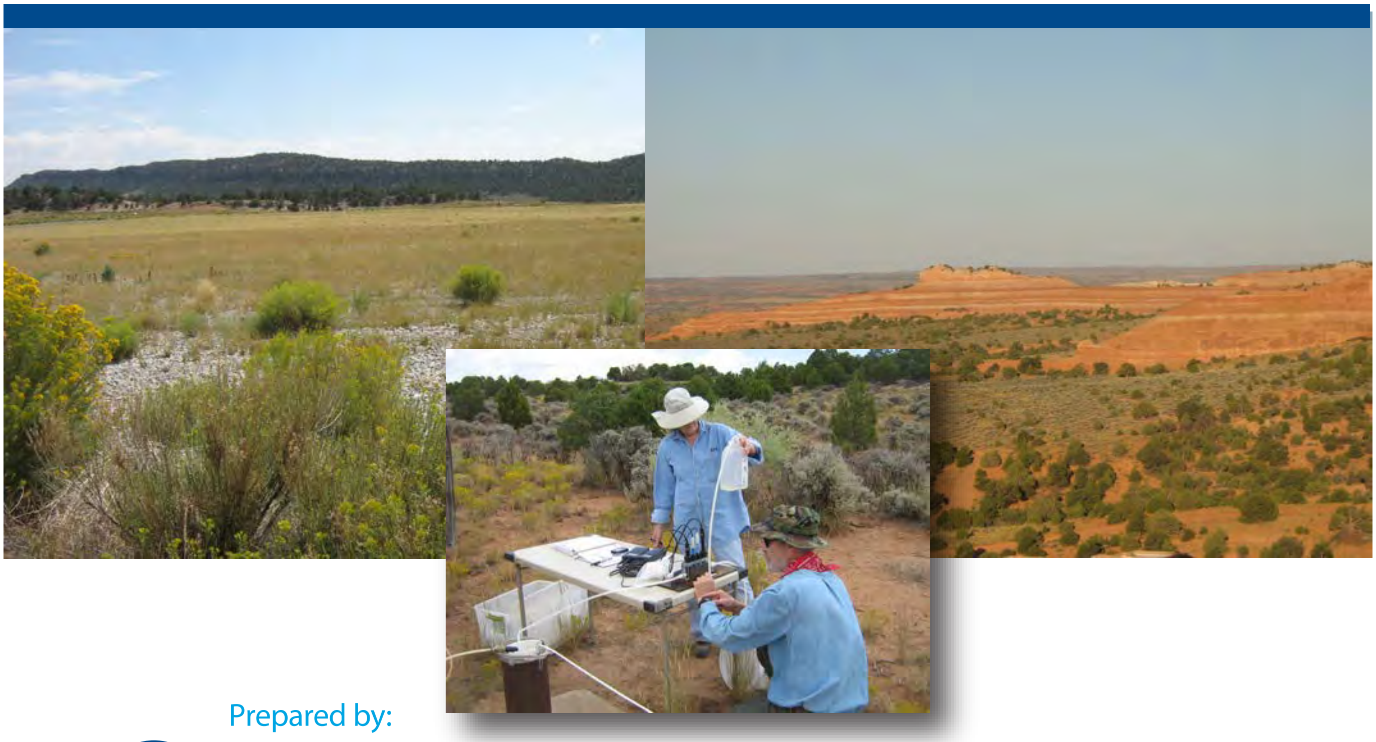
FINAL WORK PLAN
April 13, 2012

Prepared for:
Rio Algom Mining LLC

Supplemental Site Assessment to Address Out-of-Compliance Status at Trend Wells RL-1 and EF-8

Lisbon Facility



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1.0 INTRODUCTION

Montgomery & Associates (M&A) has prepared this final work plan on behalf of Rio Algom Mining LLC (RAML) for a supplemental site assessment (SSA) to address out-of-compliance (OOC) status at Trend Wells RL-1 and EF-8 at the Lisbon Facility located near La Sal, Utah (Site). An initial work plan was submitted to the Utah Division of Radiation Control (DRC) on December 16, 2011, in accordance with Condition 56 of Amendment 4 of Radioactive Materials License No. UT 1900481. The initial work plan outlined a two-phase probabilistic groundwater modeling approach to aid in development of the SSA field program, evaluation of the SSA results, and re-establishment of compliance conditions at the Site. The Phase 1 groundwater modeling (**Task 1** of the initial work plan) was completed in March 2012 as planned. This final work plan fulfills the requirements of **Task 2** of the initial work plan. **Section 3** of the final work plan outlines the pending activities for **Tasks 3 though 6**.

DRC provided comments to RAML on the initial work plan in a Request for Information (RFI) letter dated February 6, 2012. The RFI letter summarized the results of DRC's review and included a technical memorandum with detailed comments. RAML reviewed DRC's letter and memorandum and submitted a letter to DRC on February 29, 2012 that provided preliminary responses to DRC comments and proposed a meeting to review the comments, the Phase 1 model results, and the proposed site assessment program. This meeting was held at DRC offices in Salt Lake City on March 19, 2012. During the meeting, RAML requested and DRC verbally agreed to extend the final work plan submittal date to April 13, 2012. As requested by DRC, RAML formalized the request for extension in a letter to DRC dated March 19, 2012. DRC formally approved the April 13, 2012 submittal date in a letter to RAML dated March 20, 2012.

1.1 BACKGROUND INFORMATION

Uranium mining and milling occurred at the Site from 1972 to 1989. Seepage from two tailings impoundments constructed during mining is suspected to have resulted in uranium contamination in groundwater beneath the Site. The tailings impoundments were covered with impervious material in the mid-2000s to prevent further impacts. **Figure 1** shows the current site features.

Groundwater monitoring is conducted at the Site in accordance with the 2004 Long Term Groundwater Monitoring Plan (LTGMP) (Komex, 2004), which was prepared in association with the 2001 Application for Alternate Concentration Limits (ACLs) and response for further information document (Lewis Water Consultants, Inc., 2001; Komex, 2003). Groundwater monitoring activities are also conducted in accordance with Section 53 of Radioactive Materials License No. UT 1900481 issued by DRC in January 2010. The primary constituent of concern (COC) in groundwater at the Site is uranium. Other COCs include molybdenum, selenium, and arsenic. Total dissolved solids, chloride, sulfate, bicarbonate, and groundwater elevation are also monitored at the Site. The work plan activities primarily address uranium in groundwater; however, they will also further characterize the nature and extent of other COCs.

Based on results from the LTGMP, trend wells RL-1 and EF-8 are currently out of compliance because uranium concentrations in groundwater have exceeded Target Action Levels (TALs) for more than two consecutive sampling events, as shown on **Figures 2 and 3**. In the February 7, 2011 letter to RAML, DRC requested that RAML contract with an independent consultant to address the out-of-compliance status at Trend Well RL-1 (DRC, 2011). Specifically, DRC requested that the consultant carry out the following actions: (1) review pertinent information and documents, including the existing ACL model, relevant laboratory data, the LTGMP and (2) provide potential additional groundwater modeling, as appropriate. In the letter, DRC requested that RAML prepare an Action Plan to address the following performance objectives (POs):

- PO #1 – Justify whether the current RL-1 data set is or is not sufficient to depict the uranium concentration trend;
- PO #2 – Conclude with definitive evidence whether the Lisbon Valley Facility is operating within or outside of the analyzed condition of the Nuclear Regulatory Commission (NRC) approved "Application for Alternate Concentration Limits" (Approved May 11, 2004), and LTGMP, and;
- PO #3 – Determine whether the ACL model should be revisited/revised to account for more recent data.

The Action Plan was prepared by M&A on behalf of RAML and submitted to DRC on June 1, 2011 (M&A, 2011a). In accordance with the Action Plan, M&A conducted an evaluation of hydrogeologic conditions, groundwater quality, and the ACL groundwater model. A technical memorandum summarizing the evaluation was submitted to DRC on August 10, 2011 (M&A, 2011b). As discussed in the memorandum, M&A recommended that additional work be conducted at the Site before final conclusions could be reached on the POs. On October 13, 2011, representatives from RAML, M&A, and DRC met to discuss the results of the evaluation and a plan to address compliance conditions at the Site. During the meeting, conceptual aspects of the SSA were discussed and RAML agreed to submit a work plan for the SSA by December 16, 2011. This work plan was submitted by RAML on December 16, 2011 and is now known as the initial work plan. This document is the final work plan and incorporates comments from DRC on the initial work plan.

1.2 WORK PLAN ORGANIZATION

The work plan includes the following sections and appendices:

Section 1.0 – Introduction
Section 2.0 – Summary of Site Conditions
Section 3.0 – Supplemental Site Assessment Tasks
Section 4.0 – References Cited
Appendix A – Existing Well Information
Appendix B – Summary of Phase 1 Groundwater Modeling
Appendix C – Well Construction and Testing Procedures
Appendix D – Supplemental Site Assessment Groundwater Sampling Plan

1.3 RESPONSE TO COMMENTS

RAML has included responses to DRC comments on the initial work plan in **Table 1**. Where applicable, **Table 1** indicates the work plan section number where specific comments are addressed.

2.0 SUMMARY OF SITE CONDITIONS

Previous investigations, data analyses, and modeling have resulted in a substantial amount of information about the Site. Many Site features and conditions are well understood as a result of this work. The previous work served as the basis for developing the current ACLs. However, much of the previous work was conducted during dynamic groundwater conditions caused by mine operations and Corrective Action Program (CAP) pumping. These dynamic groundwater conditions complicated characterization efforts and modeling of groundwater flow and uranium transport. Since the CAP ceased in 2004, groundwater levels have been recovering. The nature of groundwater level recovery after 2004 has resulted in new data and interpretations. Review of these new data and information indicates that the hydrogeologic conceptual model at the Site needs to be refined. Because of well abandonment, data obtained after 2004 are more limited than before 2004, which results in data gaps. These data gaps need to be addressed to refine the conceptual model, conduct additional modeling, and revise the ACLs.

The sections below briefly summarize Site hydrogeologic and water quality conditions and discuss the key data gaps.

2.1 GEOLOGY

The primary geologic formations at the Site are the Burro Canyon Formation (BCF) and the Brushy Basin Member of the Morrison Formation (BBM). Uppermost groundwater at the Site is encountered in the BCF. The BCF is composed of very fine to fine grained sandstone with interbedded silt and mudstones. The BCF has primary porosity and secondary fracture porosity (Earthfax, 1989). Underlying the BCF is the BBM, which is reported to be about 390 feet thick near the Site (KOMEX, 2003). The BBM is composed of bentonitic claystone with lenses of fine grained sandstone and mudstone (Earthfax, 1989).

The geologic setting of the Site has two important hydrologic features: (1) the Lisbon Valley Anticline (LVA) and (2) the Lisbon Fault (LF). The axis of the LVA strikes southeast to northwest through the Site and passes directly under the lower tailings impoundment. The southeastern and northwestern extents of the LVA have not been characterized. The LF, located along the southwestern boundary of the Site, is a high angle reverse fault with approximately 2,200 feet of vertical displacement and strikes southeast to northwest.

2.2 HYDROGEOLOGY

The primary aquifer at the Site is the Burro Canyon Aquifer (BCA), which occurs in the BCF. The BCA is likely bounded on the southwest by low conductivity rocks on the southwest side of the LF; however, aquifer conditions along the fault could be complex as a result of fracturing associated with the LF. Folding of the BCF along the crest of the LVA causes the base of the BCF to be above the water table in some areas along the crest of the LVA. In this area, the water table is in the BBM and the BCA is dry. The shape and size of the dry area (referred to as the “dry zone” in previous Site documents) in the BCA along the LVA crest has varied since mining operations began in the early 1970s. The extent of the dry area is poorly delineated by available Site data. Additional exploratory drilling or wells are needed to improve delineation of the dry area in the BCA. Improved delineation of the dry area will improve future projection of groundwater flow and uranium transport.

The “dry zone” was previously conceptualized to separate the BCA into two separate aquifer areas: the North Aquifer and the South Aquifer. The convention of separate North and South Aquifers was developed as convenient terminology during early stages of Site characterization. However, this convention complicates communications and planning of the supplemental assessment and will no longer be used. Instead, the BCA will be considered one aquifer with areas along the LVA crest where it is dry and the water table is in the underlying BBM.

Hydraulic Conductivity

Horizontal hydraulic conductivity (K_h) of the BCA was characterized by slug tests and pumping tests (see Table 2-1, Lewis Water Consultants, Inc., 2001). The reported estimates of BCA K_h vary over several orders of magnitude due to varying degrees of fracturing. K_h tends to be higher southwest of the tailings impoundments than northwest of the tailings impoundments. Previous reports have identified three populations of K_h in the BCA: (1) unfractured rock (average K_h of 0.2 feet per day [ft/day]), (2) fractured rock (average K_h of 6 ft/day), and (3) extensively fractured rock (south aquifer only; average K_h of 100 ft/day) (Lewis Water Consultants, Inc., 2001). The vertical hydraulic conductivity (K_v) of the BCA has not been estimated. Additional hydraulic and laboratory testing are needed to develop better estimates of K_h and K_v for the BCA. Better estimates of the BCA hydraulic conductivities will enable better estimation of the rate of groundwater flow and uranium transport.

Very limited characterization of K_h and K_v of the BBM has been conducted to date. The average K_h and K_v of the BBM are expected to be less than that of the BCF based on geologic descriptions of the two formations. Fractures could enhance the K_h and K_v of the BBM. The K_h of the BBM could be on the order of 0.01 ft/day to 1 ft/day based on reported estimates from a slug test and pumping test in borehole H-72 (Site records indicate H-72 was an open borehole not a cased well) (Lewis Water Consultants, Inc., 2001). Additional hydraulic and laboratory testing are needed to develop better estimates of K_h and K_v for the upper portion of the BBM. Better estimates will improve understanding of the rate of groundwater flow and potential uranium transport in the upper portion of the BBM.

2.3 EXISTING WELLS AND GROUNDWATER CONDITIONS

Fourteen wells currently exist at the Site (**Figure 1**). **Appendix A** includes well construction schematics, where available, and a table of well information. Available records indicate that most of the wells are screened immediately above the contact between the BCA and BBM. **Table 2** below summarizes the relationship between the groundwater level and screened interval for the wells.

TABLE 2. COMPARISON OF GROUNDWATER LEVEL AND SCREENED INTERVAL IN WELLS

WELL NAME	MAY 2011 GROUNDWATER LEVEL ELEVATION (ft msl)	TOP OF SCREEN ELEVATION (ft msl)	BOTTOM OF SCREEN ELEVATION (ft msl)	TOP OF SCREEN SUBMERGENCE [a] (feet)	SATURATED THICKNESS [b] (feet)
MW-5	6,589.38	6,577	6,547	12	30
H-63	6,552.43	6,545	6,515	7	30
OW-UT-9	6,580.04	6,584	6,566	-4	***14***
LW-1	6,575.28	6,517	6,487	58	30
MW-13	6,547.63	6,513	6,433	35	80
EF-3A	6,496.19	6,408	6,378	88	30
EF-8	6,498.49	6,361	6,331	137	30
EF-6	6,495.50	6,464	6,434	32	30
RL-1	6,536.17	6,547	6,527	-11	***9***
RL-3	6,534.11	6,539	6,519	-5	***15***
RL-5	6,534.05	6,535	6,498	-1	***36***
RL-4	6,524.69	6,543	6,503	-18	***22***
ML-1	6,487.33	6,468	6,448	19	20
		6,378	6,363	109	15
RL-6	6,444.08	6,452	6,442	-8	***2***

Notes:
ft msl – feet above mean sea level
[a] negative submergence values indicate water table below top of screen
[b] bold italics indicate water table within screened interval of well

In six of the wells (OW-UT-9, RL-1, RL-3, RL-4, RL-5, and RL-6), the water table is within the screened interval. The water table wells are located north and northwest of the tailings impoundments. In eight of the wells (MW-5, H-63, MW-13, EF-3A, EF-8, EF-6, LW-1 and ML-1), the screened interval is submerged below the water table (designated as deep-screen wells). The deep-screen wells are generally located south and southwest of the tailings, with the exception of LW-1 and MW-5, which are located north and northeast of the tailings, respectively. The rationale for not constructing companion shallow water table wells near the some of the deep-screen wells is unknown. Near the deep-screen wells, it is possible that groundwater occurs under confined conditions in the area, there was evidence that poor quality water existed in the deep portion of the aquifer, or the groundwater level has recovered since the wells were drilled. Shallow wells are needed near the deep-screen wells to fully characterize groundwater quality.

Well ML-1 reportedly has a single-casing with two separate screened intervals. The rationale for this construction method is unknown. The lithologic log and well schematic for ML-1 is included in **Appendix A**. The two hydrostratigraphic zones screened by ML-1 are separated by about 70 feet. The degree of hydraulic communication between the two screened intervals is unknown. Water level data from ML-1 represent the average hydraulic head of the two screened zones. Borehole flowmeter testing in ML-1 could provide information on hydraulic gradients near the well. Depth specific sampling in ML-1 could provide information on deep and shallow groundwater quality.

Well RL-6 is approximately 18 feet deep; the depth of the other 13 existing wells ranges from 124 to 242 feet. Well RL-6 appears to be located in or near an ephemeral wash. A well schematic and lithologic log for RL-6 are not available; therefore, the rationale for the shallow well depth is unknown. It is unclear whether water level data from this well are meaningful given the small saturated thickness (about 2 feet) in the well. In addition, it is unclear if groundwater from this well is from the same hydrostratigraphic zone(s) screened by the other wells.

Groundwater Flow Directions and Gradients

Figure 4 shows a groundwater elevation contour map inferred from the May 2011 groundwater elevation data. The inferred extent of the dry area in the BCA is also shown on

Figure 4. The extent of the dry area was estimated as the difference in elevation between the May 2011 groundwater level elevation and the elevation of the geologic contact between the BCF and BBM (inferred from well lithologic logs by Lewis Water Consultants, Inc., 2001).

Inferring horizontal hydraulic gradients and groundwater flow directions from the contour map should consider the limitations and uncertainties in the groundwater data discussed above. The contour map was prepared with the typical simplifying assumption that groundwater occurs in a homogeneous and isotropic hydrostratigraphic unit. This assumption leads to smooth and continuous contours of groundwater elevation. Site conditions are known to be heterogeneous and probably anisotropic (due to fracturing and unidirectional flow by gravity); however, these conditions are not readily accounted for when contouring the existing groundwater level data unless sophisticated and subjective methods are used. Therefore, the groundwater contours shown on **Figure 4** do not take into account potential refraction across boundaries between geologic units of differing hydraulic conductivity.

Despite potential limitations in the data and considering the body of other hydrogeologic and water quality data for the Site, the inferred current direction of horizontal groundwater flow at the Site appears to be generally towards west-southwest. Actual groundwater flow directions are expected to differ from this general direction in some areas due to complexities associated with the LVA and LF. Historic hydraulic gradients and groundwater flow directions differed from current hydraulic gradients and groundwater flow directions due to drawdown created by the extraction wells and mounds created by seepage from the tailings impoundments and Bisco Lake, located east of the tailings. Current groundwater level data are insufficient to estimate vertical hydraulic gradients and groundwater flow directions. Additional wells are needed to improve delineation of horizontal and vertical hydraulic gradients and groundwater flow directions.

Estimated horizontal groundwater velocities are reported to vary from a few feet per year (ft/year) in unfractured rock to over 100 ft/year for extensively fractured rock (Lewis Water Consultants, Inc., 2001). Lower groundwater velocities may exist in areas of low hydraulic conductivity and higher groundwater velocities may exist in areas with high hydraulic conductivity (e.g., fracture zones). Additional wells will also improve estimates of groundwater velocities, which are critically important for projecting future uranium transport in groundwater and revising the ACLs.

2.4 URANIUM CONCENTRATIONS

A map depicting 2011 uranium concentration contours is presented on **Figure 5**. The concentration contours are dashed where uncertain. The contours represent the current understanding of the uranium plume in the BCA. The uranium concentration contours are based on data from water table wells and deep-screen wells. Historic data from abandoned wells indicate that uranium concentrations in the BCA were as high as 180 milligrams per liter near the tailings. Therefore, it is possible that higher uranium concentrations still exist in the BCA. Additional wells are needed to improve delineation of current uranium concentrations.

As discussed above, data from wells ML-1 and RL-6 may not be representative of the same hydrostratigraphic zone(s) screened by the other wells. Sampling records for ML-1 indicate that the deeper screened zone is sampled during the monitoring program; therefore, uranium concentration data characterize the aquifer zone immediately above the contact with the BBM. Water quality data from RL-6 may be from a shallow perched groundwater zone above the regional groundwater system in the BCA. Additional exploratory drilling and potential a new well are needed near RL-6. If possible, borehole flowmeter testing and depth specific sampling will be conducted in ML-1 to better characterize groundwater flow and water quality conditions near the well.

Seepage from the upper and lower tailings impoundments is suspected to be the primary source of uranium in groundwater. Groundwater levels near the tailings impoundments fluctuated due to mounds created by seepage and dewatering created by the CAP pumping. These fluctuations in groundwater levels may have left residual uranium in the unsaturated zone beneath and near the tailings impoundments. Groundwater level recovery near the tailings impoundments could dissolve residual uranium back into the groundwater system, where it can migrate and prolong the uranium source. Additional characterization of the vadose zone near the tailings impound would improve understanding of the potential source of residual uranium from the vadose zone. **Appendix C** includes details about the core sampling and laboratory analyses in the vadose zone near the tailings.

2.5 SUMMARY OF DATA GAPS

As indicated above, data gaps exist in the hydrogeologic conceptual model. These data gaps need to be addressed before revised ACLs can be developed. Additional shallow and deep wells, hydraulic testing, and groundwater sampling are needed to address the data gaps. The following types of additional data are needed to address the data gaps:

- **Groundwater Level Data –** additional groundwater level data from new shallow and deep wells in the BCA are needed to improve delineation of horizontal hydraulic gradients and groundwater flow directions, and provide data to characterize vertical hydraulic gradients and flow directions. Additional groundwater level data are also needed to improve estimates of groundwater velocities. Groundwater level data from wells screened in the BBM are needed to estimate horizontal hydraulic gradients and groundwater flow directions in the BBM and vertical hydraulic gradients between the BCA and BBM.
- **Hydraulic Conductivity Data –** additional and better K_h data are needed to improve estimates of groundwater velocities. If possible, K_v data should be

obtained to characterize vertical flow in the BCA and between the BCA and BBM. Additional K_h and K_v data will also improve understanding of the importance of fracture flow.

