USmag®

US Magnesium LLC
238 North 2200 West - Salt Lake City, UT 84116-2921
801/532-2043 - 800/262-9624 - FACSIMILE 801/534-1407

RECEIVED
DEC 18 2017
SM

Hand Delivered

December 15, 2017

RECEIVED
DEC 15 2017
DEPARTMENT OF
ENVIRONMENTAL QUALITY

Dan Hall, P.G.
Utah Department of Environmental Quality
Division of Water Quality
195 North 1950 West
Salt Lake City, UT 84114-4870

Subject: US Magnesium Groundwater Discharge Permit Application for US Magnesium LLC's Wastewater Pond

Dear Mr. Hall:

Enclosed please find US Magnesium LLC's (USM) Utah Ground Water Discharge Permit (GWDP) Application for the wastewater pond at its Rowley, Utah industrial facility. USM appreciates the Division's October 26, 2017 approval of USM's request for extension of the deadline to submit the application to December 15, 2017. The extension allowed USM's contractor, Stantec, to complete the thorough evaluations presented in the supporting technical reports. Consistent with the GWDP Application form, the enclosure includes the following components:

1. GWDP Application form Parts A and B, including a Process (wastewater) Flow Diagram per Part B, Item 6.
2. Part C Accompanying Reports and Plans
   - Hydrogeologic Report
   - Groundwater Discharge Control Plan, that includes:
     - Attachment A – Corrective Measures Implementation Work Plan
     - Attachment B –Draft Outline for the Construction Quality Assurance Plan
     - Attachment C – Geochemical Report
     - Attachment D – Water Balance Report
     - Attachment E – Groundwater Model Report
     - Attachment F – Barrier Wall Compatibility Testing Proposal
   - Compliance Monitoring Plan
   - Closure and Post-Closure Plan
   - Contingency and Corrective Action Plan

Consistent with your communications with Susan Eyzaguirre of Stantec, one hard copy of the GWDP Application is being submitted to DWQ that is complete with the exception of certain lengthy Appendices to the Hydrogeologic Report (e.g., laboratory data reports and historical boring logs). A flash drive with the complete application, including all document appendices, is also included in the submittal.

DWQ-2017-012861

Please contact me at 801.532.1522 ext. 1355 should you have questions.

Sincerely,

Rob J. Hartman, P.G.
Environmental Manager
US Magnesium LLC

cc: Mark Novak, DWQ (electronic only)
Tom Tripp, USM (electronic only)
Lindsay Ford, PB&L (electronic only)

GROUNDWATER DISCHARGE PERMIT APPLICATION

US MAGNESIUM FACILITY

ROWLEY, UTAH

Prepared for: US Magnesium

Prepared by: Stantec

December 15, 2015

MAIL TO:
Division of Water Quality
Utah Department of Environmental Quality
Salt Lake City, Utah 84114-4870

Application No.:_____
Date Received:_____
(leave both lines blank)

UTAH GROUND WATER DISCHARGE PERMIT APPLICATION

Part A - General Facility Information

Please read and follow carefully the instructions on this application form. Please type or print, except for signatures. This application is to be submitted by the owner or operator of a facility having one or more discharges to groundwater. The application must be signed by an official facility representative who is: the owner, sole proprietor for a sole proprietorship, a general partner, an executive officer of at least the level of vice president for a corporation, or an authorized representative of such executive officer having overall responsibility for the operation of the facility.

1. **Administrative Information.** Enter the information requested in the space provided below, including the name, title and telephone number of an agent at the facility who can answer questions regarding this application.

   Facility Name: US Magnesium LLC - Rowley Plant

   Mail Address: 15 Miles North Exit 77, I-80 Rowley, UT 84074
   (Number & Street, Box and/or Route, City, State, Zip Code)

   Facility Legal Location* County: Tooele County
   T. 2N , R. 8W , Sec. 15 , NE 1/4 of NW 1/4,
   Lat. 40 ° 54 ' 45.0684 "N. Long. 112 ° 43 ' 55.1795 "W
   *Note: A topographic map or detailed aerial photograph should be used in conjunction with a written description to depict the location of the facility, points of ground water discharge, and other relevant features/objects.

   Contact's Name: Rob Hartman Phone No.:(801) 532-1522 ext 1355
   Title: Environmental Manager

2. **Owner/Operator Information.** Enter the information requested below, including the name, title, and phone number of the official representative signing the application.

   Owner
   Name: US Magnesium LLC Phone No.:(801) 532-2043

   Mail Address: 238 N 2200 West Salt Lake City, UT 84116
   (Number & Street, Box and/or Route, City, State, Zip Code)

   Operator
   Name: US Magnesium LLC Phone No.:(801) 532-2043
   (If different than Owner's above)

   Mail Address: 238 N 2200 West Salt Lake City, UT 84116
   (Number & Street, Box and/or Route, City, State, Zip Code)

   Official Representative
   Name: Ron Thayer Phone No.:(801) 532-1522 ext 1349

   Title: President

3. **Facility Classification** (check one)

   [ ] New Facility
   [✓] Existing Facility
   [ ] Modification of Existing Facility

4. **Type of Facility** (check one)

- [x] Industrial
- [ ] Mining
- [ ] Municipal
- [ ] Agricultural Operation
- [ ] Other, please describe: _____

5. **SIC/NAICS Codes:** 3339 - Primary Smelting & Refining of Nonferrous Metals, Except Copper & Aluminum
   Enter Principal 3 Digit Code Numbers Used in Census & Other Government Reports

6. **Projected Facility Life:** 50 years

7. **Identify principal processes used, or services preformed by the facility. Include the principal products produced, and raw materials used by the facility:**
   The facility extracts magnesium from raw materials in Great Salt Lake water by employing evaporative concentration, chemical purification processes and metallurgical processes to produce principal products of elemental magnesium and chlorine (liquid).

8. **List all existing or pending Federal, State, and Local government environmental permits:**

		Permit Number
[ ]	NPDES or UPDES (discharges to surface water)	
[ ]	CAFO (concentrated animal feeding operation)	
[ ]	UIC (underground injection of fluids)	
[ ]	RCRA (hazardous waste)	
[ ]	PDS (air emissions from proposed sources)	
[ ]	Construction Permit (wastewater treatment)	
[x]	Solid Waste Permit (sanitary landfills, incinerators)	45-000379
[ ]	Septic Tank/Drainfield	
[x]	Other, specify Title V Air Permit	4500030002

9. Name, location (Lat.____° ____' ____"N,Long.____° ____' ____"W) and description of: each well/spring (existing, abandoned, or proposed), water usage(past, present, or future); water bodies; drainages; well-head protection areas; drinking water source protection zones according to UAC 309-600; topography; and man-made structures within one mile radius of the point(s) of discharge site. Provide existing well logs (include total depth and variations in water depths).

Name	Location	Description	Status	Usage
Not applicable. No drinking water sources or production wells are located within a one-mile radius of the Facility.				

The above information must be included on a plat map and attached to the application.

Part B - General Discharge Information

Complete the following information for each point of discharge to ground water. If more than one discharge point exists, photocopy and complete this Part B form for each discharge point.

1. **Location** (if different than Facility Location in Part A): County: Tooele
   T._____, R._____, Sec._____, _____1/4 of _____1/4,
   Lat._____° _____' _____"N.Long._____° _____' _____"W

2. **Type of fluid to be Discharged or Potentially Discharged**
   (check as applicable)

   Discharges (fluids discharged to the ground)

   - [ ] Sanitary Wastewater: wastewater from restrooms, toilets, showers and the like
   - [x] Cooling Water: non-contact cooling water, non contact of raw materials, intermediate, final, or waste products
   - [x] Process Wastewater: wastewater used in or generated by an industrial process
   - [ ] Mine Water: water from dewatering operations at mines
   - [x] Other, specify: Stormwater

   Potential Discharges (leachates or other fluids that may discharge to the ground)

   - [ ] Solid Waste Leachates: leachates from solid waste impoundments or landfills
   - [ ] Milling/Mining Leachates: tailings impoundments, mine leaching operations, etc.
   - [ ] Storage Pile Leachates: leachates from storage piles of raw materials, product, or wastes
   - [ ] Potential Underground Tank Leakage: tanks not regulated by UST or RCRA only
   - [ ] Other, specify:_____

3. **Discharge Volumes**
   For each type of discharge checked in #2 above, list the volumes of wastewater discharged to the ground or ground water. Volumes of wastewater should be measured or calculated from water usage. If it is necessary to estimate volumes, enclose the number in parentheses. Average daily volume means the average per operating day: ex. For a discharge of 1,000,000 gallons per year from a facility operating 200 days, the average daily volume is 5,000 gallons.

Discharge Type:	Daily Discharge Volume (Average)	(Maximum)	all in units of
Process and Cooling Water	1,584,000	2,979,400	gallons
Stormwater (estimated)	0	(2,300,000)	gallons

4. **Potential Discharge Volumes**
   For each type of potential discharge checked in #2 above, list the maximum volume of fluid that could be discharged to the ground considering such factors as: liner hydraulic conductivity and operating head conditions, leak detection system sensitivity, leachate collection system efficiency, etc. Attach calculation and raw data used to determine said potential discharge.

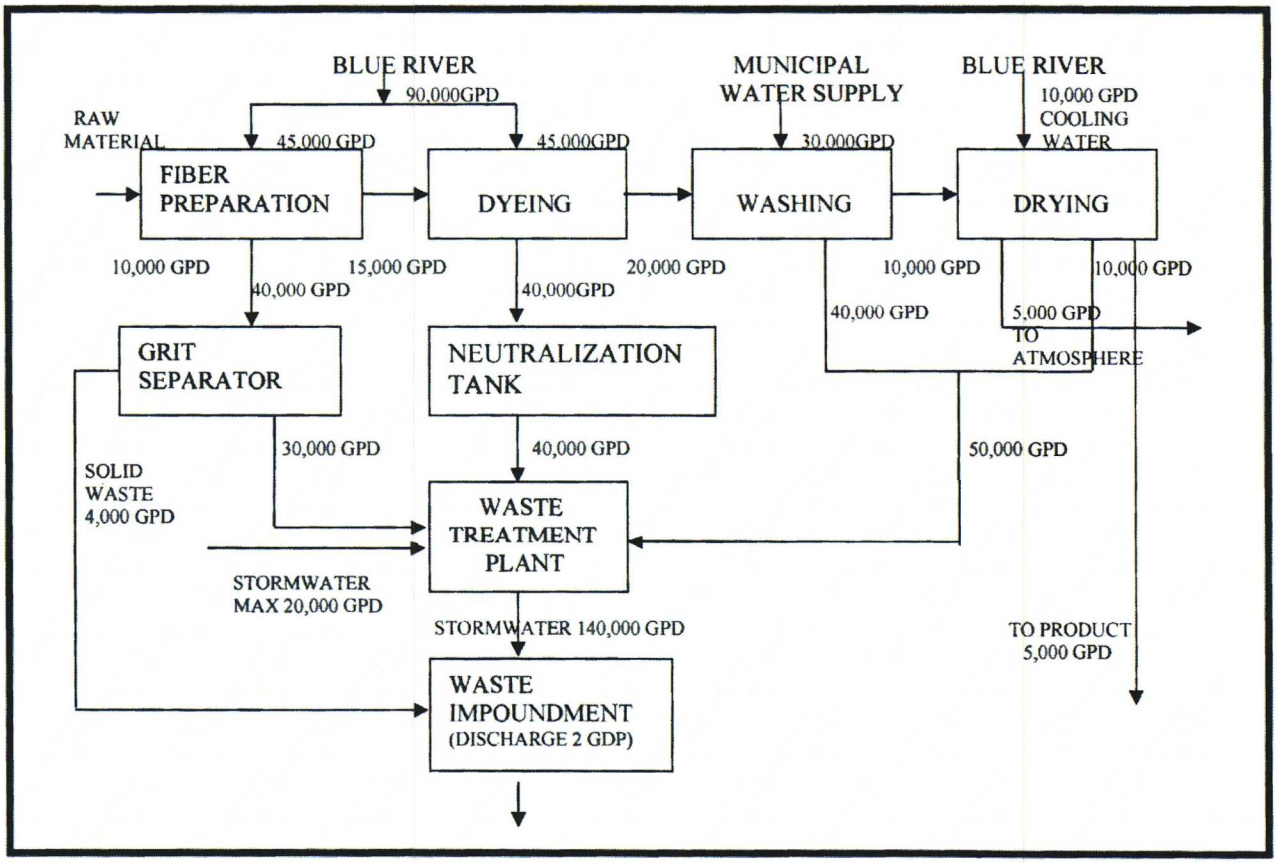
Discharge Type:	Daily Discharge Volume (Average)	(Maximum)	all in units of
Not applicable			

5. Means of Discharge or Potential Discharge (check one or more as applicable)

- [x] lagoon, pit, or surface impoundment (fluids)
- [ ] land application or land treatment
- [ ] discharge to an ephemeral drainage (dry wash, etc.)
- [x] storage pile
- [ ] landfill (industrial or solid wastes)
- [ ] other, specify_____
- [ ] industrial drainfield
- [ ] underground storage tank
- [ ] percolation/infiltration basin
- [ ] mine heap or dump leach
- [ ] mine tailings pond

6. Flows, Sources of Pollution, and Treatment Technologies

Flows. Attach a line drawing showing: 1) water flow through the facility to the ground water discharge point, and 2) sources of fluids, wastes, or solids which accumulate at the potential ground water discharge point. Indicate sources of intake materials or water, operations contributing wastes or wastewater to the effluent, and wastewater treatment units. Construct a water balance on the line drawing by showing average flows between intakes, operations, treatment units, and wastewater outfalls. If a water balance cannot be determined, provide a pictorial description of the nature and amount of any sources of water and any collection or treatment measures. See the following example.



