/2001 21 23	49 03 00	501 39 00	20 90	0 27	15 68	24 32	9 13	75 8	74 4	860,1	0 215	0 98	2 05E-08			
10/21/2001 21 25	10/24/2001 11 20	61 55 00	563 34 00	23 48	0 47	19 24	24 40	5 84	92 3	90 9	950 9	0 237	0 98	2 00E-08			
10/24/2001 11 22	10/26/2001 21 34	58 12 00	621 46 00	25 91	0 27	17 87	24 32	6 98	86 6	84 9	1035 8	0 259	0 98	1 98E-08	1 00	0 95	
10/26/2001 22 11	10/29/2001 7 19	58 08 00	679 54 00	28.33	0 45	18 35	24 31	6 60	88 1	86 7	1122 5	0 280	0 98	2 03E-08			
10/29/2001 7 21	10/31/2001 20 34	61 13 00	741 07 00	30 88	0 42	18 60	24 32	6 39	89 4	87 8	1210 2	0.302	0 98	1 95E-08	1 00	0 96	Terminated
												Avg Last 4		**1 99E-08**			
												Lower Limit		**1.49E-08**	75%		
												Upper Limit.		**2.49E-08**	125%		

Figure 4.1.3-4
Large Block Hydraulic Conductivity Data, Test Pad 1, TP1-BS-004

Sample No.: ELF-TP1-BS-004

Initial Conditions Prior to Permeation

Avg Length =	15 1	cm	Initial Water Content, w =	13 5	%
Avg Diameter =	30 4	cm			
Length/Diameter =	0 50				
Area =	725 8	cm^2			
Volume =	10960	cm^3	B value =	0 95	

Final Conditions After Permeation

Final Water Content, w =	18 9	%	Pore Volume, PV =	3879	cm^3
Degree of Saturation, S =	100 0	% (Assumed)	B value =	0 99	

Test Specification

Cell Pressure =	90	psi	Max Effective Stress =	8	psi
Inflow Pressure =	88	psi	Min Effective Stress =	2	psi
Inflow Area =	4 55	cm^2	**Avg Effective Stress =**	**5**	**psi**
Outflow Pressure =	82	psi	**Avg Gradient =**	**28 5**	
Outflow Area =	4 71	cm^2			
Pressure Difference =	6	psi			
Inflow Burette area =	0 8681	cm^2	Outflow Burette Area =	0 8720	cm^2
Inflow Anulus Factor =	4 240		Outflow Anulus Factor =	4 403	

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in} (cm^3)	Q_{out} (cm^3)	ΣQ_{out} (cm^3)	Σ PV	Q_{out}/Q_{in}	k (cm/s)	B-Value at HW	B-Value at TW	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending									
9/29/2001 20 10	10/2/2001 21 45	73 35 00	73 35 00	3 07	0.50	18 44	24 57	7 26	94 0	93 5	93 5	0 024	0 99	1 72E-08			
10/2/2001 21 47	10/6/2001 23 27	97 40 00	171 15 00	7 14	0 62	18 24	24 51	7 19	92 3	93 6	187 1	0 048	1 01	1.28E-08			
10/6/2001 23.29	10/11/2001 15 34	112.05 00	283 20 00	11 81	0 61	17 85	24 46	7 59	90 3	91 1	278.3	0 072	1 01	1 09E-08			
10/11/2001 15 36	10/16/2001 21 39	126 03 00	409 23 00	17 06	0 46	18.02	24 47	7.31	92 0	92 7	371 0	0 096	1 01	9 86E-09			
10/17/2001 11 44	10/21/2001 21.23	105 39 00	515 02 00	21 46	0 36	15 72	24 28	9.62	80 5	79.2	450.2	0 116	0.98	1 01E-08			
10/21/2001 21 26	10/26/2001 21.34	120.08 00	635 10 00	26 47	0 67	16 76	24 48	8.70	84 3	85 3	535 4	0 138	1 01	9.46E-09	0.99	0 98	
10/26/2001 22 12	10/31/2001 20 34	119 22 00	754 32 00	31 44	0 28	15 89	24 46	9 33	81 8	81 7	617 2	0 159	1 00	9 16E 09	1 00	0 99	Terminated
												Avg Last 4		9 64E-09			
												Lower Limit		7.23E-09	75%		
												Upper Limit		1.21E-08	125%		

TABLE 4.2.1-1 ELF TEST PAD 2 TEST DATA FOR SOIL CLASSIFICATION, MODIFIED PROCTOR AND SPECIFIC GRAVITY

ELF TEST PAD 2															
Location				Grain Size		Atterberg Limits									
Sample Number	Northing	Easting	Elevation	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification	Sample Moisture Content (%)	Munsell Color	Laboratory Visual Soil Description
*TP2-CL-001	192,580 30	2,184,529.98	5170 2	100	65	35	19	16				CL	9.1	10YR7/4	Moist Very Pale Brown sandy lean Clay
*TP2-CL-002	192,642.36	2,184,491 57	5170 2	100	69	39	26	13				ML	10 8	10YR8/3	Moist Very Pale Brown sandy silt
*TP2-CL-003	192,705 56	2,184,425 95	5170.3	100	68	36	22	14				CL	11.9	10YR7/4	Moist Very Pale Brown sandy lean Clay
*TP2-PR-001	192,690.74	2,184,537 10	5169 6	100	67	33	18	15	114.5	15.5		CL	11 0	10YR7/4	Moist Very Pale Brown sandy lean Clay
*TP2-PR-002	192,581 46	2,184,429 00	5169 5	100	67	35	18	17	113.5	16 0		CL	10 3	10YR7/4	Moist Very Pale Brown sandy lean Clay
TP2-PR-003	192,225 58	2,184,267 98	5179 7	100	71	41	20	21	120.0	13 0	2 71	CL	22 6	10YR7/4	Moist Very Pale Brown lean Clay with Sand
TP2-PR-004	192,200 49	2,184,267.69	5179.4	100	68	41	20	21	118 5	14 0	2.72	CL	17 5	10YR7/4	Moist Very Pale Brown sandy lean Clay
TP2-PR-005	192,291.77	2,184,245 40	5178 4	100	67	41	19	22	121.0	13 5		CL	19 8	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-006	192,170.59	2,184,245 17	5178 8	100	69	42	19	23	119.5	14 0		CL	23 8	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-007	192,284.70	2,184,266 30	5179 2	100	68	43	20	23	120.5	13.5		CL	19 6	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-008	192,138 00	2,184,270.64	5180 1	100	64	39	17	22	122 5	13.0		CL	18 1	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-009	192,200 49	2,184,248.61	5179.0	100	65	41	19	22	121 0	13 5		CL	19 7	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-010	192,227.64	2,184,248 57	5179 4	100	68	39	18	21	121.5	12.5		CL	18 7	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-011	192,201.01	2,184,266.65	5180 5	100	60	44	17	27	124.0	11.5		CL	17 7	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-012	192,258 48	2,184,265 89	5180 7	100	63	40	17	23	120 5	13 0		CL	17 2	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-013	192,253 75	2,184,232 85	5179 7	100	63	40	17	23	121 0	13 0		CL	18 4	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-014	192,240 71	2,184,246 99	5179 9	100	63	40	17	23	120 5	13 5		CL	17 4	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-015	192,275 20	2,184,280 71	5181 0	100	64	41	17	24	123 0	12 5		CL	16 8	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-016	192,254 49	2,184,266 04	5180 9	100	67	41	17	24	123 0	12 5		CL	17 6	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-017	192,300 11	2,184,238 49	5179 6	100	64	41	17	24	122 5	13 0		CL	17 0	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-018	192,179 81	2,184,236 76	5180 1	100	65	41	18	23	122 5	13 0		CL	17.8	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-019	192,241 52	2,184,283 33	5181 8	100	64	43	17	26	121 5	13 0		CL	16 8	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-020	192,267.38	2,184,269 48	5181 4	100	62	42	17	25	122.0	12 5		CL	16 6	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-021	192,241 74	2,184,251 78	5180 9	100	64	42	17	25	123 0	12 0		CL	18 0	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
TP2-PR-022	192,183 86	2,184,250 23	5180 6	100	63	42	17	25	122 5	12 5		CL	16.2	10YR6/4	Moist Light Yellowish Brown sandy lean Clay
* = Borrow Source location															

CL = Classification
PR = Modified Proctor
USCS = Unified Soil Classification System

TABLE 4.2.2-1 NUCLEAR DENSITY TEST RESULTS FOR ELF TEST PAD 2, LANE 1 (815 COMPACTOR)

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)						
ELF-TP2-DT-002	8/29/01	0		NUCLEAR	17.4	103.9	93.2%	75.1%	N/A	N/A	N/A	SUBGRADE
ELF-TP2-DT-009	9/10/01	2	4	NUCLEAR	18.2	110.7	94.0%	93.5%	4	4	Y	
ELF-TP2-DT-010	9/10/01	2	15	NUCLEAR	19.6	109.3	92.8%	96.9%	4	4	Y	
ELF-TP2-DT-011	9/10/01	2	19	NUCLEAR	20.0	108.1	91.8%	95.9%	4	4	Y	
ELF-TP2-DT-012	9/10/01	2	18	NUCLEAR	21.1	103.1	87.5%	89.1%	4	4	N	
ELF-TP2-DT-013	9/10/01	2	5	NUCLEAR	21.8	104.4	88.7%	95.3%	4	4	N	
ELF-TP2-DT-014	9/10/01	2	9	NUCLEAR	18.3	109.1	92.6%	90.1%	4	4	Y	
ELF-TP2-DT-021	9/11/01	3	3	NUCLEAR	17.2	107.2	91.0%	80.6%	4	4	N	
ELF-TP2-DT-022	9/11/01	3	14	NUCLEAR	20.8	106.1	88.1%	94.9%	4	4	N	
ELF-TP2-DT-023	9/11/01	3	11	NUCLEAR	17.4	108.6	90.1%	84.5%	4	4	N	
ELF-TP2-DT-024	9/11/01	3	6	NUCLEAR	20.2	107.4	91.2%	95.2%	4	4	Y	
ELF-TP2-DT-025	9/11/01	3	20	NUCLEAR	19.4	107.3	89.0%	91.1%	4	4	N	
ELF-TP2-DT-026	9/11/01	3	10	NUCLEAR	20.7	106.1	88.1%	94.4%	4	4	N	
ELF-TP2-DT-035	9/12/01	4	16	NUCLEAR	18.0	108.1	91.7%	86.2%	4	4	Y	
ELF-TP2-DT-036	9/12/01	4	2	NUCLEAR	19.1	107.0	90.8%	89.0%	4	4	Y	
ELF-TP2-DT-037	9/12/01	4	7	NUCLEAR	17.1	109.2	92.7%	84.4%	4	4	N	
ELF-TP2-DT-038	9/12/01	4	15	NUCLEAR	17.5	110.0	93.3%	88.0%	4	4	Y	
ELF-TP2-DT-039	9/12/01	4	4	NUCLEAR	19.0	107.1	91.0%	88.9%	4	4	Y	
ELF-TP2-DT-040	9/12/01	4	17	NUCLEAR	17.2	110.5	93.8%	87.8%	4	4	Y	
ELF-TP2-DT-047	9/13/01	5	12	NUCLEAR	14.0	107.5	89.2%	66.2%	4	4	N	
ELF-TP2-DT-048	9/13/01	5	14	NUCLEAR	16.9	111.5	92.6%	88.6%	4	4	Y	
ELF-TP2-DT-049	9/13/01	5	10	NUCLEAR	16.8	109.8	91.2%	84.3%	4	4	N	
ELF-TP2-DT-050	9/13/01	5	9	NUCLEAR	17.8	109.4	90.8%	88.3%	4	4	Y	
ELF-TP2-DT-051	9/13/01	5	18	NUCLEAR	16.1	112.7	93.6%	87.2%	4	4	Y	
ELF-TP2-DT-052	9/13/01	5	2	NUCLEAR	16.0	112.8	93.6%	86.8%	4	4	Y	
ELF-TP2-DT-059	9/14/01	6	5	NUCLEAR	19.5	108.0	89.7%	93.4%	4	4	N	
ELF-TP2-DT-060	9/14/01	6	10	NUCLEAR	16.6	113.6	94.3%	92.0%	4	4	Y	
ELF-TP2-DT-061	9/14/01	6	15	NUCLEAR	16.9	111.7	92.7%	89.0%	4	4	Y	
ELF-TP2-DT-062	9/14/01	6	13	NUCLEAR	15.8	113.2	94.0%	86.6%	4	4	Y	
ELF-TP2-DT-063	9/14/01	6	7	NUCLEAR	17.0	111.9	92.8%	89.9%	4	4	Y	
ELF-TP2-DT-064	9/14/01	6	4	NUCLEAR	18.1	108.8	90.3%	88.4%	4	4	Y	
Averages	--	--	--		**18.8**	**107.7**	**91.4%**	**88.9%**				

AZ = Acceptable Hydraulic Conductivity Zone

TABLE 4.2.2-2 NUCLEAR DENSITY TEST RESULTS FOR ELF TEST PAD 2, LANE 2 (825 COMPACTOR)

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)						
ELF-TP2-DT-001	8/29/01	0	N/A	NUCLEAR	15.0	108.6	97.4%	N/A	N/A		N/A	SUBGRADE
ELF-TP2-DT-003	9/7/01	2	11	NUCLEAR	19.6	108.1	91.8%	94.0%	4	4	Y	
ELF-TP2-DT-004	9/7/01	2	12	NUCLEAR	19.4	109.7	93.1%	97.0%	4	4	Y	
ELF-TP2-DT-005	9/7/01	2	3	NUCLEAR	20.1	106.0	90.0%	91.4%	4	4	N	
ELF-TP2-DT-006	9/7/01	2	5	NUCLEAR	19.5	107.3	91.1%	91.6%	4	4	Y	
ELF-TP2-DT-007	9/7/01	2	17	NUCLEAR	20.4	106.8	90.7%	94.7%	4	4	Y	
ELF-TP2-DT-008	9/7/01	2	16	NUCLEAR	19.7	108.1	91.8%	94.5%	4	4	Y	
ELF-TP2-DT-015	9/11/01	3	3	NUCLEAR	22.2	104.7	88.9%	97.8%	4	4	N	
ELF-TP2-DT-016	9/11/01	3	1	NUCLEAR	19.2	110.0	91.3%	96.7%	4	4	Y	
ELF-TP2-DT-017	9/11/01	3	15	NUCLEAR	24.0	102.1	84.7%	99.0%	4	4	N	
ELF-TP2-DT-018	9/11/01	3	19	NUCLEAR	20.9	105.5	89.6%	93.9%	4	4	N	
ELF-TP2-DT-019	9/11/01	3	14	NUCLEAR	21.0	106.8	90.6%	97.4%	4	4	Y	
ELF-TP2-DT-020	9/11/01	3	2	NUCLEAR	18.6	110.4	91.6%	94.6%	4	4	Y	
ELF-TP2-DT-028	9/12/01	4	13	NUCLEAR	17.4	110.1	91.3%	87.8%	4	4	Y	
ELF-TP2-DT-029	9/12/01	4	12	NUCLEAR	17.2	111.9	92.9%	91.2%	4	4	Y	
ELF-TP2-DT-030	9/12/01	4	17	NUCLEAR	17.2	109.2	90.6%	84.9%	4	4	N	
ELF-TP2-DT-031	9/12/01	4	4	NUCLEAR	17.5	111.3	92.4%	91.2%	4	4	Y	
ELF-TP2-DT-032	9/12/01	4	6	NUCLEAR	17.8	110.1	89.9%	89.9%	4	4	N	
ELF-TP2-DT-033	9/12/01	4	7	NUCLEAR	17.5	109.1	89.1%	86.1%	4	4	N	
ELF-TP2-DT-041	9/13/01	5	1	NUCLEAR	16.2	114.0	94.6%	90.8%	4	4	Y	
ELF-TP2-DT-042	9/13/01	5	10	NUCLEAR	16.0	109.0	90.4%	78.5%	4	4	N	
ELF-TP2-DT-043	9/13/01	5	13	NUCLEAR	15.8	112.5	93.4%	85.0%	4	4	Y	
ELF-TP2-DT-044	9/13/01	5	11	NUCLEAR	17.1	110.2	91.5%	86.7%	4	4	Y	
ELF-TP2-DT-045	9/13/01	5	14	NUCLEAR	17.9	108.9	90.4%	87.6%	4	4	Y	
ELF-TP2-DT-046	9/13/01	5	12	NUCLEAR	15.0	112.7	93.5%	81.1%	4	4	N	
ELF-TP2-DT-053	9/13/01	6	9	NUCLEAR	15.7	113.1	92.3%	85.7%	4	4	Y	
ELF-TP2-DT-054	9/13/01	6	20	NUCLEAR	16.1	112.7	92.0%	87.2%	4	4	Y	
ELF-TP2-DT-055	9/13/01	6	4	NUCLEAR	15.2	110.3	90.1%	77.2%	4	4	N	
ELF-TP2-DT-056	9/13/01	6	7	NUCLEAR	17.2	112.1	91.5%	91.6%	4	4	Y	
ELF-TP2-DT-057	9/13/01	6	6	NUCLEAR	18.2	108.9	88.9%	89.1%	4	4	N	
ELF-TP2-DT-058	9/13/01	6	12	NUCLEAR	17.5	111.6	91.1%	91.8%	4	4	Y	
Averages	--	--	--		**18.2**	**109.4**	**91.0%**	**90%**				

AZ = Acceptable Hydraulic Conductivity Zone

TABLE 4.2.2-3 SHELBY TUBE HYDRAULIC CONDUCTIVITY TEST RESULTS FOR ELF TEST PAD 2

LANE 1, 815 COMPACTOR

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	PERMEABILITY/ ASSOCIATED TESTING	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)							
*ELF-TP2-ST-003	9/10/01	2	11	SHELBY	20.6	104.6	88.8%	90.5%	4	4	N	K = 1.2 X 10^{-8}	
*ELF-TP2-ST-004	9/10/01	2	17	SHELBY	21.0	105 1	89.2%	93.4%	4	4	N	K = 2.1 X 10^{-8}	
*ELF-TP2-ST-007	9/11/01	3	13	SHELBY	19.7	105.5	89.6%	88.4%	4	4	N	K = 7.4 X 10^{-9}	
*ELF-TP2-ST-008	9/11/01	3	14	SHELBY	20.0	106.3	88.2%	91.5%	4	4	N	K = 1.0 X 10^{-8}	
*ELF-TP2-ST-012	9/12/01	4	7	SHELBY	17.7	107.3	91.1%	83.2%	4	4	N	K = 7.0 X 10^{-8}	
*ELF-TP2-ST-013	9/12/01	4	20	SHELBY	17.3	105.1	89.2%	76.6%	4	4	N	K = 2.6 X 10^{-6}	Poor Sample
*ELF-TP2-ST-017	9/13/01	5	17	SHELBY	17.0	110.0	91.3%	85.6%	4	4	Y	K = 2.4 X 10^{-8}	
*ELF-TP2-ST-018	9/13/01	5	5	SHELBY	18.9	107.7	89.3%	89.6%	4	4	N	K = 1.1 X 10^{-8}	
*ELF-TP2-ST-019	9/13/01	5	12	SHELBY	17.6	109.4	90.8%	87.4%	4	4	Y	K = 1.8 X 10^{-8}	
*ELF-TP2-ST-023	9/14/01	6	14	SHELBY	15.4	104.7	86.8%	67.8%	4	4	N	K = 7 4 X 10^{-6}	Voids in Sample
*ELF-TP2-ST-024	9/14/01	6	15	SHELBY	16 0	108.9	90.4%	78.3%	4	4	N	K = 2.3 X 10^{-7}	Voids in Sample
* Oven Moisture													
Averages	--	--	--		**19.4**	**105.7**	**89.5%**	**84.8%**					