- **Uranium Concentration Data** – additional uranium concentration data will improve delineation of the uranium plume.

In addition, additional characterization is needed in the following areas:

- **Near Wells RL-6 and ML-1 –** additional exploratory drilling near RL-6 and well testing in ML-1 are needed to further characterize groundwater flow and water quality conditions.
- **Tailings Source Area** – characterization of the vadose zone near the tailings impoundments is needed to improve understanding of the source area.

Section 3.0 presents a plan to address these data gaps.

3.0 SUPPLEMENTAL SITE ASSESSMENT TASKS

This section presents the proposed approach to the SSA and outlines the tasks and activities that comprise the work to be conducted. **Task 1** of the initial work plan (Phase 1 Groundwater Modeling) is complete and is summarized briefly in **Section 3.1** and in more detail in **Appendix B**. **Task 2** of the initial work plan (Final Work Plan) will be complete upon approval of this final work plan. The following tasks comprise the remainder of the SSA:

- **Task 3 –** Conduct Field Program
- **Task 4 –** Evaluate Field Data
- **Task 5 –** Conduct Phase 2 Groundwater Modeling
- **Task 6 –** Prepare Report

Task descriptions are provided below.

3.1 SUMMARY OF PHASE 1 MODELING RESULTS

A probabilistic groundwater flow model was developed and analyzed during Phase 1 groundwater modeling. The outcomes of Phase 1 groundwater modeling were used to help identify data gaps that have the potential to be valuable for additional data collection. Findings from Phase 1 modeling have been incorporated into the field program described in **Section 3.2**. Phase 1 groundwater modeling is complete and additional detail is reported in **Appendix B**.

3.2 TASK 3 – CONDUCT FIELD PROGRAM

The overall goal of the field program is to address the data gaps discussed in **Section 2.0**. As described in **Section 3.1**, the Phase 1 model results were used, in part, to identify areas where new data will meaningfully reduce uncertainty and address data gaps. In addition to the model results, recommendations and input provided by DRC in their comments on the initial work plan were used to develop the field program.

The SSA field program will include installation of new wells, conduct of hydraulic tests, coring and physical properties analysis of the BCF and BBM, coring and laboratory analyses for uranium concentrations, and groundwater sampling and laboratory analyses. RAML evaluated the possibility of conducting a geophysical survey to aid in delineating the water table and contact between the BCA and BBM along the crest of the LVA. After further evaluation and in light of the number of new wells that will be installed, RAML determined that the geophysical survey would not substantially enhance the SSA and has elected not to conduct it. Details about the field program are provided in the following sections.

3.2.1 New Wells

RAML plans to install 16 new wells at the Site. **Figure 6** shows the proposed location of the new wells. The well locations were selected based on evaluation of Site data, the results of the Phase 1 modeling, and recommendations from DRC in their RFI letter dated February 6, 2012. The locations are considered tentative until they are field verified and property access has been secured. **Table 3** provides details about the new wells. **Appendix C** provides additional details on the drilling method and construction specifications for the new wells. All new wells will be designed and constructed in compliance with UAC R317-6-6.3(I)(6), the Utah Division of Water Rights Standards (R655-4 UAC), and the Resource Conservation and Recovery Act guidance document entitled *Ground Water Monitoring Technical Enforcement Guidance Document* (U.S. Environmental Protection Agency, 1986). All wells will be constructed under the supervision of a licensed Professional Geologist and by a State of Utah licensed well driller. M&A is in the process of licensing a geologist in Utah. This process should be completed before initiation of field work. If not, the M&A project manager is an Arizona and California licensed Professional Geologist and RAML would request approval from DRC to allow the M&A project manager to oversee well design and construction.

As required by DRC, RAML will submit geologic logs and well completion diagrams for the new wells within 60 calendar days of completion. The geologic logs will be prepared by a licensed Professional Geologist (see above). DRC also requested well completion diagrams for the existing wells. Well completion diagrams are not available for all existing wells. **Appendix A** includes available well completion diagrams and a table of well information.

Well Construction Procedures

There are three general types of proposed wells: (1) water table well, (2) deep BCA well, and (3) BBM wells. Exploratory drilling will be conducted near RL-6 to determine representativeness of well. **Table 4** summarizes the expected drilling and well construction procedures for each type of well. The drilling procedures were developed based on available information and may be modified in the field in accordance with the conditions encountered. Key aspects of the drilling procedures that require pre-field planning include locating the water table and coring, drilling, and constructing the wells in a manner that avoids water quality cross-contamination between the BCA and BBM. To the extent required during the field program, RAML will communicate with DRC on drilling status and unexpected conditions.

TABLE 4. WELL TYPES AND DRILLING AND WELL CONSTRUCTION PROCEDURES

WELL TYPE	DRILLING AND WELL CONSTRUCTION PROCEDURES
Water Table Well *Well screened at water table in either BCA or BBM* *Wells: MW-101S, MW-102, MW-103, MW-104, MW-105, MW-106, MW-107S, MW-108, MW-109, MW-110, MW-111, and MW-112*	• Drill to approximately 10 feet below estimated water table depth; • If water table not encountered, drill and air-lift in 10-foot increments until water table encountered; complete well per specifications.
Deep BCA Well *Well screened more than 25 feet below water table at contact between BCA and BBM* *Well: MW-101D*	• Drill to BCA/BBM contact; • Set screen in bottom 30 feet of BCA; complete well per specifications.
BBM Well *Well screened in BBM at location where BCA is saturated* *Wells: MW-107DB and MW-111DB*	• Drill to approximate depth of water table in BCA; • Core to BCA/BBM contact; ream hole to BCA/BBM contact; install and cement conductor casing; • Drill 35 feet into BBM; screen bottom 30 feet of borehole; complete well per specifications.
EXPLORATORY BOREHOLE *Exploratory borehole planned to determine if RL-6 is screened in perched or regional groundwater; well installation will depend on conditions encountered*	• Drill to depth of RL-6 (approximately 18 feet); • Air-lift borehole to determine if water table encountered; if water table encountered, drill to contact with BBM or other fine-grained zone; • If BBM encountered, stop drilling and construct shallow well if deemed suitable for replacing RL-6; • If other fine-grained zone encountered, stop drilling; install and cement in conductor casing; • Drill and install well at appropriate depth to monitor water quality based on water quality encountered at MW-101S and MW-101D.

In general, well construction will progress from areas of good water quality to areas of poor water quality. For paired wells, the deeper well will be drilled first. RAML will provide DRC with a well construction schedule prior to startup.

3.2.2 Hydraulic Testing

Field-based hydraulic testing is planned for all new and existing wells to estimate formation K_h. Laboratory testing on cores will be conducted from selected wells. **Table 3** summarizes the planned hydraulic testing program for the new wells. **Appendix C** includes details of the testing program. Slug tests will be conducted in all existing and new wells. Step and constant rate pumping tests are planned for new well MW-101D. This well was selected for potential pumping tests for the following reasons: (1) there is a reasonable likelihood that it will yield clean water, (2) there will be a shallow well adjacent to the well that can be monitored to assess the degree of vertical hydraulic communication between the deep and shallow BCA and possibly estimate K_v, and (3) the well is located near the LF and the drawdown response during pumping may provide insight into the hydrologic effect of the LF. The length of the constant rate test would depend on the sustainable pumping at the well and the volume of water storage available. All pumped water from the step and constant rate tests would be contained, sampled for water quality, and disposed using methods approved by RAML and DRC. Conditions in MW-101D may prevent conducting the pumping test.

3.2.3 Groundwater Monitoring

Groundwater monitoring will be conducted in all new and existing wells during the field program. Monitoring will include measuring depth to water and collecting groundwater samples for laboratory analyses. **Appendix D** includes details on the monitoring program. At the request of DRC, groundwater sampling will be conducted at least one week after well development in new wells. Post-well development samples may be analyzed to obtain water quality data for planning purposes. At a minimum, samples will be analyzed for uranium, molybdenum, selenium, arsenic, TDS, chloride, sulfate, and bicarbonate. Other analyses may be conducted if warranted by conditions encountered during drilling and sampling. RAML may elect to subcontract with a groundwater monitoring firm for the sampling.

Low Flow Sampling

During review of site conditions, M&A conducted a field audit of the RAML low-flow sampling procedures at the Site. Except for a minor deficiency with the flow-through cell, the field sampling protocols were found to follow standard low-flow procedures (U.S. Environmental Protection Agency, 1996). In particular, the water level and field chemistry parameters stabilized prior to collecting samples, and thorough decontamination procedures were used. Samples collected during the audit were considered representative of groundwater conditions from the screened interval. Based on the results of the audit, RAML and M&A believe that the low-flow sampling methods are appropriate for Site conditions.

DRC expressed concerns about the adequacy of low-flow sampling at the Site in their comments on the initial work plan. DRC's primary concern is that samples collected using the low-flow method from deep, submerged screened intervals are not representative of the entire saturated groundwater zone near the wells. RAML agrees with this concern and recognizes that these samples are only representative of the groundwater zone screened by the wells. As pointed out by DRC, a companion shallow well would be needed to sample the shallower groundwater zones. RAML agrees and has included shallow wells in the field program to address this concern.

To further address DRC's concerns about sampling methods, RAML plans to conduct a comparative sampling event as part of the field program. **Appendix D** includes information on the methods and procedures for the comparative sampling event. The comparative sampling event will include collecting samples from all existing and new wells using purge, low-flow, and no-purge methods (using the HydraSleeve). Results of the comparative sampling will be evaluated and used to select the appropriate sampling method for the Site. Selection of the most appropriate sampling method will take into account limitations at the Site to dispose of contaminated purge water. Upon reaching concurrence with DRC on the sampling method, a

Sampling and Analysis Plan (SAP) will be prepared and submitted to DRC for approval. The schedule for preparing the SAP will be determined in collaboration with DRC.

3.2.4 Field Program Schedule

Figure 7 presents an estimated schedule (in months from start date) for the field program and subsequent tasks. The schedule is based, in part, on projections from the driller on the duration of well installation and development. RAML is planning a concurrent day-shift only drilling and well testing program. Including pre-drilling planning, the field program is expected to take about 4.5 months to complete. The actual start date of the field program is unknown at this time, and will depend on work plan approved by DRC, availability of subcontractors, and possible delays in securing property access to the drilling locations.

Contingency Plan

This section contains a general contingency plan outlining the basic decision-making and communication process to address unexpected conditions in the field. Significant field planning and review of Site conditions have been conducted during preparation of the work plan to avoid the need for detailed contingency planning. The primary scenarios where contingency measured might be needed include: (1) if a well needs to be relocated or (2) if a well design needs to be revised in the field. Each scenario is discussed below.

Scenario 1 – Well Relocation

A visit to the Site is scheduled for May 2012 to verify the proposed well locations and meet with other project stakeholders. During the visit, each well site will be inspected for drilling impediments (e.g., utilities, limited access, etc.). Access to the proposed drilling locations is being pursued by RAML. Once the field locations have been verified and access has been secured, the likelihood that wells will be relocated will be low. RAML will provide

DRC a final well location map before drilling commences. In the unlikely event a well needs to be relocated, RAML will determine viable options, contact DRC to discuss them, and work collaboratively with DRC to relocate the well as quickly as possible. Relocating a well will require obtaining access and preparing a new drill pad.

Scenario 2 – Modifying a Well Design

Significant planning of well construction procedures has been completed for the work plan. **Table 4** summarizes the decision-making process for drilling and constructing the wells. **Appendix C** includes the methods and procedures for well design and construction. The decision-making process is based on prior information about hydrogeologic conditions, well design, and well construction procedures; therefore, the likelihood of modifying a well in the field due to unexpected conditions is low. If a well design needs to be modified, RAML will determine viable options, contact DRC to review them, and work collaboratively with DRC to re-design the well or resolve issues. If a well needs to be abandoned and relocated, the contingency measured for Scenario 1 will apply.

If other unanticipated revisions to the field program are needed, RAML will identify and prioritize options and consult with DRC on appropriate remedial measures.

3.3 TASK 4 – EVALUATE FIELD DATA

M&A will evaluate data obtained from the field program. The evaluation is expected to include preparation of geologic logs; preparation of well schematics; interpretation, tabulation, and mapping of new water level and water quality data; preparation of hydrogeologic cross-sections; and analysis of slug tests and pumping test. **Task 4** would commence during the field program to the extent possible and is expected to take about 5.5 months to complete (**Figure 7**).

3.4 TASK 5 – CONDUCT PHASE 2 GROUNDWATER MODELING

The Phase 2 probabilistic numerical model will be used to evaluate system behavior and reestablish ACLs at the Site. Data collected during the field program will be used to update the likelihoods of the ensemble of models developed in **Task 1.** These new data will reduce the weighted likelihood of physically unrealistic models. Model outputs will be used to evaluate the efficacy of the current remedial program and develop revised ACLs. Additional details about Phase 2 probabilistic modeling are presented in **Appendix B**. **Task 5** would commence during the latter stages of **Task 4,** and is expected to take about 3 months to complete.

3.5 TASK 6 – PREPARE REPORT

A final report will be prepared that summarizes methods and results from the field and modeling efforts as well as recommendations to address compliance conditions at the Site. **Task 6** will commence during **Task 5** and will take about 6 months to complete.

The SSA is projected to take about 14 months to complete after receiving approval of the work plan from DRC and securing access to the drilling locations (**Figure 7**).

4.0 REFERENCES CITED

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Utah Division of Radiation Control, 2011, **DRC Notice of Enforcement Discretion and Confirmatory Action Letter:** letter sent to Chuck Wentz, Rio Algom Mining LLC, February 7, 2011.

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TABLE 1. RESPONSES TO COMMENTS ON INITIAL WORK PLAN FROM UTAH DIVISION OF RADIATION CONTROL

DIVISION OF RADIATION CONTROL COMMENT	RIO ALGOM MINING LLC RESPONSE
4. Review of Sections on Geology, Hydrogeology, Groundwater Flow and Uranium Concentrations 4A. Geology/Hydrogeology	No response or revision to work plan
4B. "Dry" and "Wet" Portions of the LVA Crest	See revised text in **Section 2.2**, paragraph 1; See **Section 3.2.1** for information on proposed wells that will aid in delineation of saturation in the BCA; RAML will provide cross-sections in the final report when data from the new wells are available.
4C. Potential for Westward, WSW, and WNW Flow and Transport	See **Figure 4** for a revised groundwater elevation map; RAML concurs with DRC that the potential for westward flow and transport exists and additional wells are needed to improve delineation of saturation in the BCA along the LVA crest and improve estimation of groundwater flow directions; RAML will install wells at the locations recommended by DRC (refer to **Section 3.2.1 and Figure 6** for more information).
4D. "North Aquifer" and "South Aquifer" Separate?	RAML concurs with DRC that the BCA may not have been historically and may not currently be separated by a dry zone everywhere along the LVA crest (refer to **Section 2 and Figure 4** for more information).
4E. Bounds of the "South Aquifer"	RAML concurs that the contact between saturated and dry BCA may not represent a hydrologic boundary; a change in groundwater flow direction may occur across this contact depending on the difference between the hydraulic conductivity of the BCA and BBM; RAML concurs that the LF probably acts as a low permeability barrier to westward groundwater flow, but the actual groundwater flow conditions along the fault could be complex as a result of fracturing associated with the LF; additional wells are proposed along the LF (refer to **Section 3.2.1 and Figure 6**).
4F. Hydraulic Conductivity of the Burro Canyon Formation	RAML concurs that undocumented discrepancies exist between the measured hydraulic conductivity data of the BCF and the previous groundwater model; the current probabilistic model uses a range of hydraulic conductivity values based on Site data; additional hydraulic conductivity data will be obtained during the proposed field program (refer to **Section 2.2 and Appendix B**)

TABLE 1. Continued

DIVISION OF RADIATION CONTROL COMMENT	RIO ALGOM MINING LLC RESPONSE
4G. Hydraulic Conductivity of the Brushy Basin Member	Refer **Section 2.2**; RAML proposes to install additional wells and conduct additional field and/or laboratory hydraulic testing to estimate the hydraulic conductivity of the BBM (see **Section 3.2.2 and Appendix C** for more information on hydraulic testing).
4H. Horizontal Groundwater Velocity	RAML generally concurs with DRC's analysis of groundwater velocities, although it is based on hydraulic conductivity data that are uncertain and assumed values of effective porosity; available Site data enable rough estimates of the range of groundwater velocities; the additional Site characterization proposed in the work plan will lead to better estimates of groundwater velocities; refer to **Section 2.3** for minor revisions in response to this comment.
4I. Groundwater Flow Directions 4J. Two Contiguous Dipping Formations 4K. Continuity of Contours of Head Across Formation Boundaries 4L. Mapping of Potential Per Unit Weight of Groundwater 4M. Internal Termination of Contours on Maps 4N. Refraction at Formation Boundaries 4O. Accounting for Refraction on Groundwater Level Map Needed 4P. Extension of Terminated Contours Needed 4Q. Other Contouring Issues	**Figure 4** of the initial work plan attempted to depict a water level map that accounted for the potential conceptualized hydrologic effects of the LF and LVA, and the orientation of the uranium plume based on the currently available data; RAML recognizes and agrees with DRC's thorough technical review of the original contour map and the guidelines for contouring water level data; a revised groundwater elevation contour map is provided on **Figure 4**; refer to **Section 2.3** for additional details about the groundwater elevation contour map; results from the proposed field program will provide additional water level data to improve delineation of groundwater flow directions and assess how well the conceptualized map conforms to actual conditions.
4R. Flow and Transport from Well OW-UT-9 to Well RL-1 and Elsewhere	RAML agrees with DRC's conceptualization of groundwater flow between OW-UT-9 and RL-1, and agrees that westward transport of uranium in groundwater is possible; RAML further agrees that the additional wells identified by DRC are needed and are included in the work plan; the proposed well 1,000 feet southwest of RL-1 (MW-104) was moved further to the south based on the Phase 1 modeling results.
4S. Further Groundwater Level Information in and near the LVA	RAML agrees that additional wells are needed northeast of EF-3A, and has included them in the work plan; refer to **Section 3.2.1** for additional information.
4T. Further Groundwater Level Information Needed near Highly-Fractured Zone	RAML has corrected the error associated with the length of groundwater column above the top of screen in EF-8 (refer to **Section 2.3**, **Table 2**); RAML also agrees that low-flow sampling in wells with submerged screens only characterizes the screened interval zone and does not characterize the saturated zone above the screen.

TABLE 1. Continued

DIVISION OF RADIATION CONTROL COMMENT	RIO ALGOM MINING LLC RESPONSE
4U. Need for Sampling from at Least Two Depth Intervals	RAML agrees that a companion well is needed adjacent to EF-3A and has included it in the work plan (See **Section 3.2.1**, **Figure 6, and Table 3**);, RAML plans to sample the companion well to characterize water quality conditions, conduct hydraulic testing to estimate hydraulic properties, and measure water levels to estimate groundwater levels and vertical hydraulic gradients.
4V. Low-Flow Sampling Not Appropriate for Some Wells on Site	RAML does not agree that low-flow sampling is inappropriate in wells EF-3A, EF-8, and other wells where the groundwater level is more than 10 feet above the top of the screen. Samples obtained from these wells using proper low-flow methods are representative of groundwater quality within the screened interval of the well. RAML agrees that low-flow sampling is incapable of characterizing the entire vertical zone of saturation near the wells. To address this, RAML will install a shallow companion well near EF-3A and other shallow water table wells near EF-3A and EF-8 (refer to **Section 3.2.1**, **Figure 6, and Table 3**). RAML also believes that it is premature to require standard purge sampling in wells with screens submerged more than 10 feet below the water table. To the extent practicable, RAML plans to conduct groundwater sampling using standard 3-volume purge, low-flow, and HydraSleeve methods in all wells during the field program to develop data to compare the sampling methods and select the most appropriate method (see **Appendix C**).
4W. Assessment of Vertical Components of Hydraulic Gradient Needed	RAML agrees that assessment of vertical hydraulic gradients is important and plans to install a shallow well near EF-3A and a pair of wells further to the northwest near the LF (refer to **Figure 6**).
4X. Flow near Northwestern Tip of Uranium Plume near LVA	RAML plans to install and test new wells to improve characterization of groundwater flow near the northwestern portion of the LVA (refer to **Section 3**).
4Y. Tailings Source Area	See **Appendix C** of work plan for more information about sampling in the vadose zone near the tailings.
4Z. Uranium Concentrations	RAML agrees that it is possible that uranium concentrations are higher in areas where abandoned wells existed in the past (refer to **Section 2.4**); RAML plans to drill and core in one well (MW-110) near the tailings impoundment and submit samples to a laboratory for uranium concentration to assess the potential for residual uranium in the vadose zone (see **Appendix C**).

TABLE 1. Continued

DIVISION OF RADIATION CONTROL COMMENT	RIO ALGOM MINING LLC RESPONSE
5. Review of Supplemental Site Assessment Tasks 5A. Probabilistic Modeling	RAML has completed the Phase 1 probabilistic modeling (refer to **Appendix B** for a summary of the modeling).
5B. Time Interval for Modeling	The 208 year modeling period includes the 8-year period from 2004 to 2012, and a 200-year future projection period; the pre-pumping and pumping period prior to 2004 were not included in the modeling because insufficient data exist to adequately characterize these periods for the modeling.
5C. Number of Model Runs	During early model development, the number of model runs was uncertain; a total of 8,000 runs were conducted during the Phase 1 modeling.
5D. Outcomes of Concern	"Outcomes of concern" was a concept developed for the probabilistic modeling to evaluate the importance of simulations that generally resulted in unacceptable uranium concentrations at a point of compliance in the future; RAML understands that DRC views one outcome of concern to be exceedence of the State of Utah uranium concentration standard of 0.030 milligrams per liter at locations along the Long-Term Surveillance and Maintenance Boundary. RAML will use the term "compliance conditions" from now on instead of the term "outcomes of concern."
5E. Final Work Plan	This table, in conjunction with the final work plan, addresses DRC's comments; RAML understands that satisfactory responses to comments must be provided to DRC so that the work plan achieves objectives outlined in State Rules.
5F. Key Uncertainties	RAML generally agrees with the detailed additional uncertainties identified by DRC; RAML believes the proposed modeling and field program will address the uncertainties identified by RAML and DRC.
5G. Geophysical Survey	Given the comprehensive nature of the proposed field program, RAML has decided not to conduct the geophysical survey; the potential usefulness of the survey was questionable and RAML believes that a sufficient number of new wells will be installed to address the Site data gaps.
5H. Well Construction	Refer to **Appendix C**; according to the drilling subcontractors, conventional and/or reverse air circulation drilling would have a high likelihood of success at the Site and is the preferred method.
5I. Hydraulic Testing	Refer to **Appendix C** for testing procedures and waste water management; to the extent practicable, RAML will conduct slug tests in all existing and new wells and plans to conduct one pumping test in new well (MW-101D) and estimate saturated hydraulic conductivity from cores from selected drilling/coring locations (refer to **Table 3**).