7. Discharge Effluent Characteristics

Established and Proposed Ground Water Quality Standards - Identify wastewater or leachate characteristics by providing the type, source, chemical, physical, radiological, and toxic characteristics of wastewater or leachate to be discharged or potentially discharged to ground water (with lab analytical data if possible). This should include the discharge rate or combination of discharges, and the expected concentrations of any pollutant (mg/l). If more than one discharge point is used, information for each point must be provided.

Hazardous Substances - Review the present hazardous substances found in the Clean Water Act, if applicable. List those substances found or believed present in the discharge or potential discharge.

Part C - Accompanying Reports and Plans

The following reports and plans should be prepared by or under the direction of a professional engineer or other ground water professional. Since ground water permits cover a large variety of discharge activities, the appropriate details and requirements of the following reports and plans will be covered in the pre-design meeting(s). For further instruction refer to the Ground Water Permit Application Guidance Document.

8. Hydrogeologic Report

Provide a Geologic Description, with references used, that includes as appropriate:

Structural Geology – regional and local, particularly faults, fractures, joints and bedding plane joints;
Stratigraphy – geologic formations and thickness, soil types and thickness, depth to bedrock;
Topography – provide a USGS MAP (7 ½ minute series) which clearly identifies legal site location boundaries, indicated 100 year flood plain area and applicable flood control or drainage barriers and surrounding land uses.

Provide a Hydrologic Description, with references used, that includes:
Ground water – depths, flow directions and gradients. Well logs should be included if available. Include name of aquifer, saturated thickness, flow directions, porosity, hydraulic conductivity, and other flow characteristics, hydraulic connection with other aquifers or surface sources, recharge information, water in storage, usage, and the projected aerial extent of the aquifer. Should include projected ground water area of influence affected by the discharge. Provide hydraulic gradient map indicating equal potential head contours and ground water flow lines. Obtain water elevations of nearby wells at the time of the hydrologic investigation. Collect and analyze ground water samples from the uppermost aquifer which underlies the discharge point(s). Historic data can be used if the applicant can demonstrate it meets the requirements contained within this section. Collection points should be hydraulically up and downgradient and within a one-mile radius of the discharge point(s). Ground water analysis should include each element listed in Ground Water Discharge Permit Application, Part B7.
NOTE Failure to analyze for background concentrations of any contaminant of concern in the discharge or potential discharge may result in the Executive Secretary's presumptive determination that zero concentration exist in the background ground water quality.
Sample Collection and Analysis Quality assurance – sample collection and Preservation must meet the requirements of the EPA RCRA Technical Enforcement Guidance Document, OSWER-9959.1, 1986 [UAC R317-6-6.3(I,6)]. Sample analysis must be performed by State of Utah certified laboratories and be certified for each of the parameters of concern. Analytical methods should be selected from the following sources [UAC R317-6-6.3L]: (Standard Methods for the Examination of Water and Wastewater, 20th Ed.,1998; EPA, Methods for Chemical Analysis of Water and Wastes, 1983; Techniques of Water Resources Investigation of the U.S. Geological Survey, 1998, Book 9; EPA Methods published pursuant to 40 CFR Parts 141, 142, 264 (including Appendix IX), and 270. Analytical methods selected should also include minimum detection limits below both the Ground Water Quality Standards and the anticipated ground water protection levels. Data shall be presented in accordance of accepted hydrogeolgic standards and practice.

Provide Agricultural Description, with references used, that includes:
If agricultural crops are grown within legal boundaries of the site the discussion must include: types of crops produced; soil types present; irrigation system; location of livestock confinement areas (existing or abandoned).

Note on Protection Levels:

After the applicant has defined the quality of the fluid to be discharged (Ground Water Discharge Permit Application, Part B), characterized by the local hydrogeologic conditions and determined background ground water quality (Hydrogeologic Report), the Executive Secretary will determine the applicable ground water class, based on: 1) the location of the discharge point within an area of formally classified ground water, or the background value of total dissolved solids. Accordingly, the Executive Secretary will determine applicable protection levels for each pollutant of concern, based on background concentrations and in accordance with UAC R317-6-4.

9. **Ground Water Discharge Control Plan:**
   Select a compliance monitoring method and demonstrate an adequate discharge control system. Listed are some of the Discharge Control Options available.

   No Discharge – prevent any discharge of fluids to the ground water by lining the discharge point with multiple synthetic and clay liners. Such a system would be designed, constructed, and operated to prevent any release of fluids during both the active life and any post-closure period required.

   Earthen Liner – control the volume and rate of effluent seepage by lining the discharge point with a low permeability earthen liner (e.g. clay). Then demonstrate that the receiving ground water, at a point as close as practical to the discharge point, does not or will not exceed the applicable class TDS limits and protection levels* set by the Executive Secretary. This demonstration should also be based on numerical or analytical saturated or unsaturated ground water flow and contaminant transport simulations.

   Effluent Pretreatment – demonstrate that the quality of the raw or treated effluent at the point of discharge or potential discharge does not or will not exceed the applicable ground water class TDS limits and protection levels* set by the Executive Secretary.

   Contaminant Transport/Attenuation – demonstrate that due to subsurface contaminant transport mechanisms at the site, raw or treated effluent does not or will not cause the receiving ground water, at a point as close as possible to the discharge point, to exceed the applicable class TDS limits and protection levels* set by the Executive Secretary.

   Other Methods – demonstrate by some other method, acceptable to the Executive Secretary, that the ground water class TDS limits and protection levels* will be met by the receiving ground water at a point as close as practical to the discharge point.

   *If the applicant has or will apply for an alternate concentration limit (ACL), the ACL may apply instead of the class TDS limits and protection levels.

   Submit a complete set of engineering plans and specifications relating to the construction, modification, and operation of the discharge point or system. Construction Permits for the following types of facilities will satisfy these requirements. They include: municipal waste lagoons; municipal sludge storage and on-site sludge disposal; land application of wastewater effluent; heap leach facilities; other process wastewater treatment equipment or systems.

   Facilities such as storage piles, surface impoundments and landfills must submit engineering plans and specifications for the initial construction or any modification of the facility. This will include the design data and description of the leachate detection, collection and removal system design and construction. Provide provisions for run on and run-off control.

10. **Compliance Monitoring Plan:**
The applicant should demonstrate that the method of compliance monitoring selected meets the following requirements:

Ground Water Monitoring – that the monitoring wells, springs, drains, etc., meet all of the following criteria: is completed exclusively in the same uppermost aquifer that underlies the discharge point(s) and is intercepted by the upgradient background monitoring well; is located hydrologically downgradient of the discharge point(s); designed, constructed, and operated for optimal detection (this will require a hydrogeologic characterization of the area circumscribed by the background sampling point, discharge point and compliance monitoring points); is not located within the radius of influence of any beneficial use public or private water supply; sampling parameters, collection, preservation, and analysis should be the same as background sampling point; ground water flow direction and gradient, background quality at the site, and the quality of the ground water at the compliance monitoring point.

Source Monitoring – must provide early warning of a potential violation of ground water protection levels, and/or class TDS limits and be as or more reliable, effective, and determinate than a viable ground water monitoring network.

Vadose Zone Monitoring Requirements – Should be: used in conjunction with source monitoring; include sampling for all the parameters required for background ground water quality monitoring; the application, design, construction, operation, and maintainence of the monitoring system should conform with the guidelines found in: Vadose Zone Monitoring for Hazardous Waste Sites; June 1983, KT-82-018(R).

Leak Detection Monitoring Requirements – Should not allow any leakage to escape undetected that may cause the receiving ground water the exceed applicable ground water protection levels during the active life and any required post-closure care period of the discharge point. This demonstration may be accomplished through the use of numeric or analytic, saturated or unsaturated, ground water flow or contaminant transport simulations, using actual filed data or conservative assumptions. Provide plans for daily observation or continuous monitoring of the observation sump or other monitoring point and for the reporting of any fluid detected and chemical analysis thereof.

Specific Requirements for Other Methods – Demonstrate that: the method is as or more reliable, effective, and determinate than a vable ground water monitoring well network at detecting any violation of ground water protection levels or class TDS limits, that may be caused by the discharge or potential discharge; the method will provide early warning of a potential violation of ground water protection levels or class TDS limits and meets or exceeds the requirements for vadose zone or leak detection monitoring.

Monitoring well construction and ground water sampling should conform to A Guide to the Selection of Materials for Monitoring Well Construction. Sample collection and preservation, should conform to the EPA RCRA Technical Enforcement Guidance Document, OSWER-9950.1, September, 1986. Sample analysis must be performed by State-certified laboratories by methods outlined in UAC R317-6-6.3L. Analytical methods used should have minimum detection levels which meet or are less than both the ground water quality standards and the anticipated protection levels.

11. **Closure and Post Closure Plan:** The purpose of this plan is to prevent ground water contamination after cessation of the discharge or potential discharge and to monitor the discharge or potential discharge point after closure, as necessary. This plan has to include discussion on: liquids or products, soils and sludges; remediation process; the monitoring of the discharge or potential discharge point(s) after closure of the activity.

12. **Contingency and Corrective Action Plans:** The purpose of this Contingency plan is to outline definitive actions to bring a discharge or potential discharge facility into compliance with the regulations or the permit, should a violation occur. This applies to both new and existing facilities. For existing facilities that may have caused any violations of the Ground Water Quality Standards or class TDS limits as a result of discharges prior to the issuance of the permit, a plan to correct or remedy any contaminated ground water must be included.

    Contingency Plan – This plan should address: cessation of discharge until the cause of the violation can be repaired or corrected; facility remediation to correct the discharge or violation.