LANE 2, 825 COMPACTOR

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	PERMEABILITY/ ASSOCIATED TESTING	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)							
*ELF-TP2-ST-001	9/7/01	2	8	SHELBY	19.0	106.1	90.0%	86.5%	4	4	Y	K = 2 6 X 10^{-8}	
*ELF-TP2-ST-002	9/7/01	2	19	SHELBY	17 7	107 2	91 0%	83.0%	4	4	N	K = 2.0 X 10^{-7}	Voids in Sample
*ELF-TP2-ST-005	9/11/01	3	10	SHELBY	18.4	108.8	92.3%	89.8%	4	4	Y	K = 1.0 X 10^{-8}	
*ELF-TP2-ST-006	9/11/01	3	6	SHELBY	18.1	109.6	90.9%	90.1%	4	4	Y	K = 1.1 X 10^{-8}	
*ELF-TP2-ST-009	9/12/01	4	10	SHELBY	18.5	107.8	89.4%	88.0%	4	4	N	K = 1.8 X 10^{-8}	
*ELF-TP2-ST-010	9/12/01	4	5	SHELBY	17.7	109 9	89.7%	89.0%	4	4	N	K = 2.2 X 10^{-8}	
*ELF-TP2-ST-011	9/12/01	4	18	SHELBY	17.3	109.6	90 9%	86.0%	4	4	Y	K = 2.0 X 10^{-8}	
*ELF-TP2-ST-014	9/13/01	5	12	SHELBY	15 7	112.4	93.2%	84.1%	4	4	N	K = 1.3 X 10^{-8}	
*ELF-TP2-ST-015	9/13/01	5	15	SHELBY	18.5	107.9	89.6%	88.3%	4	4	N	K = 2.3 X 10^{-8}	
*ELF-TP2-ST-016	9/13/01	5	10	SHELBY	17.9	109.2	90.7%	88.4%	4	4	Y	K = 3.7 X 10^{-8}	
*ELF-TP2-ST-020	9/13/01	6	18	SHELBY	17.8	111.0	90.6%	91.9%	4	4	Y	K = 1.5 X 10^{-8}	
*ELF-TP2-ST-021	9/13/01	6	6	SHELBY	20.7	104.6	85.4%	90.9%	4	4	N	K = 3.0 X 10^{-8}	
*ELF-TP2-ST-022	9/13/01	6	4	SHELBY	16.4	108 6	88.6%	79.8%	4	4	N	K = 3.1 X 10^{-8}	
* Oven Moisture													
Averages	--	--	--		**18.1**	**108.7**	**90.3%**	**88%**					

AZ = Acceptable Hydraulic Conductivity Zone

Table 4.2.2-4
Summary of Nuclear Density and Hydraulic Conductivity Tests

				Summary of Nuclear Density Tests									
	Test Pad 2, Lane 1						Test Pad 2, Lane 2						
Lift #	2	3	4	5	6	All Lane 1	2	3	4	5	6	All Lane 2	All Test Pad 2
Range of moisture content (%)	18 2 - 21 8	17.2 - 20 8	17 1 - 19 1	14 0 - 17 8	15 8 - 19 5	14 0 - 21 8	19 4 - 20.4	18.6 - 24 0	17 2 - 17 8	15 0 - 17 9	15 2 - 18 2	15 0 - 24.0	14.0 - 24.0
Range of Dry Density (pcf)	103 1 -109 3	106 1 - 108 6	107 0 - 110 5	107 5 - 112 8	108 0 - 113 6	103.1 - 113.6	106.0 - 109.7	102 1 - 110 4	109 1 - 111 9	108 9 - 114 0	108 9 - 113 1	102 1 - 114.0	102.1 - 114 0
Number of tests in AZ	4 (Figure 5 2 2-1)	1 (Figure 5 2 2-2a & b)	5 (Figure 5 2 2-3)	4 (Figure 5 2 2-4)	5 (Figure 5 2 2-5)	19	5 (Figure 5.2.2-6)	3 (Figure 5 2 2-7a & b)	3 (Figure 5 2 2-8a & b)	4 (Figure 5 2 2-9)	4 (Figure 5 2 2-10)	19	38
Number of tests out of AZ	2 (Figure 5 2 2-1)	5 (Figure 5 2 2-2a & b)	1 (Figure 5 2 2-3)	2 (Figure 5 2 2-4)	1 (Figure 5 2 2-5)	11	1 (Figure 5 2 2-6)	3 (Figure 5 2.2-7a & b)	3 (Figure 5 2 2-8a & b)	2 (Figure 5 2 2-9)	2 (Figure 5 2 2-10)	11	22

				Summary of Shelby Tube Permeability Tests									
	Test Pad 2 Lane 1						Test Pad 2, Lane 2						
Lift #	2	3	4	5	6	All Lane 1	2	3	4	5	6	All Lane 2	All Test Pad 2
Range of moisture content (%)	20 6 - 21 0	19 7 - 20 0	17 3 - 17 7	17 0 - 18 9	15 4 - 16 0	15 4 - 21 0	17.7 - 19 0	18 1 - 18 4	17 3 - 18 5	15 7 - 18 5	16 4 - 20 7	15 7 - 20 7	15 4 - 21 0
Range of Dry Density (pcf)	104 6 - 105 1	105 5 - 106 3	105 1 - 107.3	107 7 - 110 0	104 7 - 108 9	104 6 - 110 0	106 1 - 107 2	108 8 - 109 6	107 8 - 109.9	107 9 - 112 4	104 6 - 111 0	104 6 - 112 4	104 6 - 112.4
Number of tests in AZ	0 (Figure 5 2 2-1)	0 (Figure 5 2 2-2)	0 (Figure 5 2 2-3)	2 (Figure 5 2 2-4)	0 (Figure 5 2 2-5)	2	1 (Figure 5 2 2-6)	2 (Figure 5 2 2-7a&b)	1 (Figure 5 2 2-8a&b)	1 (Figure 5 2 2-9)	1 (Figure 5 2 2-10)	6	8
Number of tests out of AZ	2 (Figure 5 2 2-1)	2 (Figure 5 2 2-2)	2 (Figure 5 2 2-3)	1 (Figure 5 2 2-4)	2 (Figure 5 2 2-5)	9	1 (Figure 5 2 2-6)	0 (Figure 5 2 2-7a&b)	2 (Figure 5 2 2-8a&b)	2 (Figure 5 2 2-9)	2 (Figure 5.2 2 10)	7	16
Number of Passing Permeability Tests	2 (Figure 5 2 2-1)	2 (Figure 5 2 2-2)	1(Figure 5 2 2 3)	3 (Figure 5 2 2-4)	0 (Figure 5 2 2-5)	8	1 (Figure 5 2 2-6)	2 (Figure 5 2 2-7a&b)	3 (Figure 5 2 2-8a&b)	3 (Figure 5 2 2-9)	3 (Figure 5.2 2-10)	12	20

AZ = Acceptable Hydraulic Conductivity Zone

Table 4.2.3-1
Large Block Hydraulic Conductivity Data, Test Pad 2, TP2-BS-001

Sample No.· **ELF-TP2-BS-001**

Initial Conditions Prior to Permeation

Avg Length = 15.2 cm
Avg Diameter = 30 5 cm
Length/Diameter = 0 50
Area = 730 6 cm^2
Volume = 11105 cm^3

Initial Water Content, w = 17 8 %
B value = 0 95

Final Conditions After Permeation

Final Water Content, w = 19.5 %
Degree of Saturation, S = 100 0 % (Assumed)

Pore Volume, PV = 3887 cm^3
B value = 0 99

Test Specification

Cell Pressure = 90 psi
Inflow Pressure = 86 psi
Inflow Area = 4 30 cm^2
Outflow Pressure = 84 psi
Outflow Area = 4.55 cm^2
Pressure Difference = 2 psi
Inflow Burette area = 0.8744 cm^2
Inflow Anulus Factor = 3 920

Max Effective Stress = 6 psi
Min Effective Stress = 4 psi
Avg Effective Stress = 5 psi
Avg Gradient = 9.8
Outflow Burette Area = 0 8681 cm^2
Outflow Anulus Factor = 4.240

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in} (cm^3)	Q_{out} (cm^3)	Σ Q_{out} (cm^3)	Σ PV	Q_{out}/Q_{in}	k (cm/s)	B-Value at HW	B-Value at TW	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending									
11/6/2001 19 42	11/7/2001 23.29	27 47.00	27 47 00	1 16	0 90	17 47	24 20	8 19	81 5	83 9	83 9	0 022	1 03	1.16E-07			
11/7/2001 23 31	11/9/2001 11 06	35 35,00	63 22 00	2 64	0 48	16 67	24 38	8.98	79 8	80 7	164 6	0 042	1,01	8.72E-08			
11/9/2001 11,08	11/10/2001 21 40	34 32 00	97 54 00	4 08	0 43	16 21	24 39	9.59	77 6	77 6	242 1	0 062	1 00	8 66E-08			
11/10/2001 21 42	11/12/2001 21 56	48 14 00	146 08 00	6 09	0 49	17 67	24 43	7 62	84 5	88 1	330 2	0 085	1,04	6 99E-08			
11/12/2001 21 59	11/15/2001 9 17	59 18 00	205 28 00	8 56	0 43	18.39	24 50	7.27	88.4	90 3	420 5	0 108	1 02	5 91E-08			
11/15/2001 9 19	11/17/2001 22.20	61 01 00	266.27 00	11 10	0 54	16 41	24 53	9.07	78 1	81 0	501 5	0 129	1 04	5 03E-08			
11/17/2001 22 21	11/20/2001 21 42	71 21 00	337 48 00	14 08	0 49	16 90	24 57	8 80	80 7	82 6	584 2	0 150	1 02	4 43E-08			
11/20/2001 21 44	11/24/2001 11 20	85 36.00	423 24 00	17 64	0 45	17 70	24 38	7 49	84 9	86 5	672 7	0 173	1 04	3 96E-08			
11/24/2001 11 22	11/28/2001 7 29	92 07 00	515 31 00	21 48	0 45	16 80	24 50	8 62	80 4	83 2	755 9	0 194	1 03	3 44E-08			
11/28/2001 7 31	12/2/2001 12 31	101 00 00	616 31 00	25 69	0 40	16 98	24 68	8.80	81 6	83 2	839 1	0 216	1 02	3 16E 08			
12/2/2001 12 32	12/7/2001 8 13	115 41 00	732 12 00	30 51	0 60	16 30	24 50	9.50	77 2	78 6	917 7	0.236	1 02	2 60E-08			
12/7/2001 8 14	12/13/2001 9 14	145 00 00	877 12 00	36 55	0 49	17 02	24 40	8 29	81 3	84 4	1002 1	0 258	1 04	2 22E 08	0.99	0 99	Terminated
												Avg Last 4:		2 85E-08			
												Lower Limit:		2.14E-08	75%		
												Upper Limit:		3 57E-08	125%		

Table 4.2.3-2
Large Block Hydraulic Conductivity Data, Test Pad 2, TP2-BS-002

Sample No.: **ELF-TP2-BS-002**

Initial Conditions Prior to Permeation

Avg Length = 15 2 cm
Avg Diameter = 30 5 cm
Length/Diameter = 0 50
Area = 730 6 cm^2
Volume = 11105 cm^3

Initial Water Content, w = 18 7 %

B value = 0 95

Final Conditions After Permeation

Final Water Content, w = 18 8 %
Degree of Saturation, S = 100 0 % (Assumed)

Pore Volume, PV = 3773 cm^3
B value = 1 00

Test Specification

Cell Pressure = 90 psi
Inflow Pressure = 85 psi
Inflow Area = 4 28 cm^2
Outflow Pressure = 85 psi
Outflow Area = 4.71 cm^2
Pressure Difference = 0 psi
Inflow Burette area = 0 8744 cm^2
Inflow Anulus Factor = 3 895

Max Effective Stress = 5 psi
Min Effective Stress = 5 psi
Avg Effective Stress = 5 psi
Avg Gradient = 1.4

Outflow Burette Area = 0 8720 cm^2
Outflow Anulus Factor = 4 403

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	ΣQ_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
11/6/2001 19 43	11/7/2001 23 29	27:46.00	27 46 00	1 16	0 23	7 03	24 42	17 83	33 3	35 6	35 6	0.009	1 07	3 76E-07			
11/7/2001 23 32	11/9/2001 11 06	35 34 00	63 20 00	2 64	0 36	7 11	24 40	18 65	33 0	31 1	66 7	0.018	0 94	2 67E-07			
11/9/2001 11 09	11/10/2001 21 42	34 33 00	97 53 00	4 08	0 40	6 11	24 52	19 61	28 0	26 5	93 2	0 025	0 95	2 18E-07			
11/10/2001 21 44	11/12/2001 21 56	48 12 00	146 05 00	6 09	0 32	6,27	24.57	18 62	29 1	32 1	125 3	0 033	1 10	1 81E-07			
11/12/2001 22 11	11/15/2001 9 20	59 09 00	205 14 00	8.55	0 18	6,89	24 73	18 77	32 8	32 2	157 6	0 042	0,98	1 59E-07			
11/15/2001 9 22	11/17/2001 22.22	61 00 00	266 14 00	11 09	0 25	6 24	24 53	18 76	29,3	31 2	188 7	0.050	1 06	1 41E-07			
11/17/2001 22 23	11/20/2001 21 45	71 22 00	337 36 00	14 07	0 43	6 29	24 62	19 20	28 7	29 3	218 0	0.058	1 02	1 14E-07			
11/20/2001 21 47	11/25/2001 10 34	108.47 00	446 23,00	18 60	0 30	6.98	24 50	17 98	32 7	35 2	253 2	0.067	1 08	9 39E-08			
11/25/2001 10 35	11/28/2001 22 00	83 25 00	529 48 00	22 08	0 33	5 32	24,55	19 65	24 4	26 5	279 7	0.074	1 08	8 15E-08			
11/28/2001 22 02	12/3/2001 22 22	120 20 00	650 08 00	27 09	0 32	6 42	24 67	18 90	29 9	31 2	310 9	0.082	1 04	7 20E-08			
12/3/2001 22 24	12/9/2001 16 46	138 22 00	788 30 00	32 85	0 23	6 50	24 40	18 38	30 7	32 5	343 4	0.091	1 06	6 65E-08			
12/9/2001 16 48	12/13/2001 9 17	88.29 00	876 59 00	36.54	0 37	4 72	24 53	20 32	21 3	22 7	366 2	0.097	1 07	6 41E-08	1 00	1 00	Terminated
												Avg Last 4:		7.10E-08			
												Lower Limit:		5 33E-08	75%		
												Upper Limit:		8.88E-08	125%		

Table 4.2.3-3
Large Block Hydraulic Conductivity Data, Test Pad 2, TP2-BS-003

Sample No.. **ELF-TP2-BS-003**

Initial Conditions Prior to Permeation

Avg Length =	15.4	cm	Initial Water Content, w =	17 2	%
Avg Diameter =	30.3	cm			
Length/Diameter =	0 51				
Area =	722 7	cm^2			
Volume =	11130	cm^3	B value =	0 97	

Final Conditions After Permeation

Final Water Content, w =	18 4	%	Pore Volume, PV =	3557	cm^3
Degree of Saturation, S =	100 0	% (Assumed)	B value =	0 99	

Test Specification

Cell Pressure =	90	psi	Max Effective Stress =	8	psi
Inflow Pressure =	88	psi	Min Effective Stress =	2	psi
Inflow Area =	4 30	cm^2	**Avg Effective Stress =**	**5**	**psi**
Outflow Pressure =	82	psi	**Avg Gradient =**	**28 1**	
Outflow Area =	4.28	cm^2			
Pressure Difference =	6	psi			
Inflow Burette area =	0 8744	cm^2	Outflow Burette Area =	0.8744	cm^2
Inflow Anulus Factor =	3.920		Outflow Anulus Factor =	3 895	

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	Σ Q_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
12/19/2001 9 25	12/20/2001 0.03	14:38:00	14 38:00	0.61	0.49	11 52	24.56	15 87	54 3	42.5	42.5	0.012	0.78	4 46E-08			
12/20/2001 0:06	12/21/2001 9:04	32 58:00	47 36 00	1 98	0 70	17.08	24.47	8.45	80.6	78.4	121 0	0.034	0 97	3 31E-08			
12/21/2001 8:06	12/22/2001 18 13	33 07 00	80 43 00	3 36	0.57	16.12	24.42	9.32	76 5	73 9	194 9	0 055	0.97	3.11E-08			
12/22/2001 18:15	12/24/2001 6.19	36.04.00	116.47 00	4 87	0 60	15.47	24 56	9 81	73 2	72.2	267.1	0.075	0.99	2 76E-08			
12/24/2001 6.20	12/25/2001 20:24	38.04 00	154 51 00	6 45	0 61	15 59	24.40	9.54	73 7	72 7	339.8	0 096	0 99	2 63E-08			
12/25/2001 20 26	12/27/2001 17.56	45.30.00	200.21.00	8.35	0.50	17 14	24 58	8 21	81 9	80.1	419.9	0.118	0.98	2.45E-08			
12/27/2001 17.57	12/29/2001 19:15	49:18:00	249 39:00	10 40	0 52	17 73	24.72	7 60	84 7	83 8	503 7	0 142	0 99	2.35E-08			
12/29/2001 19:16	12/31/2001 19 04	47.48.00	297.27:00	12 39	0.41	16 47	24 62	8.53	79 0	78.8	582 5	0.164	1 00	2.26E-08			
12/31/2001 19:06	1/2/2002 10:20	39:14 00	336 41 00	14 03	0 30	13.06	24.70	12.08	62 8	61 8	644 3	0.181	0.98	2.16E-08	0.99	0.99	
												Avg Last 4		**2.31E-08**			
												Lower Limit:		**1.73E-08**	75%		
												Upper Limit:		**2.88E-08**	125%		