TABLE 1. Continued

DIVISION OF RADIATION CONTROL COMMENT	RIO ALGOM MINING LLC RESPONSE
5J. Monitoring and Sampling	RAML plans to sample all existing and new wells during the field program; refer to **Section 3.2.3** and **Appendix C** for details on the planned sampling effort.
5K. Well Installation	Refer to **Figure 7** for the revised schedule.
5L. Data Interpretation	Refer to **Figure 7** for the revised schedule.
5M. Phase 2 Modeling with Probabilistic Model	The Phase 2 modeling will be conducted as discussed in **Section 3.4 and Appendix B**.
5N. Report	Refer to **Figure 7** for the revised schedule.
5O. Coordination with DRC	Similarly, RAML is committed to working closely with DRC on the final work plan and on revising the ACLs.

TABLE 3. PROPOSED NEW MONITOR WELLS
SUPPLEMENTAL SITE ASSESSMENT
RIO ALGOM MINING LISBON FACILITY

WELL ID	APPROXIMATE COORDINATES NAD 1927 UTAH STATE PLANE SOUTH		ESTIMATED DEPTH (feet)	CONDUCTOR CASING LENGTH (feet)	SCREEN LENGTH (feet)	BLANK + STICK-UP	SCREENED FORMATION	SCREENED INTERVAL	POTENTIAL HYDRAULIC TESTING			RATIONALE
	Easting	Northing							PUMPING [a]	SLUG	CORE/LAB [b]	
MW-100	2,628,027	594,624	100	20	30	72	BCA/BBM	At water table		X		Confirm representativeness of RL-6 or replace RL-6 with more representative well
MW-101S	2,628,688	593,326	100	20	30	72	BCA	At water table		X		Characterize shallow hydrogeologic conditions (including fracturing) near LF
MW-101D	2,628,687	593,326	TBD	20	30	TBD	BCA	Bottom of BCA	X	X		Characterize deep hydrogeologic conditions (including fracturing) near LF at contact between BCA and BBM
MW-102	2,629,997	593,763	70	20	30	42	BCA	At water table		X		Determine whether westward groundwater flow and uranium transport has and is occurring
MW-103	2,631,802	590,634	95	20	30	67	BCA	At water table		X		Characterize shallow groundwater west of source area near LF
MW-104	2,632,414	592,559	140	20	30	112	BCA/BBM	At water table		X		Determine whether water table is in BCA or BBM near LVA crest
MW-105	2,632,594	593,636	155	20	30	127	BCA/BBM	At water table		X		Determine whether water table is in BCA or BBM near LVA crest
MW-106	2,632,824	589,286	100	20	30	72	BCA	At water table		X		Characterize shallow groundwater west of source area near LF
MW-107S	2,633,991	589,300	115	20	30	87	BCA	At water table		X		Companion well near EF-3A to characterize shallow groundwater conditions
MW-107DB	2,633,991	589,300	250	150	30	222	BBM	BBM		X	X	Characterize BBM
MW-108	2,634,373	593,379	190	20	30	162	BCA	At water table		X		Obtain uranium concentration data from historic high concentration area
MW-109	2,634,436	591,920	120	20	30	92	BCA/BBM	At water table		X		Determine whether water table is in BCA or BBM near LVA crest
MW-110	2,634,721	590,051	80	20	30	52	BCA/BBM	At water table		X	X	Obtain rock samples from vadose zone to characterize residual uranium concentration; characterize shallow groundwater conditions
MW-111S	2,636,013	592,024	205	20	30	177	BCA	At water table		X		Obtain uranium concentration data from historic high concentration area
MW-111DB	2,636,013	592,024	250	150	30	222	BBM	BBM		X	X	Characterize BBM
MW-112	2,638,938	587,445	205	20	30	177	BCA	At water table		X		Characterize groundwater conditions along LVA crest

NOTE: Water level, water quality, and lithology data will be collected at all new wells. All wells will be constructed according to Utah Division of Water Rights Standards

BCA - Burro Canyon Aquifer
BBM- Brushy Basin Member of Morrison Formation
[a] Pumping tests may be considered for wells that are expected to yield clean water
[b] Core samples from BBM would be tested in laboratory for horizontal and vertical conductivity
TBD = to be determined

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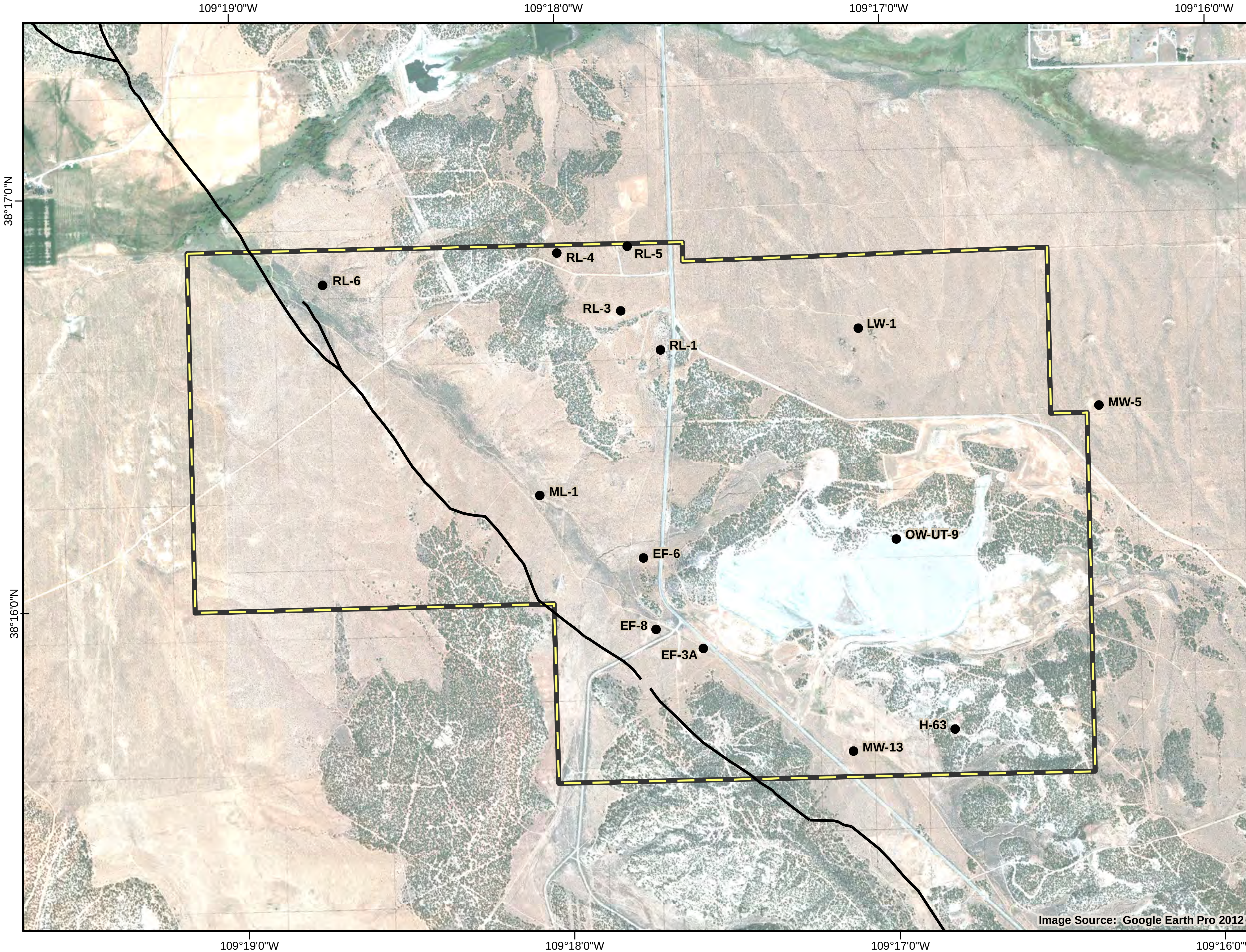

EXPLANATION

MW-5 Well and Identifier

Lisbon Valley Fault

Long Term Surveillance and Maintenance Boundary

N

0 1,000 2,000 3,000 4,000

Feet

RIO ALGOM MINING LLC
LISBON FACILITY

SITE OVERVIEW MAP

MONTGOMERY & ASSOCIATES
Water Resource Consultants

2012

FIGURE 1

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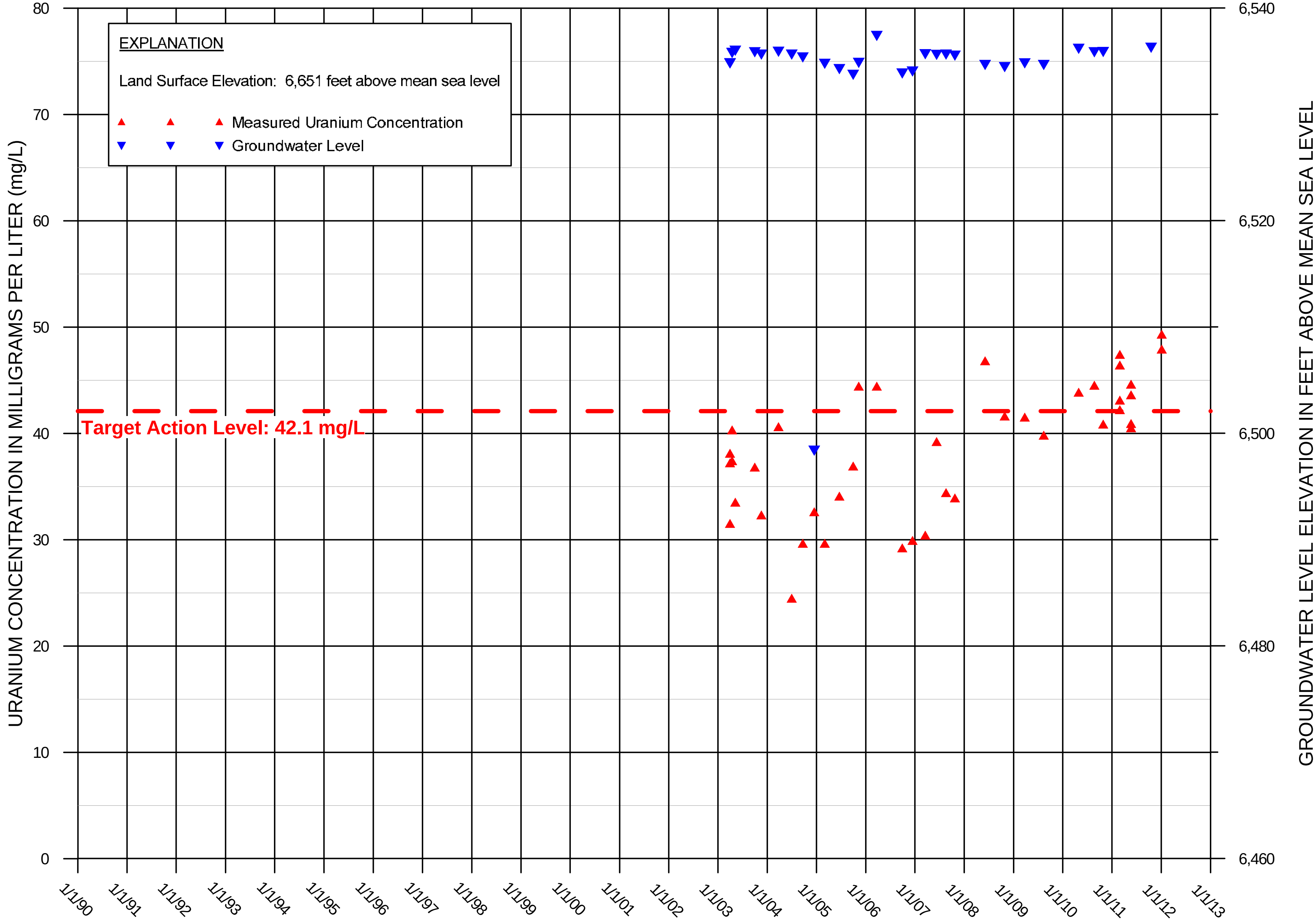


FIGURE 2. URANIUM CONCENTRATIONS AND GROUNDWATER LEVELS FOR TREND WELL RL-1, LISBON FACILITY, RIO ALGOM MINING LLC

MONTGOMERY & ASSOCIATES

1350 - S:\projects\1350 - Rio Algom\Sampling\Plots_and_Data\RL_1_REV2.grf 4/12/2012

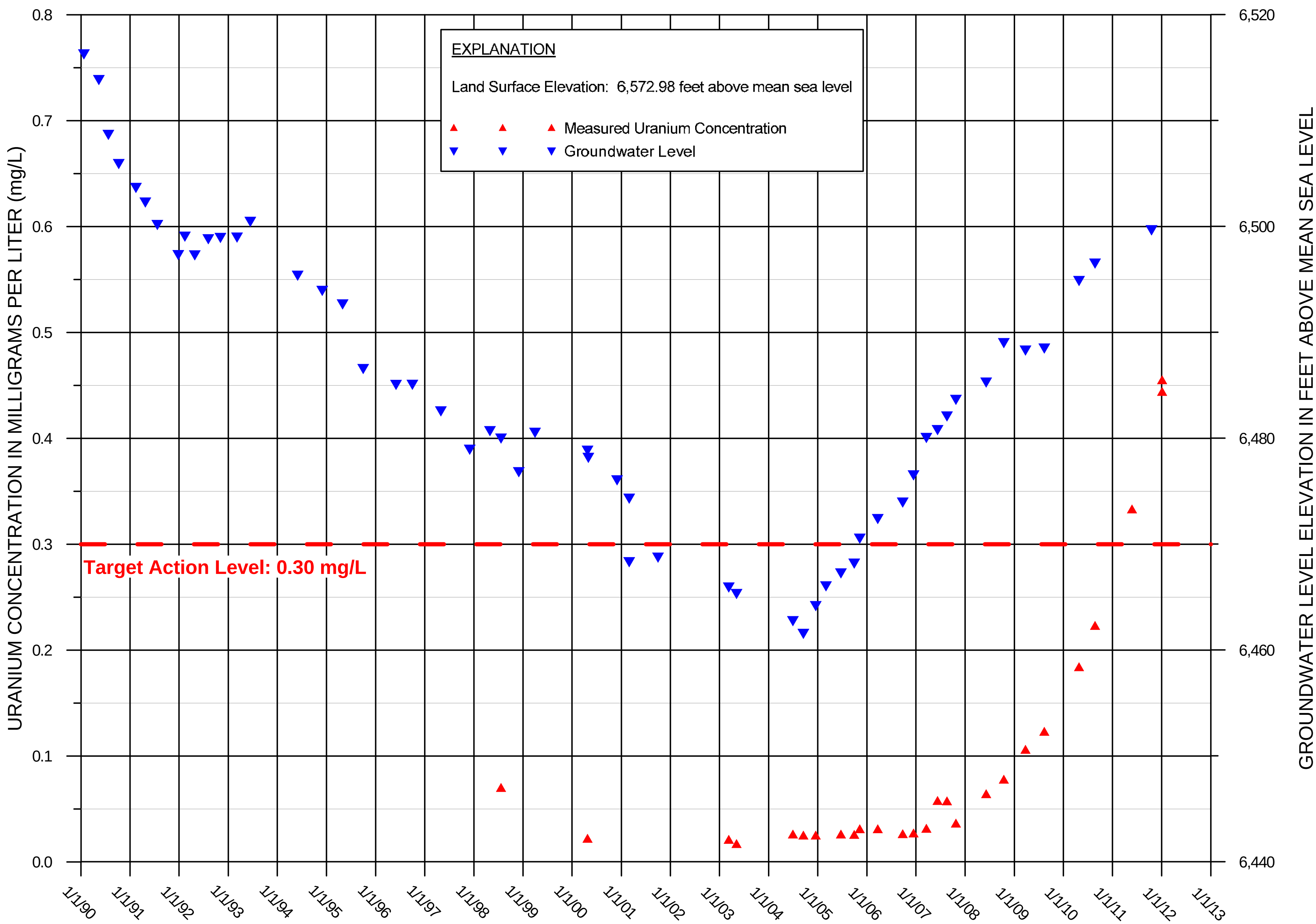
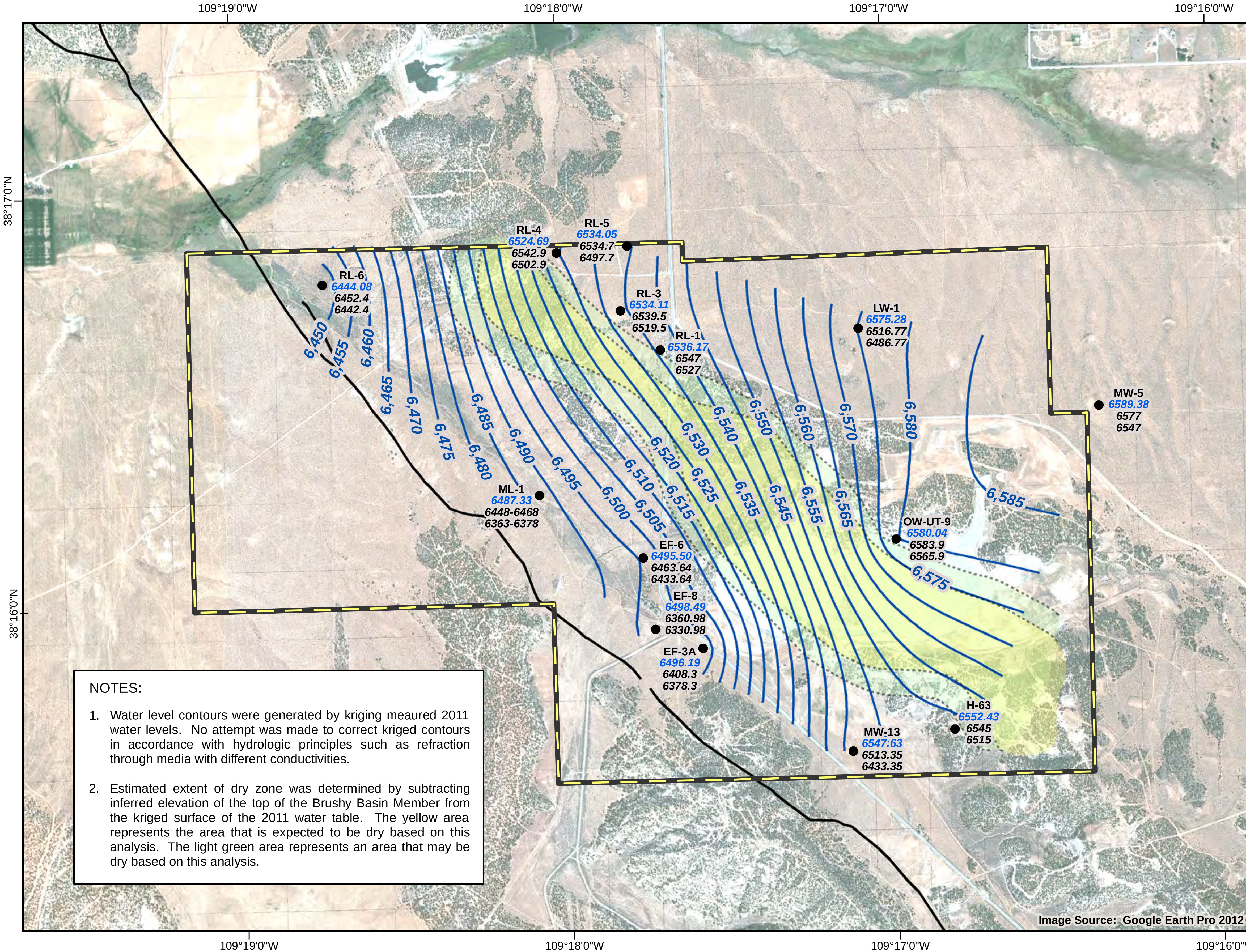


FIGURE 3. URANIUM CONCENTRATIONS AND GROUNDWATER LEVELS FOR TREND WELL EF-8, LISBON FACILITY, RIO ALGOM MINING LLC

MONTGOMERY & ASSOCIATES



NOTES:

1. Water level contours were generated by kriging meaured 2011 water levels. No attempt was made to correct kriged contours in accordance with hydrologic principles such as refraction through media with different conductivities.

2. Estimated extent of dry zone was determined by subtracting inferred elevation of the top of the Brushy Basin Member from the kriged surface of the 2011 water table. The yellow area represents the area that is expected to be dry based on this analysis. The light green area represents an area that may be dry based on this analysis.