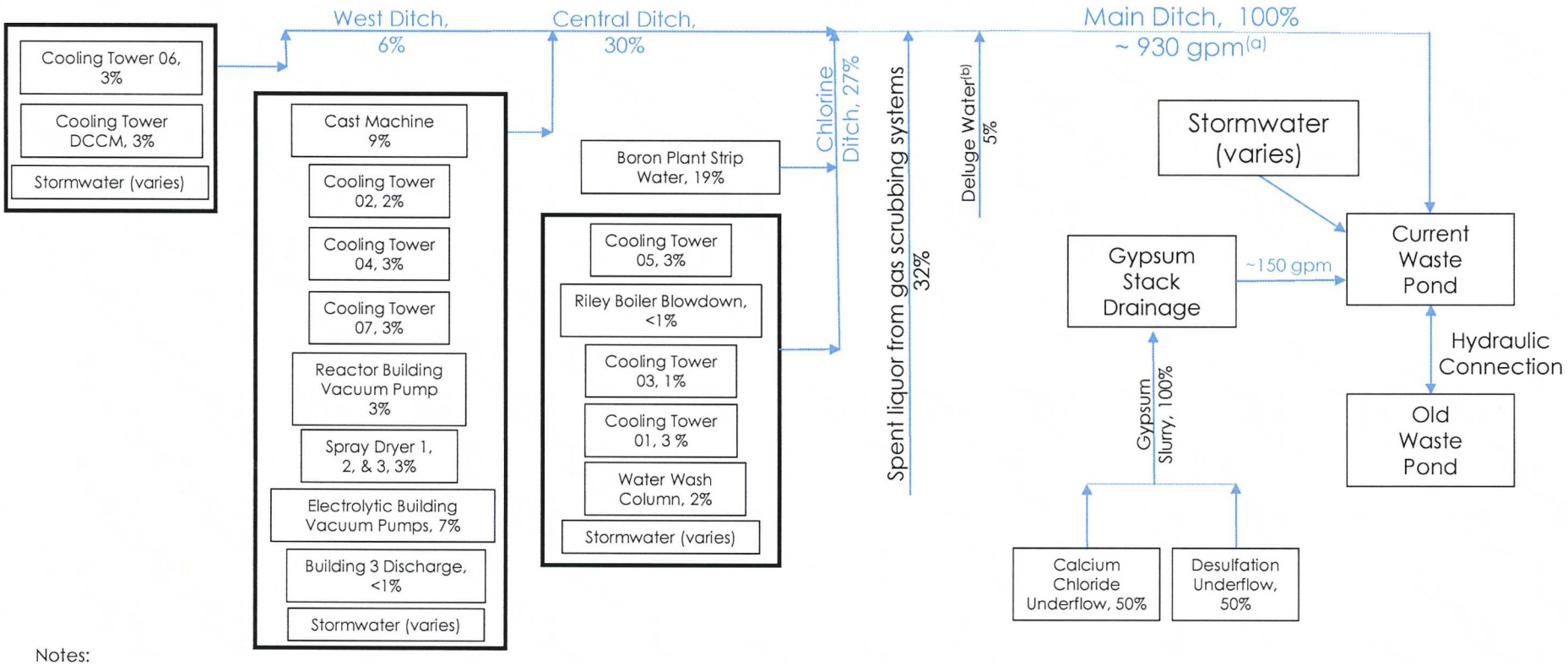
    Corrective Action Plan – for existing facilities that have already violated Ground Water Quality Standards, this plan should include: a characterization of contaminated ground water; facility remediation proposed or ongoing including timetable for work completion; ground water remediation.

Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Ron Thayer, President	(801) 532-1522 ext 1349
NAME & OFFICIAL TITLE (type or print)	PHONE NO. (area code & no.)
Ron Thayer	12/14/17
SIGNATURE	DATE SIGNED

Process Flow Diagram
UTAH GROUNDWATER DISCHARGE PERMIT APPLICATION – DECEMBER 2017
US Magnesium LLC, Rowley, Utah



Notes:

(a) As part of remedial actions, the west, central, chlorine, and main ditches will cease waste water transport. Prior to remediation of the ditches, these flows will be captured in pipe-systems, which will discharge at the Current Waste Pond.

(b) Episodic flow

Hydrogeologic Report

Groundwater Discharge
Permit Application – Part C

Prepared for:
US Magnesium LLC

Prepared by:
Stantec

December 15, 2017

Sign-off Sheet

This document entitled Hydrogeologic Report was prepared by Stantec Inc. ("Stantec") for the account of US Magnesium LLC (US Magnesium). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and US Magnesium. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

Jacob Trauscht

Reviewed by _____

Susan Eyzaguirre, PE, PG

Approved by _____

Hhan Olsen, PG

Table of Contents

1.0 INTRODUCTION 1
1.1 PURPOSE 1
1.2 ORGANIZATION 1
2.0 REGIONAL PHYSICAL SETTING 2
2.1 GREAT SALT LAKE 2
2.2 REGIONAL GEOLOGY 3
2.2.1 Structural Features 3
2.2.2 Stratigraphy 4
2.3 TOPOGRAPHY, CLIMATE, AND VEGETATION 5
2.4 REGIONAL GROUNDWATER 6
2.5 SURFACE WATER HYDROLOGY 7
3.0 GEOLOGY AND HYDROGEOLOGY OF THE CWP/OWP AREA 7
3.1 GEOLOGY AND STRATIGRAPHY OF THE CWP/OWP AREA 8
3.1.1 Stratigraphy of the OWP/CWP Area 9
3.1.2 Deeper Silty Clay Unit 11
3.1.3 Geochemistry of Sediments Below the CWP 11
3.2 GROUNDWATER QUALITY 12
3.2.1 Upper Aquifer Zone Groundwater Quality 13
3.2.2 Lower Aquifer Zone Groundwater Quality 16
3.3 HYDROGEOLOGY OF THE OWP AND CWP AREA 17
3.3.1 Aquifer Properties 17
3.3.2 Groundwater Levels, Flow Direction and Hydraulic Gradients 18
3.3.3 Density Corrections 19
3.4 SURFACE WATER AND GROUNDWATER INTERACTIONS 19
4.0 SUMMARY 20
4.1 CHARACTERIZATION OF SHALLOW AQUIFER AND DEEPER SILTY CLAY UNIT 20
4.2 GENERAL GROUNDWATER QUALITY 21
4.3 SUBSURFACE SOIL GEOCHEMICAL EVALUATION 21
5.0 REFERENCES 22

LIST OF APPENDICES

Appendix A – Geology and Lithology Data
Appendix B – Aquifer Properties Results and Data
Appendix C – Water Quality Field Forms and Lab Data

LIST OF TABLES (follow at end of report)

Table 3-1 Geotechnical Test Results for Undisturbed Soil Samples – June 2017
Table 3-2 Main Ditch and Baseline Groundwater Quality
Table 3-3 Estimates of Hydraulic Parameters from Pneumatic Slug Tests
Table 3-4 Estimates of Hydraulic Parameters from 2017 and Historical Pumping Tests
Table 3-5 Groundwater Elevation Measurements
Table 3-6 Vertical Hydraulic Gradients Across the Deeper Silty Clay Unit

LIST OF FIGURES (follow at end of report)

Figure 1-1 Location Map
Figure 2-1 Surface Area and Volume of Great Salt Lake as a Function of Lake Elevation as Observed at Gilbert Bay (South Arm)
Figure 2-2 USGS Topographic Map of the US Magnesium Site Area
Figure 2-3 Schematic of Groundwater Recharge in the Great Salt Lake Region
Figure 3-1a Site Map and Cross Section Locations
Figure 3-1b Cross Section B-B'-B"
Figure 3-1c Cross Section I-I'
Figure 3-1d Cross Section J-J'
Figure 3-2a Elevation of Top of Deeper Silty Clay Unit
Figure 3-2b Thickness of Deeper Silty Clay Unit
Figure 3-3 Calcium Carbonate Content of Soils Beneath the CWP
Figure 3-4a Potentiometric Surface of the Upper Aquifer Zone (No Density Correction Applied)
Figure 3-4b Potentiometric Surface of the Upper Aquifer Zone (Density Correction Applied)
Figure 3-4c Potentiometric Surface of the Lower Aquifer Zone (No Density Correction Applied)
Figure 3-4d Potentiometric Surface of the Lower Aquifer Zone (No Density Correction Applied)
Figure 3-4e Potentiometric Surface of the Upper Aquifer Zone (No Density Correction Applied)
Figure 3-4f Potentiometric Surface of the Upper Aquifer Zone (Density Correction Applied)
Figure 3-4g Potentiometric Surface of the Lower Aquifer Zone (No Density Correction Applied)
Figure 3-4h Potentiometric Surface of the Lower Aquifer Zone (No Density Correction Applied)
Figure 3-5 Total Dissolved Solids Isocontour Map

Acronyms and Abbreviations

amsl	above mean sea level
bgs	below ground surface
BLM	Bureau of Land Management
cm/s	centimeters per second
CSM	Conceptual Site Model
CWP	Current Waste Pond
DFFSL	Division of Forestry, Fire and State Lands
DWQ	Division of Water Quality
Facility	US Magnesium facility
ft/day	feet per day
ft^2	feet squared
GSL	Great Salt Lake
GWDP	Groundwater Discharge Permit
ID	identification
m/day	meters per day
mg/L	milligrams/liter
mV	millivolts
NOAA	National Oceanic and Atmospheric Administration
OWP	Old Waste Pond
PCB	polychlorinated biphenyls
ppm	parts per million
RI	Remedial Investigation
SVOC	semi-volatile organic compounds
TDS	total dissolved solids
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
UDNR	Utah Division of Natural Resources
USGS	US Geological Survey
VOC	volatile organic compounds

1.0 INTRODUCTION

1.1 PURPOSE

This Hydrogeologic Report fulfills one of the requirements of Part C (Accompanying Reports and Plans) of the Groundwater Discharge Permit (GWDP) application for the US Magnesium facility (Facility) located in Rowley, Utah (**Figure 1-1**). This report follows the guidelines presented in the 'Utah Ground Water Discharge Permit Application' form and the Utah Department of Environmental Quality (UDEQ) Division of Water Quality (DWQ) Ground Water Quality Protection Permitting Information Document (UDEQ, 2006).

The specific purposes of this report are:

- Define and characterize the geologic and hydraulic conditions that control the occurrence and movement of groundwater in the vicinity of the Facility
- Provide a technical foundation for other reports and plans in this application including: Compliance Monitoring Plan, Groundwater Discharge Control Plan, Contingency and/or Corrective Action Plans, and Closure/Post-closure Plans.

Focused groundwater and geochemical investigations were performed to gather specific data related to the shallow aquifer system in the vicinity of the Facility. Subsurface investigations were conducted in 2017 to better characterize three units of the shallow aquifer: the Upper Aquifer Zone, a Deeper Silty Clay Unit (a confining layer), and a Lower Aquifer Zone. The intent was to understand the ability of the Upper Aquifer Zone to receive low-pH wastewater from a proposed Retrofitted Waste Pond (RWP) that will have engineered controls to prevent horizontal migration of the wastewater. The vertical migration of low-pH wastewater will be controlled by the low vertical hydraulic conductivity of the confining layer and from the natural neutralization capacity of the carbonate-rich native lake bed sedimentary deposits below the proposed pond.

The focused investigation data along with data collected historically across the Facility were used to prepare a Discharge Control System conceptual design and other plans in support of the GWDP application.

1.2 ORGANIZATION

The remainder of this report is divided into two primary sections, Section 2.0 describes the regional setting of the facility and includes a description of Great Salt Lake (GSL) (Section 2.1), the regional geology (Section 2.2), the regional topography, vegetation, and climate (Section 2.3), the regional groundwater (Section 2.4) and the regional surface water hydrology (Section 2.5). Section 3.0 focuses on the geology and hydrogeology of the area of the Current Waste Pond (CWP) and Old Waste Pond (OWP) area for which the permit application is intended, including site geology,

lithology, and hydrogeology as well as groundwater quality and groundwater/surface water relationships in the area of the CWP and the OWP.

2.0 REGIONAL PHYSICAL SETTING

The Facility is located along the southwest corner of GSL in northern Utah, approximately 27 miles northwest of the town of Tooele and 11 miles north of Interstate 80 as shown in **Figure 1-1**.

2.1 GREAT SALT LAKE

Great Salt Lake (GSL) is a terminal, shallow saline playa lake and the largest existing remnant of ancient Lake Bonneville, which at one time covered most of western Utah including the US Magnesium Site. GSL receives water inputs from direct precipitation (~31%), groundwater inflow (~3%), and from three major tributaries: the Jordan, Weber, and Bear Rivers (~66%) (USGS, 2007). Due to the terminal nature of the lake, evaporation concentrates the salts delivered by the tributaries, resulting in water that ranges in salinity from 6% to over 27%. GSL is divided into a North Arm (Gunnison Bay) and a South Arm (Gilbert Bay) by the Union Pacific Causeway constructed in 1959, with two culverts that previously allowed minimal flow between the two arms. The three major freshwater sources discussed above flow into the South Arm, with the result that the North Arm has historically had lower water levels and higher salinity than the south arm. In December 2016 Union Pacific constructed a new 180 feet long breach in the causeway to replace the two culverts that had been closed in 2013 due to structural instability. This breach will likely allow an equilibrium to be established resulting in the north and south arms having similar water levels and salinity (UDNR, 2016).