Table 4.2.3-4
Large Block Hydraulic Conductivity Data, Test Pad 2, TP2-BS-004

Sample No. **ELF-TP2-BS-004**

Initial Conditions Prior to Permeation

Avg Length = 15 4 cm
Avg Diameter = 31 0 cm
Length/Diameter = 0 50
Area = 754 8 cm^2
Volume = 11623 cm^3

Initial Water Content, w = 17 1 %
B value = 0 97

Final Conditions After Permeation

Final Water Content, w = 17 9 %
Degree of Saturation, S = 100 0 % (Assumed)

Pore Volume, PV = 3924 cm^3
B value = 1 00

Test Specification

Cell Pressure = 90 psi
Inflow Pressure = 88 psi
Inflow Area = 4 55 cm^2
Outflow Pressure = 82 psi
Outflow Area = 4 71 cm^2
Pressure Difference = 6 psi
Inflow Burette area = 0 8681 cm^2
Inflow Anulus Factor = 4 240

Max Effective Stress = 8 psi
Min Effective Stress = 2 psi
Avg Effective Stress = 5 psi
Avg Gradient = 28.0
Outflow Burette Area = 0 8720 cm^2
Outflow Anulus Factor = 4 403

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	Σ Q_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
12/19/2001 9:26	12/20/2001 0:03	14 37 00	14 37 00	0 61	0.67	18 90	24 50	8 95	95 5	84 0	84.0	0.021	0 88	8 10E-08			
12/20/2001 0.06	12/20/2001 19.09	19.03 00	33 40 00	1 40	0.74	18 38	24 51	7 77	92.4	90.4	174 5	0 044	0 98	6.33E-08			
12/20/2001 19 11	12/21/2001 20.05	24 54 00	58:34 00	2 44	0 90	19.91	24 46	6.26	99 6	98.3	272 8	0 070	0 99	5 27E-08			
12/21/2001 20.06	12/22/2001 18:13	22 07 00	80.41 00	3 36	0 66	16 31	24 37	9 11	82 0	82 4	355 2	0 091	1 01	4 88E-08			
12/22/2001 18 16	12/23/2001 20.19	26.03 00	106 44 00	4 45	0 67	16.71	24 47	8 60	84 0	85 7	441 0	0 112	1.02	4 28E-08			
12/23/2001 20 20	12/24/2001 19.48	23.28 00	130 12 00	5 43	0.67	14 60	24 47	10 75	73 0	74 1	515 1	0.131	1 02	4 10E-08			
12/24/2001 19 50	12/25/2001 20.24	24.34 00	154 46 00	6.45	0 67	14 28	24 43	10 94	71 3	72 9	588.0	0.150	1 02	3 83E-08			
12/25/2001 20.27	12/27/2001 7 34	35 07 00	189.53:00	7 91	0 66	18 31	24 63	7,14	92 5	94 5	682 5	0 174	1 02	3 51E-08			
12/27/2001 7 35	12/28/2001 20.10	36 35.00	226.28 00	9.44	0 52	17 92	24 52	7 50	91 2	92 0	774.5	0 197	1.01	3 30E 08			
12/28/2001 20.12	12/30/2001 7.40	35 28 00	261.56 00	10 91	0 57	16 95	24 70	9.28	85 8	83 3	857 8	0 219	0 97	3 13E-08			
12/30/2001 7 42	12/31/2001 19.04	35.22 00	297 18 00	12 39	0 52	14 31	24 72	11.01	72 3	74 1	931 9	0 237	1 03	2 70E-08			
12/31/2001 19 07	1/2/2002 10 20	39 13 00	336 31 00	14 02	0 42	14 15	24 68	10 93	71 9	74 3	1006 1	0 256	1 03	2 43E 08	1 00	1 00	
												Avg Last 4:		2.89E-08			
												Lower Limit		2 17E-08	75%		
												Upper Limit.		3 61E-08	125%		

TABLE 4.3.1-1 ELF TEST PAD 3 TEST DATA FOR SOIL CLASSIFICATION, MODIFIED PROCTOR AND SPECIFIC GRAVITY

ELF TEST PAD 3															
Location				Grain Size		Atterberg Limits									
Sample Number	Northing	Easting	Elevation	% Finer #4 Sieve	% Finer #200 Sieve	LL	PL	PI	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Specific Gravity	USCS Classification	Sample Moisture Content (%)	Munsell Color	Laboratory Visual Soil Description
*TP3-CL-012	187,692 32	2,184,650 22	5250 2	100	65	30	20	10				CL	13 3	10YR4/6	Moist Dark Yellowish Brown sandy lean Clay
*TP3-CL-013	187,810.56	2,184,699.25	5250.6	100	70	32	19	13				CL	19.9	10YR4/4	Moist Dark Yellowish Brown sandy lean Clay
**TP3-PR-001	187,356 37	2,184,247 65	5246 5	100	50	29	21	8	124.5	11.0		CL	9 7	10YR5/6	Moist Yellowish Brown sandy lean Clay
**TP3-PR-002	187,218 67	2,184,206 89	5249 5	100	44	28	21	7	125.5	11 0		SC-SM	8 1	10YR5/6	Moist Yellowish Brown silty clayey Sand
TP3-PR-003	187,258.64	2,184,252 06	5250.2	100	78	35	19	16	123.5	12 0	2.71	CL	16 9	10YR3/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-004	187,317.91	2,184,236.99	5248.7	100	86	37	19	18	122 5	12 5		CL	20.0	10YR3/4	Moist Dark Yellowish Brown sandy lean Clay
TP3-PR-005	187,334 47	2,184,206.99	5248 4	100	71	33	19	14	124 0	11 5	2 71	CL	15.9	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-006	187,228 83	2,184,219 83	5250 3	100	75	34	19	15	123 5	12 5		CL	17 9	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-007	187,302 07	2,184,245 79	5249 2	100	75	35	18	17	124.5	12.0		CL	16 7	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-008	187,259 60	2,184,251 66	5250.0	100	77	35	19	16	124.0	12 0	2 70	CL	18 4	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-009	187,256 93	2,184,216 26	5250 4	100	81	37	19	18	123 0	12 0		CL	18 3	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-010	187,216 30	2,184,203.42	5250.6	100	82	37	19	18	122 0	12 5	2 71	CL	21 2	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-011	187,348.08	2,184,234.80	5248.7	100	84	39	19	20	122 5	12 5		CL	20.1	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-012	187,331 09	2,184,235.38	5249 2	100	84	39	18	21	123 0	12.0		CL	17 1	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-013	187,317 51	2,184,198 89	5249 8	100	84	39	18	21	123 0	12.0	2.72	CL	19 9	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-014	187,348 36	2,184,218 88	5248 8	100	83	39	18	21	122 5	12.5		CL	17 4	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-015	187,332 66	2,184,247 39	5249 3	100	85	40	19	21	122 0	13 0		CL	20 3	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-016	187,315 11	2,184,237 09	5250 0	100	84	38	19	19	122 0	13 0		CL	19 5	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-017	187,275 36	2,184,220 74	5251 0	100	85	39	19	20	122 0	12.5		CL	18 9	10YR4/4	Moist Dark Yellowish Brown Clay with sand
TP3-PR-018	187,271 26	2,184,203 85	5251 2	100	83	39	19	20	122 0	13.0	2.72	CL	18 3	10YR4/4	Moist Dark Yellowish Brown Clay with sand
** = Test Pad Subgrade															
* = Borrow Source location															

CL = Classification
PR = Modified Proctor
USCS = Unified Soil Classificaiton System

TABLE 4.3.2-1 NUCLEAR DENSITY TEST RESULTS FOR ELF TEST PAD 3, LANE 1 (815 COMPACTOR)

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)						
ELF-TP3-DT-002A	9/20/01	0	9	NUCLEAR	11.3	115.5	92.0%	65.8%	N/A	N/A	N/A	Subgrade
ELF-TP3-DT-009	9/28/01	2	11	NUCLEAR	17.2	110.8	91.2%	88.5%	4	4	Y	
ELF-TP3-DT-010	9/28/01	2	19	NUCLEAR	17.8	109.9	90.5%	89.5%	4	4	Y	
ELF-TP3-DT-011	9/28/01	2	12	NUCLEAR	17.7	109.6	90.2%	88.2%	4	4	Y	
ELF-TP3-DT-012	9/28/01	2	2	NUCLEAR	15.6	115.0	94.6%	89.6%	4	4	Y	
ELF-TP3-DT-013	9/28/01	2	6	NUCLEAR	17.1	113.2	93.2%	93.8%	4	4	Y	
ELF-TP3-DT-014	9/28/01	2	3	NUCLEAR	15.9	114.2	94.0%	89.6%	4	4	Y	
ELF-TP3-DT-021	10/1/01	3	2	NUCLEAR	15.4	114.9	94.6%	88.3%	4	4	Y	
ELF-TP3-DT-022	10/1/01	3	16	NUCLEAR	18.3	110.5	90.9%	93.3%	4	4	Y	
ELF-TP3-DT-023	10/1/01	3	13	NUCLEAR	17.8	113.2	93.1%	97.4%	4	4	Y	
ELF-TP3-DT-024	10/1/01	3	8	NUCLEAR	20.2	106.9	88.0%	94.0%	4	4	N	
ELF-TP3-DT-025	10/1/01	3	14	NUCLEAR	19.1	110.0	90.5%	96.2%	4	4	Y	
ELF-TP3-DT-026	10/1/01	3	6	NUCLEAR	16.1	113.4	93.4%	88.8%	4	4	Y	
ELF-TP3-DT-034	10/3/01	4	13	NUCLEAR	19.3	109.7	90.3%	96.5%	4	4	Y	
ELF-TP3-DT-035	10/3/01	4	4	NUCLEAR	19.1	106.9	88.0%	88.8%	4	4	N	
ELF-TP3-DT-036	10/3/01	4	11	NUCLEAR	20.3	106.2	87.4%	92.6%	4	4	N	
ELF-TP3-DT-037	10/3/01	4	19	NUCLEAR	18.7	110.3	90.8%	94.9%	4	4	Y	
ELF-TP3-DT-038	10/3/01	4	10	NUCLEAR	19.8	106.3	87.5%	90.6%	4	4	N	
ELF-TP3-DT-039	10/3/01	4	20	NUCLEAR	16.7	112.3	92.4%	89.2%	4	4	Y	
ELF-TP3-DT-046	10/4/01	5	9	NUCLEAR	19.6	107.9	88.8%	93.4%	4	4	N	
ELF-TP3-DT-047	10/4/01	5	20	NUCLEAR	17.1	111.4	91.7%	89.4%	4	4	Y	
ELF-TP3-DT-048	10/4/01	5	4	NUCLEAR	20.3	103.9	85.5%	87.6%	4	4	N	
ELF-TP3-DT-049	10/4/01	5	12	NUCLEAR	19.7	104.9	86.4%	87.2%	4	4	N	
ELF-TP3-DT-050	10/4/01	5	13	NUCLEAR	20.8	105.9	87.1%	94.3%	4	4	N	
ELF-TP3-DT-051	10/4/01	5	17	NUCLEAR	19.1	107.7	88.7%	90.7%	4	4	N	
Averages	--	--	--		**18.3**	**109.8**	**90.4%**	**91.4%**				

AZ = Acceptable Hydraulic Conductivity Zone

TABLE 4.3.2-2 NUCLEAR DENSITY TEST RESULTS FOR ELF TEST PAD 3, LANE 2 (825 COMPACTOR)

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)						
ELF-TP3-DT-001A	9/20/01	0	20	NUCLEAR	10.7	123.7	98.5%	78.8%	N/A	N/A	N/A	Subgrade
ELF-TP3-DT-003	9/24/01	2	13	NUCLEAR	16.2	110.1	90.6%	81.7%	4	4	N	
ELF-TP3-DT-003A	9/24/01	2	13	NUCLEAR	18.0	110.4	90.9%	91.7%	4	4	Y	
ELF-TP3-DT-004	9/24/01	2	17	NUCLEAR	14.0	114.5	94.2%	79.4%	4	4	N	
ELF-TP3-DT-005	9/24/01	2	10	NUCLEAR	18.5	108.1	89.0%	88.7%	4	4	N	
ELF-TP3-DT-006	9/24/01	2	5	NUCLEAR	16.0	114.5	94.2%	90.7%	4	4	Y	
ELF-TP3-DT-007	9/24/01	2	9	NUCLEAR	16.2	114.0	93.8%	90.8%	4	4	Y	
ELF-TP3-DT-008	9/24/01	2	1	NUCLEAR	18.0	110.6	91.0%	92.1%	4	4	Y	
ELF-TP3-DT-015	9/28/01	3	17	NUCLEAR	16.3	113.7	93.6%	90 4%	4	4	Y	
ELF-TP3-DT-016	9/28/01	3	1	NUCLEAR	15.8	114.4	94.2%	89.5%	4	4	Y	
ELF-TP3-DT-017	9/28/01	3	18	NUCLEAR	15.3	115.4	95.0%	89.1%	4	4	Y	
ELF-TP3-DT-018	9/28/01	3	13	NUCLEAR	19.2	109 1	89.8%	94.6%	4	4	N	
ELF-TP3-DT-019	9/28/01	3	7	NUCLEAR	16.9	113.5	93.4%	93.4%	4	4	Y	
ELF-TP3-DT-020	9/28/01	3	3	NUCLEAR	16.5	114 0	93.8%	92.3%	4	4	Y	
ELF-TP3-DT-027	10/2/01	4	15	NUCLEAR	16 5	113.5	93 4%	91.1%	4	4	Y	
ELF-TP3-DT-028	10/2/01	4	6	NUCLEAR	18.2	109 6	90.2%	90 8%	4	4	Y	
ELF-TP3-DT-029	10/2/01	4	13	NUCLEAR	16.8	114.0	93 8%	93.9%	4	4	Y	
ELF-TP3-DT-030	10/2/01	4	3	NUCLEAR	16 3	110.8	91.2%	83.9%	4	4	N	
ELF-TP3-DT-031	10/2/01	4	4	NUCLEAR	17.7	111.0	91.3%	91.4%	4	4	Y	
ELF-TP3-DT-032	10/2/01	4	17	NUCLEAR	18.8	109.0	89.7%	92.3%	4	4	N	
ELF-TP3-DT-040	10/3/01	5	8	NUCLEAR	18.1	108.3	89.1%	87.2%	4	4	N	
ELF-TP3-DT-041	10/3/01	5	17	NUCLEAR	20.3	105 2	86.5%	90.3%	4	4	N	
ELF-TP3-DT-042	10/3/01	5	5	NUCLEAR	19 9	104.6	86.1%	87.3%	4	4	N	
ELF-TP3-DT-043	10/3/01	5	15	NUCLEAR	18.4	110.1	90.6%	93.0%	4	4	Y	
ELF-TP3-DT-044	10/3/01	5	12	NUCLEAR	17.4	109.8	90.4%	87.2%	4	4	Y	
ELF-TP3-DT-045	10/3/01	5	9	NUCLEAR	18.4	107.7	88.6%	87.3%	4	4	N	
Averages	--	--	--		**17.3**	**111.0**	**91.4%**	**89.6%**				

AZ = Acceptable Hydraulic Conductivity Zone

TABLE 4.3.2-3 SHELBY TUBE HYDRAULIC CONDUCTIVITY TEST RESULTS FOR ELF TEST PAD 3

LANE 1, 815 COMPACTOR

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	PERMEABILITY/ ASSOCIATED TESTING	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)							
*ELF-TP3-ST-004	9/28/01	2	20	SHELBY	15.9	113.9	93 7%	88.8%	4	4	Y	K = 3.4 X 10^{-8}	
*ELF-TP3-ST-005	9/28/01	2	7	SHELBY	15.7	115.1	94.7%	90.3%	4	4	Y	K = 2.5 X 10^{-8}	
*ELF-TP3-ST-008	10/1/01	3	9	SHELBY	15.5	112.7	92.8%	83.9%	4	4	N	K = 4.6 X 10^{-8}	
*ELF-TP3-ST-009	10/1/01	3	1	SHELBY	16.6	110.0	90.6%	83.7%	4	4	N	K = 6.3 X 10^{-8}	
*ELF-TP3-ST-013	10/3/01	4	2	SHELBY	17.6	109.0	89.7%	86.3%	4	4	N	K = 3.2 X 10^{-8}	
*ELF-TP3-ST-014	10/3/01	4	15	SHELBY	19.0	108.5	89.3%	92.0%	4	4	N	K = 2.3 X 10^{-8}	
*ELF-TP3-ST-018	10/4/01	5	15	SHELBY	19.3	107.7	88.7%	91.6%	4	4	N	K = 6 9 X 10^{-8}	
*ELF-TP3-ST-019	10/4/01	5	13	SHELBY	20.2	106.2	87 4%	92.2%	4	4	N	K = 2.9 X 10^{-8}	
* Oven Moisture													
Averages	--	--	--		**17.5**	**110.4**	**90.9%**	**88.6%**					

LANE 2, 825 COMPACTOR

TEST NUMBER	DATE	LIFT	GRID	MOISTURE/DENSITY TEST VALUES			PERCENT COMPACTION TO MODIFIED PROCTOR	DEGREE OF SATURATION	HYDRATION TIME (DAYS)	NUMBER OF COMPACTION EQUIPMENT PASSES	WITHIN AZ	PERMEABILITY/ ASSOCIATED TESTING	COMMENTS
				TEST TYPE	MOISTURE CONTENT (%3017)	DRY DENSITY (PCF)							
*ELF-TP3-ST-001	9/24/01	2	18	SHELBY	17.6	111.6	91.9%	92.6%	4	4	Y	K = 4.2 X 10^{-8}	
*ELF-TP3-ST-002	9/24/01	2	7	SHELBY	16 6	111.7	91.9%	87.3%	4	4	Y	K = 3.7 X 10^{-8}	
*ELF-TP3-ST-003	9/24/01	2	17	SHELBY	15.2	113.8	93.7%	84.6%	4	4	N	K = 3.4 X 10^{-8}	
*ELF-TP3-ST-006	9/28/01	3	15	SHELBY	17.3	111.1	91.4%	89.6%	4	4	Y	K = 3.6 X 10^{-8}	
*ELF-TP3-ST-007	9/28/01	3	13	SHELBY	17 4	111 1	91 4%	90 1%	4	4	Y	K = 4.6 X 10^{-8}	
*ELF-TP3-ST-010	10/2/01	4	8	SHELBY	19.5	107.5	88.5%	92.2%	4	4	N	K = 1.6 X 10^{-8}	
*ELF-TP3-ST-011	10/2/01	4	16	SHELBY	16.7	109 9	90.5%	84.0%	4	4	N	K = 3.5 X 10^{-8}	
*ELF-TP3-ST-012	10/2/01	4	3	SHELBY	16.5	107.5	88.5%	77.9%	4	4	N	K = 2.6 X 10^{-8}	
*ELF-TP3-ST-015	10/3/01	5	18	SHELBY	18 4	109 3	90.0%	90.9%	4	4	N	K = 6.3 X 10^{-8}	
*ELF-TP3-ST-016	10/3/01	5	17	SHELBY	18.4	105.5	86.8%	82.5%	4	4	N	K = 3.2 X 10^{-8}	
*ELF-TP3-ST-017	10/3/01	5	5	SHELBY	20 9	104.7	86.1%	91.7%	4	4	N	K =1.9 X 10^{-6}	Very Sandy
* Oven Moisture													
Averages	--	--	--		**17.7**	**109.4**	**90.1%**	**87.6%**					