EXPLANATION

MW-5 — Existing Well and Identifier

6588.6 — Water Level Elevation (feet above mean sea level)

6577 — Top of Screen Elevation (feet above mean sea level)

6547 — Bottom of Screen Elevation (feet above mean sea level)

6,585 — Water Level Contour, in feet above mean sea level

Lisbon Valley Fault

Long Term Surveillance and Maintenance Boundary

Estimated Minimum Extent of Dry Zone in Burro Canyon Aquifer

Estimated Maximum Extent of Dry Zone in Burro Canyon Aquifer

N

0 1,000 2,000 3,000 4,000

Feet

RIO ALGOM MINING LLC
LISBON FACILITY

2011 GROUNDWATER LEVEL CONTOURS

MONTGOMERY & ASSOCIATES
Water Resource Consultants

2012

FIGURE 4

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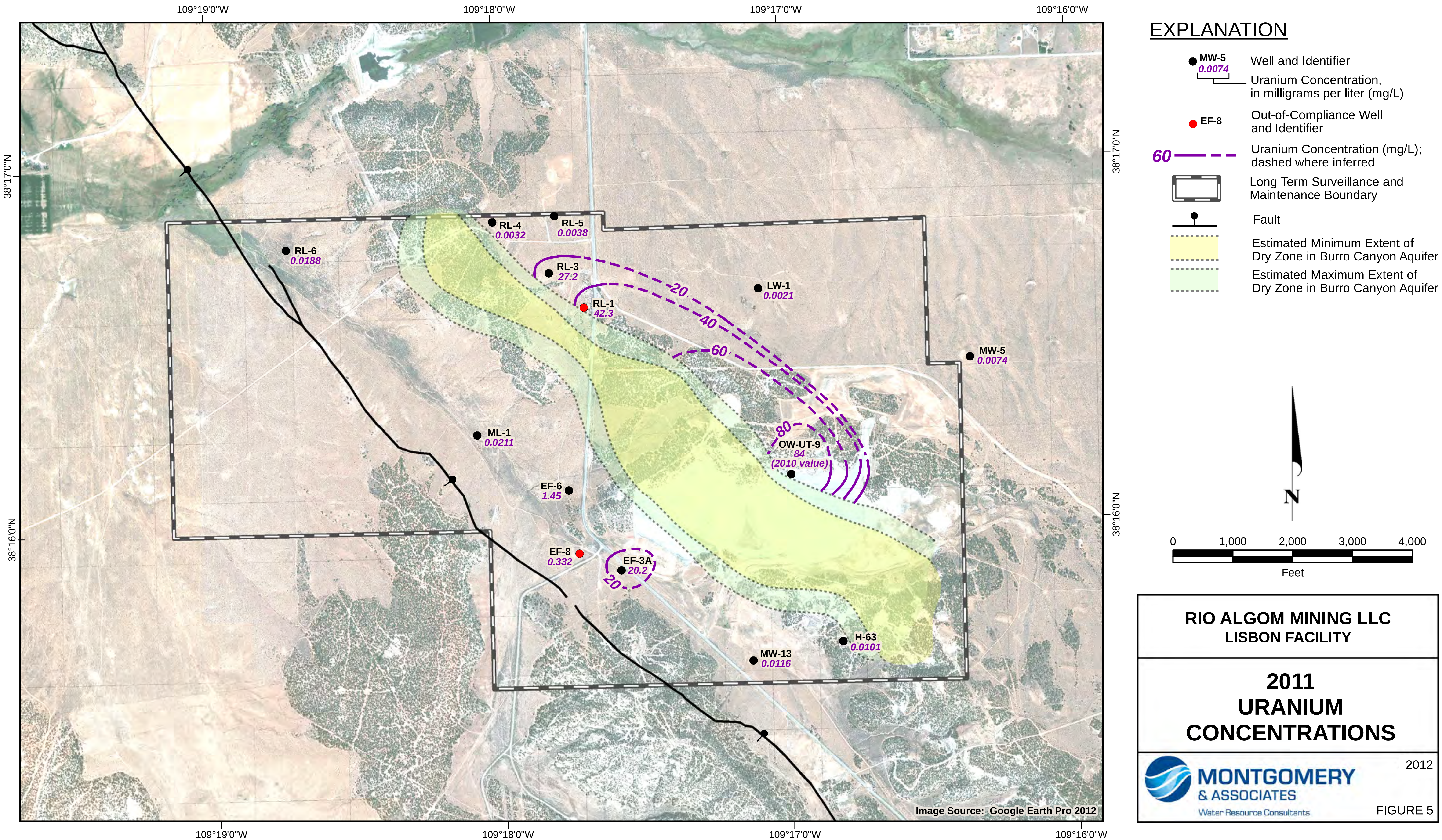

RIO ALGOM MINING LLC
LISBON FACILITY

2011 URANIUM CONCENTRATIONS

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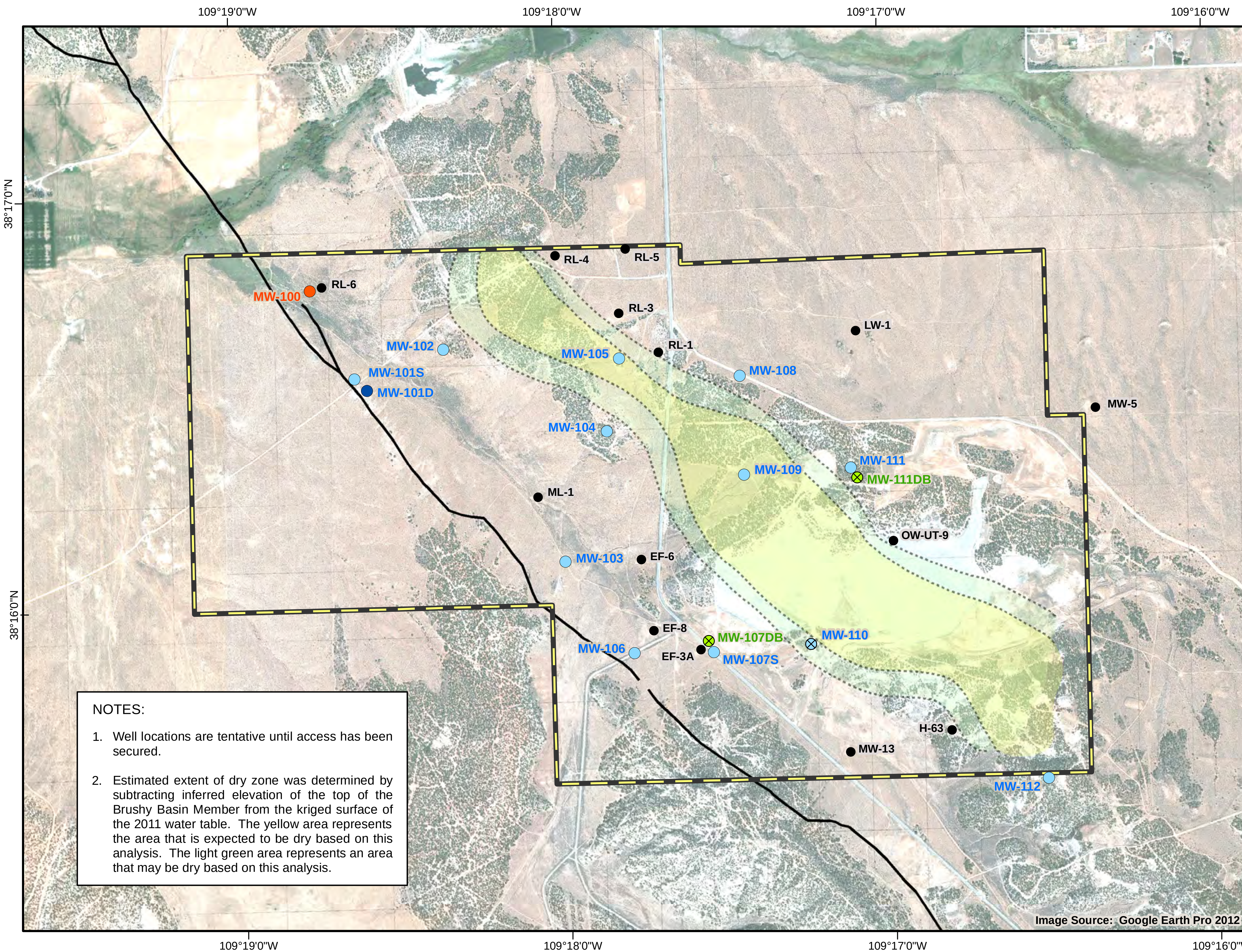
Water Resource Consultants

2012

FIGURE 5

GIS\1350.09\2011_Uranium_Aerial\12April2012 NAD27_SP_Utah_So.



NOTES:

1. Well locations are tentative until access has been secured.
2. Estimated extent of dry zone was determined by subtracting inferred elevation of the top of the Brushy Basin Member from the kriged surface of the 2011 water table. The yellow area represents the area that is expected to be dry based on this analysis. The light green area represents an area that may be dry based on this analysis.

EXPLANATION

- MW-5 — Existing Well and Identifier
- MW-108 — Water Table Well and Identifier
- MW-101D — Deep Burro Canyon Aquifer Well and Identifier
- MW-111DB — Brushy Basin Member Well and Identifier
- MW-100 — Exploratory Borehole and Identifier
- Cored Borehole
- Lisbon Valley Fault
- Long Term Surveillance and Maintenance Boundary
- Estimated Minimum Extent of Dry Zone in Burro Canyon Aquifer
- Estimated Maximum Extent of Dry Zone in Burro Canyon Aquifer

N

0 1,000 2,000 3,000 4,000

Feet

RIO ALGOM MINING LLC
LISBON FACILITY

PROPOSED INVESTIGATION WELL LOCATION MAP

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Water Resource Consultants

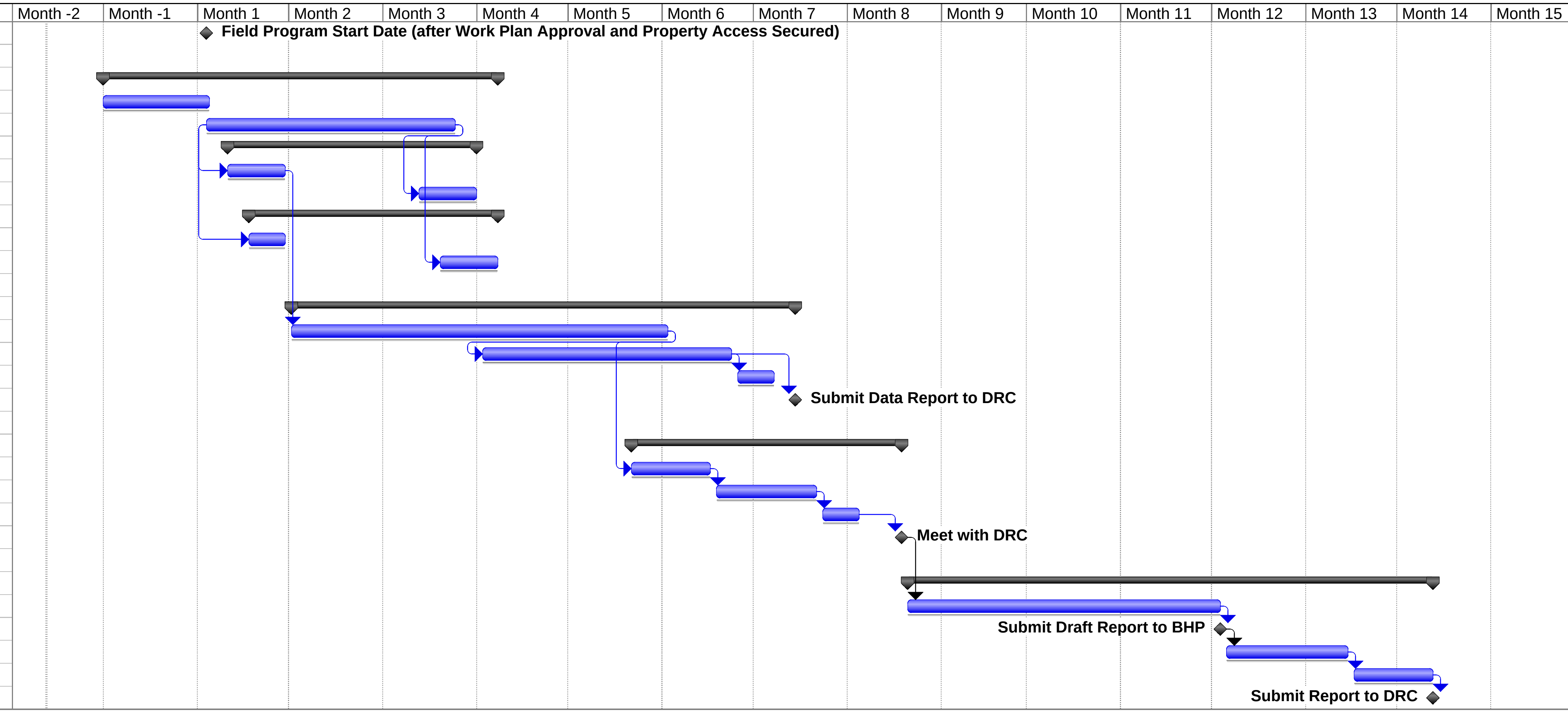
2012

FIGURE 6

GIS\1350.09\ProposedWellLoc\12April2012 NAD27_SP_Utah_So.

FIGURE 7. SCHEDULE
SUPPLEMENTAL SITE ASSESSMENT TO ADDRESS OUT-OF-COMPLIANCE STATUS AT TREND WELLS RL-1 AND EF-8
LISBON FACILITY
RIO ALGOM MINING LLC

ID	Task Name
1	Field Program Start Date (after Work Plan Approval and Property Access Secured)
2	
3	**TASK 3 - CONDUCT FIELD PROGRAM**
4	Prepare for Field Work (including pre-drilling field visits)
5	Drilling/Well Construction/Development
6	**Hydraulic Testing**
7	Existing Wells
8	New Wells
9	**Groundwater Sampling**
10	Existing Wells
11	New Wells
12	
13	**TASK 4 - EVALUATE FIELD DATA**
14	Evaluate Data
15	Prepare Data Report
16	BHP Review
17	Submit Data Report to DRC
18	
19	**TASK 5 - CONDUCT PHASE 2 GROUNDWATER MODELING**
20	Revise Groundwater Model
21	Conduct Model Simulations
22	Develop New Alternate Concentration Limits (ACLs)
23	Meet with DRC
24	
25	**TASK 6 - PREPARE REPORT**
26	Prepare Draft Report
27	Submit Draft Report to BHP
28	BHP Review
29	Incorporate Comments/Revise Report
30	Submit Report to DRC



Project: Fig 7 Schedule
Date: Thu 4/12/12

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

MONTGOMERY & ASSOCIATES

APPENDIX A

EXISTING WELL INFORMATION

TABLE A1. EXISTING WELL INFORMATION LISBON FACILITY RIO ALGOM MINING LLC

WELL ID NUMBER	COORDINATES in UTM FEET NAD27		LAND SURFACE ELEVATION (feet)	CASING INNER DIAMETER (inches)	TYPE OF CASING MATERIAL	SCREENED ZONE LENGTH (feet)	DEPTH OF WELL (feet)	TOP OF CASING TO TOP OF SCREEN (feet)	TOP OF CASING TO PUMP INLET (feet)
	EASTING	NORTHING							
EF-3A	649,426	4,236,334	6,579.0	4.0	PVC	30	215	173	190
EF-6	649,157	4,236,742	6,568.0	4.0	PVC	30	137	105	125
EF-8	649,218	4,236,426	6,573.0	4.0	PVC	30	244	212	230
H-63	650,572	4,236,000	6,685.0	4.0	PVC	30	172	140	155
LW-1	650,282	4,237,871	6,720.0	4.0	PVC	30	223	203	215
ML-1	648,691	4,237,015	6,529.1	4.0	PVC	20	157	60	
						15	157	150	152
MW-13	650,101	4,235,891	6,638.3	4.0	PVC	80	206	125	165
MW-5	651,186	4,237,459	6,742.0	5.0	PVC	30	197	165	180
OW-UT-9	650,281	4,236,845	6,701.9	4.0	PVC	18	142	118	127
RL-1	649,220	4,237,678	6,651.0	5.0	PVC	20	124	104	
RL-3	649,039	4,237,845	6,702.6	4.0	PVC	20	183	163	178
RL-4	648,745	4,238,101	6,679.9	5.0	PVC	40	178	137	165
RL-5	649,061	4,238,141	6,684.7	4.0	PVC	37	186	150	170
RL-6	647,593	4,237,975	6,460.0	5.0	PVC	10	20	7.65	18.0

PVC = Poly Vinyl Chloride
UTM = Universal Transverse Mercator
NAD = North American Datum

MONTGOMERY & ASSOCIATES

HGS-01

Project Name: Piezometer Installation

Client: Rio Algom

Location: LaSal, Utah

Drilled By: Rex Wyatt

Drill Date: Mar. 20, 2003 **Surface Elevation:** 6651.0ft

Compiled By: D. Foster

KOMEX INTERNATIONAL LTD.

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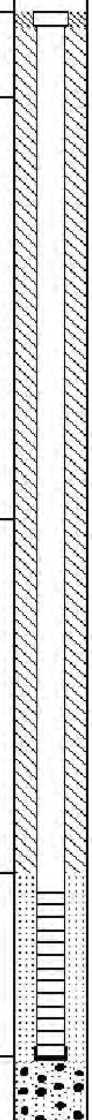
Monitoring Well #: RL-1

Depth (ft)	Symbol	Description	Well Data	Comments
0		Ground Surface		
0–10		**SANDY SILT ALLUVIUM (0-10ft)** Light reddish brown (5YR 6/4), dry, loose.		Stove Pipe Surface Completion Locking expansion cap Grout 0-2ft
10–60		**SANDSTONE (10-60ft)** Light yellowish brown (10YR 6/4), poorly sorted, fine to coarse grained, angular to subrounded, bumpy drilling. At 20ft, as above, smooth drilling. At 30ft, semi-bumpy drilling. At 40ft, as above, semi-bumpy drilling. At 45ft, smooth drilling. At 50ft, as above, well sorted, fine to medium grained.		
60–102		**SANDSTONE (60-102ft)** Very pale brown (10YR 7/3), well sorted, fine to medium grained, bumpy drilling. At 90ft, as above, poorly sorted, fine to coarse grained, angular to subrounded.		5" dia. Sch 40 PVC Blank Casing 8.75" dia. borehole Bentonite Chips 2-102ft
102–123.5		**SANDSTONE (102-123.5ft)** White (10YR 8/1), well sorted, fine grained. At 120ft, as above, moderately to well sorted, fine to medium grained, trace coarse grained, angular.		Top of Sand 102ft Top of Screen 104ft 5" dia. Sch 40 PVC Screen (0.010" Slot) Sand Filter Pack Bottom of Sand and Screen 124ft
123.5–132		**SHALE (123.5-132ft)** Reddish brown (2.5YR 7/4).		Native Backfill 124-132ft
132		132ft Total Drilled Depth		



File Path: J:\sacramento\logs\rl-1 Generated By: WH Date Generated: May 2, 2003 Page: 1 of 1

Figure 2-1. Boring log and well construction for RL-1.

HGS-01

Project Name: Piezometer Installation
Client: Rio Algom
Location: LaSal, Utah
Drilled By: Rex Wyatt
Drill Date: Mar. 22, 2003 **Surface Elevation:** 6648.6ft
Compiled By: D. Foster

KOMEX INTERNATIONAL LTD.
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Pilot Borehole #: RL-2

Depth (ft)	Description	Comments
0	Ground Surface	
0–5	***SANDY SILT ALLUVIUM (0-5ft)*** Light reddish brown (5yr 6/4), dry, loose.	Boring filled with Bentonite Chips on Apr. 25, 2003
5–40	***SANDSTONE (5-40ft)*** Reddish brown (5YR 4/4), very fine to fine grained.	
20	At 20ft, smooth drilling (with button-hammer bit) - pilot hole observation.	
30	At 30ft, fine to medium grained.	
40–105	***SANDSTONE (40-105ft)*** Very pale brown (10YR 7/3), fine to medium grained.	
50	At 50ft, as above, fine grained.	
60	At 60ft, same as above.	
70	At 70ft, as above, slightly lighter (10YR 8/3).	
80	At 80ft, as above, very pale brown (10YR 7/3), fine to medium grained.	
90	At 90ft, as above, trace coarse grained.	
98	At 98ft, color change to pale brown (10YR 6/3), poorly sorted, fine to coarse grained, angular to subrounded.	
105–110	***SHALE (105-110m)*** Reddish brown (2.5YR, 7/4).	
110	110ft Total Drilled Depth	

File Path: J:\sacramento\logs\rl-2 Generated By: WH Date Generated: May 2, 2003 Page: 1 of 1

Figure 2-2. Boring log and well construction for RL-2.

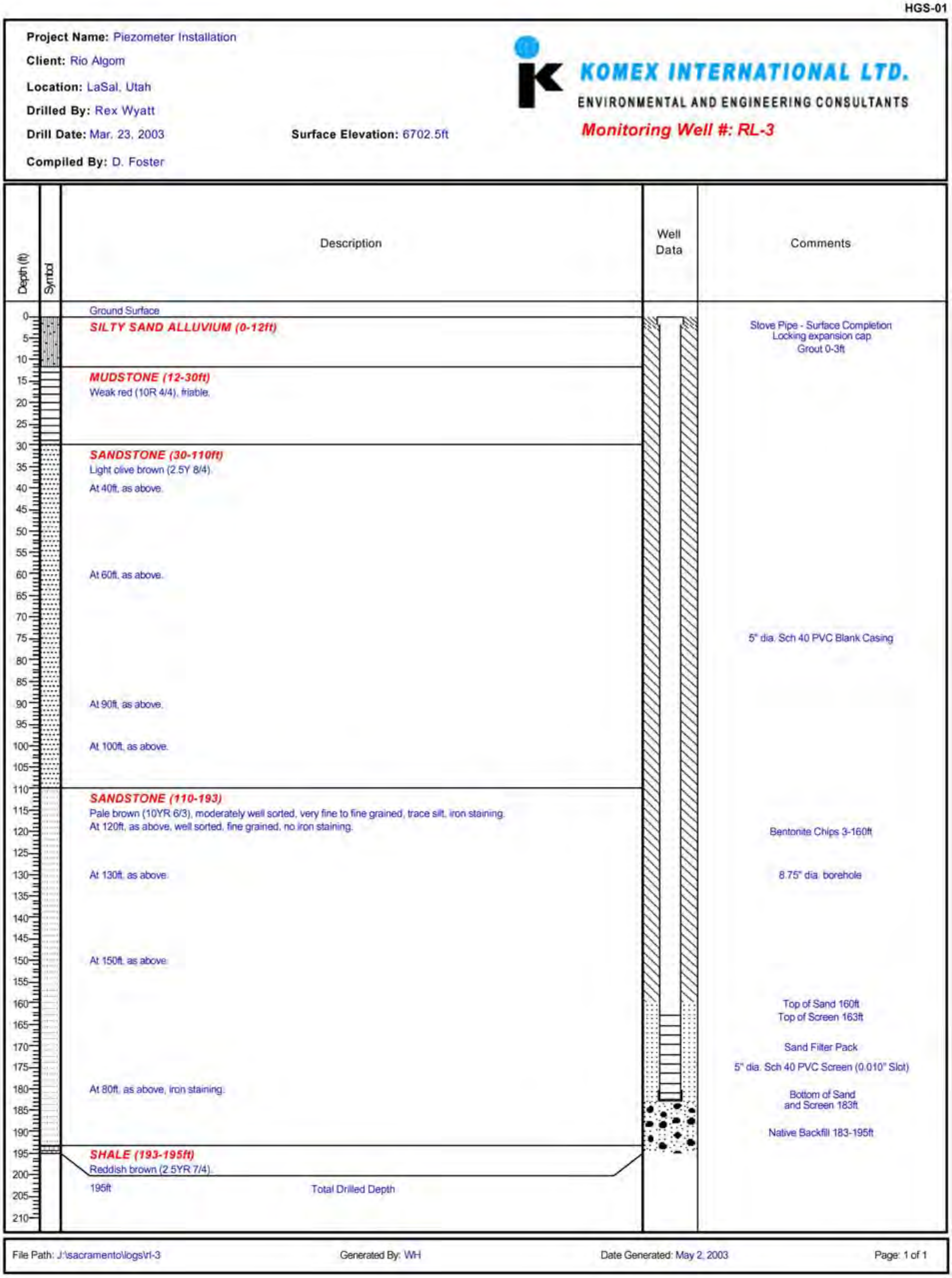


Figure 2-3. Boring log and well construction for RL-3.