The footprint of GSL averages approximately 75 miles long by 35 miles wide with a corresponding average surface elevation of 4,200 feet above mean sea level (amsl). At this elevation, the lake covers an area of approximately 1,615 square miles (1,034,000 acres) and has an average depth of about 14 feet with a maximum depth of about 33 feet (DFFSL, 2013). Due to the shallow nature of the lake, relatively small changes in water levels can result in significant changes in the surface area (**Figure 2-1**). On average, the lake level fluctuates one to two feet annually, rising to its highest level typically during March through May (following the melting of mountain snowpack) and dropping to its lowest point during October through November. Since recording of lake levels began (1847 to present), fluctuations of the lake level have varied over a range of 20 feet from a low of 4,191.35 feet amsl in 1963 to a high of 4,211.85 feet amsl in 1986-1987, with a historical average elevation of around 4,200 feet amsl. At the lake's maximum recorded high of 4,211.85 feet amsl, the lake covered an area of approximately 2,300 square miles (1,472,000 acres) and had a maximum depth of about 45 feet (USGS, 2017a). The lake was measured at approximately 4,194 feet amsl in November 2017, corresponding to approximately 1,500 square miles (960,00 acres) (**Figure 2-1**).

The Plant site is situated at an elevation of approximately 4,220 feet amsl, or about eight feet above the maximum-recorded lake elevation. In order for the lake to reach a level of 4,220 feet amsl, it would need a maximum extent of approximately 3,000 square miles (1,919,940 acres), or a 30-percent increase over its historic high elevation. Water levels measured at the Saltair Boat Harbor along the southern shore indicate a 10-year low in lake levels was reached in 2016 (~4,192 ft amsl) feet and was at 4,194 feet amsl during November 2017 (USGS, 2017a).

Salinity of GSL is inversely proportional to lake level, with increasing freshwater inflows resulting in lower salinity water (USGS, 2017b). Because the south arm has historically had more freshwater inputs than the north arm, the salinity of water in the south arm has historically varied more than the salinity in the north; however, seasonal variations are observed in both arms. A 1960 study estimated 2.7 million metric tons of salt annually loading into GSL; however, more recent studies estimate that load to be much higher, likely closer to 14 million metric tons per year (Shope, 2013).

2.2 REGIONAL GEOLOGY

The US Magnesium site is located in northwestern Utah in the Basin and Range Province of the western United States, is within three to five miles of the present GSL shoreline, and is about 60 miles west of the north-south-trending Wasatch Mountain Range. The site is located within the Basin and Range Province, which is characterized by a series of nearly parallel, north-south-oriented mountain ranges separated by wide sediment-filled basins. The Basin and Range province extends westward through Utah and Nevada to the Sierra Nevada Range in California and is bounded on the east by the Wasatch Mountains. In general, the mountain ranges are complex, maturely dissected fault blocks that have been upthrown and tilted to the east. Interconnecting valley basins comprise the downthrown fault blocks (graben valleys) and are filled with unconsolidated sediments derived from the adjoining mountain ranges (MWH, 2004).

The site is located within one of the valley basins known as Lakeside Valley, which is an extension of Skull Valley. Skull Valley is characteristic of other basins in the province, except for the features of GSL, which comprises the eastern portion of the valley and covers most of the northern portions of the coalescing Tooele Valley east of Skull Valley. The Lakeside Mountain Range borders Lakeside Valley and Skull Valley on the west and is located approximately four miles west of the site, as shown on **Figure 2-2**. The Great Salt Lake Desert is located about 25 miles to the west of the site and extends west to the Utah-Nevada state line.

2.2.1 Structural Features

As previously described, the site lies within a downthrown sediment-filled graben valley. Faulting near the site is generally confined to the Lakeside Mountains. Considerable activity has occurred along this range, causing irregular displacements and offsetting of the tilted, generally westward-dipping strata. Stansbury Island, located about ten miles

to the east of the site, is also crossed with faults that have caused disturbance and offsetting of rock strata. The most prominent structural feature in the area of GSL is the Wasatch Fault Zone, situated about 60 miles to the east of the site.

2.2.2 Stratigraphy

There are four major soil types known to be present in this area of the Great Salt Lake Basin:

- Calcareous clays, silts and fine sands (including oolitic sand) are the most abundant sediments encountered at the site as described by Dames & Moore during exploration drilling as part of geotechnical investigations conducted at the site (Dames and Moore, 1969, 1970a, 1970b, 1971, 1972).
- Oolitic sands – found in varying abundance in the calcareous fine sands, with the most abundant occurrence found in silty cemented sands at approximately 15 feet below ground surface (bgs).
- Algal reefs – encountered in the same silty cemented sands.
- Saline precipitates – encountered in thin layers and fragments within the calcareous fine sands.

Under the present depositional environments, the calcareous clays, silts, and fine sands can be found on the presently occupied lake bottom and in the barren mud flats that surround most of the lake. Oolitic sand deposits can be found in areas of shallow water, along shorelines, and in adjoining areas where re-deposition has occurred due to wind activity. Algal reef deposits are the result of biochemical precipitates of calcium carbonate formed where conditions are favorable for the growth of blue-green algae. Saline deposits, both soluble and insoluble, are precipitated along the shoreline and on the bottom of the lake (MWH, 2004).

Shoreline terrace deposits characteristic of each of the four major stages of former Lake Bonneville are present at their respective elevations along the eastern face of the Lakeside Mountains. The highest level (Bonneville Stage) exists near 5,200 feet amsl, around 1,000 feet above the US Magnesium facility elevation. Evidence of the intermediate Lake Bonneville levels (Provo and Stansbury Stages) have largely been erased since deposition due to erosion. Recent deposits of alluvial and eolian soils are intermixed with lake sediments in the higher shoreline areas adjoining the mountain ranges.

Consolidated sediments (rock) at the site are not present at the surface, nor were they encountered within the maximum depth penetrated during pre-plant construction drilling operations at the site (Dames & Moore, 1969, 1970a, 1970b, 1971, and 1972). However, bedrock has been encountered at a depth of 116 feet below ground surface (feet bgs) approximately 2.3 miles west of the site (See **Appendix** A for well borings).

The Lakeside Mountains and adjoining Stansbury Mountains are comprised mostly of Paleozoic deposits and consist of sediments ranging from limestone, dolomite, and shales to quartzitic sandstones and conglomerates (Young, 1955).

2.3 TOPOGRAPHY, CLIMATE, AND VEGETATION

The site area slopes very gently to the east-northeast toward the barren mud flats that bound the site on the east. Maximum relief, as measured from a topographic map of the area, is approximately eight feet (**Figure 2-2**). The most prominent topographic feature is a crescent-shaped dune that is located in the center of the site.

The area is semi-arid in nature, with the greatest amounts of precipitation occurring during the late-winter and early-spring months. Annual average precipitation at the Facility from 2012 to 2015 was measured at 7.24 inches, while precipitation at three nearby National Oceanic and Atmospheric Administration (NOAA) weather stations (Utah Test Range, Grantsville, and Antelope Island) range from 9 to 14 inches per year.

Vegetation consists of cheat grass, minor amounts of perennial grasses, shad scale, salt cedar, sagebrush, and greasewood. Site specific vegetation is described in the *Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model* report (ERM, 2016) based on information from the Utah Department of Natural Resources, Division of Forestry, Fire and State Lands (DFFSL, 2013).

The primary habitats associated with the US Magnesium facility are:

- Mudflats and Playas – These aquatic habitats dominate the GSL shoreline. Mudflats may have no vegetation cover; playas are created by GSL water fluctuations and have limited vegetation cover (5 to 25 percent) and a characteristic salt accumulation on the soil surface. Vegetation typically observed in wetland playas consists of halophytes such as iodine bush (Allenrolfea occidentalis), pickleweed (Salicornia spp.), seepweed (Suaeda spp.), greasewood (Sarcobatus vermiculatus), saltgrass (Distichlis spicata), and saltbush (Atriplex spp.) (DFFSL, 2013).
- Uplands – Upland habitats are found at slightly higher elevations than GSL wetlands and are characterized by dry ground and grasses, forbs, and shrubs. GSL uplands are typically dominated by shadscale (Atriplex confertifolia)-greasewood associations, but are often a mixture of shrublands, grasslands, and barren areas (DFFSL, 2013).
- Dunes and Sand Bars - Dunes and sand bars along the shore of GSL are composed of white, calcareous oolitic sand. Vegetation is usually restricted to shoreline areas with infrequent waves and flooding. Vegetation on dunes and sandbars may be distinct from surrounding playas and uplands, or may contain a mixture of upland- wetland species (DFFSL, 2013).

- Dikes, Levees, and Human-Made Structures – When present, vegetation on these structures varies from a mixture of wetland and upland species, to upland shrublands and grasslands (DFFSL, 2013).

No agricultural crops, irrigation systems, or confined livestock areas are located within the Facility boundaries or on adjacent property.

2.4 REGIONAL GROUNDWATER

Groundwater in the Skull Valley region is typical of basin/range recharge, wherein groundwater is derived entirely from precipitation that falls within the drainage basin, primarily from snowmelt and rainfall on lands above 6,000 feet (**Figure 2-3**). Water is conveyed from the mountains to the unconsolidated valley sediments as discharge from bedrock or losses and underflow from the streams that drain from the mountains. Recharge to groundwater occurs through consolidated rocks in and near the mountains (bedrock) and unconsolidated valley sediments (**Figure 2-3**) (Hood and Waddell, 1968).

Groundwater in the unconsolidated sediments in nearby large valleys (e.g., Tooele Valley, Salt Lake Valley, Utah Valley) typically occurs in a shallow unconfined aquifer toward the center of the valleys that overlies one or more artesian aquifers in the Lake Bonneville and the older (deeper) valley-fill deposits. Closer to the mountain flanks, the confining bed and shallow aquifer are typically absent, where groundwater is encountered at a greater depth and is unconfined; this deeper groundwater is an unconfined portion of the principal aquifer that is under artesian pressure further into the valleys. The deep confined (artesian) and unconfined aquifer near the mountains represent the principal aquifer (Hely et al., 1971). Near the mouths of the mountain canyon drainages, lenticular and discontinuous (perched) aquifers often exist in the permeable deposits of buried stream channels. Within the valley bottoms the shallow aquifer is generally defined as the uppermost permeable unit within the unconsolidated lake sediments and it typically overlies a low permeability bed that confines the principal (artesian) aquifer (Hely et al., 1971).

The principal aquifer has not been encountered during historical investigations in the vicinity of the Facility, however a shallow aquifer is evident. The shallow aquifer extends from the bedrock mountain front of the Lakeside Mountains easterly to GSL and is composed of Quaternary clay, silt, and sand with increasing sands and gravels immediately west of the site. The shallow aquifer can be either confined or unconfined depending on the presence of low-permeability interbeds within the aquifer. The unconfined portion of the shallow aquifer has been encountered to roughly 35 feet bgs and is referred to as the upper portion of the shallow aquifer (Upper Aquifer Zone), and below this confined portions of the shallow aquifer have been encountered to approximately 100 feet and are referred to as the lower portion of the shallow aquifer (Lower Aquifer Zone). A low-permeability silty clay confining unit (Deeper Silty Clay Unit)

is present between the Upper Aquifer Zone and Lower Aquifer Zone that is pervasive across the Facility.

2.5 SURFACE WATER HYDROLOGY

Surface water in Skull Valley consists of four known perennial streams (Barlow, Indian Hickman, Antelope and Lost Creeks), all of which drain from the Stansbury Mountains south of the site (MWH, 2004). These streams supply water to ranches in Townships 3-6 South, Range 8 West, and to the Skull Valley Indian Reservation (Hood and Waddell, 1968). Perennial streams do not flow through or near the Facility; however, seasonal and occasional surface water flow occurs west of the Facility in the Lakeside Mountains originating from seasonal springs and snowmelt that discharge into canyons along the eastern flank of the Lakeside Mountains. These include Parch, Mountain Sheep, Peepstone, Vindicator, Craner and Carter Canyons as shown on **Figure 2-2**.

3.0 GEOLOGY AND HYDROGEOLOGY OF THE CWP/OWP AREA

Several prior investigations have been used to develop conceptual geological and hydrogeological models for the CWP and OWP general area as well as a computer groundwater flow model that is documented in the Groundwater Discharge Control Plan for the GWDP application (Stantec, 2017). These investigations include, but are not limited to, Dames & Moore (1969a, 1969b, 1970a, 1970b, 1971, and 1972), MWH (2004 and 2015), ERM (2016), and most recently the focused investigations performed by Stantec in June/July 2017.