AZ = Acceptable Hydraulic Conductivity Zone

Table 4.3.2-4
Summary of Nuclear
Density and Hydraulic Conductivity Tests

				Summary of Nuclear Density Tests							
	Test Pad 3, Lane 1					Test Pad 3, Lane 2					
Lift #	2	3	4	5	All Lane 1	2	3	4	5	All Lane 2	All Test Pad 3
Range of moisture content (%)	15 6 - 17 8	15 4 - 20 0	16 7 - 20.3	17.1 - 20.8	15.4 - 20.8	14.0 - 18.5	15 3 - 19 2	16 3 - 18 8	17 4 - 20 3	14 0 - 20 3	14 0 - 20 8
Range of Dry Density (pcf)	109.6 - 115.0	106.9 - 114 9	106 2 - 112 3	103 9 - 111 4	103 9 - 115 0	108 1 - 114 5	102 1 - 110.4	109.0 - 114.0	104.6 - 110.1	102.1 - 114.5	102.1 - 115.0
Number of tests in AZ	6 (Figure 5 3 2-1)	5 (Figure 5 3 2-2)	3 (Figure 5 3 2-3)	1 (Figure 5 3 2-4)	15	4 (Figure 5.3 2-6)	5 (Figure 5 3 2-7)	4 (Figure 5 3 2-8)	2 (Figure 5 3 2-9)	15	30
Number of tests out of AZ	0 (Figure 5 32 1)	1 (Figure 5 3 2-2)	3 (Figure 5 3 2-3)	5 (Figure 5 3 2-4)	9	2 (Figure 5.3 2-6)	1 (Figure 5 3 2-7)	2 (Figure 5 3 2-8)	4 (Figure 5 3 2-9)	9	18
				Summary of Shelby Tube Hydraulic ConductivityTests							
	Test Pad 3 Lane 1					Test Pad 3, Lane 2					
Lift #	2	3	4	5	All Lane 1	2	3	4	5	All Lane 2	All Test Pad 3
Range of moisture content (%)	15 7 - 15 9	15.5 - 16.6	17 6 - 19 0	19 3 - 20 2	15 7 - 20.2	15 2 - 17 6	17.3 - 17.4	16 5 - 19 5	18 4 - 20 9	15 2 - 20 9	15 2 - 20 9
Range of Dry Density (pcf)	113 9 - 115 1	110 0 - 112.7	108.5 - 109 0	106 2 - 107.7	106.2 - 115.1	111.6 - 113.8	111 1 - 111 1	107 5 - 109 9	104 7 - 109 3	104 7 - 113 8	104 7 - 113 8
Number of tests in AZ	2 (Figure 5 3 2-1)	0 (Figure 5 3 2-2)	0 (Figure 5 3 2-3)	0 (Figure 5 3 2-4)	2	2 (Figure 5 3 2-6)	2 (Figure 5 3 2-7)	3 (Figure 5 3 2-8)	0 (Figure 5 3 2-9)	7	9
Number of tests out of AZ	0 (Figure 5 3.2-1)	2 (Figure 5 3.2-2)	2 (Figure 5 3 2-3)	2 (Figure 5 3 2 4)	6	1 (Figure 5 3 2-6)	0 (Figure 5.3 2-7)	0 (Figure 5 3 2-8)	3 (Figure 5 3 2-9)	4	10
Number of Passing Permeability Tests	2 (Figure 5 3 2-1)	2 (Figure 5 3 2-2)	2(Figure 5.31 2-3)	2 (Figure 5 3 2-4)	8	3 (Figure 5.3 2-6)	2 (Figure 5 3 2-7)	3 (Figure 5. 2-8)	2 (Figure 5 3 2-9)	10	18

AZ = Acceptable Hydraulic Conductivity Zone

Table 4.3.3-1
Large Block Hydraulic Conductivity Data, Test Pad 3, TP3-BS-001

Sample No. ELF-TP3-BS-001

Initial Conditions Prior to Permeation

Avg Length = 15.4 cm
Avg Diameter = 30 5 cm
Length/Diameter = 0.50
Area = 730 6 cm^2
Volume = 11251 cm^3

Initial Water Content, w = 14 3 %
B value = 0 95

Final Conditions After Permeation

Final Water Content, w = 16.7 %
Degree of Saturation, S = 100 0 % (Assumed)

Pore Volume, PV = 4000 cm^3
B value = 0 98

Test Specification

Cell Pressure = 90 psi
Inflow Pressure = 88 psi
Inflow Area = 4 35 cm^2
Outflow Pressure = 82 psi
Outflow Area = 4 87 cm^2
Pressure Difference = 6 psi
Inflow Burette area = 0 8744 cm^2
Inflow Anulus Factor = 3 972

Max Effective Stress = 8 psi
Min Effective Stress = 2 psi
Avg Effective Stress = 5 psi
Avg Gradient = 28.5

Outflow Burette Area = 0 8775 cm^2
Outflow Anulus Factor = 4 550

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	Σ Q_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
12/24/2001 6.52	12/27/2001 17.58	83 06 00	83 06.00	3 46	0 37	12 91	24 41	14 77	62 3	53 5	53 5	0 013	0 86	9 38E-09			
12/27/2001 18 04	1/1/2002 8.12	110 08.00	193 14 00	8 05	0 32	12 01	24 58	14 33	58 1	56 9	110 4	0.028	0 98	6.99E-09			
1/1/2002 8.14	1/6/2002 8 56	120 42 00	313 56 00	13 08	0.41	11 49	24 57	14 57	55 1	55.5	165 9	0 041	1.01	6 13E-09			
1/6/2002 8.58	1/11/2002 9 04	120 06 00	434 02 00	18 08	0.40	10.20	24 52	15.37	48 7	50.8	216 7	0 054	1.04	5 52E-09			
1/11/2002 9 06	1/16/2002 9 22	120 16 00	554 18 00	23 10	0 30	9 67	24 43	15 93	46 6	47 2	263 8	0 066	1.01	5 19E-09			
1/16/2002 9 23	1/21/2002 10.04	120 41 00	674 59 00	28 12	0 35	9 17	24 60	16 42	43 9	45 4	309 2	0 077	1 04	4 91E-09			
1/21/2002 10.06	1/26/2002 9 54	119 48 00	794 47 00	33 12	0.36	8 88	24 59	16 71	42 4	43 7	353 0	0 088	1.03	4 77E-09	0 99	0 98	Terminated
												Avg Last 4:		5.10E-09			
												Lower Limit:		2.55E-09	50%		
												Upper Limit.		7.65E-09	150%		

Table 4.3.3-2

Large Block Hydraulic Conductivity Data, Test Pad 3, TP3-BS-002

Sample No.: **ELF-TP3-BS-002**

Initial Conditions Prior to Permeation					
Avg Length =	15 1	cm	Initial Water Content, w =	17 8	%
Avg Diameter =	30 6	cm			
Length/Diameter =	0.49				
Area =	735 4	cm^2			
Volume =	11105	cm^3	B value =	0.95	
Final Conditions After Permeation					
Final Water Content, w =	19 4	%	Pore Volume, PV =	4000	cm^3
Degree of Saturation, S =	100 0	% (Assumed)	B value =	0.99	
Test Specification					
Cell Pressure =	90	psi	Max Effective Stress =	8	psi
Inflow Pressure =	88	psi	Min Effective Stress =	2	psi
Inflow Area =	4 35	cm^2	**Avg Effective Stress =**	**5**	**psi**
Outflow Pressure =	82	psi	**Avg Gradient =**	**29 2**	
Outflow Area –	4 87	cm^2			
Pressure Difference =	6	psi			
Inflow Burette area =	0 8744	cm^2	Outflow Burette Area =	0.8775	cm^2
Inflow Anulus Factor =	3 972		Outflow Anulus Factor =	4 550	

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	ΣQ_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
12/24/2001 6 53	12/27/2001 17.58	83 05 00	83 05 00	3 46	0 37	11 55	24 50	17 14	55 6	40.8	40 8	0.010	0 73	7 60E-09			
12/27/2001 18 05	1/1/2002 8:12	110.07 00	193 12.00	8 05	0 41	10.30	24 53	16.09	49.2	46.8	87 7	0.022	0.95	5 87E-09			
1/1/2002 8.15	1/6/2002 8.56	120:41 00	313:53:00	13 08	0 45	9.70	24 57	16 07	46 0	47 2	134 9	0.034	1 03	5 00E-09			
1/6/2002 8.59	1/11/2002 9:04	120.05 00	433:58 00	18 08	0 48	8.45	24.57	16.83	39 6	43 0	177 8	0.044	1 08	4 44E-09			
1/11/2002 9:06	1/16/2002 9:22	120:16 00	554:14 00	23 09	0 40	7 99	24 51	17 36	37 7	39 7	217 5	0.054	1 05	4 15E-09			
1/16/2002 9:24	1/21/2002 10:04	120 40:00	674:54 00	28 12	0 40	7 36	24 65	17 82	34 6	37 9	255.4	0.064	1 10	3 87E-09			
1/21/2002 10:07	1/26/2002 9:54	119 47 00	794 41 00	33 11	0 30	6 97	24 59	18 18	33 2	35 6	291.0	0 073	1 07	3 69E-09	0.99	0 99	Terminated
												Avg Last 4:		**4 04E-09**			
												Lower Limit:		**2.02E-09**	50%		
												Upper Limit:		**6.06E-09**	150%		

Table 4.3.3-3

Large Block Hydraulic Conductivity Data, Test Pad 3, TP3-BS-003

Sample No.: **ELF-TP3-BL-003**

Initial Conditions Prior to Permeation

Avg Length = 15 5 cm
Avg Diameter = 30 5 cm
Length/Diameter = 0 51
Area = 730 6 cm^2
Volume = 11325 cm^3

Initial Water Content, w = 16 5 %

B value = 0 97

Final Conditions After Permeation

Final Water Content, w = %
Degree of Saturation, S = %

Pore Volume, PV = 4000 cm^3 (Assumed)
B value =

Test Specification

Cell Pressure = 90 psi
Inflow Pressure = 88 psi
Inflow Area = 4 30 cm^2
Outflow Pressure = 82 psi
Outflow Area = 4 28 cm^2
Pressure Difference = 6 psi
Inflow Burette area = 0.8744 cm^2
Inflow Anulus Factor = 3 920

Max Effective Stress = 8 psi
Min Effective Stress = 2 psi
Avg Effective Stress = 5 psi
Avg Gradient = 28.4

Outflow Burette Area = 0 8744 cm^2
Outflow Anulus Factor = 3 895

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in} (cm^3)	Q_{out} (cm^3)	ΣQ_{out} (cm^3)	Σ PV	Q_{out}/Q_{in}	k (cm/s)	B-Value at HW	B-Value at TW	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending									
1/6/2002 9 12	1/8/2002 22.09	60 57 00	60 57 00	2 54	1 14	11 62	23 28	17 86	51 6	26 5	26 5	0 007	0 51	8 60E-09			
1/8/2002 22 12	1/12/2002 9 36	83 24 00	144 21.00	6 01	0 50	8 51	23 57	17 97	39 4	27 4	53 9	0.013	0 70	5 35E-09			
1/12/2002 9 38	1/16/2002 9 24	95 46 00	240 07 00	10 00	0 41	8.36	24 54	17.45	39 1	34 7	88 6	0.022	0 89	5 15E 09			
1/16/2002 9 26	1/20/2002 9 35	96 09 00	336 16 00	14 01	0 42	7 66	24 57	17.75	35 6	33 4	122 0	0 031	0 94	4 79E-09			
1/20/2002 9 38	1/24/2002 18 36	104 58 00	441 14 00	18 38	0 36	7 55	24 57	17 53	35 4	34 5	156 5	0 039	0 97	4 44E-09			
												Avg Last 4		**4 93E-09**			
												Lower Limit		**2 47E-09**	50%		
												Upper Limit:		**7 40E-09**	150%		

Sample No : ELF-TP3-BL-004

Table 4.3.3-4
Large Block Hydraulic Conductivity Data, Test Pad 3, TP3-BS-004

Initial Conditions Prior to Permeation

Avg Length = 15 6 cm
Avg Diameter = 30 6 cm
Length/Diameter = 0 51
Area = 735 4 cm^2
Volume = 11472 cm^3

Initial Water Content, w = 17 9 %

B value = 0 96

Final Conditions After Permeation

Final Water Content, w = %
Degree of Saturation, S = %

Pore Volume, PV = 4000 cm^3 (Assumed)
B value =

Test Specification

Cell Pressure = 90 psi
Inflow Pressure = 88 psi
Inflow Area = 4 55 cm^2
Outflow Pressure = 82 psi
Outflow Area = 4 71 cm^2
Pressure Difference = 6 psi
Inflow Burette area = 0 8681 cm^2
Inflow Anulus Factor = 4.240

Max Effective Stress = 8 psi
Min Effective Stress = 2 psi
Avg Effective Stress = 5 psi
Avg Gradient = 28.1

Outflow Burette Area = 0.8720 cm^2
Outflow Anulus Factor = 4 403

Date &Time		Δt	Σt		Inflow Reading		Outflow Reading		Q_{in}	Q_{out}	Σ Q_{out}	Σ PV	Q_{out}/Q_{in}	k	B-Value	B-Value	Comment
Starting	Ending			(days)	Starting	Ending	Starting	Ending	(cm^3)	(cm^3)	(cm^3)			(cm/s)	at HW	at TW	
1/6/2002 9 13	1/8/2002 22 09	60 56 00	60 56 00	2 54	1 64	11 95	22 80	13 62	54.0	49 6	49 6	0 012	0.92	1 15E-08			
1/8/2002 22 13	1/12/2002 9 36	83 23 00	144 19 00	6 01	0 53	10 14	24 43	15 57	50 4	47 9	97 5	0.024	0 95	7 91E-09			
1/12/2002 9 38	1/16/2002 9 24	95 46 00	240 05 00	10.00	0 42	10.21	24 47	15 31	51 3	49.5	147 0	0.037	0 96	7 07E-09			
1/16/2002 9 27	1/20/2002 9.35	96 08.00	336 13 00	14 01	0.48	9 39	24 32	15 71	46 7	46 5	193 5	0.048	1 00	6 50E-09			
1/20/2002 9 39	1/24/2002 18 36	104 57 00	441 10 00	18 38	0 33	9 07	24 55	15 82	45 8	47.2	240 6	0.060	1.03	5 93E-09			
												Avg Last 4:		6.85E-09			
												Lower Limit		3.43E-09	50%		
												Upper Limit		1 03E-08	150%		

ATTACHMENT F
SUPPORTING DOCUMENTATION FOR INTERROGATORY PR R317-6-6.3G-29/03: SURFACE WATER CONTROLS

TETRA TECH

CLIENT: Uranium One
MADE BY: EKB
DATE: 4/10/2008
JOB TITLE: Shootaring Mill Operations
CHECKED:
JOB NUMBER: 114-181692
SUBJECT: PMP Estimation
APPROVED:
SHEET: 1 of 1

Local Storm PMP Calculations:

HMR 49 Step:

6.3A Local storm PMP computation

1. Average 1-hr, 1-mi^2 PMP for drainage [fig. 4.5] 8.3 in.

2. a. Reduction for elevation [5% per 1000' above 5000'] 0.0 %
   b. step 1 x (100 - 2a). 8.3 in

3. Average 6/1-hr ratio for drainage [fig 4.7] 1.10

		DURATION (HRS)									
		0.25	0.5	0.75	1	2	3	4	5	6	
4.	Durational variation for 6/1-hr ratio of step 3 [table 4.4]	86	93	97	100	107	109	110	110	110	%
5.	1-mi^2 PMP for indicated durations [2b x 4]	7.1	7.7	8.1	8.3	8.9	9.0	9.1	9.1	9.1	in
6.	Areal reduction [fig. 4.9]	100	100	100	100	100	100	100	100	100	%
7.	Areal reduced PMP [5 x 6]	7.1	7.7	8.1	8.3	8.9	9.0	9.1	9.1	9.1	in

8. Incremental PMP [successive subtraction of 7]

	1	2	3	4	5	6	
	8.3	0.6	0.2	0.1	0.0	0.0	in

	1	2	3	4	
	7.1	0.6	0.3	0.2	} 15-min increments

9. Time sequence of incremental PMP according to:

a. HMR No. 5 Hourly increments [table 4.7]

order:	5	3	1	2	4	6
in	**0.0**	**0.2**	**8.3**	**0.6**	**0.1**	**0.0**
hrs	**1**	**2**	**3**	**4**	**5**	**6**

b. EM-1110-2-1411 Hourly increments [table 4.7]

order:	6	4	2	1	3	5
in	**0.0**	**0.1**	**0.6**	**8.3**	**0.2**	**0.0**
hrs	**1**	**2**	**3**	**4**	**5**	**6**

c. Four largest 15-min increments [table 4.8]

order:	1	2	3	4
in	**7.1**	**0.6**	**0.3**	**0.2**
hrs	**0.25**	**0.50**	**0.75**	**1.00**