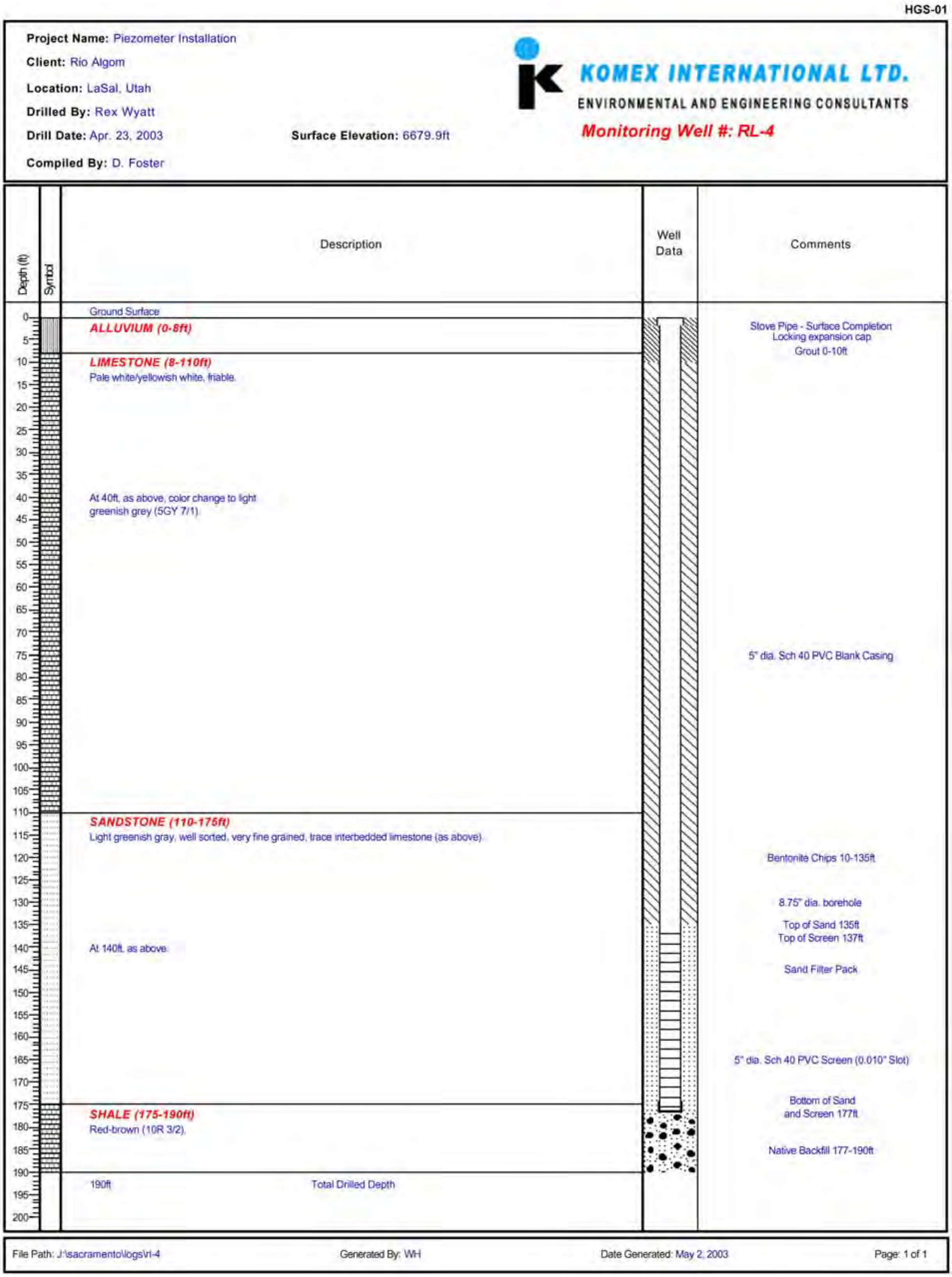


Figure 2-4. Boring log and well construction for RL-4.

HGS-01

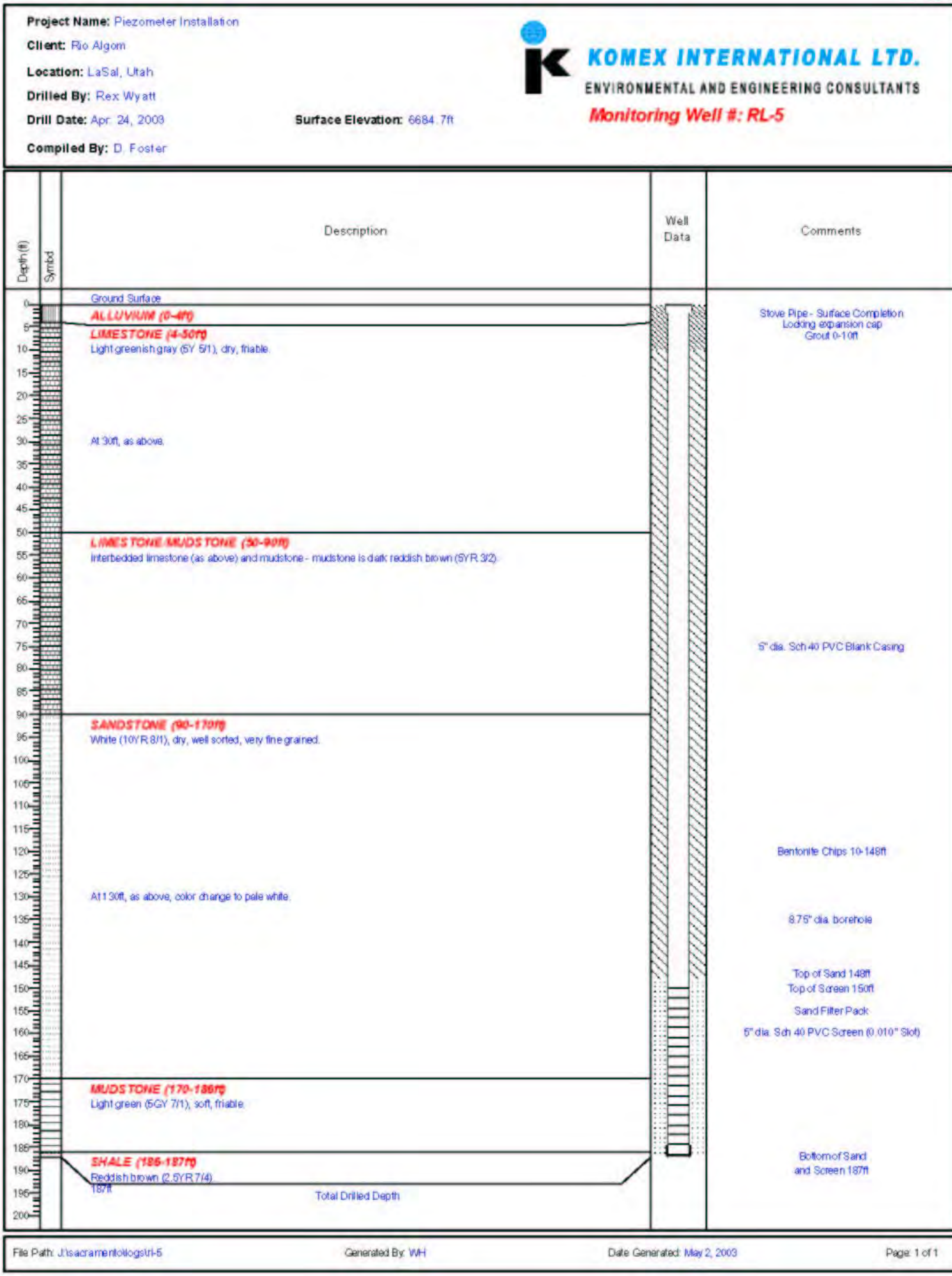


Figure 2-5. Boring log and well construction for RL-5.

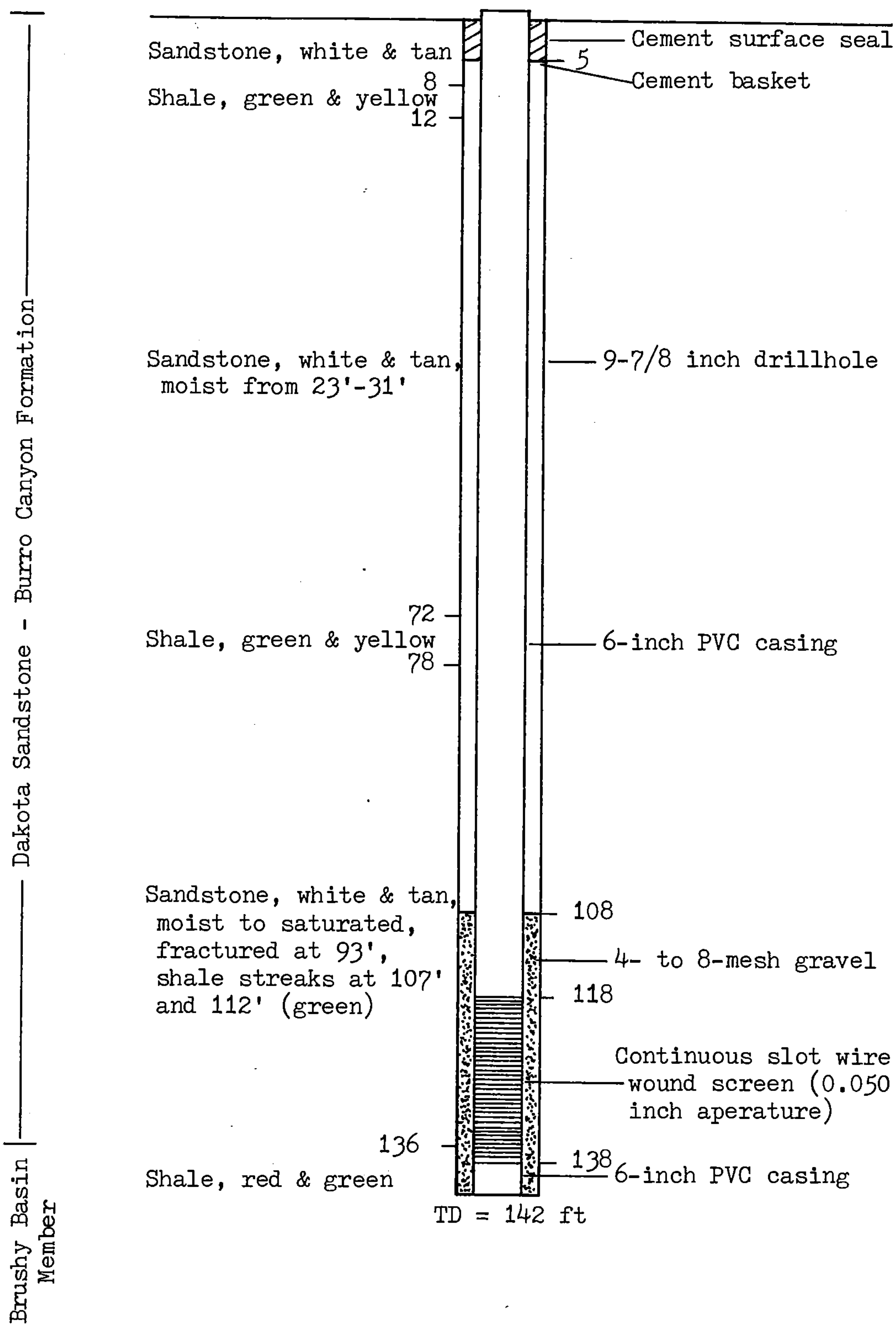
HOLE NO.: OW-UT9

GROUND SURFACE ELEV.: 6701.9 feet

DATE DRILLED: 29 Jun 1983

VERTICAL SCALE: 1 inch = 20 feet

LITHOLOGIC LOG | **WELL COMPLETION DETAILS**



Lewis Water Consultants
Environmental Science/Engineering/Modeling

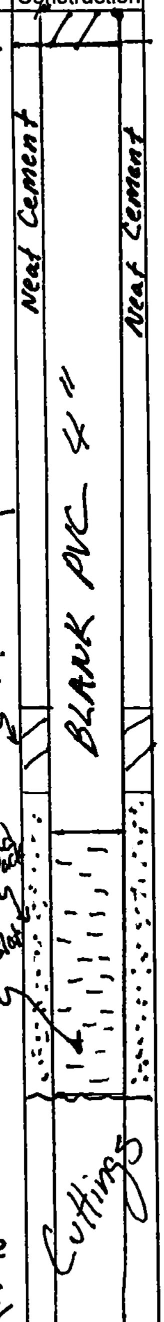
BORING / WELL LOG

Date: 9/9/98, 9/10/98
Client: RAMC
Project: Lisbon CAP Review
Drilling Contractor: H. Beeman
Drilling Crew:
Geologist/Engineer(s): Bob Lewis
Location Detail:

Boring/Well Number: ML-1
Total Depth: 175 ft.
Well Depth: 168 ft.
Surface Elev.:
Casing Elev.:
Depth to First Water: 85 ft.
Static Water Level:

Depth (ft)	Sample Interval	Sample Number	OVM/PID (ppm)	Water Quality	Begin 2:40 9/9 Description
0	AL			pH 7.85 CND = 824 14.2°C (Make-up H_2O)	Silty Sand (Alluvium), v.f-f. grained, reddish-brown (0-13'). End 5:05 pm. Begin 8:05 am 9/10.
10–20	SS				Sandstone (13-23'), v.f. grained, reddish-brown to grey, dry.
30	SH/SLT				Mudstone and siltstone (23-33'), grey-olive, w/ some v.f. grained sandstone, very hard, dry.
40–50	SS				Sandstone (33-57), v.f.-med. grained, buff brown-grey, siliceous, very hard, w/ minor dk. grey mudstone and micritic limestone
60	SLT/LS				Siltstone w/ v.f. grained sandstone (57-59'), grey-green, hard. Limestone (59-61'), micritic, greenish-grey.
70	SLT/SS				Siltstone and v.f. grained sandstone (61-71'), grey-green, Hard.
80	SS				Sandstone, f.-med. grained, buff-brn, moist.
90	CG/SS				▽ Water @ 85 ft. Well making > 40 gpm. Gravelly sandstone, buff-brown, med-v. coarse grained, granule-pebble gravel ~20%, lithic, wet.

Well Construction



Lewis Water Consultants
Environmental Science/Engineering/Modeling

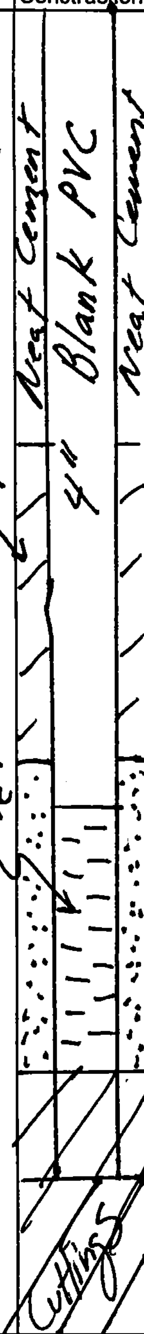
BORING / WELL LOG

Date: 9/10/98
Client: RAMC
Project: Lisbon CAP Review
Drilling Contractor: H. Beeman
Drilling Crew:
Geologist/Engineer(s): Bob Lewis
Location Detail:

Boring/Well Number: ML-1
Total Depth: 175 ft.
Well Depth: 168 ft.
Surface Elev.:
Casing Elev.:
Depth to First Water: 85 ft.
Static Water Level:

Depth (ft)	Sample Interval	Sample Number	OVM/PID (ppm)	Water Quality	Description
90	CG/SS				Well making > 50 gpm.
					Conglomerate and sandstone, buff-brn, med-v. coarse grained, granule-pebble gravel, lithic, angular (85-117').
100					
110				pH=7.9 CND=716 14.3°C	
120	SS				Sandstone (117-168'), v.f. grained, white, hard, w/ trace granule gravel
130				pH=8.0 CND=821 13.3°C	As above, very hard (slow drilling ~5'/hr.)
140				pH=8.0 CND=695 13.8°C	Becoming coarser w/ gravel at 143', yellow-brn.
150					As above, grey-green, trace lithic gravel.
160				pH=8.2 CND=820 14.3°C	
170	SH			pH=7.9 CND=819 14.6°C	Shale, greyish-green, soft (168-170').
					Shale, red, very hard (Brushy Basin).
180					T.D. @ 175 ft @ 2:35 pm.

Well Construction



MONTGOMERY & ASSOCIATES

APPENDIX B

SUMMARY OF PHASE 1 GROUNDWATER MODELING

APPENDIX B

PHASE 1 PROBABILISTIC MODELING

PHASE 1 PROBABILISTIC MODEL DEVELOPMENT

Important uncertainties exist at the Site that limit our ability to adequately model uranium fate and transport at the Site. Some of these uncertainties relate to the sparse nature of data available over the last 8 years, while other uncertainties relate to insufficient understanding of contaminant sources and hydrogeologic structures, properties, and conditions. Phase 1 probabilistic modeling was used to investigate these uncertainties and help guide the development of the field program so that valuable data for reducing key uncertainties are collected in advance of Phase 2 probabilistic modeling.

During Phase 1 modeling, a total of 8,000 groundwater flow models were run. Model likelihoods were then calculated based on the residuals between head data collected in the field during the years 2004-2011 and model projected heads. Due to complications with running the transport models using the Monte-Carlo method, the thirty best groundwater flow models were selected and transport models were run for each of them. Models in which uranium reached the Long Term Surveillance and Maintenance (LTSM) boundary were identified as important. Each model was then weighted based on the model likelihood and the importance of the model. Areas in which important and likely models vary significantly in their projections of head and uranium concentration were identified as areas where data should be collected.

Phase 1 modeling was adapted from the KOMEX (2003) model. The numerical groundwater modeling code MODFLOW 1996 (McDonald and Harbaugh, 1996) was used to develop a transient, three-dimensional, finite-difference groundwater flow model. The model setup and execution was facilitated using the industry standard modeling software, Groundwater Vistas (Rumbaugh and Rumbaugh, 2007). The KOMEX (2003) model was modified, to eliminate known shortcomings of the model and to investigate additional conceptualizations of the system. Changes made to the KOMEX model (2003) are presented in **Table B1**.

TABLE B1. MODIFICATIONS TO THE KOMEX MODEL (2003)

Model Feature	Komex Model	Phase 1 Model
Type of model	Steady state	Transient
Rewetting/ dry zone of BCA	Cell rewetting is inactive. Beginning in 2004 cells resaturate instantly. The dry zone in the BCA is assumed to be constant and is represented by no flow cells.	Cells resaturate when adjacent cells exceed a water level threshold. Initial water levels are interpolated from 2003 heads. The extent of the dry zone of the BCA changes throughout model time and uniquely for each model.
Elevation of bottom of BBM	The bottom of the BBM is uniformly set to 5,900 ft above mean sea level.	The bottom of the BBM is uniformly set to 6,233 ft above mean sea level. This elevation was chosen so that the BBM is 50 ft thick in the thinnest active model cell.
Hydraulic conductivity zones	The majority of the BCA is a single zone. Two localized zones have higher conductivity representing areas of fracturing. BBM is represented as a single zone.	The BCA is divided into four zones as shown on **Figure B1.** The BBM is represented as a single zone. Conductivities are assigned via stochastic modeling.
Recharge zones not including the tailings	Recharge is assigned in two zones that combined cover the entire model domain area.	Recharge is assigned in one zone that covers the entire model domain area. The recharge rate varies depending on the model conceptualization.
Boundary conditions	Single set of boundary conditions used.	Two sets of boundary conditions used depending on the model conceptualization. These boundary conditions are depicted on **Figures B2 and B3.**
BCA/BBM layer boundaries	Layer boundary based on top of BBM contour used by Komex (2003) as shown on **Figure B4.**	Layer boundaries based on top of BBM contours shown used by Komex (2003) **Figure B4** and conceptualized contour as shown on **Figure B5**.

NOTE: Rows highlighted in light green indicate variables that were changed stochastically.
Rows highlighted in light blue represent variables changed as conceptual models.

Parameterizations and conceptualizations were varied in the probabilistic, Monte-Carlo modeling process. In this context, “parameterizations” refers to variables that could easily be modified using a random number generator. The only parameter modified in this way was hydraulic conductivity. Conceptualizations are variables or boundary conditions that could not be modified using a random number generator. This type of variable was instead modified by manually setting up the conceptual models. Flow models were run for 1,000 parameterizations for each of 8 different conceptual models. This led to a total of 8,000 different groundwater flow models. The 8 different conceptual models were composed of 2 options for each of 3 different variables (2^3 possible combinations). The conceptual model variables were:

- extent of anticline (basic or extended)
- amount of recharge (0 inches per year or 0.9 inches per year)
- boundary conditions along eastern/north-eastern boundary of model (constant head or no flow)

Model layer one, the Burro Canyon Aquifer (BCA), has four hydraulic conductivity zones as shown on **Figure B1.** Model zone 2 is the area to the southwest of the Lisbon Valley Anticline (LVA). Within this zone, reported hydraulic conductivity values ranged from 0.01 feet per day (ft/day) to 798 ft/day. Zone 3 is the area in the northwest portion of the model. Hydraulic conductivity values have not been reported for this zone. Zone 4 is the zone to the northeast of the LVA. Hydraulic conductivity values reported in this zone range from 0.04 ft/day to 34 ft/day. Zone 5 is the thin zone running parallel to the Lisbon Fault. Hydraulic conductivity values have not been reported for this zone. Model layer two, the Brushy Basin Member (BBM), is model zone 1 has one uniform hydraulic conductivity zone. Hydraulic testing in the BBM occurred in wells H-72. Reported values ranged from 0.01 to 0.96 ft/day. Hydraulic conductivity of the BBM is minimally characterized and therefore uncertain.