The 2017 investigation was performed for the purpose of filling data gaps in support of a GWDP application prepared for submittal to the DWQ. Data were collected to support the conceptual hydrogeologic model for the CWP/OWP area as well as a computer groundwater flow model intended to support the groundwater discharge control system proposed in the GWDP application. (A groundwater flow model report is included as an attachment to the Groundwater Discharge Control Plan [Stantec, 2017], a component plan of the GWDP application.) The 2017 subsurface investigations consisted of:

1. Drilling of seven boreholes to obtain lithological and geochemical data of the soils adjacent to and beneath the CWP

2. Installation of four new monitoring wells for the following purposes:
    - Obtaining lithological and geochemical data of soils along the eastern embankment of the CWP
    - Conducting an aquifer pumping test
    - Obtaining baseline groundwater quality data (for future GWDP compliance monitoring).

3. Performing a pumping test at MW-22B (a new monitoring well installed in June 2017) in order to characterize the Lower Aquifer Zone and to observe potential responses in Upper Aquifer Zone wells (**Appendix B**)

4. Performing pneumatic slug tests at ten wells across the Facility to obtain hydraulic conductivity data to support updating of the hydrogeologic conceptual model and preparing input for a planned numerical groundwater flow model (**Appendix B**)

5. Collecting groundwater level measurements (seasonally) to understand seasonal variability of groundwater levels and support the planned groundwater flow model (**Appendix D**)

6. Collecting and analyzing groundwater samples from ten wells along the eastern dike to characterize the baseline groundwater quality in the area of the CWP (**Appendix C**)

7. Collecting and analyzing water samples from the combined Facility wastewater ditch to compare source water quality with groundwater quality results (**Appendix C**)

3.1 GEOLOGY AND STRATIGRAPHY OF THE CWP/OWP AREA

Recent and historical investigations have characterized the geology beneath the CWP/OWP to a depth of approximately 100 feet bgs. The geology beneath the CWP/OWP includes a variety of sediments deposited during historical lake periods dating back to ancient Lake Bonneville, and consists of continuous and discontinuous layers of oolite-containing sands/silty sands/fine-grained sands, clays/silty clays as well as cemented and un-cemented gravel. Stratigraphic units within the area generally slope towards the east, with units being encountered at shallower depths on the west side than on the east side of the CWP/OWP. Notably the sediments beneath the pond include two layers of low-permeability clay/silty clay, the deeper of which (the Deeper Silty Clay Unit), was confirmed during the 2017 investigation to be continuous throughout the CWP/OWP area. The Deeper Silty Clay Unit effectively acts as a confining bed, dividing the shallow aquifer beneath the CWP/OWP into two units, the Upper Shallow Aquifer Zone (Upper Aquifer Zone) and the Lower Shallow Aquifer Zone (Lower Aquifer Zone). In general the stratigraphy beneath the CWP/OWP consists of the following:

- Ground Surface to less than 5 feet bgs: Fine-grained sand, silt/sandy silt/clayey silt with areas of oolitic sands and imported fill material in most boring locations.
- Approximately 5 to 10 feet bgs: Low to medium plasticity clay/silty clay varying in thickness from 2 to 8 feet.

- Approximately 10 to 35 feet bgs: Silty/fine-grained sand, oolitic in part, interbedded with silt and clay, oolitic in part; gravel and cemented gravel present in top 5 feet.
- Approximately 35 to 55 feet bgs: Low to medium plasticity clay/silty clay layer. This Deeper Silty Clay Unit ranges in thickness between 11 and 18 feet in the CWP/OWP area, and generally is encountered at greater depths and thickens towards the east side of the CWP (refer to Section 3.1.2.)
- Greater than approximately 55 feet bgs: Silty sand/fine-grained sand interbedded with lenses and layers of low to medium plasticity clay/silty clay.

No bedrock nor evidence of the principal artesian aquifer were found in boreholes completed beneath the CWP/OWP area, however bedrock has been encountered west of the site as described below.

Most of the sediments underlying the CWP/OWP consist of a percentage of carbonate, an important consideration as the low-pH wastewater discharged to the CWP is potentially reactive with these carbonate containing sediments. Stratigraphy of the CWP/OWP area, including geochemistry of the sediments, is discussed in more detail below in Sections 3.1.1 through 3.1.3.

3.1.1 Stratigraphy of the OWP/CWP Area

Information from the 2017 subsurface investigation was utilized to update and expand portions of the site-wide conceptual geologic setting that was described in the 2016 Hydrgologic Conceptual Site Model (CSM) report (ERM, 2016). As part of the 2016 CSM report a series of geologic cross sections were developed (**Figure 3-1a**, A-A' through H-H'). To support the GWDP application, data from the 2017 drilling activities were used to extend cross-section B-B' through the upland area, and create two new cross-sections, J-J' and I-I' (**Figures 3-1b, c & d**). These three cross sections are shown in **Figures 3-1b, c**, and **d**, and are described below.

3.1.1.1. Cross Section B-B'-B" (Figure 3-1b). Cross section B-B', originally produced in 2016, has been extended through the upland area towards the Lakeside Mountains west of the site to point B" utilizing historic data from wells drilled on Bureau of Land Management (BLM) and private property west of the Facility. (Refer to **Appendix A** for drilling logs of new as well as historical wells/borings.) This B-B'-B" cross section summarizes the subsurface lithology across the site from the foot of the Lakeside Mountains to the eastern terminus of the OWP.

A number of off-site wells were drilled by Desert Power Company to deeper depths for water production purposes in the upland area towards the Lakeside Mountains. Although the well logs do not provide detailed data of the alluvial sediments encountered, depths to bedrock were recorded on these well logs and have proved useful and thus were incorporated into cross section B-B'-B". The deepest boring in this upland area (well 35129) was drilled to 323 feet bgs yet did not encounter the principal

aquifer discussed in the Regional Groundwater section of this report (Section 2.4), but did encounter limestone bedrock at approximately 220 feet bgs. Depth to groundwater measurements were recorded for many of these wells and are also shown on this cross-section, but should be considered as estimated depths. This limestone bedrock rises sharply towards the west where it is encountered approximately 150 feet higher at well 35212 which is located furthest west, approximately ½ mile west of well 35126.

From the location of soil boring SB-7 (drilled in June 2017), located just west of the Facility, eastward the stratigraphy is relatively well known for the first 100 feet bgs, with four primary units that all generally dip towards the east. A continuous layer of clay/silty clay is present near or at the surface, occasionally overlain by a thin layer of silty sand/fine-grained sand that includes oolitic sands, notably near the CWP. Below this is a relatively continuous layer of well-graded sand, oolitic in part, that also includes occasional gravel and cemented gravel. This layer thickens substantially east of the CWP. Below this lies a thicker layer of silty sand/fine-grained sand that also includes oolites, as the sandy units above. This layer is relatively continuous in thickness beneath the Facility, but thins out near the east side of the OWP. A second, thicker layer of low to medium plasticity clay/silty clay (the Deeper Silty Clay Unit) lies beneath this layer and is continuous from west of the Facility to the east side of the OWP. Below the Deeper Silty Clay Unit is a continuous layer of silty sand and fine-grained sand which contain oolites as do the sandy layers above. Below this are alternating layers of clay, silty clay, fine-grained sands and silty sands, and gravel extending to the maximum boring depths.

3.1.1.2. Cross Section I-I' (Figure 3-1c). Cross section I-I' extends through the eastern edge of the CWP utilizing historical drilling logs as well as new information obtained during the 2017 subsurface investigations (drilling logs are included in **Appendix A**). The stratigraphy at this location is important because it confirms the continuous extent and thickness of the Deeper Silty Clay Unit beneath the CWP/OWP. Confirming trends identified in **Figure 3-1b**, the layers generally dip towards the east. A layer of oolite-containing silty sand/fine-grained sand overlies an upper unit of low to medium plasticity clay and silty clay, with a layer of oolite-containing sand and partly cemented gravel below that thickens towards the southeast. Below this is a 15 to 25 feet thick layer of silty-sand/fine-grained sand that overlies the Deeper Silty Clay Unit which is found across the extent of cross section I-I' and varies in thickness from 15 to 20 feet. Beneath the Deeper Silty Clay Unit are layers of silty sand/fine-grained sand interbedded with clays extending to the maximum boring depths.

3.1.1.3. Cross Section J-J' (Figure 3-1d). The stratigraphy beneath the northern extent of the CWP/OWP is presented in cross section J-J', which generally dips towards the east as also seen in **Figures 3-1b** and **c**. The shallow clay/silty-clay layer found in **Figures 3-1 b** and **c** is largely not present, with the partly oolitic fine-grained sands being the first unit encountered near the CWP, overlying a 12 to 24 feet thick layer of partly oolitic silty

sand/fine-grained sand. The Deeper Silty Clay Unit is continuous beneath this layer from 20 to 40 feet bgs, with greater depths towards the east.

3.1.2 Deeper Silty Clay Unit

The CWP/OWP area is underlain by two stratigraphic units of low to medium plasticity clay/silty clay, one near the surface (5-10 feet bgs) and one, the Deeper Silty Clay Unit, found further beneath the surface (in the approximate depth range of 35-55 feet bgs). Historical operations at the pond, notably the construction of the eastern dike of the CWP in 1990 in response to GSL flooding, have likely impacted the shallow silty clay unit, particularly along the northern embankment (**Figure 3-1d**)(ERM, 2016).

The Deeper Silty Clay Unit consists of low to medium plasticity clay and silty clays, and historical borings as well as the subsurface investigations of 2017 have confirmed the spatial continuity of the layer beneath the CWP/OWP as indicated on contour maps presented in **Figures 3-2a&b**. The Deeper Silty Clay Unit generally dips towards the east, with the top of the unit varying in elevation from 4208 feet amsl at its estimated western extent approximately 1.2 miles west of the Facility, to 4168 feet amsl along the eastern edge of the OWP (**Figure 3-2a**).

The thickness of the Deeper Silty Clay Unit varies between approximately 11 and 18 feet in thickness in the area of the CWP/OWP and increases from west to east across the site (**Figure 3-2b**). Variations in the top and bottom elevations of the Deeper Silty Clay near the main plant site and office buildings likely reflect the density of historical geotechnical borings drilled in this area prior to construction of the Facility when the surface grade and elevation differed from current conditions and also are likely influenced by the sampling interval used (i.e. every five feet versus continuous sampling). Based on recent and historical drilling data, the Deeper Silty Clay Unit is estimated to be 10 to 18 feet thick beneath the CWP/OWP area (**Figure 3-2b**). In addition to verifying the spatial continuality of the Deeper Silty Clay Unit, the 2017 subsurface investigations also included obtaining samples of the Unit for geotechnical laboratory tests (**Table 3-1**). These samples indicate the Deeper Silty Clay Unit to be a medium to high plastic clay (Plasticity Index of 12-28 %) with a low percentage of sand (average <9%) and high percentage of fines (average >91%) (**Table 3-1**).

Undisturbed samples of the Deeper Silty Clay Unit sediments were found to have relatively high porosity with an average value of 43%, and low vertical hydraulic conductivities ($8x10^{-5}$ to $3x10^{-4}$ ft/day [$3x10^{-8}$ to $1x10^{-7}$ cm/s]), indicating the Deeper Silty Clay Unit effectively impedes hydraulic interaction between the Upper and Lower Aquifer Zones (**Table 3-1**). (Aquifer properties of the shallow aquifer, both Upper and Lower Aquifer Zones, are discussed in Section 3.3.1.)

3.1.3 Geochemistry of Sediments Below the CWP

Due to the presence of low-pH water in the CWP, the geochemical characteristics of the sediments beneath the CWP are of importance to the relationship between surface

water and subsurface sediments/soils and lithology, specifically the presence of potentially reactive sediments.

Clay mineralogy analyses of the Deeper Silty Clay Unit (depths approximately 35 to 55 feet bgs) identified the majority of the clay to be composed of quartz, calcite, aragonite, dolomite, halite, plagioclase, mica/illite, and smectite.

Calcium carbonate equivalency beneath the CWP, an indication of potential reactivity of the sediments with low-pH water, range from 20-80 percent by weight (weight %) within the upper 20 feet and 10-50 weight% from 20 feet to 65 feet beneath the pond (**Figure 3-3**). Calcium carbonate laboratory analyses indicate overall carbonate content within the Deeper Silty Clay Unit ranges from approximately 11 to 43 percent by weight. (Refer to the Groundwater Discharge Control Plan [Stantec, 2017] for a full presentation of geochemical analyses results and detailed evaluation.)