Shootaring Mill PMP - Local Storm

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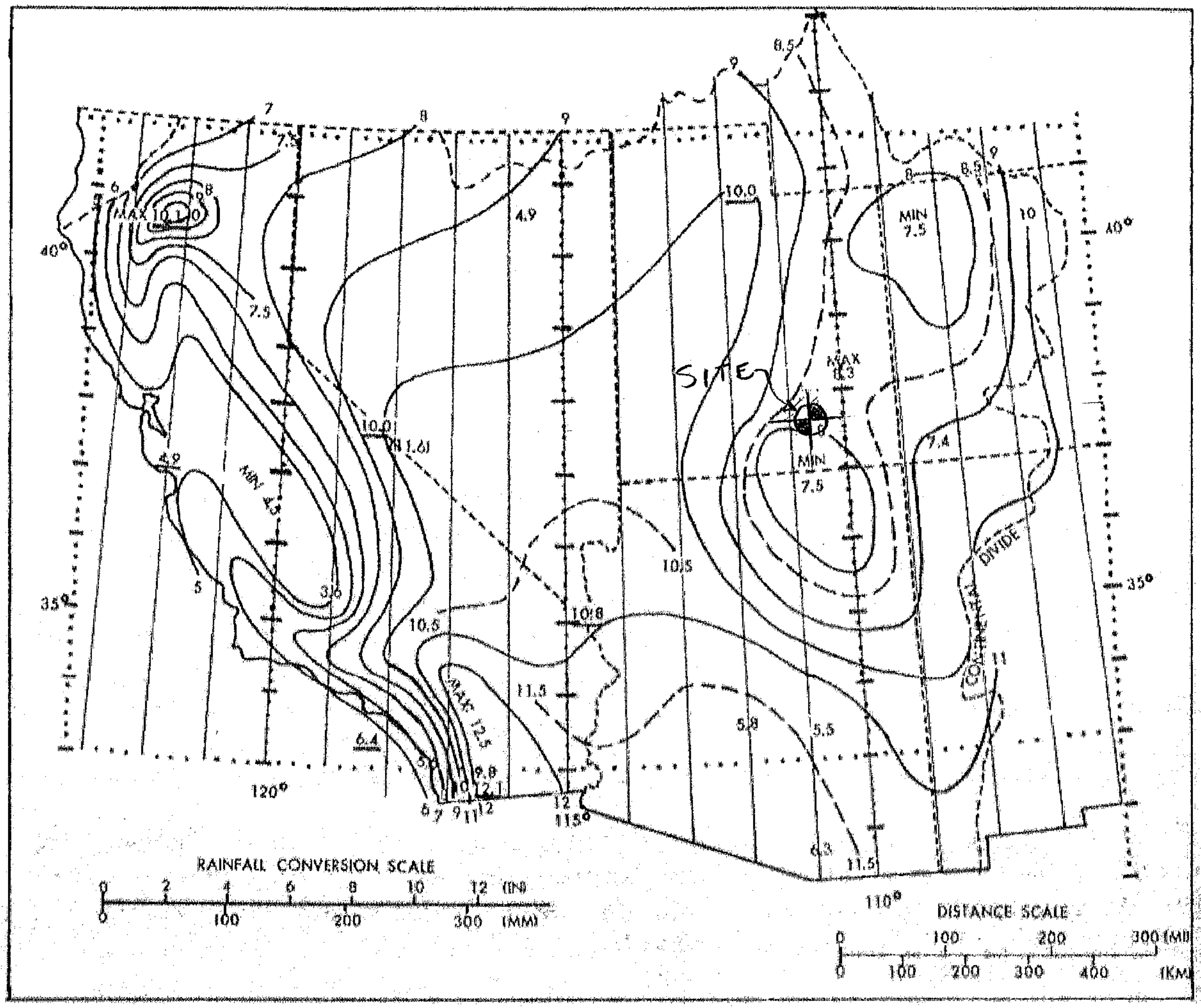

1 mi², 1 hr. Local PMP = 8.3" (conservative)

Figure 4.5--Local-storm PMP for 1 mi^2 (2.6 km^2) 1 hr. Directly applicable for locations between sea level and 5000 ft (1524 m). Elevation adjustment must be applied for locations above 5000 ft.

events. In contrast to figure 4.4, figure 4.5 maintains a maximum between these two locations. There is no known meteorological basis for a different solution. The analysis suggests that in the northern portion of the region maximum PMP occurs between the Sierra Nevada on the west and the Wasatch range on the east.

A discrete maximum (> 10 inches, 254 mm) occurs at the north end of the Sacramento Valley in northern California because the northward-flowing moist air is increasingly channeled and forced upslope. Support for this PMP center comes from the Newton, Kennett, and Red Bluff storms (fig. 4.1). Although the analysis in this region appears to be an extension of the broad maximum through the center of the Southwestern Region, it does not indicate the direction of moist inflow. The pattern has evolved primarily as a result of attempts to tie plotted maxima into a reasonable picture while considering inflow directions, terrain effects, and moisture potential.

Shootaring Mill PMP-Local Storm

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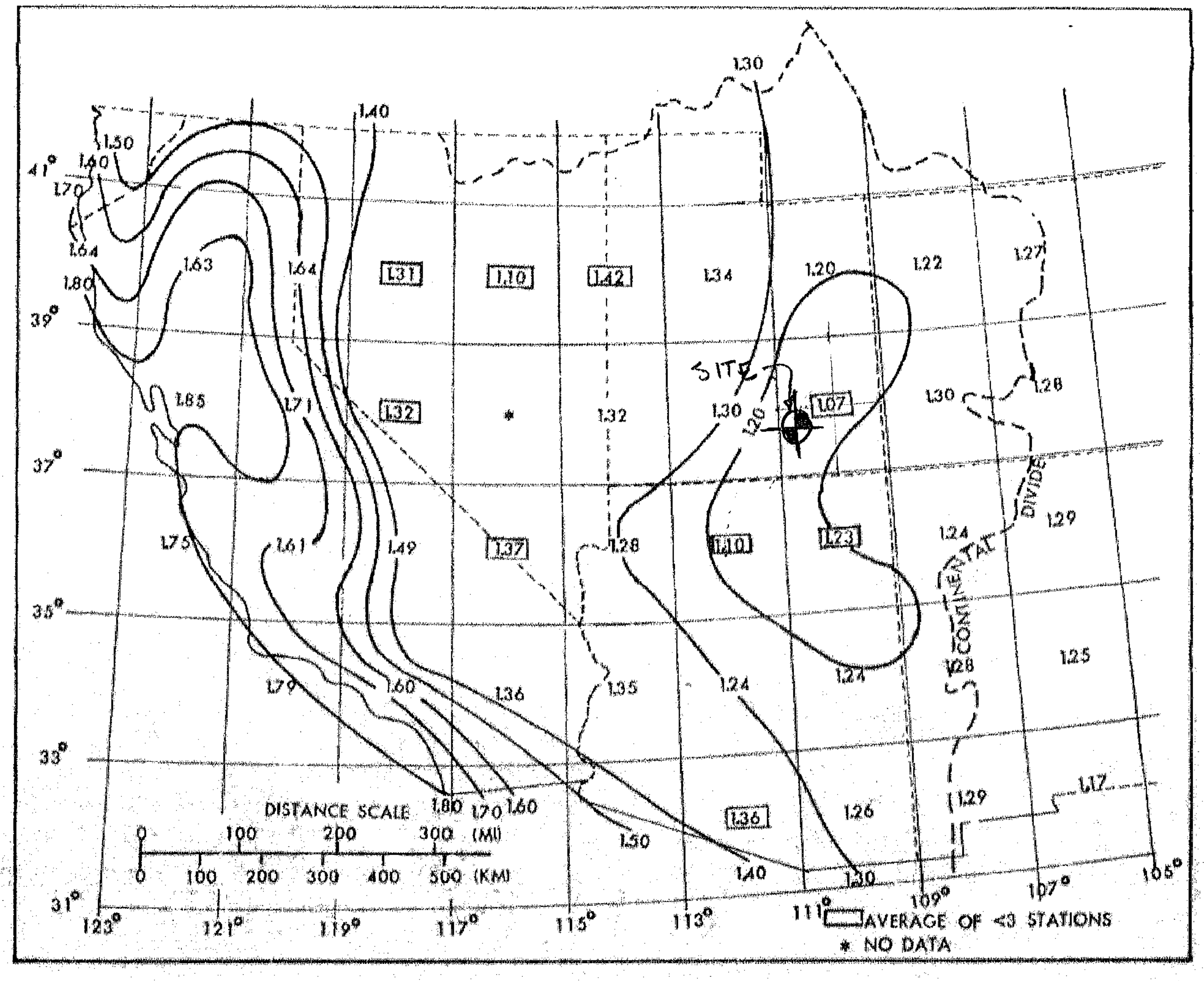

Figure 4.7.--Analysis of 6/1-hr ratios of averaged maximum station data (plotted at midpoints of a 2° latitude-longitude grid).

6/1-hr Ratio = 1.1

establish the basic depth-duration curve, then structure a variable set of depth-duration curves to cover the range of 6/1-hr ratios that are needed.

Three sets of data were considered for obtaining a base relation (see table 4.3 for depth-duration data).

a. An average of depth-duration relations from each of 17 greatest 3-hr rains from summer storms (1940-49) in Utah (U. S. Weather Bureau 1951b) and in unpublished tabulations for Nevada and Arizona (1940-63). The 3-hr amounts ranged from 1 to 3 inches (25 to 76 mm) in these events.

b. An average depth-duration relation from 14 of the most extreme short-duration storms listed in Storm Rainfall (U. S. Army, Corps of Engineers 1945-). These storms come from Eastern and Central States and have 3-hr amounts of 5 to 22 inches (127 to 559 mm).

Shootaring Mill PMP—Local Storm

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ratios than storms with high 3/1-hr ratios. The geographical distribution of 15-min to 1-hr ratios also were inversely correlated with magnitudes of the 6/1-hr ratios of figure 4.7. For example, Los Angeles and San Diego (high 6/1-hr ratios) have low 15-min to 1-hr ratios (approximately 0.60) whereas the 15-min to 1-hr ratios in Arizona and Utah (low 6/1-hr ratios) were generally higher (approximately 0.75).

Depth-duration relations for durations less than 1 hour were then smoothed to provide a family of curves consistent with the relations determined for 1 to 6 hours, as shown in figure 4.3. Adjustment was necessary to some of the curves to provide smoother relations through the common point at 1 hour.

We believe we were justified in reducing the number of the curves shown in figure 4.3 for durations less than 1 hour, letting one curve apply to a range of 6/1-hr ratios. The corresponding curves have been indicated by letter designators, A-D, on figure 4.3. As an example, for any 6-hr amount between 115% and 135% of 1-hr, 1-mi^2 (2.6-km^2) PMP, the associated values for durations less than 1 hour are obtained from the curve designated as "B".

Table 4.4 lists durational variations in percent of 1-hr PMP for selected 6/1-hr rain ratios. These values were interpolated from figure 4.3.

To determine 6-hr PMP for a basin, use figure 4.3 (or table 4.4) and the geographical distribution of 6/1-hr ratios given in figure 4.7.

Table 4.4.--Durational variation of 1-mi^2 (2.6-km^2) local-storm PMP in percent of 1-hr PMP (see figure 4.3)

6/1-hr	Duration (hr)								
ratio	1/4	1/2	3/4	1	2	3	4	5	6
1.1	86	93	97	100	107	109	110	110	110
1.2	74	89	95	100	110	115	118	119	120
1.3	74	89	95	100	114	121	125	128	130
1.4	63	83	93	100	118	126	132	137	140
1.5	63	83	93	100	121	132	140	145	150
1.6	43	70	87	100	124	138	147	154	160
1.8	43	70	87	100	130	149	161	171	180
2.0	43	70	87	100	137	161	175	188	200

4.5 Depth-Area Relation

We have thus far developed local-storm PMP for an area of 1 mi^2 (2.6 km^2). To apply PMP to a basin, we need to determine how 1-mi^2 (2.6-km^2) PMP should decrease with increasing area. We have adopted depth-area relations based on rainfalls in the Southwest and from consideration of a model thunderstorm.

Shootaring Mill PMP- Local Storm

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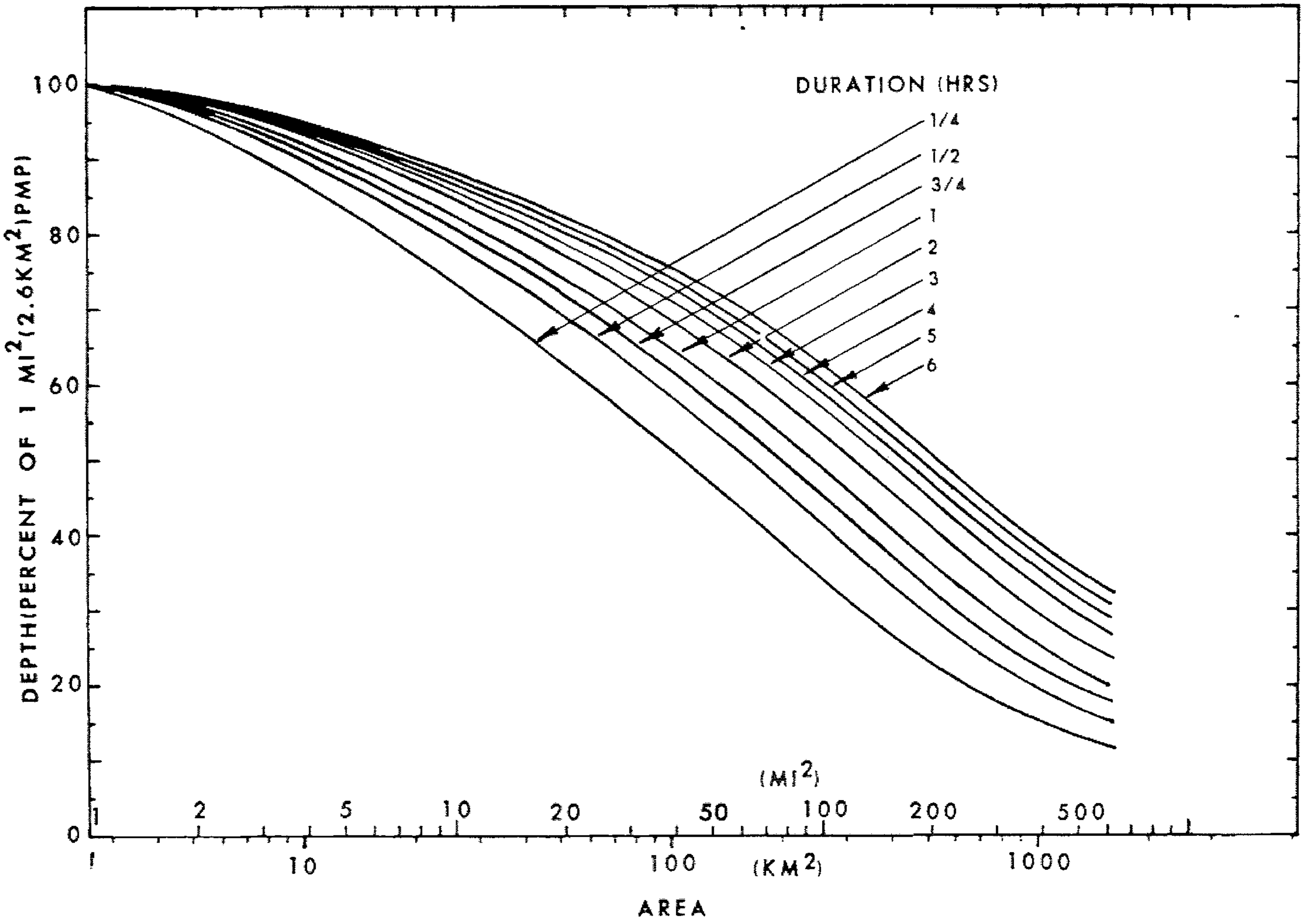

Figure 4.9.--Adopted depth-area relations for local-storm PMP.

D.A. < 1 mi² → No areal reduction

Shootaring Mill PMP- Local Storm

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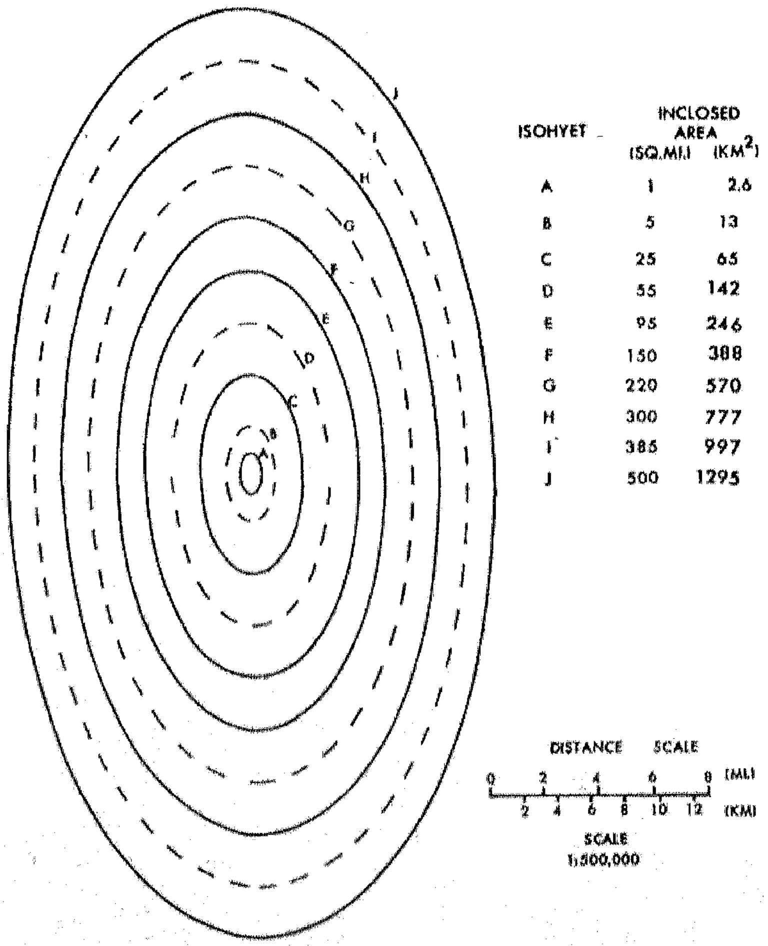

ISOHYET	INCLOSED AREA (SQ.MI.)	(KM²)
A	1	2.6
B	5	13
C	25	65
D	55	142
E	95	246
F	150	388
G	220	570
H	300	777
I	385	997
J	500	1295

Figure 4.10.--Idealized local-storm isohyetal pattern.

storm period. The sequence of hourly incremental PMP for the Southwest 6-hr thunderstorm in accord with this study is presented in column 2 of table 4.7. A small variation from this sequence is given in Engineering Manual 1110-2-1411 (U. S. Army, Corps of Engineers 1965). The latter, listed in column 3 of table 4.7, places greater incremental amounts somewhat more toward the end of the 6-hr storm period. In application, ~~the choice~~ of either of these distributions is left to the user since one may prove to be more critical in a specific case than the other.

Table 4.7.--Time sequence for hourly incremental PMP in 6-hr storm

	HMR No. 5[1]	EM1110-2-1411[2]
Increment	Sequence Position	
Largest hourly amount	Third	Fourth
2nd largest	Fourth	Third
3rd largest	Second	Fifth
4th largest	Fifth	Second
5th largest	First	Last
least	Last	First

---

[1] U. S. Weather Bureau 1947.