Probability distributions and ranges were used by the random number generator to generate hydraulic conductivity values for each model zone. All hydraulic conductivity zones were assigned log-uniform probability distributions. This means that an equal number of values are sampled within each order of magnitude of the range assigned to each zone. The range assigned to each hydraulic conductivity zone included each order of magnitude reported within each model zone. Since model zones 3 and 5 did not have any hydraulic conductivity values reported, the entire range of values reported in all other BCA zones was considered possible. In model zone 1, which represents the BBM, the parameter range was extended by one order of magnitude on each side of the reported values due to the limited amount of data for the BBM. The 1,000 model parameterizations were comprised of hydraulic conductivity values randomly sampled from log-uniform probability distributions for each of five model hydraulic conductivity zones. Probability distributions, and minimum and maximum values for each hydraulic conductivity zone are displayed in **Table B2.**

TABLE B2. PROBABILISTIC MODEL PARAMETERS

Variables	Zone	Low	High	Distribution	Description
Horizontal Hydraulic Conductivity (ft/day)	1	0.001	10	Log Uniform	Uniform within Brushy Basin Member
	2	0.01	1,000	Log Uniform	South West of Lisbon Valley Anticline
	3	0.01	1,000	Log Uniform	Northwest region of model
	4	0.01	100	Log Uniform	North East of Lisbon Valley Anticline
	5	0.01	1,000	Log Uniform	Thin zone along Lisbon Valley Fault

Modeling of contaminant transport utilized MT3DMS (Zheng and Wang, 1999). Only advective transport was simulated; this assumption was made because advective transport is believed to dominate diffusive transport and attenuation processes are considered negligible. Otherwise initial conditions and transport parameters were identical to those used by KOMEX (2003).

During Phase 1 transport modeling, problems were encountered when running MT3DMS stochastically. Because of this issue, it was not possible to run all flow models as transport models during Phase 1 modeling. Contaminant transport models were run for only the thirty best fitting flow models. Troubleshooting of the transport simulation process will be done before Phase 2 modeling.

FINDINGS FROM PHASE 1 MODELING RESULTS

After each model was run, models were given a “likelihood” and “importance” weight. Models that are “likely” are simulations that show a good fit between projected and measured groundwater levels and uranium concentrations during the period 2004-2011 at currently monitored wells. This goodness of fit was calculated using a normalized Root Mean Squared Error statistic. Models were then evaluated to determine if they are important. Models that projected uranium reaching the northern LTSM boundary any time during the 200 year model period were identified as important. The model likelihood and importance were then combined to calculate a single likelihood-importance weight for each model. Models that have a weight close to one are both important and likely; models that have a weight close to zero were neither important nor likely. Finally, the likelihood-importance weighted head and concentration variance among all models was calculated resulting in a data discrimination index. The data discrimination index is highest in areas where models that match historic data well and result in important outcomes have the most variance. The data discrimination index was used to help guide the development of the field program and is integrated into the proposed field program.

Other interesting findings can be noted from the Phase 1 modeling and will be of value in Phase 2 modeling. For example, the best fitting flow models have a relatively high hydraulic conductivity (10s to 100s of ft/day) in zone 5 and a lower hydraulic conductivity (0.1 to 2 ft/day) in zone 2. Also, the best fitting flow models have a very low conductivity in the BBM (on the order of 0.001 ft/day). These findings are not a claim about the actual nature of hydrogeologic units at the Site. However, if hydraulic property data collected in the field program are in agreement with these findings the range of hydraulic conductivity values used in Phase 2 models can be constrained. If hydraulic property data collected in the field program are in disagreement with these findings, it may point to other modeling conceptualizations that need to be addressed.

A third key finding from Phase 1 modeling is that some flow and transport models that fit historic data well project uranium reaching the northern LTSM boundary while the majority of the models do not. This finding supports the use of probabilistic modeling. The non-unique nature of solutions to groundwater flow and transport results from uncertainty associated with data collection, model conceptualization, parameter estimation, and numerical modeling methods. For this reason, consideration of multiple models is essential for robust decision making.

PHASE 2 MODELING

Phase 2 modeling will be used for establishing compliance conditions after the completion of the field program as outlined in this work plan. Phase 2 modeling is expected to build on Phase 1 modeling and will utilize probabilistic modeling as a means of the determining appropriate ACLs at the Site. While Phase 2 modeling will build off of Phase 1 modeling, it will have several improvements. Additionally, Phase 2 will not be used to develop a data discrimination index since Phase 2 modeling is expected to be the final phase of modeling at the Site. The Phase 2 modeling approach is outlined below:

- Based on Phase 1 modeling – The model grid, numerical techniques, and general model design are expected to remain the same as in Phase 1 modeling.
- Revision of parameter ranges – Parameter ranges for hydraulic conductivity will be revised based on findings in hydraulic testing of aquifer properties and parameters values correlated to highly unlikely models from Phase 1 modeling.
- Addition of stochastically generated parameters – Effective porosity may be added as a stochastic parameter.
- Addition of second initial distribution of mass – Phase 2 modeling will include a second initial distribution of mass as an additional conceptual model.
- Revision of conceptual models - Conceptual models will be revised as needed based on data obtained in the field program.

- Incorporation of field data in model likelihood calculations – Water level and uranium concentration data obtained in the field program will be added to the existing data set and will be used to update model likelihoods.
- Monte-Carlo transport modeling – MT3DMS will be run in Monte-Carlo mode once issues with transport modeling have been resolved.
- Probabilistic likelihood weighted projections – Models will be weighted by their likelihood and used collectively to generate probability distributions of concentration levels. Projections will have the form of "We are X% confident that the uranium concentration at well A will not exceed Y mg/l."
- Additional changes – Any other changes deemed necessary for optimal development of ACL's may be incorporated into Phase 2 modeling.

REFERENCES CITED

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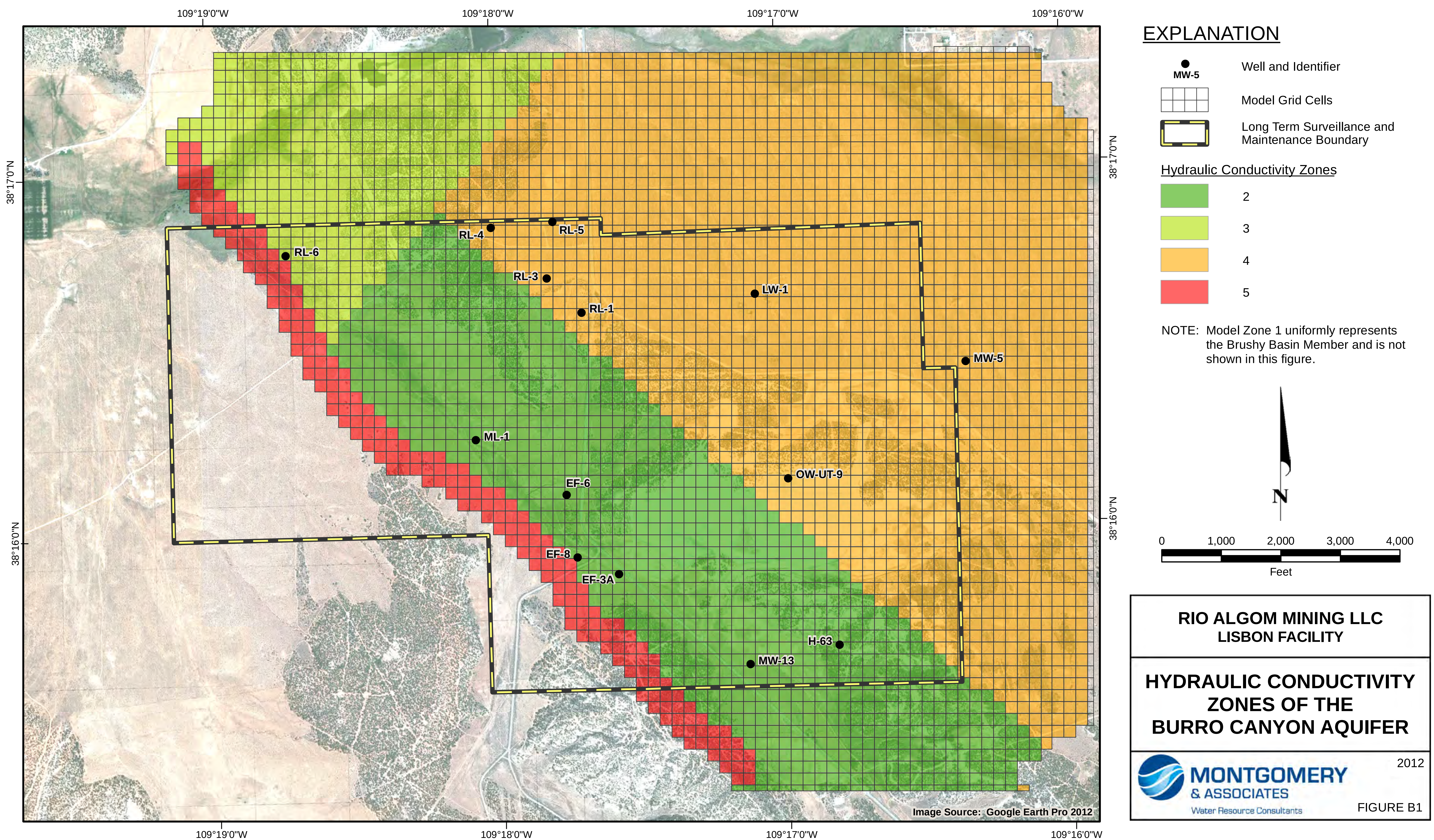

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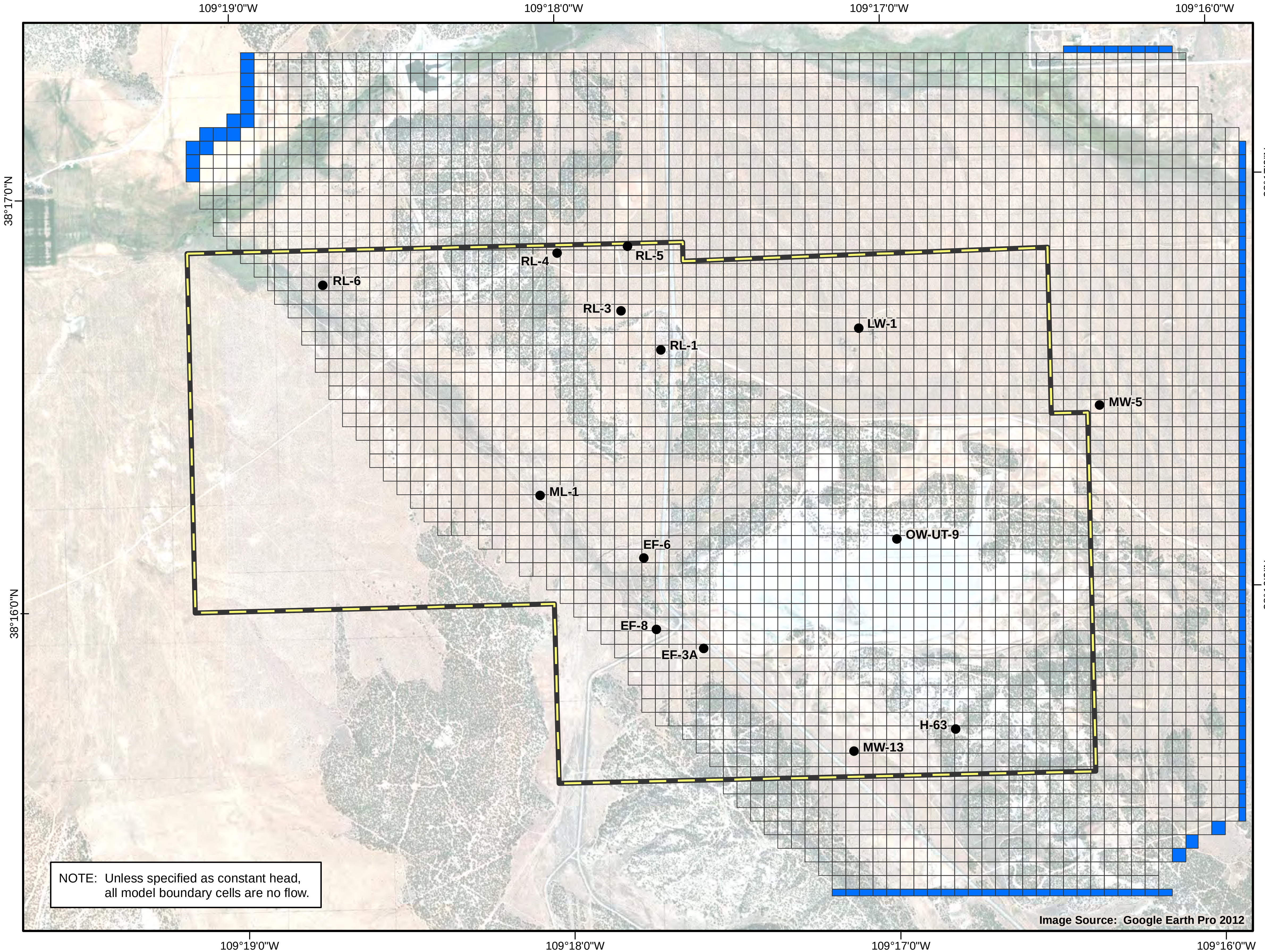

EXPLANATION

- MW-5 — Well and Identifier
- Model Grid Cells
- Constant Head Boundary Cells
- Long Term Surveillance and Maintenance Boundary

N

0 1,000 2,000 3,000 4,000
Feet

RIO ALGOM MINING LLC
LISBON FACILITY

BURRO CANYON AQUIFER BOUNDARY CONDITION CONCEPTUALIZATION 1

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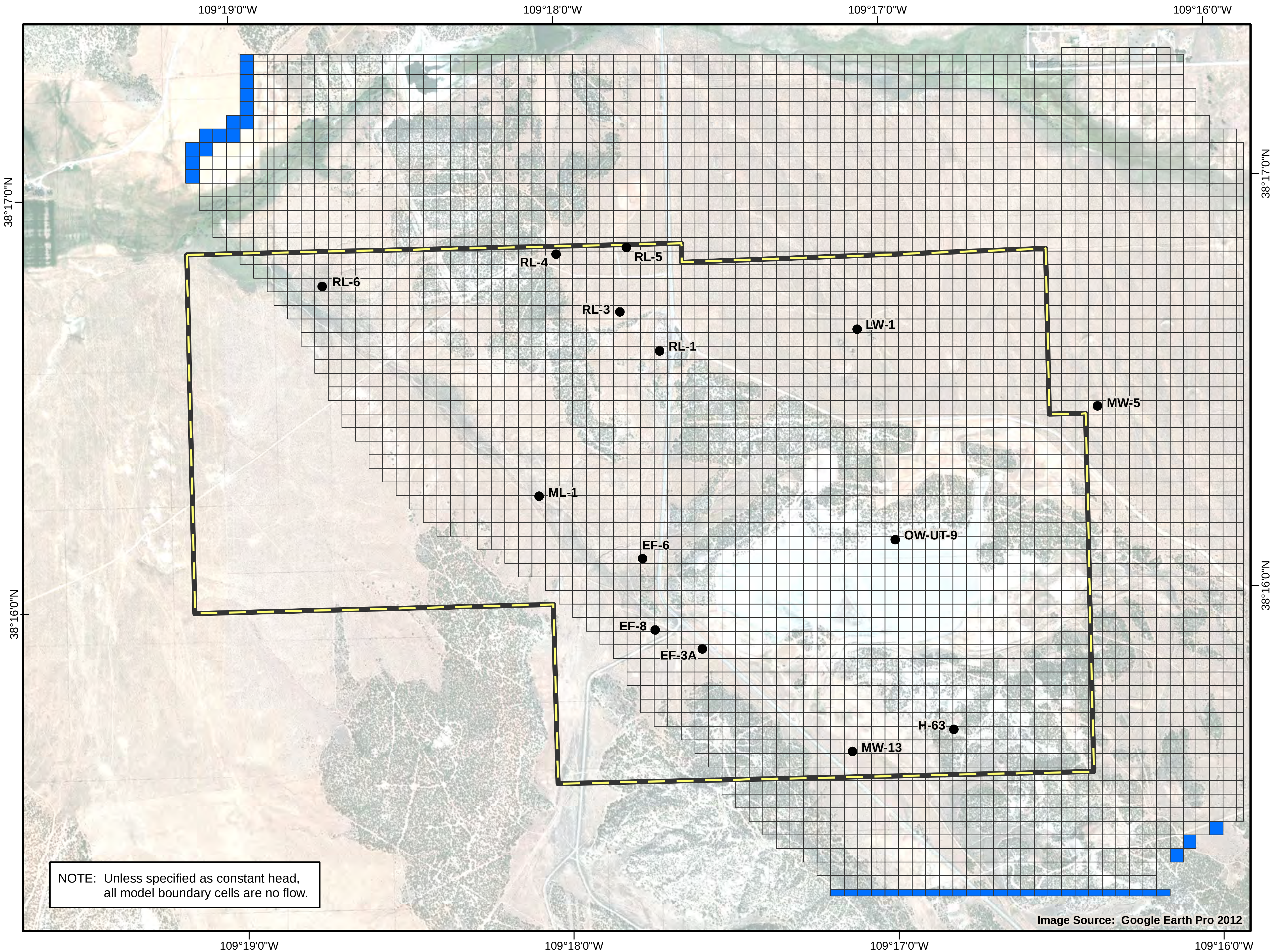
2012

FIGURE B2

GIS\1350.09\BoundaryConditionConceptual1\11April2012 NAD27_SP_Utah_So.



EXPLANATION

MW-5 — Well and Identifier

Model Grid Cells

Constant Head Boundary Cells

Long Term Surveillance and Maintenance Boundary

N

0 1,000 2,000 3,000 4,000

Feet

RIO ALGOM MINING LLC
LISBON FACILITY

BURRO CANYON AQUIFER BOUNDARY CONDITION CONCEPTUALIZATION 2

2012

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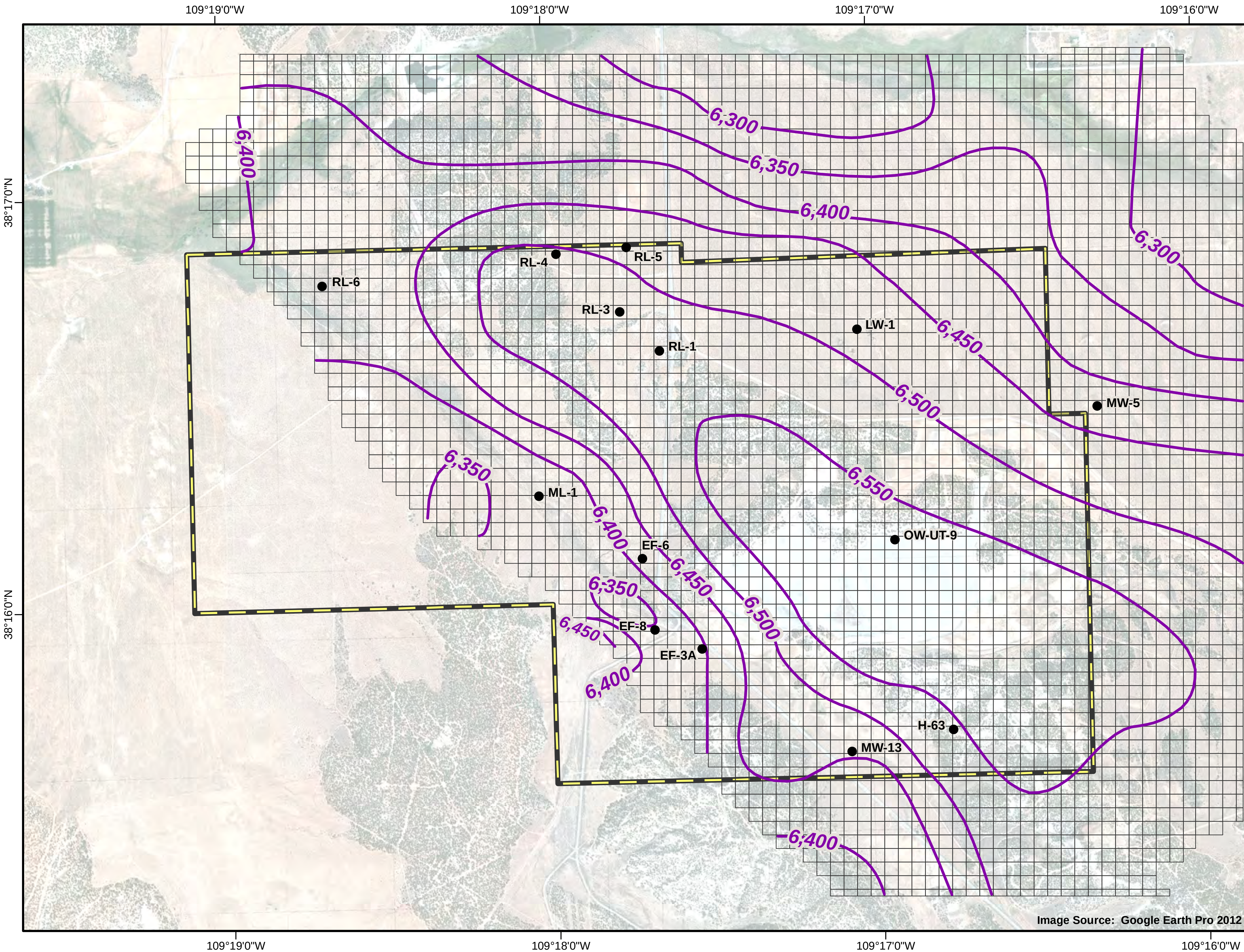
Water Resource Consultants

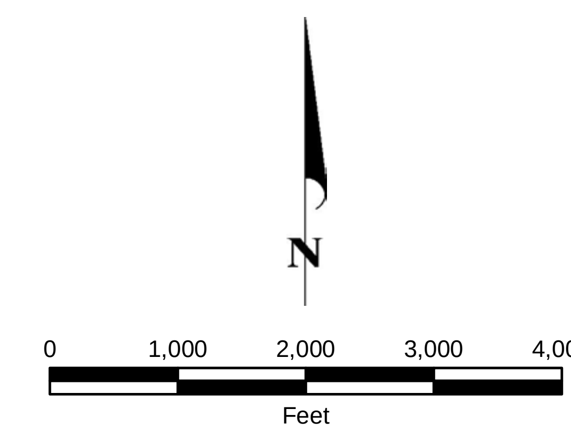
FIGURE B3

GIS\1350.09\BoundaryConditionConceptual2\11April2012 NAD27_SP_Utah_So.