The presence of significant percentages of carbonate in the sediments underlying the CWP act to buffer the pH in the groundwater, resulting in neutral to slightly acidic groundwater (pH > 5) despite proximity to the low pH (pH < 2) impoundment waters (refer to Section 3.2 for a more detailed discussion of groundwater quality). However, the carbonate containing sediments also are susceptible to dissolution due to the same reactions that buffer the pH. An estimate of the remaining buffering capacity of soils beneath the CWP and the Deeper Silty Clay Unit itself is 155 and 460 years assuming constant exposure to impacted waters with an average pH of 0.59 (Stantec, 2017).

3.2 GROUNDWATER QUALITY

Groundwater beneath the Facility is not considered acceptable for human consumption (Utah Administrative Code [UAC] R309-200 & R317-6-4.7), and due to naturally occurring total dissolved solids (TDS) concentrations above 10,000 milligrams per liter (mg/L) the groundwater is classified as Class IV (Saline) per UDEQ standards. Consequently, GWDP groundwater protection levels are not prescribed but are to be "established to protect human health and environment." TDS concentrations near the CWP in the Upper Aquifer Zone range from 29,000 mg/L (MW-6) on the west side of the CWP to 300,000 mg/L (PZ-01) to the east, while concentrations in the Lower Shallow Aquifer Zone are generally greater than 100,000 mg/L in the CWP area ranging from 56,000 to 160,000 mg/L.

In general, water quality in wells screened in the Upper Aquifer Zone immediately downgradient of the CWP are influenced by Facility wastewater while wells located upgradient of the CWP are not influenced by Facility wastewater. However, wells downgradient of the CWP that are screened near the bottom of the Upper Aquifer Zone and within the Lower Aquifer Zone, are not influenced by facility wastewater.

The following sections describe groundwater quality at the site by summarizing findings of historical investigations, including MWH work in 2004, 2005 and 2015 and ERM in 2014/2015, as well as the recent 2017 field investigation. Section 3.2.2 summarizes results

of three groundwater sampling rounds performed at the three wells installed in the Lower Aquifer Zone during the 2017 field effort. For a more detailed analysis of groundwater quality the CWP/OWP area, refer to the 2016 *Hydrologic Conceptual Site Model* (MWH 2005, 2015 & ERM, 2016).

3.2.1 Upper Aquifer Zone Groundwater Quality

Groundwater investigations at the Facility began in 2003 for the purposes of updating the hydrogeologic CSM and to acquire baseline data for design and implementation of a groundwater monitoring plan (MWH, 2006). Four quarterly groundwater monitoring events were performed during 2004 and 2005 and included analyses of both organic and inorganic constituents. Since that time additional groundwater sampling rounds have been performed including field activities conducted in 2014 and 2015 in support of the 2016 pond area Hydrologic Conceptual Site Model (ERM, 2016), sampling in the upland area in 2015 in support of a feasibility study for a new waste pond (MWH, 2015), and most recently groundwater sampling in 2017 in support of the GWDP application. Except for the 2017 work, these investigations primarily focused on wells screened above the Deeper Silty Clay Unit in the Upper Aquifer Zone. Section 3.2.2 discusses findings of the 2017 sampling events which included newly installed wells screened in the Lower Aquifer Zone.

3.2.1.1. General Water Quality. Groundwater beneath the site is generally classified as Class IV (Saline) groundwater (TDS >10,000 mg/L), with higher TDS concentrations observed (>100,000 mg/L) in deeper wells (**Figure 3-5**). Samples collected in 2017 confirm these findings with TDS results ranging from 32,000 mg/L to 100,000 mg/L, and a maximum TDS concentration detected at MW-22A which is screened at the bottom of the Upper Aquifer Zone (**Table 3-2**).

Groundwater across the site is typical of reducing conditions. Historical data indicate oxygen reduction potential (ORP) values of -129 to -413 millivolts [mV]) which are compatible with dissolved oxygen concentrations historically measured across the site (average of 0.90 parts per million (ppm)). Results from samples collected in 2017 confirm reducing conditions in the groundwater (ORP average of -215 mV) and average dissolved oxygen of 0.6 mg/L (**Table 3-2**).

3.2.1.2. pH. Field pH measurements of shallow groundwater samples collected upgradient of The Facility (PZ-4, PMW-1S) are higher than of those near the CWP (PZ-8, PZ-26, MW-13A, MW-14 and MW-15A). In addition, comparison of pH measured in 2005 to measurements of pH made in 2015 show a decrease in pH over time.

Monitoring Well	Relative Location to CWP	Monitoring Dates	pH	Change
PZ-8	Downgradient	6/1/2005 7/14/2015	7.40 5.42	-1.98
PZ-26	Cross Gradient	6/1/2005 7/14/2015	6.73 5.43	-1.30
PZ-3	Upgradient	5/26/2005 7/14/2015	7.40 6.80	-0.60

Measurements of pH ranged from 5.1 to 7.8 during 2017 sampling events, with pH at PZ-8 averaging 5.8 indicating that the buffering capacity at this location has not changed substantially since 2015. Measured pH at MW-22A, screened just above the Deeper Silty Clay Unit, is consistently higher than wells screened over shallower depths of the Upper Aquifer Zone (**Table 3-2**).

3.2.1.3. Anions/Cations. Groundwater at the site can broadly be grouped into two categories, those generally non-impacted by wastewater (i.e. wastewater discharge and waters of the CWP) and those impacted. These waters fall into two groups defined by their dominant anions/cations. The impacted group located adjacent to and downgradient of the CWP (PZ-16, PZ-10, & PZ-12) is dominated by $Ca^{2+}/Mg^{2+}/Cl^-$. The non-impacted group, located upgradient of the CWP (MW-17, MW-19A, PZ-22 and PZ-24) are dominated by $Na^+/K^+/Mg^{2+}/Cl^-/SO_4^{2-}$. Anion/cation concentrations in PZ-6, located on the northeastern corner of the OWP (more than one mile from the CWP), is indicative of a mixture of the above water types, suggesting it has been impacted to a lesser degree by wastewater. Wells sampled in the Upper Aquifer Zone during the 2017 field effort largely fall into the impacted category, with waters dominated by $Ca^{2+}/Mg^{2+}/Cl^-$ and relatively lower concentrations of $Na^+/K^+/SO_4^{2-}$ (**Table 3-2**). MW-22A, which is screened at the bottom of the Upper Aquifer Zone, is the exception to this observation because anion/cation concentrations are dominated by $Na^+/K^+/Cl^-/SO_4^{2-}$ with relatively low concentrations of Mg^{2+}/Ca^{2+}. A similar distinction was identified in the Hydrologic CSM report (ERM, 2016) in which it was noted that MW-19B, screened significantly deeper than adjacent MW-19A, had an appreciably different chemical signature than shallow wells in the same area (**Table 3-2**). These data indicate that the groundwater in the deeper portion of the Upper Aquifer Zone are relatively unimpacted by wastewater; this conclusion is further corroborated by the higher and near neutral pH measured at MW-22A (**Table 3-2**).

3.2.1.4. Metals. Groundwater in the vicinity of the CWP has previously been found to have elevated concentrations of arsenic, barium, cobalt, manganese, molybdenum, nickel and zinc (ERM, 2016). Impacted groundwater in the CWP/OWP area contains relatively higher concentrations of manganese, molybdenum and nickel relative to locations thought to be relatively unimpacted (i.e. MW-19B and PZ-18) (ERM, 2016). Iron also has been detected in high concentrations at impacted locations relative to

unimpacted locations. Metals concentrations detected in PZ-6, located in the northeastern corner of the OWP (more than one mile from the CWP), are relatively low compared to concentrations detected in impacted groundwater located closer to the CWP, indicating this well has had limited impacts from wastewater. Metals concentrations detected in samples collected in 2017 from wells screened in the Upper Aquifer Zone are generally indicative of impacted groundwater with elevated iron, manganese and nickel concentrations; however molybdenum concentrations were largely not detected at the groundwater sampling locations. One exception is PZ-13, where molybdenum was detected at a trace concentration, below the laboratory reporting limit (**Table 3-2**).

MW-22A is again the exception to this pattern, with low concentrations of Iron, manganese, nickel and iron, indicating the deeper portion of the Upper Aquifer Zone is not impacted by wastewater (**Table 3-2**).

3.2.1.5. Organic Compounds. Organic constituents have been detected at varying concentrations in groundwater at the site including dioxins/furans, polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs) and volatile organic compounds (VOCs) (ERM, 2016). During the 2017 field investigation the only Upper Aquifer Zone wells sampled and analyzed for organics were MW-22A and PZ-13. These data are summarized in detail in a preliminary report which also includes an evaluation of organic water chemistry for the wells screened in the Lower Aquifer Zone (ERM, 2017).

Dioxins/furans have been detected at groundwater and surface water sampling locations throughout the site from the plant area (monitoring well MW-4A) to the western edge of the OWP (piezometer PZ-6). Dioxin/furans were not detected in PZ-13 and MW-22A during the July 2017 sampling event (ERM, 2017).

PCBs were routinely detected at low concentrations in groundwater samples in the CWP/OWP areas. With the exception of monochlorobiphenyls, concentrations of PCBs were generally one or more orders of magnitude lower than surface water measurements (ERM, 2016). PCBs were detected in low concentrations in PZ-13 and MW-22A during the July 2017 sampling event (ERM, 2017).

SVOCs were detected at groundwater sampling locations at the site, notably bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, and naphthalene were detected in more than half of groundwater samples collected and analyzed during the 2014/2015 sampling events. VOCs detected in groundwater include bromoform, chloroform, acetone, 2-butanone, bromodichloromethane and dibromochloromethane. In general, concentrations of SVOCs and VOCs were higher and more prevalent in groundwater samples than in surface water samples; however, they were not as widespread as the dioxin/furans described above, with no VOC detection in PZ-6, located in the northwest corner of the OWP (ERM, 2016). SVOCs were generally not detected or were reported at trace concentrations (an estimated value between the laboratory reporting limit and the method detection limit) in samples collected during

the July 2017 sampling effort with the exception of acetophenone which was detected in MW-22A (ERM, 2017).

3.2.2 Lower Aquifer Zone Groundwater Quality

Groundwater samples were collected during June/July, August, September and November 2017 at three new wells screened in the Lower Aquifer Zone (MW-21, MW-22B and MW-23) (**Figure 3-1a**). The first round of sampling at these wells included sampling for inorganic constituents in June 2017 and organic constituents in July 2017, which was performed and analyzed by ERM as part of the Remedial Investigation (RI) Phase IA Study (ERM, 2017).

Water quality in the Lower Aquifer Zone is notably different than impacted groundwater in the Upper Shallow Aquifer Zone which suggests the Lower Aquifer Zone is not hydraulically connected to the impacted waters of the overlying Upper Aquifer Zone. Following is a more detailed discussion of the water quality of the Lower Aquifer Zone.

3.2.2.1. General Water Quality. TDS concentrations in wells screened in the Lower Aquifer Zone (56,000 to 160,000 mg/L) are generally higher than in those screened in the Upper Aquifer Zone (32,000 to 100,000 mg/L). These TDS values also classify the groundwater in the Lower Aquifer Zone as Class IV groundwater. Both zones of the shallow aquifer can be classified as hypersaline (TDS > 35,000 mg/L). Groundwater in the Lower Aquifer Zone is typical of reducing conditions (with oxygen reduction potential average value of -377 mV) and an average dissolved oxygen concentration of 0.40 mg/L.

3.2.2.2. pH. Field measured groundwater pH results in the Lower Aquifer Zone range between 6.7 and 7.5, which are generally higher than values measured in the Upper Aquifer Zone.

3.2.2.3. Anions/Cations. Groundwater of the Lower Aquifer Zone is characterized as $Na^{+}/Cl^{-}/SO_4^{2-}$ type water with relatively low concentrations of Mg^{2+}/Ca^{2+} relative to impacted groundwater of the Upper Aquifer Zone.

3.2.2.4. Metals. Sodium, magnesium, manganese, calcium, and potassium are all consistently found in wells screened in the Lower Aquifer Zone, while all other metals are sporadically detected, detected at trace levels, or not detected (**Table 3-2**). Metals indicative of wastewater and impacted groundwater (iron, manganese, molybdenum and nickel) are generally non-detect or low with the exception of manganese which is consistently found at MW-23 (**Table 3-2**).