[2] U. S. Corps of Engineers 1952.

Shootaring Mill PMP - Local Storm

6|6

Also of importance is the sequence of the four 15-min incremental PMP values. We recommend a time distribution, table 4.8, giving the greatest intensity in the first 15-min interval (U.S. Weather Bureau 1947). This is based on data from a broad geographical region. Additional support for this time distribution is found in the reports of specific storms by Keppell (1963) and Osborn and Renard (1969).

Table 4.8.--Time sequence for 15-min incremental PMP within 1 hr.

Increment	Sequence Position
Largest 15-min amount	First
2nd largest	Second
3rd largest	Third
least	Last

4.8 Seasonal Distribution

The time of the year when local-storm PMP is most likely is of interest. Guidance was obtained from analysis of the distribution of maximum 1-hr thunderstorm events through the warm season at the recording stations in Utah, Arizona, and in southern California (south of 37°N and east of the Sierra Nevada ridgeline). The period of record used was for 1940-72 with an average record length for the stations considered of 27 years. The month with the one greatest thunderstorm rainfall for the period of record at each station was noted. The totals of these events for each month, by States, are shown in table 4.9.

Table 4.9.--Seasonal distribution of thunderstorm rainfalls.

(The maximum event at each of 108 stations, period of record 1940-72.)

	Month						
	M	J	J	A	S	O	No. of Cases
Utah	1	5	9	14	5		34
Arizona		4	16	19	4		43
S. Calif.*		14	10	7			31
No. of cases/mo.	1	23	35	40	9	0	

*South of 37°N and east of Sierra Nevada ridgeline.

TETRA TECH

CLIENT: Uranium One
MADE BY: EKB
DATE: 5/12/2008
JOB TITLE: Shootaring Mill Operations Plan
CHECKED:
JOB NUMBER: 114-181692
SUBJECT: Tailings Impoundment Freeboard Calculations
APPROVED:
SHEET:

Tailings Impoundment Area and Volume

Volumes determined using average end areas.

South Cell

Elevation (ft)	Area (ft^2)	Incr. Volume (ft^3)	Cum. Volume (ft^3)	Area (ac)	Incr. Volume (ac-ft)	Cum. Volume (ac-ft)
4360	20647	0	0	0.47	0	0
4370	183916	1022815	1022815	4.22	23.48	23.48
4380	423337	3036265	4059080	9.72	69.70	93.18
4390	705404	5643705	9702785	16.19	129.56	222.75
4400	958848	8321260	18024045	22.01	191.03	413.78
4410	1108011	10334295	28358340	25.44	237.24	651.02
4420	1209713	11588620	39946960	27.77	266.04	917.06
4430	1315462	12625875	52572835	30.20	289.85	1206.91
4440	1490284	14028730	66601565	34.21	322.06	1528.96
4450	1583228	15367560	81969125	36.35	352.79	1881.75
4455	1630927	8035388	90004512.5	37.44	184.47	2066.22
4460	1678626	8273883	98278395	38.54	189.94	2256.16
4466	1737064	10247070	108525465	39.88	235.24	2491.40
4468	1756738	3493802	112019267	40.33	80.21	2571.61

North Cell

Elevation (ft)	Area (ft^2)	Incr. Volume (ft^3)	Cum. Volume (ft^3)	Area (ac)	Incr. Volume (ac-ft)	Cum. Volume (ac-ft)
4404	6137	0	0	0.14	0	0
4410	89211	286044	286044	2.05	6.57	6.57
4420	355732	2224715	2510759	8.17	51.07	57.64
4430	779590	5676610	8187369	17.90	130.32	187.96
4440	1171163	9753765	17941134	26.89	223.92	411.87
4450	1520354	13457585	31398719	34.90	308.94	720.82
4455	1585132	7763714	39162432.8	36.39	178.23	899.05
4460	1649909	8087601	47250034	37.88	185.67	1084.71
4466	1710598	10081521	57331555	39.27	231.44	1316.15
4468	1730985	3441583	60773138	39.74	79.01	1395.16

TETRA TECH

CLIENT: Uranium One
MADE BY: EKB
DATE: 5/12/2008
JOB TITLE: Shootaring Mill Operations
CHECKED:
JOB NUMBER: 114-181692
SUBJECT: Tailings Impoundment Freeboard Calculations
APPROVED:
SHEET:

Catchment Area and Design Flood Volume.

Tailings impoundment must be able to contain the water rise due to the design flood, plus wind and wave action. Design flood is the 6-hour PMF series, per NRC Regulatory Guide 3.11 (1977), and proposed Revision Three of RG 3.11, issued February 2008 as Draft Regulatory Guide DG-3032.

6-hour Local Storm PMP (in) = 9.1 (See PMP estimates)
40% of 6-hour PMP (in) = 3.64
100-year, 6-hour precipitation (in) = 1.79 (NOAA Atlas 14 rainfall, reproduced below)
Total PMF-series precipitation (in) = 14.53
Assumed runoff coefficient = 0.90 (assumed to apply to both tailings and offsite areas)
Runoff depth (in) = 13.08 (Runoff depth = Total precipitation x Runoff coefficient)

ARI* (years)	Duration (hours)				
	6	12	24	48	192
1	0.55	0.67	0.79	0.88	1
2	0.69	0.83	1	1.11	1.26
5	0.89	1.05	1.29	1.42	1.62
10	1.06	1.23	1.53	1.68	1.91
25	1.31	1.49	1.86	2.06	2.32
50	1.52	1.69	2.12	2.36	2.65
100	**1.79**	1.91	2.4	2.69	3.01
200	2.14	2.2	2.7	3.03	3.38
500	2.71	2.74	3.11	3.53	3.92
1000	3.24	3.27	3.44	3.93	4.34

* ARI = Approximate Recurrence Interval

Phase:	1	2	2
Cell:	South		North
Cell Area (ac):	34.52	41.85	40.31
Outside Area Contributing Runon (ac):	41.44	33.13	109.37
Total Area (ac):	75.96	74.99	149.67
Runoff volume (ac-ft):	82.77	81.72	163.11
Maximum liner elevation (ft):	4430.0	4466.0	4466.0
Assumed operating water surface elev.(ft):	4420.0	4455.0	4455.0
Surface area at operating WSE (ac):	27.77	37.44	36.39
WSE rise due to design flood (ft):	2.98	2.18	4.48

Runoff volume [ac-ft] = Total Area [ac] * Runoff depth [in] / 12 [in/foot]
WSE = Water surface elevation
WSE rise due to design flood [ft] = Runoff volume [ac-ft] / Surface area [ac]

TETRA TECH

CLIENT: Uranium One
MADE BY: EKB
DATE: 5/12/2008
JOB TITLE: Shootaring Mill Operations
CHECKED:
JOB NUMBER: 114-181692
SUBJECT: Tailings Impoundment Freeboard Calculations
APPROVED:
SHEET:

Windspeed, fetch, and wind setup

Fetch:

Wind setup is typically calculated using roughly twice the effective fetch, but here the straight-line fetch was determined directly, so no adjustments to effective fetch are required.

Straight-line fetch was measured as the longest distance across the lined area for each cell in any direction. This method is conservative because it ignores the possibility that the design windspeed may not necessarily occur along the measured fetch, and because the liner extents exceed the possible pool extents due to the presence of freeboard and the width of horizontal liner atop the perimeter bench.

Water depth over fetch was assumed constant, at the operating water level plus the rise due to the design storm. The shallow depth was selected to lead to a conservative (high) estimate of wind setup, which increases with decreasing depth. Use of the shallow water depth does not affect the wave-height or wave runup determinations, which were not sensitive to operating water depth within the range of reasonable depths.

Phase:	1	2	2
Cell:	South		North
WSE Rise due to design flood (ft):	2.98	2.18	4.48
Operating water depth (ft):	2.00	2.00	2.00
Fetch (ft):	1625	1625	1961
Fetch (mi):	0.31	0.31	0.37

Fastest-mile wind speed

Design wind at 100 -year recurrence interval, based on adjustment of 50-year windspeed.

50-year windspeed based on Figure 1 in ANSI/ASCE 7-93 "Minimum Design Loads for Buildings and Other Structures".

Use importance factor, I = 1.07, for "essential facilities" (Category III), which has the effect of converting the 50-year windspeed to a 100-year value.

Revisions to ANSI/ASCE 7-93 requiring use of the 3-second gust instead of the fastest-mile windspeed are not applicable to reservoir wind-wave effects analysis in general, or this case in particular. For the present analysis, the duration of the controlling windspeed is between 0.2 and 0.3 hours (see individual cell-phase calculation sheets). Short gusts do not control wave growth.

Fastest-mile 10-m overland windspeed, V = 70.00 mph
Importance factor to obtain 100-year windspeed, I = 1.07 (Exposure Class C)
Use 100-yr fastest-mile wind speed, I x V = 75 mph (rounded)
= 110.0 fps

TETRA TECH

CLIENT: Uranium One
MADE BY: EKB
DATE: 5/12/2008
JOB TITLE: Shootaring Mill Operations
CHECKED:
JOB NUMBER: 114-181692
SUBJECT: Tailings Impoundment Freeboard Calculations
APPROVED:
SHEET:

Adjustments to Wind Speed

See CEM II-2-1-i.(3), "Procedure for adjusting observed winds" for figures & detailed explanation of methods.

Level:

$U_{10} = U_z\ (10/z)^{1/7}$ For z < 20 m; z must be in meters

Use CEM Fig II-2-6 if air-sea temperature data is available, or if z exceeds 20 meters
Assume wind speed read at 10 m; no correction required

$U / U_{10} =$ 1.0 for measurements taken at 10 m

$U_{10} = U_f / (U / U_{10}) =$ 75.00 mph

Location (overland or overwater):

Location and stability adjustments are applied after duration adjustments in the table below
Use CEM Fig II-2-7 for windspeed measurements taken over land

$R_L = U_W / U_L =$ 1.2 for winds blowing off the water

If fetch < 10 miles & wind data is taken over land, $U_W = 1.2\ U_L$, and R_T is not applied (equivalent to $R_L = R_T = 1.1$).
This applies here; fetches do not exceed 1 mile.

Boundary layer stability:

Location and stability adjustments are applied after duration adjustments in the table below
Use CEM Fig II-2-8 when air-sea temperature difference is known; $R_T = 1.1$ otherwise
No air-sea temperature information is available; therefore

$R_T = W_C / W_W =$ 1.0 R_T is not applicable to fetches < 10 miles.

Adjusted fastest-mile windspeed, $U_{f(adj)} = U_{10} * R_L * R_T =$ 90.00 mph = 132.00 fps
40.23 m/s

Duration:

Equation from CEM Fig II-2-2 (SPM Fig 3-12), Duration of the fastest mile windspeed as a function of windspeed:

$t = 3600 / U_f$ (U_f in mph)

Equations from CEM Fig II-2-1 (SPM Fig. 3-13), Ratio of windspeed of any duration U_t to the 1-hour windspeed U_{3600}:

$U_t / U_{3,600} =$ $1.277 + 0.296 \tanh [0.9 \log_{10} (45/t)]$ 1 sec < t < 3,600 sec
$-0.15 \log_{10} t + 1.5334$ 3,600 sec < t < 36,000 sec

Return Period (yr)	$U_{f(adj)}$ (mph)	t (sec)	$U_t / U_{3,600}$	$U_{3,600}$ (mph)	$U_{3,600}$ (fps)
100	90.00	40.0	1.291	69.7	102.3

Duration is further modified during determination of the design wave conditions.

TETRA TECH

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Wind Setup:

Use Zuider-Zee formula, from EM-1110-2-1420 "Hydrologic Engineering Requirements for Dams" (31 Oct 97)

$$S = \frac{U^2 F}{1400 D}$$

S = Wind tide (setup)
U = Average wind velocity over the fetch (fastest-mile, adjusted to overwater value)
F = Fetch
D = Average depth of water along the fetch line

U = 90.0 mph (fastest-mile speed, adjusted to overwater value)

Phase:	1	2	2
Cell:	South		North
Fetch, F (mi):	0.31	0.31	0.37
WSE Rise due to design flood (ft):	2.98	2.18	4.48
Operating water depth (ft):	2.00	2.00	2.00
Water depth, D (ft):	4.98	4.18	6.48
Wind setup, S (ft):	0.36	0.43	0.33

Wind setup is not included in water depth for computation of the design wave height, but is used to compute the wave runup at the shoreline

Design Wave & Wave Runup:

See sheets for individual Cell-Phase combinations for design wave and wave runup computations.

Total Freeboard

Total freeboard is the sum of the rise due to the design flood, wind setup, and wave runup.

Phase:	1	2	2
Cell:	South		North
WSE Rise due to design flood (ft):	2.98	2.18	4.48
Wind setup (ft):	0.36	0.43	0.33
Wave runup (ft):	2.85	2.34	2.59
Total freeboard (ft):	6.19	4.94	7.40
Use: rounded up to the next half-foot (ft)	6.50	5.00	7.50

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Design Wave Conditions, Phase 1, South Cell:

Inputs:

Use:

Adjusted 100-yr, 1-hr windspeed, U_{3600} =	69.7	mph	102.3	fps
Effective fetch, X =	0.31	miles =	1625	ft (use straight-line fetch, conservative)
Water depth, d =	4.98	feet		(minimum operating depth + design storm rise)

Equations:

CEM now recommends computing deepwater wave heights for shallow water, subject to the limiting wave period given by CEM Eq II-2-39, and a limiting height of 0.6 times the depth. See pp. II-2-45 through 47.

Time required for waves crossing a fetch X under a velocity u to become fetch-limited (CEM Eq II-2-35):

$$t_{x,u} = \frac{77.23\ X^{0.67}}{u^{0.34}\ g^{0.33}}$$

CEM Fig II-2-3, "Equivalent duration for wave generation as a function of fetch and wind speed," gives the same same information graphically for fetches up to 10 km.

Limiting wave period in shallow water:

$T_p = 9.78\ (d/g)^{1/2}$ CEM Eq II-2-39

Equations governing wave growth with fetch (CEM Eq II-2-36):

$gH_{mo} / u_*^2 = 0.0413\ (\ g\ X / u_*^2\ )^{1/2}$

$gT_p / u_* = 0.651\ (\ g\ X / u_*^2\ )^{1/3}$

$C_D = u_*^2 / U_{10}^2$

$C_D = 0.001\ (1.1 + 0.035\ U_{10})$ (Requires U_{10} in m/s)

where

X = straight line fetch distance over which the wind blows
H_{mo} = energy-based significant wave height
T_p = frequency
C_D = drag coefficient
U_{10} = wind speed at 10 m elevation
u_* = friction velocity

The fully-developed wave height is given by CEM Eq II-2-30:

$H_{:} = \lambda_5\ u^2 / g = 0.27\ u^2 / 32.2$ (u in ft/s)

The fully-developed wave height (upper limit to wave growth for any wind speed) is given by CEM Eq II-2-30:

$gH_{m0} / u_*^2 = 211.5$

$gT_p / u_* = 239.8$

For duration-limited conditions, duration is converted into an equivalent fetch using CEM Eq II-2-38:

$gX / u_*^2 = 0.00523\ (\ g\ t / u_*\ )^{3/2}$ (where t is the duration)

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Calculations:

Wind Velocity and Duration						Fetch-Limited Conditions			
Duration, t (hr)	t (sec)	$U_t / U_{3,600}$	U_t (mph)	$t_{x,u}$ (hrs)	u_*^2 (ft^2/sec^2)	gH_{m0} / u_*^2	gT_p / u_*	H_{m0} (ft)	T_p (sec)
0.01	36	1.303	90.8	0.18	44.76	1.4	6.9	1.96	1.42
0.1	360	1.078	75.2	0.20	27.69	1.8	8.0	1.54	1.32
0.2	720	1.042	72.6	0.20	25.39	1.9	8.3	1.48	1.30
0.234	842.4	1.035	72.2	0.20	25.01	1.9	8.3	1.47	1.29
0.235	846	1.035	72.2	0.20	25.00	1.9	8.3	1.47	1.29
0.3	1080	1.027	71.6	0.20	24.47	1.9	8.4	1.45	1.29
1	3600	1.000	69.7	0.20	22.90	2.0	8.6	1.40	1.27
2	7200	0.955	66.6	0.20	20.42	2.1	8.9	1.33	1.25
4	14400	0.910	63.4	0.21	18.11	2.2	9.3	1.25	1.23
6	21600	0.883	61.6	0.21	16.84	2.3	9.5	1.20	1.21
8	28800	0.864	60.3	0.21	15.97	2.4	9.7	1.17	1.20
10	36000	0.850	59.3	0.21	15.32	2.4	9.8	1.15	1.19

Duration, t (hr)	Duration-Limited Conditions						Controlling Conditions		
	gX / u_*^2	X (mi)	gH_{m0} / u_*^2	gT_p / u_*	H_{m0} (ft)	T_p (sec)	Limitation	H_{m0} (ft)	T_p (sec)
0.01	12	0.0	0.1	1.5	0.20	0.31	Duration	0.20	0.31
0.1	541	0.1	1.0	5.3	0.83	0.87	Duration	0.83	0.87
0.2	1632	0.2	1.7	7.7	1.32	1.20	Duration	1.32	1.20
0.234	2089	0.3	1.9	8.3	1.47	1.29	Duration	1.47	1.29
0.235	2103	0.3	1.9	8.3	1.47	1.30	Fetch	1.47	1.29
0.3	3083	0.4	2.3	9.5	1.74	1.46	Fetch	1.45	1.29
1	19718	2.7	5.8	17.6	4.12	2.61	Fetch	1.40	1.27
2	60767	7.3	10.2	25.6	6.46	3.59	Fetch	1.33	1.25
4	188086	20.0	17.9	37.3	10.07	4.93	Fetch	1.25	1.23
6	364928	36.1	24.9	46.5	13.05	5.93	Fetch	1.20	1.21
8	584561	54.9	31.6	54.4	15.66	6.76	Fetch	1.17	1.20
10	842909	76.0	37.9	61.5	18.04	7.48	Fetch	1.15	1.19

Controlling hindcast wave: Fetch-limited

H_{mo} = 1.47 feet

T_p = 1.29 sec

Limiting wave period: $T_p = 9.78 (d/g)^{0.5}$ = 3.85 sec

Period OK, use deepwater values

Limiting wave height: 0.6*d = 3.0 feet

Wave height OK

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Check Maximum Breaking Wave:

Fig 2-2 of EM 1110-2-1614, or SPM Fig 7-4, gives the maximum breaker height, H_b

Nearshore slope, m:

Assume nearshore slope, m = **0.000** ft/ft (tailings surface assumed level)

Depth at structure, d_s:

Operating water depth = 2.00 ft
Rise due to PMF series = 2.98 ft
Wind setup = 0.36 ft
Depth at structure, d_s = 5.34 ft

Controlling wave height:

Wave period, T = 1.29 sec
d_s / gT^2 = 0.0992
Not used H_s / H_{mo} = $\exp [C_0 (d / gT_p^2)^{-C1}]$ Where C_0=0.00089 (0.00136 conservative) & C_1=0.834
Not used H_s / H_{mo} = 1.009
Not used H_s = 1.48

H_b / d_s = 0.78 (EM 1110-2-1614, Fig 2-2, "Design Breaker Height," or SPM Fig 7-4, at computed m and d_s/gT^2.)
Maximum breaker height, H_b = 4.16 ft at T
Hindcast wave height, H_{m0} = 1.47 feet
Controlling wave height, H = **1.47** feet **(Hindcast wave height controls)**

Check maximum breaker height at a variety of wave periods other than the hindcast period (after CETN-III-2):
Typical range of periods from 0.5*T to 1.9*T = 0.65 sec to 1.16 sec

Assumed T* (sec)	d_s / gT^2	H_b / d_s	H_b (ft)	
0.65	0.3966	0.78	4.2	at 0% slope
1.16	0.1224	0.78	4.2	at 0% slope
3.85	0.0112	0.78	4.2	at 0% slope
3.85	0.0112	1.2	6.4	at 10% slope (assumed max; not actual)
10.00	0.0017	0.8	4.3	at 0% slope

*3.85 sec is the limiting period, computed above.