EXPLANATION

- MW-5 — Well and Identifier
- Inferred Elevation of Top of Brushy Basin Member (KOMEX, 2003)
- Model Grid Cells
- Long Term Surveillance and Maintenance Boundary



RIO ALGOM MINING LLC
LISBON FACILITY

BASIC ANTICLINE STRUCTURE

2012

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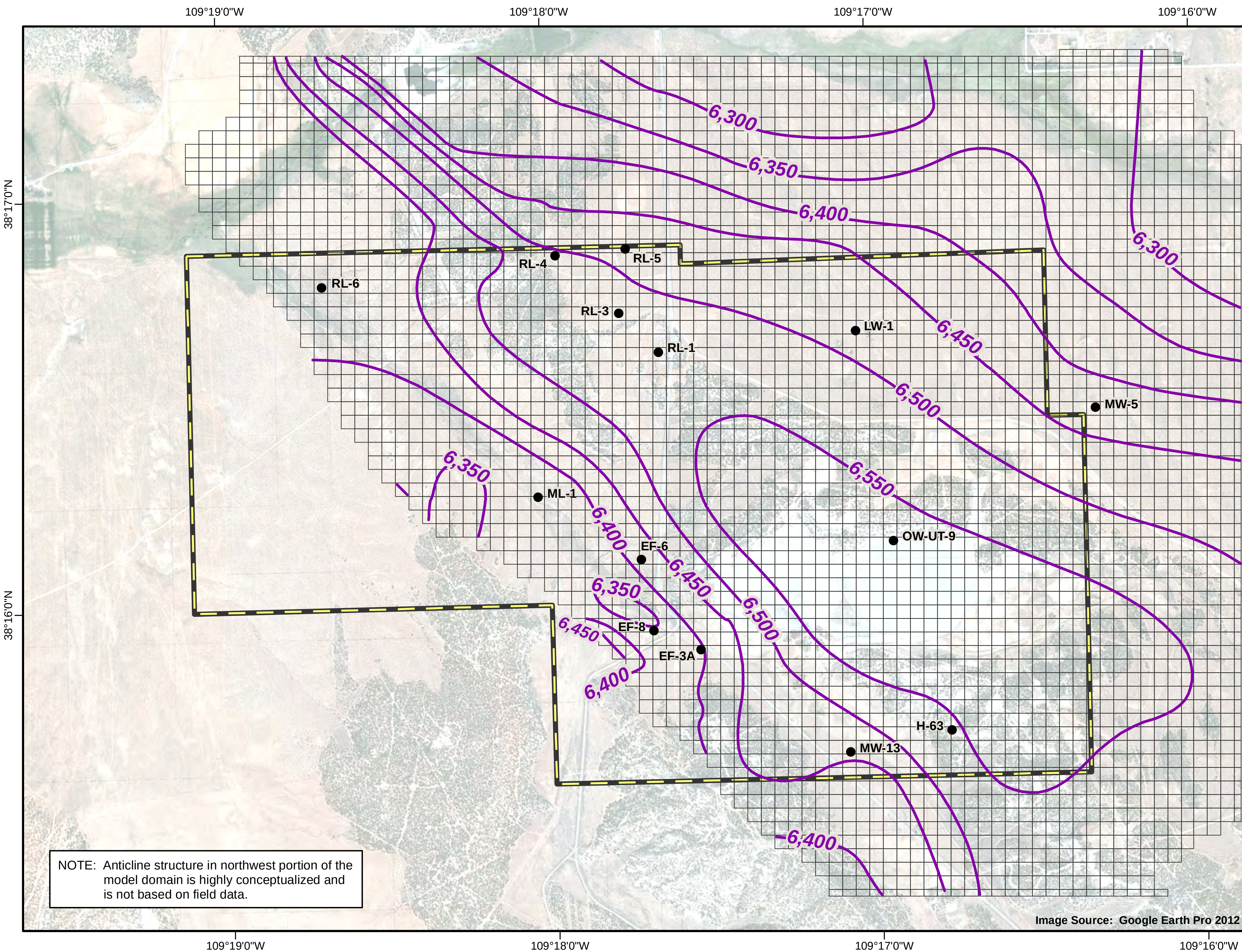
Water Resource Consultants

FIGURE B4

GIS\1350.09\BasicAnticline\11April2012 NAD27_SP_Utah_So.



EXPLANATION

- MW-5 — Well and Identifier
- Inferred Elevation of Top of Brushy Basin Member
- Model Grid Cells
- Long Term Surveillance and Maintenance Boundary

N

0 1,000 2,000 3,000 4,000

Feet

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EXTENDED ANTICLINE STRUCTURE

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2012

FIGURE B5

GIS\1350.09\ExtendedAnticline\12April2012 NAD27_SP_Utah_So.

MONTGOMERY & ASSOCIATES

APPENDIX C

WELL CONSTRUCTION AND TEST PROCEDURES

APPENDIX C

WELL INSTALLATION METHODS AT RIO ALGOM MINING LLC LISBON FACILITY

SCOPE AND APPLICABILTIY

The following sections describe methods for the drilling, installation, and development of wells at the Rio Algom Mining LLC Lisbon facility (RAML) in Lisbon, Utah. The methods are intended to be general in nature. As the work progresses, appropriate revisions may be necessary and may be implemented as required to meet project objectives.

DRILLING PREPARATION

Sixteen well borings will be drilled using conventional or reverse-circulation air drilling methods. Drilling will be conducted by an approved well constructor, licensed in the State of Utah. Wells will be designed and constructed in accordance with Utah Administrative Codes (UAC) R317-6-6.3(I)(6), UAC R655-4-15, and U.S. EPA RCRA *Ground Water Monitoring Technical Enforcement Guidance Document*. Prior to commencing the drilling program, proposed well locations will be field-verified. Each well site will be inspected for drilling impediments (e.g., utilities, limited access, etc.).

DRILLING AND WELL CONSTRUCTION

There are three general types of proposed wells: (1) water table well, (2) deep Burro Canyon Aquifer (BCA) well, and (3) Brushy Basin Member of the Morrison Formation (BBM) wells. An exploratory borehole will be drilled near existing well RL-6 and, if conditions warrant, a well will be installed. Drilling procedures were developed based on available information and may be modified in the field in accordance with the conditions encountered.

Water Table Wells

Most wells in the field program will be water table wells (e.g., the well screen will bridge the water table). The water table will be encountered in the BCA or BBM. For each water table well, steel conductor casing will be advanced to the top of the BCF and cemented in place to seal off overburden/alluvium. The total drilling depth of the shallow water table wells will be determined by the depth of the water table. When drilling has reached the suspected water table depth (based on water levels in existing vicinity wells), boreholes will be monitored for water production at 10-foot increments. At each increment, the borehole will be evacuated of drill water by airlifting; airlifting will continue for a prescribed period of time to determine whether the borehole is producing water. Once a determination has been made that the water table is encountered, drilling will continue approximately 25 feet below the water table and the well will be built.

Deep BCA Well

Wells completed in the deep portion of the BCA below the water table are designated deep BCA wells. Steel conductor casing will be advanced to the top of the BCF and cemented in place to seal off overburden/alluvium. The borehole will then be advanced to the BCF/BBM contact. The well will be constructed with the bottom of the 30-foot screened interval at the BCF/BBM contact.

BBM Wells

Wells completed in the BBM below saturated areas of the BCF are designated BBM wells. Boreholes will be advanced to approximately 10 feet below the estimated water table in the BCF. A core barrel will be advanced to collect continuous core to the BCF/BBM contact. After the cored borehole is reamed to the appropriate diameter, a steel conductor casing will be installed to the contact and cemented in place to seal off the BCF aquifer and prevent cross contamination to the BBM. Once the integrity of the seal has been verified, continuous core will be collected 35 feet into the BBM. After the cored borehole is reamed, the well will be built with 30 feet of screened interval in the BBM.

Exploratory Drilling Near Existing Well RL-6

One boring will be advanced near existing well RL-6 to determine if it is screened in a perched water zone or the regional groundwater. The borehole will be advanced to the total depth of well RL-6 (approximately 18 feet). The borehole will be evacuated of drill water by airlifting and airlifting will continue for a prescribed period of time to determine whether the borehole is producing water. If the water table is encountered, drilling will continue to the BCF/BBM contact or other fine grained unit. If the BBM is encountered, a shallow well will be built with a 30-foot screened interval just above the contact. If a fine grained “perching unit” in the BCF is encountered, a steel conductor casing will be installed into this unit and cemented in place to seal off the perched water. Once the integrity of the seal has been verified, drilling will continue. Final drilling depth will be determined by lithologic observations made during the drilling of MW-101S and MW-101D.

Core Samples

Coring will be conducted to retrieve undisturbed samples for hydrochemical analyses. Borings will be cored using an HQ (2.5-inch diameter) core barrel. For hydrochemical analyses of the vadose zone to assess residual uranium concentrations, a core barrel will be advanced to the estimated depth of the water table to collect continuous core samples. Selected core samples will be submitted to a certified hydrochemical laboratory licensed by the State of Utah for analysis of leachable uranium by U.S. EPA Method 1311 TCLP metals extraction. Once coring is completed, the cored borehole will be reamed to the appropriate diameter and drilling will continue as describe above.

Coring will also be conducted to retrieve undisturbed samples for physical properties analyses. In this case, undisturbed core will be retrieved from the approximate depth of the water table to the bottom of the borehole in the BBM. The coring and reaming procedures will be as follows: (1) core from water table to BCF/BBM contact, (2) ream hole to BCF/BBM contact, (3) cement in steel conductor casing and let cure, (4) core to total depth of approximately 35 feet into BBM, (5) ream bottom cored section, (6) complete well. The number of samples from each well location will be determined by the lithology encountered during drilling and field observations of physical properties. Core samples will be submitted to a physical properties laboratory and analyzed for saturated vertical and horizontal hydraulic conductivity by ASTM D2434M rigid wall method.

Well Construction

All new wells will be constructed with 4-inch diameter flush-threaded schedule 40 PVC casing and well screen with 0.010 machine slots. Each well will be constructed with a 30-foot screened interval. A filter pack consisting of 10/20 washed silica sand (or similar appropriate material) will be placed in the annulus extending 2 to 5 feet above the screened interval. A 2-foot layer of fine transitional sand will be placed above the filter pack and the annulus will be sealed to ground surface using high solids bentonite grout (or similar appropriate material).

Wells will be completed with a locking above-grade steel monument. The PVC well casing will extend at least 1 foot above grade. Three steel protective posts and a concrete pad will be installed at each site to protect the surface completion.

FIELD DOCUMENTATION

Drilling and well construction will be overseen by a qualified professional geologist. The geologist will document daily site conditions, drilling activities, and well construction. The field geologist will also provide lithologic descriptions of materials encountered during drilling. Copies of the driller’s logs/daily reports will be maintained by the field geologist.

DECONTAMINATION

All down-hole drilling equipment including rods, hammers, bits, core barrels, and temporary casing will be steam cleaned between borings.

WELL DEVELOPMENT

New wells will be developed as needed after installation. Wells will be surged using a surge block and purged until development water is free of sediment and field parameters including pH, specific conductance, and temperature have stabilized.

INVESTIGATION DERIVED WASTE

All drill cuttings, drilling fluids, decontamination water, and development water will be containerized during drilling activities and properly disposed using methods approved by RAML and Utah Division of Radiation Control (DRC).

REPORTING

As-built reports for new wells will be submitted to the Executive Secretary for approval within 60 calendar days of completion in accordance with DRC requirements. As-built reports will be prepared under the direction of a Professional Geologist licensed by the State of Utah, or a senior geologist approved beforehand by the Executive Secretary. Reports will include the following:

- Geologic logs detailing lithology and physical properties of all subsurface materials encountered during drilling.

- Well completion diagrams detailing the following:
    - Total depth and diameter of the borehole
    - Depth, type, diameter, and physical properties of well casing and screen
    - Well screen slot size
    - Depth intervals, type, and properties of annular filter pack and seal
    - Design and construction of protective surface casing
    - Horizontal coordinates and water level elevation measuring point measured to the nearest 0.01 feet by an engineer or land surveyor licensed by the State of Utah

REFERENCES

U.S. EPA, 1986, **RCRA Ground Water Monitoring Technical Enforcement Guidance Document**: September 1986.

Utah Division of Water Rights, 2011, **State of Utah Water Well Handbook, Based on the Administrative Rules for Water Wells (R655-4 UAC)**: April 2011.

Utah Division of Administrative Rules, 2012, **Utah Administrative Code Rule R317-6 Ground Water Quality Protection**: April 1, 2012.

APPENDIX C

STANDARD OPERATING PROCEDURES FOR HYDRAULIC TESTING AT RIO ALGOM MINING LLC LISBON FACILITY WELLS

SCOPE AND APPLICABILTIY

The following sections describe standard operating procedures (SOPs) for conducting slug tests and pumping tests at monitoring wells at the Rio Algom Mining LLC Lisbon facility (RAML) in Lisbon, Utah. The SOPs are intended to be general in nature. As the work progresses, appropriate revisions may be necessary and may be implemented as needed to meet project objectives.

SLUG TESTING METHOD

A slug test involves the near instantaneous injection or withdrawal of a volume or slug of water or solid cylinder. The test is conducted by displacing a known volume of water from a well and measuring the artificial fluctuation of the groundwater level. A solid cylinder will be used for all slug tests conducted at the RAML facility. Tests will comprise the introduction of a solid slug into the groundwater, with a subsequent delay allowing for groundwater head to return to static conditions, followed by rapid removal of the slug and measurement of rising head.

Under the current proposed hydraulic testing program, slug testing will be conducted at all new and existing wells at the RAML facility. The following SOPs are followed when conducting falling-head (slug lowered into a well) and a rising-head (slug removed from the well) slug tests.

Materials and Equipment

The following equipment is needed to perform slug tests. All equipment which comes in contact with the well should be decontaminated prior to commencing field activities.

- Field logbook
- Field test data sheets
- Integrated pressure transducer/datalogger, data cables, and field computer
- Solid cylinder slug and competent tether
- Stopwatch

Test Preparation

1. Review the well construction records for the well specifically focusing on total depth of the well, well diameter, and screen position and length. Tests will be conducted by a qualified groundwater professional.

2. Connect integrated pressure transducer/datalogger to field computer.

3. Synchronize the computer and transducer clocks. Check the battery in the transducer to ensure full power supply.

4. Select a logging rate of one reading per second. Set the transducer to start logging data. Record in the field logbook the transducer ID number being used.

Test Procedures

1. Open the well and manually measure the depth to water to the nearest 0.01 foot. Record this information on the field test data sheet and in the field logbook.

2. Lower the transducer into the well and place it at least 2 feet deeper than the length of the solid cylinder slug. The submerged depth of the transducer should not exceed the maximum submerged design depth for the transducer used.

3. Fasten the transducer data cable at the top of the well so that the transducer cannot move. Re-connect to the field computer for real-time monitoring.

4. Allow the transducer to equilibrate for at least 15 minutes.

5. Measure the water level again to verify that water level has returned to equilibrium after the deployment of the transducer. If it has not, repeat this step in 5-minute intervals until equilibrium is reached. Record this information on the field test data sheet and in the field logbook.

6. Lower the slug into the well and place the slug just above the water level.

7. Lower the slug quickly into the water. Record the time that the slug was placed into the water on the field test data sheet and in the field logbook.

8. Monitor the water level until it has recovered to within 90 percent of the static water level. This portion of the test is now complete.

9. Allow time for the water level to recover to a static condition. Quickly pull the slug out of the water. Record the time that the slug was pulled from the water on the field test data sheet and in the field logbook.

10. Monitor the water level until it has recovered to within 90 percent of the static water level.

11. Conduct a minimum of two slug tests at each well to ensure the data are repeatable. Where practical as time permits, conduct three slug tests at each well. The data collected from the transducer should be reviewed in the field to determine if additional slug tests are required.

12. Stop transducer from logging data. Download the data files from the transducer and record the file names on the field test data sheet and in the field logbook.

13. Decontaminate the transducer and data cable, water level meter, and slug for next use.

Investigation Derived Waste

No potentially contaminated groundwater will be removed from wells during slug testing. All equipment used during slug testing will be decontaminated after each use to prevent cross contamination. Decontamination water will be containerized, sampled for water quality, and properly disposed using methods approved by RAML and Utah Division of Radiation Control (DRC).

Data Analysis

Data collected during the slug testing will be evaluated using one or more appropriate analytical methods consistent with the conceptual model to estimate the hydraulic conductivity of the formation. Analytical solutions and software used to calculate the formation hydraulic conductivity will depend on the hydraulic responses observed during slug testing.

- Butler, J. J., 1998, The Design, Performance, and Analysis of Slug Tests, 252 p.

- Standard Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests), ASTM D 4104-96.

- Standard Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test), ASTM D 5785-95.

PUMPING TESTS

The following sections describe standard operating procedures (SOPs) for step drawdown testing and constant rate discharge testing. Step and constant rate discharge tests will only be conducted at wells located in areas that are known <u>not</u> to be impacted by contaminants of concern. Hydraulic testing will not be conducted at any well until sufficient groundwater sampling has been completed and results confirm water quality in the vicinity of the well facilitates testing. Hydraulic testing will be conducted in a manner which prevents the following:

1. Removal of contaminated groundwater to the surface in a manner which impacts surficial materials, near-surface materials, or other subsurface materials

2. Migration of impacted groundwater causing impacts to a clean test well

3. Alteration of the hydraulics of the subsurface in such a way that a nearby contaminant plume is enlarged or migrates to a formerly unimpacted location other than the clean test well

Under the current proposed hydraulic testing program, step and constant rate discharge testing is planned for proposed new well MW-101D. The following SOPs are followed when conducting step drawdown and constant rate discharge tests.

Pump Equipment

Pumping will be conducted with an electric submersible pump with the capacity to provide adequate pumping rates during testing. A check valve will be installed at the base of the pump column pipe in the pumped well to prevent the back flow of water from the column pipe into the well when the pumping portion of the test is terminated and the recovery begins. Flow rate will be controlled with a valve on the discharge line. An inline flowmeter will be installed in accordance with manufacturer's recommendations on the discharge line and will be used to maintain a constant flow rate during testing. The valve will be placed a minimum of five pipe diameters down-stream from the in-line flowmeter, to ensure that the pipe is full and flow is not disturbed by excessive turbulence.

Step Drawdown Test

A step drawdown test will be conducted prior to the constant rate discharge test. The step test will be conducted to evaluate well performance and determine optimal pump settings (depth and pumping rate) for the constant rate test. The step drawdown test will include a minimum of four 60-minute steps of increasing flow rates. The initial step will be conducted long enough to demonstrate that well storage effects have dissipated. Each remaining step will continue for a length of time identical to the initial step. Step drawdown tests will be conducted as follows:

1. Step testing will be supervised by a qualified groundwater professional. Install and program an integrated pressure transducer/datalogger into the test well as described above.

2. The step drawdown test will consist of a minimum of four consecutive discharge steps, with each step utilizing a higher pumping rate. Each step will be conducted for at least 60 minutes.

3. During each step, monitor and record flow meter readings every minute to maintain the target discharge rates. Rates will be maintained within 10 percent of the starting rate for the duration of each step.

4. Monitor pressure transducer/data logger in the test well periodically. Measure and record water level in the test well on a frequent basis to confirm that pressure transducers are functioning properly.

5. Plot drawdown versus time to monitor the status and effectiveness of the test.

6. Determine the appropriate pumping rate and pumping depth as established from the step drawdown test. Use these values for conducting the constant rate discharge test.

Constant Rate Discharge Test

After completion of the step drawdown test, the well will be allowed to recover for a period at least as long as the duration of the step test. A constant rate discharge test will then be conducted for a period of up to 12 hours. The actual length of the constant rate discharge test will be determined by target flow rate and the capacity of on-site containers to store discharge water. Integrated pressure transducers/data loggers will be installed in the test well and nearby wells to record water levels during the discharge tests. Constant rate discharge tests will be conducted as follows:

1. Constant rate discharge testing will be supervised by a qualified groundwater professional. Install and program integrated pressure transducer/dataloggers into the test well and observation wells as described above.

2. Monitor water levels at the test well and observation wells to determine that water levels are static and at the same elevations that existed prior to the step drawdown tests. Program the data loggers in the test well and observation wells to record water levels with the appropriate frequency for the constant rate discharge test.

3. Set the test well control valve to the maximum sustainable pumping rate determined during step testing.

4. Once pumping begins, monitor and record flowmeter readings every minute to maintain the target discharge rate. After establishing that the pumping rate is constant, the pumping rate will be monitored and recorded on a 10 to 20 minute basis. The rate will be maintained within 10 percent of the starting rate for the duration of the test.

5. Monitor pressure transducer/dataloggers in the test well and observation wells periodically. Measure and record water level in the test well and observation wells on a frequent basis to confirm that pressure transducers are functioning properly.

7. Plot drawdown versus time to monitor the status and effectiveness of the test. The plot of drawdown versus time will reveal the effects of boundaries or other hydraulic features if they are encountered during the test, and will indicate when enough data for a solution have been recorded.

8. Recovery will be monitored beginning at the moment the pump is shut off. The recovery period will continue until the water level has returned to within 95 percent of the initial, pre-pumping static water level or for a period equal to the length of the discharge. Measurement frequency will conform to the same frequencies as were used for the discharge portion of the test.

Investigation Derived Waste

Potentially contaminated groundwater removed from the test well during the step and constant rate pumping tests will be containerized and properly disposed. All equipment used during pumping tests will be decontaminated after each use to prevent cross contamination. Decontamination water will be containerized, sampled for water quality, and properly disposed using methods approved by RAML and DRC.

Data Analysis

Results of the pumping tests will be evaluated using one or more technically appropriate analytical methods. The analytical methods will be selected to be consistent with the conceptual model of the aquifer and the drawdown and recovery results of the pumping test. Analytical solutions and software used to calculate the hydraulic properties will depend on the hydraulic responses observed during pumping tests.