Organic Compounds. Total PCB concentrations were detected at low concentrations in Lower Aquifer Zone wells, and these detections are likely due to laboratory contamination or low-level laboratory background (noise). In addition, the organics that are indicative of the wastewater stream (PCB-209, octachlorodibenzofuran and halogenated organic compounds) were not detected in any wells screened in the Lower Aquifer Zone (ERM, 2017). VOCs detected in the Lower Aquifer Zone were limited

to benzene, carbon disulfide, ethylbenzene and toluene and are well below Utah water quality criteria and Groundwater Quality Standards (ERM, 2017).

3.3 HYDROGEOLOGY OF THE OWP AND CWP AREA

Groundwater beneath the CWP area is divided into three primary units: the Upper Aquifer Zone (0-33.5 feet bgs), the Deeper Silty Clay Unit (33.5-49.5 feet bgs), and the Lower Aquifer Zone which extends below approximately 49.5 feet bgs to an undetermined depth. The Upper Aquifer Zone is an unconfined aquifer that extends down to the Deeper Silty Clay Unit which effectively acts as a confining layer and forms the upper boundary of the Lower Aquifer Zone.

3.3.1 Aquifer Properties

Several investigations have characterized the properties of the Upper Aquifer Zone, to a limited extent the Lower Aquifer Zone, and the Deeper Silty Clay Unit in the OWP/CWP area (MWH, 2004 ERM, 2016).

3.3.1.1. Geotechnical Laboratory Analyses. During the 2017 drilling activities, geotechnical samples were collected from ten borings/wells in the area of the CWP including 4 new monitoring well borings. Soil samples were analyzed for grain size, plasticity, and Unified Soil Classification System groups, as well as porosity and hydraulic conductivity. Sample locations, depths, results, and associated hydrogeologic units for these samples are listed in **Table 3-1**.

Vertical hydraulic conductivity tests were conducted on undisturbed samples collected from the Deeper Silty Clay Unit and the deeper intervals of the Upper Aquifer Zone in 2017. Vertical hydraulic conductivity results are generally lower than horizontal hydraulic conductivity values most likely due to the anisotropic nature of clay particles present throughout the sediments caused by the typical horizontal alignment of clay minerals (**Table 3-1**). Vertical hydraulic conductivity values in the Deeper Silty Clay Unit, which impedes upward flow to the Lower Aquifer Zone, are in the range of 7.9×10^{-5} ft/day (3×10^{-8} cm/s) to 3.1×10^{-4} ft/day (1×10^{-7} cm/s) whereas the Upper and Lower Aquifer Zones have vertical hydraulic conductivities at least an order of magnitude higher, in the 2.3×10^{-4} ft/day (8.0×10^{-8} cm/s) to 1.6×10^{-1} ft/day (5.6×10^{-5} cm/s) range (**Table 3-1**).

Laboratory porosity results for the three primary hydrogeological units are inversely related to hydraulic conductivity, with higher porosities measured in samples collected from the Deeper Silty Clay Unit (~43%) and lower porosities measured in the Upper and Lower Aquifer Zones (~23-26%) (**Table 3-1**). While the presence of fine-grained silts and clays increases the porosity of the Deeper Silty Clay Unit, the tight packing of this material in a silty clay (CL, CH) results in limited interconnectivity of the pores and therefore an inverse relationship between hydraulic conductivity and porosity.

3.3.1.2. Aquifer Tests. In order to better characterize horizontal hydraulic conductivities across the site, pneumatic slug tests were performed at ten wells across the site (**Table**

3-3). In addition to pneumatic slug tests, a 48-hour pumping test was performed at MW-22B, screened below the Deeper Silty Clay Unit, in order to characterize the hydraulic conductivity of the Lower Aquifer Zone (**Table 3-4**). The pumping test also was used to observe any hydraulic response in observation wells screened in the Upper Aquifer Zone (above the Deeper Silty Clay Unit) and in the Lower Aquifer Zone. Water level responses were recorded in four observation wells/piezometers screened in the Upper Aquifer Zone (MW-22A, PZ-10, PZ-6, and MW-13A), and in five wells screened in the Lower Aquifer Zone (MW-21, MW-23, PZ-28, MW-10, and MW-9). Negligible to no drawdown was observed in observation wells/piezometers completed in the Upper Aquifer Zone: minimal drawdown (0.24 feet) was observed at MW-22A, screened just above the Deeper Silty Clay Unit; and no response was observed at the other observation wells screened in the Upper Aquifer Zone. No impact on water levels in observation wells/piezometers completed in the Lower Aquifer Zone were observed. Results and analysis of the 2017 aquifer tests are presented in **Appendix B**.

Horizontal hydraulic conductivities for the Upper and Lower Aquifer Zones were calculated from data collected during pumping tests conducted in 2004 and 2017. Upper Aquifer Zone horizontal hydraulic conductivity results are in the range of 14 to 30 ft/day, whereas horizontal hydraulic conductivity results for the Lower Aquifer Zone are generally lower, in the range of 0.7 to 4 ft/day due to the higher percentages of silty sands and clays observed within the Lower Aquifer Zone (**Table 3-4**).

3.3.2 Groundwater Levels, Flow Direction and Hydraulic Gradients

Groundwater levels within the Upper Aquifer Zone range from approximately 4,215 feet amsl (PZ-03) west of the site to approximately 4,202 feet amsl (PZ-6) at the Northeast corner of the OWP (**Table 3-5**), with a calculated gradient of approximately 0.00096 across the site. Measured groundwater level elevations indicate horizontal groundwater flow direction within the shallow aquifer is generally from southwest to northeast with a groundwater mound in the vicinity of the wastewater discharge ditches that convey wastewater to the CWP and in the vicinity of the Star Pond (**Figure 3-4a, b**).

Due to the large variability in TDS (density) across the site, application of a density correction factor (see Section 3.3.3 for methodology used) has been applied to all measured groundwater elevations in order to account for density driven gradients which generally counter-act hydraulic gradients. Applying a density adjustment referenced to the waters of GSL effectively dampens the gradient to 0.00081 across the site (**Figure 3-4a,b**).

Water levels in the Lower Aquifer Zone range from approximately 4,217 feet amsl (MW-02) to the west of the site to approximately 4,202 feet amsl (MW-10) at the northeast corner of the OWP (**Table 3-5**), with a (uncorrected) gradient of approximately 0.0011 across the site and a corrected gradient of approximately 0.00081 (**Figure 3-4c,d**).

Horizontal groundwater flow within the deeper aquifer is generally from the west to east (**Figure 3-4c,d**).

Higher groundwater elevations in the Lower Aquifer Zone demonstrate a vertical hydraulic gradient that induces a slight upward flow of groundwater within the OWP/CWP area; this is particularly evident for density corrected vertical hydraulic gradient calculations (**Table 3-6**). This indicates the CWP lies in the discharge zone within the regional groundwater system (**Table 3-6**).

Groundwater elevations are typically highest in late spring following recharge from melting snow in the nearby lakeside mountains and typically higher precipitation, and lowest in late summer following months of low precipitation and high evapotranspiration (**Table 3-5**). Groundwater elevations begin to increase again by December, due to increased precipitation and low evapotranspiration, however these changes do not alter the flow direction of groundwater within the Facility area (**Figures 3-4e, f, g, h).**

3.3.3 Density Corrections

Due to the variable salinity of groundwater found beneath the site, density corrections to measured water levels have historically been utilized to account for density driven gradients (MWH 2004, ERM 2016, Post 2007). These reports have generally utilized a density correction referenced to freshwater. However, since GSL is the ultimate receiving body of the groundwater (i.e. discharge point) a density correction referenced to the waters of GSL water has been utilized. This has the same effect as a freshwater correction, in that it adds a correction factor to account for density gradients within the water, which results in a dampened hydraulic gradient at the site as described below. The corrected densities were calculated utilizing the following equation:

$$WL_{corr} = \left[(WL_{uncorr} - WL_{GSL}) * \left(\frac{\rho_{well}}{\rho_{GSL}}\right)\right] + WL_{GSL}$$

Where:

WL_{corr} is the water elevation with a density correction applied,
WL_{uncorr} is the measured water elevation in the well,
WL_{GSL} is the GSL water elevation,
ρ_{well} is the density of the water in the well, and
ρ_{GSL} is the density of GSL water

3.4 SURFACE WATER AND GROUNDWATER INTERACTIONS

The presence of large, unlined ponds sitting above an unconfined, shallow aquifer result in hydraulic connectivity between the surface water and groundwater. As part of the 2016 CSM, chemical signatures of wastewater and impacted and non-impacted groundwater were utilized to identify locations of groundwater and surface water

interactions. For a detailed analysis of these findings see the 2016 Hydrologic CSM report (ERM, 2016).

In general surface water conveyed through unlined ditches to the CWP and waters of the CWP discharge wastewater to the Upper Aquifer Zone beneath the pond; however, based on pond water and groundwater quality data, impacts of this discharge appears to be limited to the uppermost portion of the Upper Aquifer Zone, because water quality in the deeper portions of the Upper Aquifer Zone and the Deeper Aquifer Zone are not indicative of interactions with the Facility wastewater.

Standing water located downgradient of the CWP within the footprint of the OWP, as well as standing water located north of the CWP, are indicative of locations where groundwater is discharging to the surface. Water quality data from surface water samples collected north of the CWP have two distinct signatures, one indicative of wastewater and the other indicative of upgradient groundwater. This indicates that some upgradient, unimpacted groundwater is discharging to the ground surface at this location in addition to impacted wastewater. Water quality of standing water located east of the CWP, within the footprint of the OWP, is indicative of wastewater and is likely seepage from the CWP either through or beneath the eastern CWP embankment.

4.0 SUMMARY

Data from several historical investigations (2004/2005, 2014/2015) were used to develop and refine conceptual geological and hydrogeological models for the CWP/OWP area, and additional data were collected in 2017 to fill identified data gaps to support a GWDP application for a proposed Retrofitted Waste Pond at the Facility. Characteristics of the updated CSM have been input into a computer groundwater flow model that has been used to support the proposed Groundwater Discharge Control System conceptual design, as discussed in detail in the Groundwater Discharge Control Plan (Stantec, 2017).

Data collected during the 2017 subsurface investigation filled key hydrogeologic data gaps pertinent to the GWDP application, as described in the following subsections.

4.1 CHARACTERIZATION OF SHALLOW AQUIFER AND DEEPER SILTY CLAY UNIT

Subsurface investigation data collected in 2017 confirmed that the shallow aquifer in the area of the CWP/OWP can be separated into three distinct units: (1) an Upper Aquifer Zone (extending to ~35 feet bgs); (2) the Deeper Silty Clay Unit (observed within an approximate interval of 35-55 feet bgs); and (3) a Lower Aquifer Zone (below approximately 55 feet bgs).

The Deeper Silty Clay Unit was found to be continuous across the CWP/OWP area and to range in thickness between approximately 11 and 18 feet. Laboratory vertical hydraulic conductivity results from seven samples collected from the Deeper Silty Clay

Unit in 2017 indicate vertical hydraulic conductivity of the Deeper Silty Clay is at or below 1 x 10^{-7} cm/s (results range between 1.1 x 10^{-7} and 2.8 x 10^{-8} cm/s).

A 48-hour pumping test conducted in the Lower Aquifer Zone in 2017 resulted in negligible response in the nested well installed adjacent to the pumping well and completed immediately above the Deeper Silty Clay Unit. No drawdown response at all was observed at eight additional observation wells/piezometers completed in the Upper and Lower Aquifer Zones. These results indicate negligible to zero hydraulic interaction between the two shallow aquifer zones during the test.

4.2 GENERAL GROUNDWATER QUALITY

Groundwater beneath the site is classified as Class IV (Saline) groundwater (TDS >10,000 mg/L), with higher TDS concentrations observed (>100,000 mg/L) in deeper wells. Samples collected in 2017 confirm these findings with TDS results ranging from 17,000 mg/L to 190,000 mg/L, with higher TDS concentrations generally occurring in the Lower Aquifer Zone and near the Star Pond in the Upper Aquifer Zone.

Field pH measurements of shallow groundwater samples collected upgradient of the Facility (PZ-4, PMW-1S) are higher than of those near the CWP (PZ-8, PZ-26, MW-13A, MW-14 and MW-15A). In addition, comparison of pH measured in 2005 to measurements of pH made in 2015 and 2017 show a decrease in pH over time, indicating a decrease in the buffering capacity of the calcium carbonate rich sediments in the area of the CWP.