Use for design:

H = 1.47 feet
T_p = 1.29 sec

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Check Wave Runup:

Input data:

Design wave height, H_{mo} = 1.47 feet

Design wave period, T_p = 1.29 sec

Revetment slope, $\cot\theta$ = 2 Upstream face of dam is 2:1 in PH 1; divider berm is 2.5:1

Equations:

Maximum runup by irregular waves on riprap covered revetments is estimated by:

$$R_{max} / H_{mo} = \frac{a\,\xi}{1 + b\,\xi}$$ (Eq 2-6 in EM 1110-2-1614)

where

R_{max} = maximum vertical height of runup above swl

a, b = regression coefficients determined as 1.022 and 0.247, respectively
The more conservative value of a = 1.286 is used here.

ξ = surf parameter defined by:

$$\xi = \frac{\tan\theta}{(\,2\,\pi\,H_{mo} / g\,T_p^{\,2}\,)^{1/2}}$$

Results for slopes other than riprap or quarrystone can be adjusted by the factors in Table 2-2 of EM-1110-2-1614. See pages 2-6 & 2-7 of that manual for details.
The surf parameter equation above is equivalent to that in CEM, Eqn II-4-1.

For quarrystone at 2:1 slope, Rough slope runup correction factor r = 0.615

Calculations:

ξ = 1.21

R_{max} / H_{mo} = 1.20

R_{max} = 1.76 feet

Wave runup, R_{max} / r = 2.85 feet

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Design Wave Conditions, Phase 2, South Cell:

Inputs:

Use:

Adjusted 100-yr, 1-hr windspeed, U_{3600} =	69.7	mph	102.3	fps	
Effective fetch, X =	0.31	miles =	1625	ft (use straight-line fetch, conservative)	
Water depth, d =	4.18	feet	(minimum operating depth + design storm rise)		

Equations:

CEM now recommends computing deepwater wave heights for shallow water, subject to the limiting wave period given by CEM Eq II-2-39, and a limiting height of 0.6 times the depth. See pp. II-2-45 through 47.

Time required for waves crossing a fetch X under a velocity u to become fetch-limited (CEM Eq II-2-35):

$$t_{x,u} = \frac{77.23\ X^{0.67}}{u^{0.34}\ g^{0.33}}$$

CEM Fig II-2-3, "Equivalent duration for wave generation as a function of fetch and wind speed," gives the same same information graphically for fetches up to 10 km.

Limiting wave period in shallow water:

$T_p = 9.78\ (d/g)^{1/2}$ CEM Eq II-2-39

Equations governing wave growth with fetch (CEM Eq II-2-36):

$gH_{mo} / u_*^2 = 0.0413\ (\ g\ X / u_*^2\ )^{1/2}$

$gT_p / u_* = 0.651\ (\ g\ X / u_*^2\ )^{1/3}$

$C_D = u_*^2 / U_{10}^2$

$C_D = 0.001\ (1.1 + 0.035\ U_{10})$ (Requires U_{10} in m/s)

where

X = straight line fetch distance over which the wind blows
H_{mo} = energy-based significant wave height
T_p = frequency
C_D = drag coefficient
U_{10} = wind speed at 10 m elevation
u_* = friction velocity

The fully-developed wave height is given by CEM Eq II-2-30:

$H_{:} = \lambda_5\ u^2 / g = 0.27\ u^2 / 32.2$ (u in ft/s)

The fully-developed wave height (upper limit to wave growth for any wind speed) is given by CEM Eq II-2-30:

$gH_{m0} / u_*^2 = 211.5$

$gT_p / u_* = 239.8$

For duration-limited conditions, duration is converted into an equivalent fetch using CEM Eq II-2-38:

$gX / u_*^2 = 0.00523\ (\ g\ t / u_*\ )^{3/2}$ (where t is the duration)

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Calculations:

Wind Velocity and Duration						Fetch-Limited Conditions			
Duration, t (hr)	t (sec)	U_t / $U_{3,600}$	U_t (mph)	$t_{x,u}$ (hrs)	u_*^2 (ft^2/sec^2)	gH_{m0} / u_*^2	gT_p / u_*	H_{m0} (ft)	T_p (sec)
0.01	36	1.303	90.8	0.18	44.76	1.4	6.9	1.96	1.42
0.1	360	1.078	75.2	0.20	27.69	1.8	8.0	1.54	1.32
0.2	720	1.042	72.6	0.20	25.39	1.9	8.3	1.48	1.30
0.234	842.4	1.035	72.2	0.20	25.01	1.9	8.3	1.47	1.29
0.235	846	1.035	72.2	0.20	25.00	1.9	8.3	1.47	1.29
0.3	1080	1.027	71.6	0.20	24.47	1.9	8.4	1.45	1.29
1	3600	1.000	69.7	0.20	22.90	2.0	8.6	1.40	1.27
2	7200	0.955	66.6	0.20	20.42	2.1	8.9	1.33	1.25
4	14400	0.910	63.4	0.21	18.11	2.2	9.3	1.25	1.23
6	21600	0.883	61.6	0.21	16.84	2.3	9.5	1.20	1.21
8	28800	0.864	60.3	0.21	15.97	2.4	9.7	1.17	1.20
10	36000	0.850	59.3	0.21	15.32	2.4	9.8	1.15	1.19

Duration, t (hr)	Duration-Limited Conditions						Controlling Conditions		
	gX / u_*^2	X (mi)	gH_{m0} / u_*^2	gT_p / u_*	H_{m0} (ft)	T_p (sec)	Limitation	H_{m0} (ft)	T_p (sec)
0.01	12	0.0	0.1	1.5	0.20	0.31	Duration	0.20	0.31
0.1	541	0.1	1.0	5.3	0.83	0.87	Duration	0.83	0.87
0.2	1632	0.2	1.7	7.7	1.32	1.20	Duration	1.32	1.20
0.234	2089	0.3	1.9	8.3	1.47	1.29	Duration	1.47	1.29
0.235	2103	0.3	1.9	8.3	1.47	1.30	Fetch	1.47	1.29
0.3	3083	0.4	2.3	9.5	1.74	1.46	Fetch	1.45	1.29
1	19718	2.7	5.8	17.6	4.12	2.61	Fetch	1.40	1.27
2	60767	7.3	10.2	25.6	6.46	3.59	Fetch	1.33	1.25
4	188086	20.0	17.9	37.3	10.07	4.93	Fetch	1.25	1.23
6	364928	36.1	24.9	46.5	13.05	5.93	Fetch	1.20	1.21
8	584561	54.9	31.6	54.4	15.66	6.76	Fetch	1.17	1.20
10	842909	76.0	37.9	61.5	18.04	7.48	Fetch	1.15	1.19

Controlling hindcast wave: Fetch-limited

H_{mo} = 1.47 feet

T_p = 1.29 sec

Limiting wave period: $T_p = 9.78 (d/g)^{0.5} =$ 3.52 sec

Period OK, use deepwater values

Limiting wave height: 0.6*d = 2.5 feet

Wave height OK

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Check Maximum Breaking Wave:

Fig 2-2 of EM 1110-2-1614, or SPM Fig 7-4, gives the maximum breaker height, H_b

Nearshore slope, m:

Assume nearshore slope, m = **0.000** ft/ft (tailings surface assumed level)

Depth at structure, d_s:

Operating water depth = 2.00 ft
Rise due to PMF series = 2.18 ft
Wind setup = 0.43 ft
Depth at structure, d_s = 4.61 ft

Controlling wave height:

Wave period, T = 1.29 sec
d_s / gT^2 = 0.0856
Not used H_s / H_{mo} = $\exp [C_0 (d / gT_p^2)^{-C1}]$ Where C_0=0.00089 (0.00136 conservative) & C_1=0.834
Not used H_s / H_{mo} = 1.011
Not used H_s = 1.48

H_b / d_s = 0.78 (EM 1110-2-1614, Fig 2-2, "Design Breaker Height,"
Maximum breaker height, H_b = 3.59 ft at T or SPM Fig 7-4, at computed m and d_s/gT^2.)
Hindcast wave height, H_{m0} = 1.47 feet
Controlling wave height, H = **1.47** feet **(Hindcast wave height controls)**

Check maximum breaker height at a variety of wave periods other than the hindcast period (after CETN-III-2):
Typical range of periods from 0.5*T to 1.9*T = 0.65 sec to 1.16 sec

Assumed T* (sec)	d_s / gT^2	H_b / d_s	H_b (ft)	
0.65	0.3424	0.78	3.6	at 0% slope
1.16	0.1057	0.78	3.6	at 0% slope
3.52	0.0115	0.78	3.6	at 0% slope
3.52	0.0115	1.2	5.5	at 10% slope (assumed max; not actual)
10.00	0.0014	0.8	3.7	at 0% slope

*3.52 sec is the limiting period, computed above.

Use for design:
H = 1.47 feet
T_p = 1.29 sec

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Check Wave Runup:

Input data:

Design wave height, H_{mo} =	1.47	feet	
Design wave period, T_p =	1.29	sec	
Revetment slope, cotθ =	2.5	Upstream face of dam and divider berm are both 2.5:1 in PH 2.	

Equations:

Maximum runup by irregular waves on riprap covered revetments is estimated by:

$$R_{max} / H_{mo} = \frac{a\,\xi}{1 + b\,\xi}$$ (Eq 2-6 in EM 1110-2-1614)

where

R_{max} = maximum vertical height of runup above swl

a, b = regression coefficients determined as 1.022 and 0.247, respectively

The more conservative value of a = 1.286 is used here.

ξ = surf parameter defined by:

$$\xi = \frac{\tan\theta}{(2\,\pi\,H_{mo} / g\,T_p^{\,2})^{1/2}}$$

Results for slopes other than riprap or quarrystone can be adjusted by the factors in Table 2-2 of EM-1110-2-1614. See pages 2-6 & 2-7 of that manual for details.

The surf parameter equation above is equivalent to that in CEM, Eqn II-4-1.

For quarrystone at 2.5:1 slope, Rough slope runup correction factor r = 0.63

Calculations:

ξ =	0.97	
R_{max} / H_{mo} =	1.00	
R_{max} =	1.47	feet
Wave runup, R_{max} / r =	2.34	feet

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Design Wave Conditions, Phase 2, North Cell:

Inputs:

Use:
Adjusted 100-yr, 1-hr windspeed, U_{3600} = 69.7 mph 102.3 fps
Effective fetch, X = 0.37 miles = 1961 ft (use straight-line fetch, conservative)
Water depth, d = 6.48 feet (minimum operating depth + design storm rise)

Equations:
CEM now recommends computing deepwater wave heights for shallow water, subject to the limiting wave period given by CEM Eq II-2-39, and a limiting height of 0.6 times the depth. See pp. II-2-45 through 47.

Time required for waves crossing a fetch X under a velocity u to become fetch-limited (CEM Eq II-2-35):

$$t_{x,u} = \frac{77.23\ X^{0.67}}{u^{0.34}\ g^{0.33}}$$

CEM Fig II-2-3, "Equivalent duration for wave generation as a function of fetch and wind speed," gives the same same information graphically for fetches up to 10 km.

Limiting wave period in shallow water:

$$T_p = 9.78\ (d/g)^{1/2}$$

CEM Eq II-2-39

Equations governing wave growth with fetch (CEM Eq II-2-36):

$$gH_{mo} / u_*^2 = 0.0413\ (\ g\ X / u_*^2\ )^{1/2}$$

$$gT_p / u_* = 0.651\ (\ g\ X / u_*^2\ )^{1/3}$$

$$C_D = u_*^2 / U_{10}^2$$

$$C_D = 0.001\ (1.1 + 0.035\ U_{10})$$

(Requires U_{10} in m/s)

where
X = straight line fetch distance over which the wind blows
H_{mo} = energy-based significant wave height
T_p = frequency
C_D = drag coefficient
U_{10} = wind speed at 10 m elevation
u_* = friction velocity

The fully-developed wave height is given by CEM Eq II-2-30:

$$H_{:} = \lambda_5\ u^2 / g = 0.27\ u^2 / 32.2$$

(u in ft/s)

The fully-developed wave height (upper limit to wave growth for any wind speed) is given by CEM Eq II-2-30:

$$gH_{m0} / u_*^2 = 211.5$$

$$gT_p / u_* = 239.8$$

For duration-limited conditions, duration is converted into an equivalent fetch using CEM Eq II-2-38:

$$gX / u_*^2 = 0.00523\ (\ g\ t / u_*\ )^{3/2}$$

(where t is the duration)

TETRA TECH

CLIENT: Uranium One
MADE BY: EKB
DATE: 5/12/2008
JOB TITLE: Shootaring Mill Operations
CHECKED:
JOB NUMBER: 114-181692
SUBJECT: Tailings Impoundment Freeboard Calculations
APPROVED:
SHEET:

Calculations:

Wind Velocity and Duration						Fetch-Limited Conditions			
Duration, t (hr)	t (sec)	U_t / $U_{3,600}$	U_t (mph)	$t_{x,u}$ (hrs)	u_*^2 (ft^2/sec^2)	gH_{m0} / u_*^2	gT_p / u_*	H_{m0} (ft)	T_p (sec)
0.01	36	1.303	90.8	0.21	44.76	1.6	7.3	2.16	1.52
0.1	360	1.078	75.2	0.22	27.69	2.0	8.6	1.70	1.40
0.2	720	1.042	72.6	0.22	25.39	2.1	8.8	1.62	1.38
0.266	957.6	1.031	71.9	0.22	24.72	2.1	8.9	1.60	1.37
0.267	961.2	1.031	71.9	0.22	24.71	2.1	8.9	1.60	1.37
0.3	1080	1.027	71.6	0.23	24.47	2.1	8.9	1.59	1.37
1	3600	1.000	69.7	0.23	22.90	2.2	9.1	1.54	1.36
2	7200	0.955	66.6	0.23	20.42	2.3	9.5	1.46	1.33
4	14400	0.910	63.4	0.23	18.11	2.4	9.9	1.37	1.30
6	21600	0.883	61.6	0.24	16.84	2.5	10.1	1.32	1.29
8	28800	0.864	60.3	0.24	15.97	2.6	10.3	1.29	1.28
10	36000	0.850	59.3	0.24	15.32	2.7	10.4	1.26	1.27

Duration, t (hr)	Duration-Limited Conditions						Controlling Conditions		
	gX / u_*^2	X (mi)	gH_{m0} / u_*^2	gT_p / u_*	H_{m0} (ft)	T_p (sec)	Limitation	H_{m0} (ft)	T_p (sec)
0.01	12	0.0	0.1	1.5	0.20	0.31	Duration	0.20	0.31
0.1	541	0.1	1.0	5.3	0.83	0.87	Duration	0.83	0.87
0.2	1632	0.2	1.7	7.7	1.32	1.20	Duration	1.32	1.20
0.266	2554	0.4	2.1	8.9	1.60	1.37	Duration	1.60	1.37
0.267	2569	0.4	2.1	8.9	1.61	1.38	Fetch	1.60	1.37
0.3	3083	0.4	2.3	9.5	1.74	1.46	Fetch	1.59	1.37
1	19718	2.7	5.8	17.6	4.12	2.61	Fetch	1.54	1.36
2	60767	7.3	10.2	25.6	6.46	3.59	Fetch	1.46	1.33
4	188086	20.0	17.9	37.3	10.07	4.93	Fetch	1.37	1.30
6	364928	36.1	24.9	46.5	13.05	5.93	Fetch	1.32	1.29
8	584561	54.9	31.6	54.4	15.66	6.76	Fetch	1.29	1.28
10	842909	76.0	37.9	61.5	18.04	7.48	Fetch	1.26	1.27

Controlling hindcast wave: Fetch-limited

H_{mo} = 1.60 feet

T_p = 1.37 sec

Limiting wave period: $T_p = 9.78\ (d/g)^{0.5}$ = 4.39 sec

Period OK, use deepwater values

Limiting wave height: 0.6*d = 3.9 feet

Wave height OK

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Check Maximum Breaking Wave:

Fig 2-2 of EM 1110-2-1614, or SPM Fig 7-4, gives the maximum breaker height, H_b

Nearshore slope, m:

Assume nearshore slope, m = **0.000** ft/ft (tailings surface assumed level)

Depth at structure, d_s:

Operating water depth = 2.00 ft
Rise due to PMF series = 4.48 ft
Wind setup = 0.33 ft
Depth at structure, d_s = 6.81 ft

Controlling wave height:

Wave period, T = 1.37 sec
d_s / gT^2 = 0.1121
Not used H_s / H_{mo} = exp [C_0 (d / gT_p^2)$^{-C1}$] Where C_0=0.00089 (0.00136 conservative) & C_1=0.834
Not used H_s / H_{mo} = 1.008
Not used H_s = 1.62

H_b / d_s = 0.78 (EM 1110-2-1614, Fig 2-2, "Design Breaker Height,"
Maximum breaker height, H_b = 5.31 ft at T or SPM Fig 7-4, at computed m and d_s/gT^2.)
Hindcast wave height, H_{m0} = 1.60 feet
Controlling wave height, H = **1.60** feet **(Hindcast wave height controls)**

Check maximum breaker height at a variety of wave periods other than the hindcast period (after CETN-III-2):
Typical range of periods from 0.5*T to 1.9*T = 0.69 sec to 1.24 sec

Assumed T* (sec)	d_s / gT^2	H_b / d_s	H_b (ft)	
0.69	0.4483	0.78	5.3	at 0% slope
1.24	0.1384	0.78	5.3	at 0% slope
4.39	0.0110	0.78	5.3	at 0% slope
4.39	0.0110	1.2	8.2	at 10% slope (assumed max; not actual)
10.00	0.0021	0.8	5.5	at 0% slope

*4.39 sec is the limiting period, computed above.