REFERENCES

ASTM, 1991, **Standard Guide for Selection of Aquifer Test Method in Determining of Hydraulic Properties by Well Techniques**: D 4043, 1991.

American Society for Testing and Materials (ASTM), 2002, **Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers**: D 4044-96, 2002.

Butler, J. J., 1998, **The Design, Performance, and Analysis of Slug Tests**: 252 p.

U.S. Environmental Protection Agency (U.S. EPA), 1993, **Suggested Operating Procedure for Aquifer Pumping Tests**: February 1993.

_____, **Slug Tests**: Standard Operating Procedure No. 2046, October 1994.

Standard Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests), ASTM D 4104-96.

Standard Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test), ASTM D 5785-95.

MONTGOMERY & ASSOCIATES

APPENDIX D

SUPPLEMENTAL SITE ASSESSMENT GROUNDWATER SAMPLING PLAN

APPENDIX D

STANDARD OPERATING PROCEDURES FOR GROUNDWATER MONITORING AT RIO ALGOM MINING LLC LISBON FACILITY WELLS

SCOPE AND APPLICABILTIY

The following sections describe standard operating procedures (SOPs) for measurement of water levels in wells and for collection of water quality samples from wells at the Rio Algom Mining, LLC Lisbon facility (RAML) in Lisbon, Utah. The SOPs described below are intended to be general in nature. As the work progresses, appropriate revisions may be necessary and may be implemented as needed to meet project objectives.

Under the current groundwater sampling program for the RAML facility, groundwater samples are obtained from existing wells using low-flow purging and sampling methods. As part of the additional characterization work to be conducted in 2012, a field evaluation of various groundwater sampling methods will be performed to determine the most appropriate method for representative sample collection. Comparative samples will be collected from all new and existing wells using the purgeless HydraSleeve method, the low flow minimal purge method, and volume-based standard purge method. SOPs for each sample collection method are described in the following sections.

GENERAL CONSIDERATIONS

Potential hazards associated with the planned tasks shall be thoroughly evaluated prior to conducting field activities. The site-specific Health and Safety Plan (HASP) for the RAML facility provides a description of potential hazards and associated safety and control measures.

Field personnel must wear powder-free nitrile gloves while performing the procedures described in this SOP. Specifically, powder-free nitrile gloves must be worn while measuring water levels, preparing sample bottleware, preparing and decontaminating sampling equipment, collecting samples, and packing samples. At a minimum, nitrile gloves must be changed prior to the collection of each sample, or as necessary to prevent the possibility of cross-contamination with the sample, the sample bottleware, or the sampling equipment.

Field sampling equipment shall be decontaminated prior to each use. Although water level measurement and sampling should typically be conducted from least to most impacted location, field logistics may necessitate other sample collection priorities. When sampling does not proceed from least to most impacted location, extra precautions must be taken to ensure that appropriate levels of decontamination are achieved.

WATER LEVEL MEASURMENT

Water levels will be measured in wells prior to purging or sampling. Construction details and any previous measurements for each well will be reviewed by the field staff before obtaining measurements.

Materials and Equipment

The following equipment is needed to measure water levels and well depth. All equipment which comes in contact with the well should be decontaminated prior to commencing field activities.

- Records of well construction details and previous measurements
- Electronic water level indicator with accuracy of 0.01 feet
- Field log or data sheet
- Weighted tape graduated to the nearest 0.01 feet

Measuring Point

Well depth and water level measurements will be referenced from a measuring point, established and marked at the top of the inner casing of each monitoring well. Generally, this point will be on the north side of the top of the casing. The measuring point will be permanently marked using an indelible marker or a notch cut into the casing. A licensed surveyor will survey the measuring point elevation of each monitoring well and reference this measurement to the local datum for location and elevation.

Well Depth Measurements

The total depth of each new well will be measured with a weighted measuring tape immediately after construction and will be verified periodically thereafter. The weighted tape will be lowered into the well until the tape becomes slack indicating the bottom of the well. Care will be taken to lower the tape slowly to avoid damage to the bottom of the well by the weight. The tape will be raised until it becomes taut. With the tape in this fixed position, the total depth of the well will be measured to the nearest 0.01 feet below the measuring point.

Water Level Measurements

Manual water level measurements will be obtained from wells with an electronic water level indicator prior to purging or sampling. If the well is equipped with an automated monitoring device (pressure transducer), recorded data will be downloaded and viewed in the field on a portable computer. Water level will then be measured manually to verify that the automated device is functioning properly. The SOP for measuring water levels with an electronic water level indicator is as follows:

1. Open the protective outer cover of the monitoring well and remove any debris that has accumulated around the riser near the well plug. If water is present above the top of the riser and well plug, remove the water prior to opening the well plug. Do not open the well until the water above the well head has been removed.

2. Allow well to equilibrate for at least 5 minutes before measuring the water level.

3. Using an electronic water level indicator accurate to 0.01 feet, determine the distance between the established measuring point and the surface of the standing water present in the well. Repeat as necessary until two successive readings agree to within 0.01 feet. Record date and time of each water level measurement and the serial number of the water level indicator used.

4. Decontaminate the water level indicator in preparation for next use.

The accuracy of electronic water level indicators will be verified at least annually as part of routine maintenance. The entire length of the graduated tape/cable will be compared to a steel surveyor's tape of the same or greater length to determine accuracy at 100-foot increments. Water level indicators will be checked more frequently if there is reason to suspect the tape/cable was stretched during field operations.

GROUNDWATER SAMPLE COLLECTION PROCEDURES

As described above, a field evaluation of groundwater sampling methods will be performed in 2012 to determine the most appropriate method for representative sample collection. Once the appropriate sample method is selected for the ongoing RAML facility monitoring program, sampling procedures for this method will be duplicated to the maximum extent practical during subsequent sampling events.

Groundwater samples will be collected from new wells no sooner than seven days after the well has been developed. For the field evaluation of sample methods, the sequence of the concurrent sampling will comprise sample collection by the purgeless HydraSleeve method, followed by the low flow minimal purge method, followed by the volume-based standard purge method. SOPs for the three sampling methods are described below.

Materials and Equipment

The following equipment is needed to collect groundwater samples from wells. All equipment which comes in contact with the well should be decontaminated prior to commencing field activities.
General Materials and Equipment:
- Monitoring instruction sheet for each site
- Field logbook
- Field sampling data sheets (FSDS)

- Site maps
- Health & Safety Plan
- Indelible black-ink pens and markers
- Sample labels
- Chain-of-custody forms
- Custody seals
- Shipping labels
- Water level meter
- pH/conductivity/temperature/ORP meter, turbidity meter, and dissolved oxygen meter
- Insulated cooler(s)
- Laboratory-supplied sample containers
- Ice
- Decontamination equipment: Liquinox or similar, and jugs for potable water

Equipment for HydraSleeve Sampling:

- HydraSleeve
- Static deployment line calibrated with footmarks
- Weight with attachment clip
- Recovery reel

Equipment for Low-Flow and Standard Purge Sampling:

- Variable rate electric submersible pump and controller
- Portable generator
- Flow-through cell
- Disposable discharge tubing

Purgeless Sample Method

Purgeless sample collection will be conducted using the HydraSleeve method, which comprises deployment of a clean, flat, empty bailer into the well screen. A HydraSleeve consists of a disposable polyethylene tube-shaped bag, sealed at the bottom and flared open at the top with a check-valve. This method requires that a minimum of 6 feet of well screen be submerged below the water level for proper deployment. The benefits of purgeless sampling include little or no purge water generated for disposal and little or no decontamination since the equipment is either dedicated or disposable.

HydraSleeve Deployment

1. Measure and record the depth to water to nearest 0.01 feet as described above. Compare water level with well construction details to confirm that the HydraSleeve sampling device can be deployed. Record this information on the FSDS and in the field logbook.

2. Install the HydraSleeve sampling device approximately 2 feet below the midpoint of the screened interval of the well and at least 4 feet below water level. Deployment of the sampler causes a disturbance to the well water chemistry by allowing mixing with the "stagnant" water contained in the well pipe above the screened portion of the well and by disturbance of any sediment attached to the well pipe. The device will be deployed at least 24 hours prior to sample collection.

3. Fasten the weight to the bottom of the device and attach to the deployment line with a snap hook. Determine the expected footmark on the graduated line at the top of casing when the top of the device is in the planned position. Deploy the sampling device slowly into the well.

4. For wells with a planned deployment depth near the bottom of the open screen a top weight will be used. The top weight (available from the HydraSleeve manufacturer) is a weighted stainless-steel pipe sized to fit around the outside of the top of the device. It is held in place by a clip that also holds the mouth of the device open. Upon deployment, the top weight compresses the device in the bottom of the well effectively lowering the deployment depth to approximately 6 to 12 inches above the bottom of the well.

HydraSleeve Retrieval and Sampling

1. After at least 24 hours, retrieve the HydraSleeve with one smooth motion of approximately 4 feet. If the top of the well casing is too high to raise the device in one motion, the sampler can partially raise the device then adjust his grip on the tether to complete the stroke. The device must be removed at a rate of 1 to 2 feet per second or faster to allow water to pass the check valve.

2. Perforate the top of the device with the provided discharge tube and direct the water to the appropriate laboratory-supplied sample containers. Apply labels to bottles and immediately return to ice chest.

3. Record sampling information on the FSDS and in the field logbook.

4. Decontaminate deployment line and associated equipment for next use.

Low Flow (Minimal Purge) Sample Method

U.S. EPA recommends the use of adjustable-rate bladder and electric submersible pumps during low-flow purging and sampling activities. The following SOPs assume that a non-dedicated electric variable rate submersible pump will be used to purge and sample wells by the low flow method. The following procedures will be used for low flow sampling:

Low Flow Well Purging

1. Prepare sampling equipment including calibration of field meters prior to use.
2. Measure and record the depth to water to the nearest 0.01 feet as described above. Using the specific details of well construction and current water-level measurement, determine the pump set depth, typically the mid-point of the saturated well screen or other target sample collection depth adjacent to specific high-yield zones. If disposable tubing is to be used, cut appropriate length of disposable tubing from roll and attach to pump.
3. Remove the decontaminated pump from the pump holder and rinse the pump off with water. Slowly lower the pump into the well to the target depth. Record the depth of the pump intake after lowering the pump into location.
4. Connect the cable for the control box to the pump reel. Start the generator. Make sure the generator is kept downwind from the sampling system.
5. Connect the discharge tubing from the pump to the **base** of the flow-through cell. Place the probes for the calibrated field meters into the flow-through box. Attach small section of discharge tubing to the top of the flow-through cell and place end of hose into bucket to catch purge water.
6. Place water level probe in well and record static water level on the field sampling data sheets (FSDS).
7. If the well has been previously sampled using low-flow purging and sampling methods, begin purging at the rate known to induce minimal drawdown. Frequently check the drawdown rate to verify that minimum drawdown is being maintained. If sampling the well for the first time, begin purging the well at the minimum pumping rate of 100 milliliters per minute (mL/min) and slowly increase the pumping rate to no more than 500 mL/min. Monitor and record drawdown in well (if any). Record data on FSDS. If drawdown exceeds 0.3 feet from static, adjust flow rate until drawdown stabilizes (if possible).
8. For wells **screened below the static water level**, if the drawdown does not stabilize at a pumping rate of 100 mL/min, continue pumping until the drawdown reaches a depth of two feet above the top of the well screen. Stop pumping and collect a groundwater sample once the well has recovered sufficiently to collect the appropriate sample volume. Document the details of purging, including the purge start time, rate, and drawdown on the FSDS and in the field logbook.

   For wells **screened across the static water level**, if the drawdown does not stabilize at 100 mL/min, continue pumping. However, do not draw down the water level more than 25 percent of the distance between the static water level and pump intake depth. If the recharge rate of the well is lower than the minimum pumping rate, then collect samples at this point even though indicator field parameters have not stabilized. Begin sampling as soon as the water level has recovered sufficiently to collect the required sample volumes. Allow the pump to remain undisturbed in the well during this recovery period to minimize the turbidity. Document the details of purging on the FSDS and in the field logbook.

9. Start recording field parameters on the FSDS sheet every 3 minutes. Purging should continue at a constant rate until the parameters stabilize. Stabilization is considered achieved when three sequential measurements are within the ranges listed below:
    - pH ± 0.1 standard units
    - Specific Conductance ± 3%
    - Temperature ± 3%
    - ORP ± 10 millivolts
    - Turbidity ± 10% (for values greater than 5 NTUs)
    - Dissolved Oxygen ± 10%

Low Flow Well Sampling

1. After specified parameters have stabilized, reduce flow rate on control box to approximately 100 mL/min.
2. Disconnect discharge tubing base of flow-through cell, being careful to contain water within the cell. Cut off approximately 0.5 feet from end of discharge tubing. Place a bucket beneath sampling tube to catch water.
3. Fill necessary sample bottles. Label sample bottles with a unique sample number, time and date of sampling, the initials of the sampler, and the requested analysis on the label. Additionally, provide information pertinent to the preservation materials or chemicals used in the sample. Record comments pertinent to the color and obvious odor. Record sampling information on FSDS sheet and in field logbook.
4. Fill all sample containers with minimal turbulence by allowing the groundwater to flow from the tubing gently down the inside of the container. Immediately seal each sample and place the sample on ice in a cooler to maintain sample temperature preservation requirements. Fill bottles in the following order:

    - Metals, and Radionuclides
    - Filtered Metals and Radionuclides
    - Other water-quality parameters.

5. Remove the pump from the well taking care that the tubing does not contact the ground while being retrieved. Decontaminate pump and tubing for next use.
6. Containerize and properly dispose of purge water and decon water generated during sampling.

Volume Based (Standard Purge) Sample Method

The following SOPs assume that a non-dedicated electric variable rate submersible pump will be used to purge and sample wells by the volume-based method. The following procedures will be used for standard purge sampling:

Well Purging

1. Prepare sampling equipment including calibration of field meters prior to use.
2. Measure and record the depth to water to the nearest 0.01 feet as described above. Calculate a casing volume for the well based on the specific details of well construction, the current depth to water measurement, and casing diameter. For wells with multiple casing diameters, calculate the volume for each segment and use the sum of the values.
3. Remove the decontaminated pump from the pump holder and rinse the pump off with water. Slowly lower the pump into the well to the target depth. Set the pump immediately above the top of the well screen or three to 5 feet below the top of the water table. Lower the pump if the water level drops during purging. Record the depth of the pump intake after lowering the pump into location.
4. Connect the cable for the control box to the pump reel. Start the generator. Make sure the generator is kept downwind from the sampling system.
5. Purge the well until at least three borehole volumes are removed. Maintain a purge rate so that recharge water is not entering the well in an agitated manner and the water level in the well does drop below the pump intake. Containerize all purge water.

6. Record field parameters periodically and after each casing volume is purged. Stabilization is considered achieved when three sequential measurements are within the ranges listed below:

   - pH ± 0.1 standard units
   - Specific Conductance ± 3%
   - Temperature ± 3%
   - ORP ± 10 millivolts
   - Turbidity ± 10% (for values greater than 5 NTUs)
   - Dissolved Oxygen ± 10%

   If the indicator parameters have not stabilized after the removal of six casing volumes, field instruments will be recalibrated. If no problems are found, sampling can be conducted; however, the project manager will be notified and all information will be recorded in the field notebook and/or field purge record.
7. If the yield of the well is low such that it can be pumped dry, then the recharged groundwater in the well will be considered representative regardless of the number of casing volumes of groundwater removed. If a well is purged dry, the well may be sampled after 80 percent recovery.

Sampling after Standard Purge

1. Collect samples within 2 hours of purging, if possible. It is acceptable to collect samples within 24 hours of purging. Do not collect samples after 24 hours has passed.

2. Fill necessary sample bottles. Label sample bottles with a unique sample number, time and date of sampling, the initials of the sampler, and the requested analysis on the label. Additionally, provide information pertinent to the preservation materials or chemicals used in the sample. Record comments pertinent to the color and obvious odor. Record sampling information on FSDS sheet and in field logbook.
3. Fill all sample containers with minimal turbulence by allowing the groundwater to flow from the tubing gently down the inside of the container. Immediately seal each sample and place the sample on ice in a cooler to maintain sample temperature preservation requirements. Fill bottles in the following order:

   - Metals and Radionuclides
   - Filtered Metals and Radionuclides
   - Other water-quality parameters.

4. Remove the pump from the well taking care that the tubing does not contact the ground while being retrieved. Decontaminate pump and tubing for next use.
5. Containerize and properly dispose of purge water and decon water generated during sampling.

Sample Analyses

Groundwater samples will be submitted for hydrochemical analysis to analytical laboratories certified by the State of Utah. At a minimum, samples will be analyzed for uranium, molybdenum, selenium, arsenic, TDS, chloride, sulfate, and bicarbonate. Other analyses may be conducted if warranted by conditions encountered during drilling and sampling. The list of hydrochemical parameters and approved analysis methods are given in **Table 1**.

TABLE 1. GROUNDWATER SAMPLING PARAMETER LIST

Parameter [a]	Analytical Method	Lab Reporting Limit [b]	Preserve Method	Holding Time	Container & Size [c]
Total Dissolved Solids	SM 2540C	10	Cool	7 days	Plastic-250 mL
Bicarbonate, as $CaCO_3$ Chloride Sulfate	SM 2320B EPA 300.0 EPA 300.0	5 1 4	Cool	28 days	Plastic-250 mL
Arsenic (As) Molybdenum (Mo) Selenium (Se) Uranium (U)	EPA 200.8[d] EPA 200.8 EPA 200.8 EPA 200.8	0.001 0.1 0.001 0.04	HNO_3	6 months	Plastic-250 mL

[a] Concentration for all parameters in milligrams per liter (mg/L)
[b] Laboratory reporting limits in mg/L and based on Utah regulations and laboratory standard practice.
[c] Containers are abbreviated as: P = plastic. Container size given in milliliters (mL).
[d] All metals will be sampled and reported as dissolved

Sample Filtration

Samples collected for dissolved parameters will be field-filtered using a disposable, in-line, 0.45 micron filter. When the HydraSleeve sampling method is used water will be transferred from a clean unpreserved sample container, through the filter, and into the appropriate preserved sample container using a hand pump or syringe. When sampling using low flow or standard purge methods, the water samples will be pumped through the filter attached directly to the discharge tubing of the groundwater pumping system. A new filter and tubing will be used for each sample.

Quality Control Sampling

Quality Assurance/Quality Control (QA/QC) samples will consist of split samples, duplicate samples, and equipment rinsate blanks. For QA/QC purposes all QA/QC samples will be blind labeled. QA/QC samples will be clearly identified on the field sampling forms.

- Duplicate groundwater samples will be collected at a frequency of 10 percent of the total number of groundwater samples collected.
- A split sample will be collected at one well location using all three sample methods. At this location a second set of sample containers will be filled, and the two sets will be submitted to different laboratories.
- At least two equipment rinsate blanks will be collected to assess the effectiveness of equipment decontamination procedures. Equipment blanks will be prepared by pouring or pumping ASTM Type II reagent-grade water over or through sampling devices after decontamination procedures have been conducted.

Decontamination Procedures

Before use at each location, the submersible pump, temperature, pH, specific conductivity, ORP, dissolved oxygen meters, and depth to water indicators will be washed using a solution of water and Liqui-Nox™ and water, rinsed with potable water, sprayed with methanol or isopropanol, and rinsed a second time with distilled/deionized water.

Investigation Derived Waste

Investigation derived waste (IDW) generated during groundwater sampling will include monitoring well purge water and equipment decontamination water. Purge and decontamination water will be placed in drums (or similar approved containers) and labeled as "Non-Hazardous Waste". The label will also include the accumulation date, facility contact, contact phone number, and a list of the monitoring wells from which the water was derived. The containers will be placed on the RAML property. Water generated during groundwater sampling will be properly disposed following receipt of laboratory analytical results and disposal characterization. The site owner will remain as the generator of all wastes to be disposed, and will sign all transport and disposal manifests as such.

SAMPLE MANAGEMENT

Sample Containers/Sample Handling

The sample containers will be prepared and provided by the analytical laboratory. Samples will be preserved consistent with conditions presented in **Table 1**. The type and size of container used for each parameter and the type of preservative added, if any, will be recorded on the field sampling data form. Sample containers will be placed in an iced cooler immediately after sample collection. The sample containers will be kept closed, maintained under custody, and refrigerated until analysis. Maximum holding times from the time of sample collection until sample analysis are provided in **Table 1**.

Sample Designation and Labeling

All groundwater samples collected from monitoring wells, including any duplicate samples, will be recorded on field sampling data sheets. Each sample will be given a unique blind 4-digit sample identifier. Groundwater samples collected from the same well using different sample methods will be considered distinct samples and will be given unique sample identifiers. Sample containers will be labeled with the sample identifier, project name, data and time of sampling, and sampler's initials.

Sample Custody

At the end of each sampling day and before samples are transferred off site, chain-of-custody entries will be made on the Chain-of-Custody/Laboratory Analysis Request form to document sample custody. Information on the container labels will be compared to the information on the chain-of-custody form and on the field sampling data forms, and the field logbook.

Once a sample is collected, it will remain in the custody of the sampler or other authorized personnel, until it is shipped to the laboratory. Upon transfer of sample possession to subsequent custodians, the persons transferring custody will sign the chain-of-custody form. During interstate transport, the chain-of-custody form will be placed in a resealable plastic bag and accompany each sample cooler to the laboratory. Signed and dated chain-of-custody seals will be placed on coolers prior to shipping. When the samples are received at the laboratory, the custody seal on the shipping container will be broken and the condition of the samples recorded by the laboratory custodian. Chain-of-custody records will be included in the analytical report prepared by each laboratory. Copies of the chain-of-custody records will be retained in the project file.

Upon receipt of the samples, the laboratory will complete the chain-of-custody record. The condition of each sample container will be noted. The laboratory will also maintain a sample-tracking record that will follow each sample through the laboratory process. The sample-tracking record must show the dates of sample extraction or preparation, and sample analysis for each sample. These records will be used to determine compliance with specified holding times.

REFERENCES

American Society for Testing and Materials (ASTM), 2002, **Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations**: D 6771-02. 2002.

U.S. EPA, Region 9, **Standard Operating Procedure for the Standard/Well-Volume Method for Collecting a Ground-Water Sample from Monitoring Wells for Site Characterization**. (Date not specified).

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U.S. EPA, 2002, **Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers**: EPA 542-S-02-001. May 2002.

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