Use for design:

H = 1.60 feet
T_p = 1.37 sec

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Check Wave Runup:

Input data:

Design wave height, H_{mo} =	1.60	feet
Design wave period, T_p =	1.37	sec
Revetment slope, $\cot\theta$ =	2.5	All side slopes are 2.5:1 for the North Cell

Equations:

Maximum runup by irregular waves on riprap covered revetments is estimated by:

$$R_{max} / H_{mo} = \frac{a\,\xi}{1 + b\,\xi}$$ (Eq 2-6 in EM 1110-2-1614)

where

R_{max} = maximum vertical height of runup above swl

a, b = regression coefficients determined as 1.022 and 0.247, respectively
The more conservative value of a = 1.286 is used here.

ξ = surf parameter defined by:

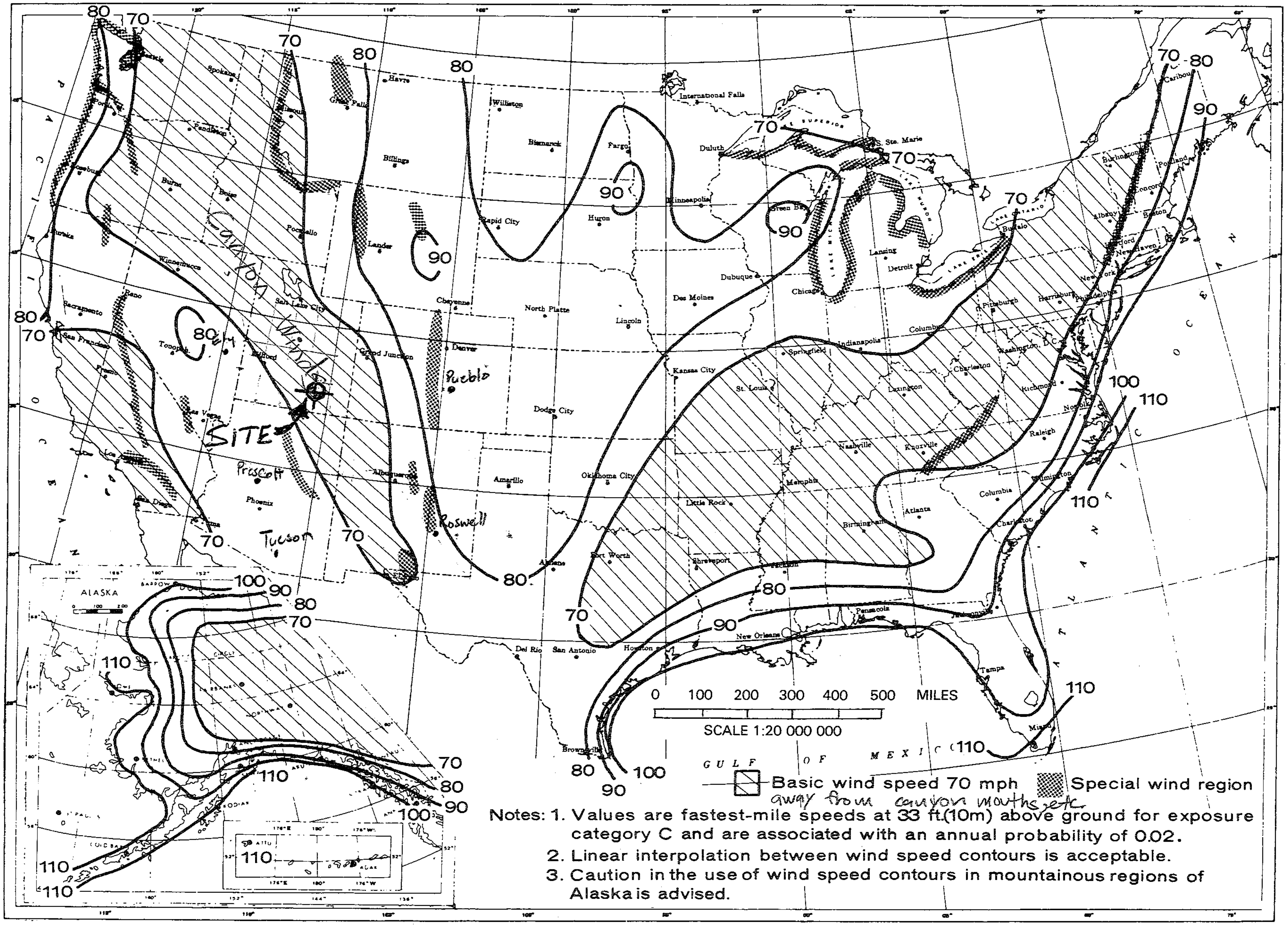
$$\xi = \frac{\tan\theta}{(2\,\pi\,H_{mo} / g\,T_p^{\,2})^{1/2}}$$

Results for slopes other than riprap or quarrystone can be adjusted by the factors in Table 2-2 of EM-1110-2-1614. See pages 2-6 & 2-7 of that manual for details.
The surf parameter equation above is equivalent to that in CEM, Eqn II-4-1.

For quarrystone at 2.5:1 slope, Rough slope runup correction factor r = 0.63

Calculations:

ξ =	0.98	
R_{max} / H_{mo} =	1.02	
R_{max} =	1.63	feet
Wave runup, R_{max} / r =	2.59	feet



Basic wind speed 70 mph ▨ Special wind region

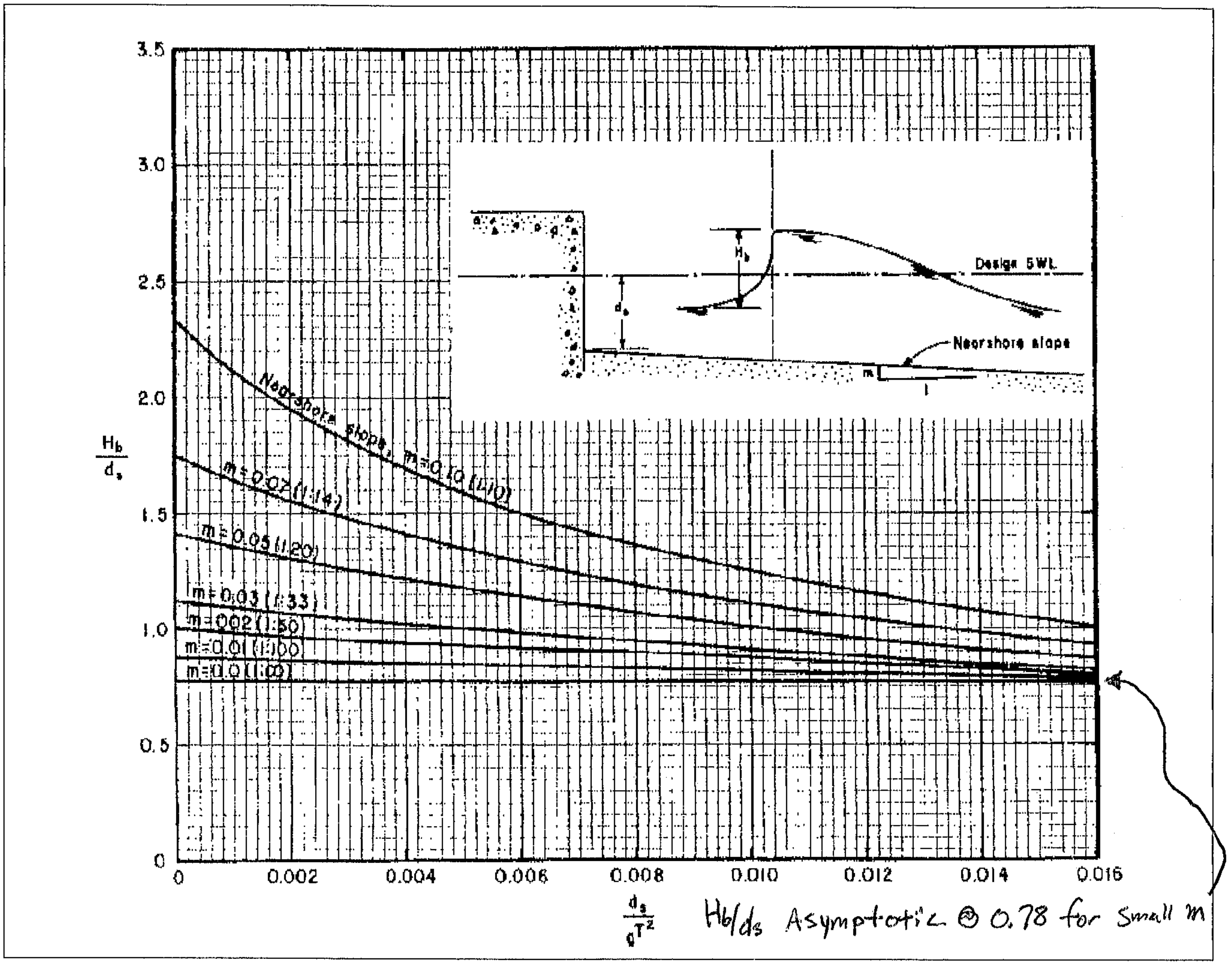
away from canyon mouths etc

Notes: 1. Values are fastest-mile speeds at 33 ft.(10m) above ground for exposure category C and are associated with an annual probability of 0.02.

2. Linear interpolation between wind speed contours is acceptable.

3. Caution in the use of wind speed contours in mountainous regions of Alaska is advised.

Fig. 1. Basic Wind Speed (mph)



Hb/ds Asymptotic @ 0.78 for Small m

Figure 2-2. Design breaker height

a. Rough slope runup.

(1) Maximum runup by irregular waves on riprap-covered revetments may be estimated by (Ahrens and Heimbaugh 1988)

$$\frac{R_{max}}{H_{mo}} = \frac{a\xi}{1 + b\xi} \tag{2-6}$$

where

R_{max} = maximum vertical height of the runup above the swl

a, b = regression coefficients determined as 1.022 and 0.247, respectively

ξ = surf parameter defined by

$$\xi = \frac{\tan\theta}{\left(\frac{2\pi H_{mo}}{gT_p^2}\right)^{1/2}} \tag{2-7}$$

where θ is the angle of the revetment slope with the horizontal. Recalling that the deepwater wavelength may be determined by

ATTACHMENT G
SUPPORTING DOCUMENTATION FOR INTERROGATORY R313-24-4-36/03: OPERATIONAL DUST CONTROL

Fugitive Dust Control

Procedure AP-5

Prepared by

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May 27, 2008

Revision 0.0

Prepared by: ______________________________ Date: ______________
Project Lead

Approved by: ______________________________ Date: ______________
Corporate Radiation Safety Officer

Approved by: ______________________________ Date: ______________
Mill Superintendent

REVISION HISTORY

Date	Version	Description	Author
April 11, 2008	1.0	Initial Draft	Neil Wrubel

CONTENTS

ACRONYMS, ABBREVIATIONS, AND INITIALISMS

CFR	Code of Federal Regulations
CRSO	Corporate Radiation Safety Officer
RSO	Radiation Safety Officer
UDEQ	Utah Department of Environmental Quality
SOP	Standard Operating Procedure

Standard Operating Procedure AP-5

Fugitive Dust Control

1 PURPOSE

The purpose of this procedure is to provide consistent guidance and methods to monitor and control fugitive dust emissions at the Shootaring Mill site.

2 DEFINITIONS

None

3 APPLICABILITY

This procedure is applicable only to the inspection and control of potential sources of fugitive dust emissions at the Shootaring Mill site, specifically ore stockpiles, roads, and the tailings impoundments. It is anticipated that the procedures listed in this SOP will be revised as required when an air permit is obtained from the State of Utah. It is expected that the air permit will address mill operations and not the ore stocks or tailings impoundments.

4 DISCUSSION

The primary objective of controlling fugitive dust emissions at the Shootaring Mill site is to keep occupational and public doses from airborne radionuclides at levels that are within regulatory limits and are As Low As Reasonably Achievable (ALARA) and to comply with applicable emission permits. The main sources of fugitive dust at the Shootaring Mill site are from road dust from haul/access roads, ore stockpiling, direct particulate emissions from the ore stocks and tailings impoundments, and construction activities.

Controlling fugitive dust emissions requires constant awareness of potential significant releases as weather conditions change during a typical day. Uranium One SOP AP-3, Inspections of Tailings or Waste Retention Systems requires daily inspections of the tailings pile(s) and includes fugitive dust as an item in the checklist. In addition, management and employees working in an area are expected to report evidence of fugitive dust emissions to the appropriate manager so that dust suppression measures may be taken.

A new tailings disposal facility has been designed and proposed for use once milling operations resume. The current tailings and cell liner will be removed and reconfigured. This SOP has been written to apply to the new facility as proposed. This SOP will also apply during the construction of the new tailings facility, during which fugitive dust emissions will be monitored and controlled.

Fugitive emissions from the tailings impoundments will be minimized through design and the routine implementation of ponding and spraying. Tailings will be discharged as a slurry containing approximately 50 percent solids, into two tailings cells. Tailings will be deposited by alternating back and forth between the cells during the operational lifetime of the facility, ensuring that only a single cell less than 40 acres is in operation at any one time. The surface of the cell that is not in active deposition will remain flooded or wetted via spray application of tailings waters to serve the dual role of radon cover and evaporative surface. A tailings pool will cover a portion of the area of the active cell. Tailings water will be sprayed on the remainder of the cell for dust control.

Fugitive emissions from roads and other actively worked areas will be controlled by application of water or chemical agents as the need arises.

5 RESPONSIBILITY

The General Site Foreman, or equivalent, or his designee is responsible for the inspections and controls as outlined in this procedure. Designated field inspectors have the responsibility of immediately notifying the General Site Foreman of any significant abnormal conditions. The General Site Foreman has the responsibility for assuring that actions are taken in a timely manner to minimize emissions. When appropriate, information is given to the RSO in a timely manner so that reportable incidents are reported to the Executive Secretary of the UDEQ-DRC according to the criteria and time schedules given in SOP AP-3. Inspection reports will be submitted to the General Site Foreman with copies to the RSO.

6 EQUIPMENT AND MATERIALS

For inspections:

- Pen, Field Log Book or equivalent

For dust control:

- Chemical agents (as needed) to stabilize surfaces
- Water tank (on truck or portable tanks)
- Sprinkler systems
- Grass seed and mulch suitable to the terrain and climate
- Appropriate personal protective equipment
- Two-way radio or other communication system

7 PROCEDURE

All observations shall be recorded and any item(s) that are out of normal (defined as not noted during the last inspection or any occurrence that is not within the range of expected observations) shall be recorded and reported to the General Site Foreman immediately.

7.1 Daily Inspections

Daily inspections are addressed as part of Uranium One SOP AP-3. The General Site Foreman, or equivalent, or his designee will educate all personnel on site, particularly the field inspectors, about the importance of controlling fugitive dust emissions. In turn, fugitive dust emanating from ores, roads, tailings, and/or construction activities shall be among the field inspector’s daily observations. All personnel will be instructed to be vigilant in reporting visible dust emissions. Management will be responsible to instruct field personnel to report evidence of fugitive dust. Daily inspections shall include, if appropriate:

- Tailings impoundments or ore stockpiles should be examined for any evidence of erosion.
- Tailings impoundments and ore stockpiles and surrounding areas (including conveying and screening operations) should be examined for fugitive dust emissions.
- Roads within the mill site should be examined for fugitive dust emissions.
- Areas under construction should be examined at least daily for fugitive dust emissions.
- Other areas, particularly those newly disturbed and/or prone to dust emissions should be examined daily.

Results of daily inspection shall be documented on Form AP-3A or equivalent and submitted to the General Site Foreman for review and subsequent corrective action, if needed.

7.2 Dust Control Measures

1. Obtain all necessary supplies and transport vehicles. Confirm proper operation of vehicles and communications systems.
2. Control fugitive emissions from actively disturbed areas by watering on an as-needed basis to maintain a surface moisture content that reduces dust emissions to acceptable levels.
3. When blowing tailings sand or dusting is observed, the spray system should be operated until a crystal crust develops on the sands surface. Move the spray lines as necessary. The spray lines may require periodic cleaning. Spray lines should not be operated in periods of high winds.
4. If applicable, apply interim covers over tailings. Apply Rip Rap over compacted surfaces for final stabilization.
5. If applicable, apply wind breaks in the form of straw bales/waddle and snow fencing in strategic locations to minimize dust emissions.
6. Reseed, water, and apply mulch to surfaces that may be left undisturbed for six months and longer, to promote and maintain vegetation growth. If not reseeded, stabilize the area by chemical treatment to minimize blowing dust. Reseeding is unnecessary in areas that re-vegetate naturally before six months.
7. On an as-needed basis, use water spray to control fugitive dust from ore conveying and screening areas.
8. The speed limit for vehicles on unpaved surfaces is 20 mph. Post speed limit signs at appropriate locations. Cover haul vehicle for off-site transport of ore or soil with a tarp.
9. When in use, water unpaved haul roads on an as-needed basis to minimize fugitive dust or less if weather conditions permit. Chemical dust suppressant may also be used to minimize fugitive dust potential from unpaved haul roads.

10. Control tracking of mud and dirt onto paved surfaces using gravel entry ways, washing haul vehicles prior to entering, covering loads, and limiting load sizes.
11. Wash vehicles contaminated by radioactive materials at decontamination pads before leaving the restricted area.
12. Stop vehicle movement and earthworks onsite when wind speeds exceed 40 mph continuously.

8 QUALITY ASSURANCE

The General Site Foreman will assure quality by:

- Implementing a training program for field inspectors and other employees by an experienced professional
- Adherence to this SOP
- Promptly reviewing Inspection Documents
- Documenting corrective actions, when appropriate, resulting from site inspection.

9 RECORDS

The following forms will be completed and maintained in the project office with copies sent to the CRSO. These forms shall be retained for three years from the date of inspection.

- Form AP-3A Daily Inspection Form, Tailings, Ore Stockpiles, and Waste Retention Systems

10 REFERENCES

R313-24-4, 10CFR40.26(c)(2)

R313-24-4, 10CFR40 Appendix A(8)(a)

R317-6-6.3 (O)