Groundwater at the site can broadly be grouped into two categories, groundwater that is generally not impacted by wastewater and groundwater that has been impacted. These waters fall into two groups defined by their dominant anions/cations. The impacted group located adjacent to and downgradient of the CWP (PZ-16, PZ-10, & PZ-12) is dominated by $Ca^{2+}/Mg^{2+}/Cl^-$. The non-impacted group, located upgradient of the CWP (MW-17, MW-19A, PZ-22 and PZ-24) is dominated by $Na^+/K^+/Mg^{2+}/Cl^-/SO_4^{2-}$.

4.3 SUBSURFACE SOIL GEOCHEMICAL EVALUATION

A geochemical evaluation of subsurface sediments of the Upper Aquifer Zone and the Deeper Silty Clay Unit indicate the presence of significant percentages of carbonate in the sediments underlying the CWP. These carbonates will provide a significant buffering capacity for low pH impacted groundwater over time. However, the carbonate containing sediments also are susceptible to dissolution due to the same reactions that buffer the pH. An estimate of the remaining buffering capacity of soils beneath the CWP and the Deeper Silty Clay Unit itself is 155 and 460 years assuming constant exposure to impacted waters with an average pH of 0.59. (Refer to the geochemical evaluation included in the Groundwater Discharge Control Plan for more detailed data evaluation and discussion [Stantec, 2017]).

5.0 REFERENCES

Dames & Moore, 1969. Report of Preliminary Foundation Investigation, Proposed Metal-Chemical Complex, Near Grantsville, Utah, For the National Lead Company, May 27, 1969 (supplemented June 19, 1969).

Dames & Moore, 1970a. Report of Comprehensive Investigation, Oolitic Sand Deposits, Proposed Magnesium Project, Tooele County, Utah, For National Lead Company, January 23, 1970.

Dames & Moore, 1970b. Report of Soils Study, Proposed Borrow Area, Proposed Metal-Chemical Complex, Near Grantsville, Utah, For National Lead Company, January 23, 1970.

Dames & Moore, 1971. Report of Field Percolation Tests, Disposal Ponds, Metal-Chemical Complex, Tooele County, Utah, For NL Industries, 22 June.

Dames & Moore, 1972. Report of Soil and Ground Water Studies, Plant Discharge Evaporation Ponds, Rowley, Utah, For NL Industries, July 21, 1972.

ERM, 2016. Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model, US Magnesium LLC. June 2016.

ERM, 2017. Technical Memorandum: July 2017 Groundwater Sampling per Phase 1A SAP Modification 14-C-2-29. December 2017.

Hood, J.W. and Waddell, K.M., 1968. Hydrologic Reconnaissance of Skull Valley, Tooele County, Utah. Prepared by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources – Division of Water Rights. 57pp.

Hely, Allen, Mower, R.W., and Harry, Albert C., 1971, Water Resources of Salt Lake County, Utah. State of Utah, Department of Natural Resources. Technical Publication 31.

MWH, 2004. Groundwater Characterization and First Quarter Groundwater Monitoring Report. US Magnesium LLC. September 1, 2004.

MWH, 2006. US Magnesium, LLC: Annual Groundwater Monitoring Report. October 2006.

MWH, 2015. Draft Preliminary Design Basis and Feasibility Evaluation Report Proposed New Evaporation Pond. August 2015.

Post, 2007. Using Hydraulic Head Measurements in Variable-Density Ground Water Flow Analyses. Ground Water, Vol. 34, No.6. November, 2007

Shope, Christopher L., 2015. Calculating salt loads to Great Salt Lake and the associated uncertainties for water year 2013; updating a 48 year old standard. Science of the Total Environment, 536 (2015) 391-405. July 2015.

Stantec, 2017. US Magnesium Groundwater Discharge Control Plan. December 2017.

UDEQ, 2006. Ground Water Quality Protection Permitting Information Document. Utah Department of Environmental Quality Division of Water Quality Ground Water Protection Section. December 2006.

USGS, 2007. Great Salt Lake, Utah. USGS Water-Resources Investigation Report 1999-4189. Accessed online at http://pubs.usgs.gov/wri/wri994189/.

USGS, 2017a. National Water Information System: Web Interface. Accessed online at https://waterdata.usgs.gov/ut/nwis/uv?site_no=10010000.

USGS, 2017b. Utah Water Science Center: Great Salt Lake – Lake Elevations and Elevation Changes. Accessed online at https://ut.water.usgs.gov/greatsaltlake/elevations/.

Utah Department of Natural Resources (UDNR), 2003. Final Great Salt Lake Comprehensive Management Plan and Record of Decision. March 2013.

UDNR, 2016. Union Pacific Railroad Causeway Breach to Proceed After Dec. 1. November 2016. Accessed online at https://naturalresources.utah.gov/dnr-newsfeed/union-pacific-railroad-causeway-breach-to-proceed.

Young, John C., 1955. Geology of the Southern Lakeside Mountains, Utah: Utah Geological and Mineralogical Survey Bulletin 56, October, 1955.

TABLES

TABLE 3-1
GEOTECHNICAL TEST RESULTS FOR UNDISTURBED SOIL SAMPLES - JUNE 2017
GROUNDWATER DISCHARGE PERMIT APPLICATION
US MAGNESIUM, ROWLEY, UTAH

Boring ID	Sampling Interval (ft bgs)[b]		Unified Soil Classification	Water Content (%)	Dry Unit Weight (pcf)	Total Porosity (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Gravel (%)	Sand (%)	Fines (%)	Hydraulic Conductivity (cm/s)	Hydraulic Conductivity (ft/day)	Associated Shallow Aquifer Unit
MW-21	17	19	SM	--	--	--	NP	NP	NP	0.0	79.2	20.8	--	--	Upper Aquifer Zone (0-33.5 ft bgs)
	26	28	SM	--	--	--	NP	NP	NP	0.1	74.6	25.3	--	--	
	28	29.5	--	15.87	126.4	16.3	--	--	--	--	--	--	1.7E-06	4.8E-03	
	35	37	CL	--	--	--	36	19	17	0.0	21.0	79.0	--	--	Deeper Silty Clay Unit (33.5 - 49.5 ft bgs)
	36	38	--	23.85	112.9	26.4	--	--	--	--	--	--	4.8E-08	1.4E-04	
	41	43	--	22.98	99.6	31.1	--	--	--	--	--	--	2.8E-08	7.9E-05	
	47	49	CL	--	--	--	46	22	24	0.0	2.4	97.6		--	
	50	52	CL	--	--	--	37	19	18	0.0	27.3	72.7	--	--	Lower Aquifer Zone (below 49.5 ft bgs)
	55	57	SM	--	--	--	NP	NP	NP	0.0	73.1	26.9	--	--	
	61	63	--	20.33	119	22.7	--	--	--	--	--	--	5.7E-05	1.6E-01	
MW-22B	13	15	SM	--	--	--	51	37	14	12.4	68.6	19.0	--	--	Upper Aquifer Zone (0-36.0 ft bgs)
	23	25	SM	--	--	--	NP	NP	NP	0.0	72.8	27.2	--	--	
	29.5	31.5	--	14	128.9	28.6	--	--	--	--	--	--	7.3E-08	2.1E-04	
	37	39	CL	--	--	--	45	22	23	0.0	6.0	94.0	--	--	Deeper Silty Clay Unit (36.0 - 48.5 ft bgs)
	37.2	39.2	--	27.7	96.9	44.1	--	--	--	--	--	--	1.1E-07	3.1E-04	
	45	47	CL	--	--	--	42	22	20	0.0	8.9	91.1	--	--	
	45.5	47.5	--	39.6	90.8	53.7	--	--	--	--	--	--	6.2E-08	1.8E-04	
	54.9	56.9	--	34.7	93.2	50.4	--	--	--	--	--	--	2.0E-07	5.7E-04	
	57	60	SC	--	--	--	27	19	8	0.0	56.2	43.8	--	--	Lower Aquifer Zone (below 48.5 ft bgs)
	63	65	SM	--	--	--	NP	NP	NP	0.0	79.2	20.8	--	--	
MW-23	14	16	CH	--	--		77	27	50	0.0	3.5	96.5	--	--	Upper Aquifer Zone (0-36.0 ft bgs)
	25.0	27.0	SM	--	--		NP	NP	NP	0.0	74.7	25.3	--	--	
	27.0	29.0	--	16.62	121.6	34.9	--	--	--	--	--	--	2.1E-06	6.0E-03	
	45.0	47.0	CH	--	--		51	23	28	0.0	5.1	94.9	--	--	Deeper Silty Clay Unit (43.0 - 52.8 ft bgs)
	47.0	49.0	--	32.04	97.6	49.8	--	--	--	--	--	--	3.4E-08	9.6E-05	
	52.0	54.0	CL	--	--		44	21	23	0.0	5.7	94.3	--	--	
	52.0	54.0	--	34.37	98.3	50.7	--	--	--	--	--	--	4.1E-08	1.2E-04	
	62.0	64.0	SM	--	--		NP	NP	NP	0.0	70.4	29.6	--	--	Lower Aquifer Zone (below 52.8 ft bgs)
	65.0	67.0	CL	--	--		41	19	22	0.0	10.9	89.1	--	--	
	67.0	69.0	--	29.89	98.9	47.7	--	--	--	--	--	--	8.2E-08	2.3E-04	
SB-1	36.0	37.0	CL	--	--	--	39	20	19	0	10.1	89.9	--	--	Deeper Silty Clay Unit (>36 ft bgs)[a]
	42.0	43.0	CL	--	--	--	41	22	19	0	7.1	92.9	--	--	
SB-2	42.4	43.1	CL	--	--	--	38	19	19	0	13.8	86.2	--	--	Deeper Silty Clay Unit (>41.5 ft bgs)[a][b]
	45.3	46.0	CL	--	--	--	41	22	19	0	4.8	95.2	--	--	
SB-3	37.5	38.2	CL	--	--	--	34	19	15	0	12	88	--	--	Deeper Silty Clay Unit (>36.7 ft bgs)[a][b]
	40.3	41.0	CL	--	--	--	49	24	25	0	5.1	94.9	--	--	
SB-4	39.0	40.0	CL	--	--	--	44	23	21	0	7.2	92.8	--	--	Deeper Silty Clay Unit (>37.2 ft bgs)[a]
	44.0	45.0	CL	--	--	--	45	23	22	0	3	97	--	--	
SB-5	31.1	31.8	CL	--	--	--	36	19	17	0	8.1	91.9	--	--	Deeper Silty Clay Unit (>29.4 ft bgs)[a]
	33.9	34.6	CL	--	--	--	37	21	16	0	10.6	89.4	--	--	
SB-6	30.4	31.1	CL	--	--	--	28	16	12	0	23.2	76.8	--	--	Deeper Silty Clay Unit (>29.3 ft bgs)[a]
	34.6	35.4	CL	--	--	--	35	19	16	0	15.3	84.7	--	--	
	37.5	38.2	CL	--	--	--	39	22	17	0	11.1	88.9	--	--	
SB-7	20.0	22.0	SM	--	--	--	NP	NP	NP	0	73.1	26.9	--	--	Upper Aquifer Zone (0-26.5 ft bgs)
	26.0	28.0	--	27.97	25.5	45.3	--	--	--	--	--	--	8.7E-08	2.5E-04	Deeper Silty Clay Unit (26.5 - 34.5 ft bgs)
	33.0	35.0	CL	--	--	--	38	21	17	0	12.5	87.5	--	--	
	38.0	40.0	SM	--	--	--	NP	NP	NP	0	86.4	13.6	--	--	Lower Aquifer Zone (below 34.5 ft bgs)

Soil samples were collected from soil borings drilled beneath and adjacent to the current waste pond at the US Magnesium Facility on June 8 through 22, 2017.
(a) Soil borings SB-1 through SB-6 were advanced to the deeper silty clay unit, but did not fully penetrate the deeper silty clay unit.
(b) Soil borings SB-2, SB-3, SB-5, and SB-6 were drilled at a 45-degree angle from the horiztonal. Actual soil sample identifications in geotechnical laboratory reports reflect the interval along the boring length, not depth bgs.
Sample depths for angled borings were calculated assuming the angle of drilling remained at a constant 45-degree angle.

Notes:

--	not analyzed
SM	silty sand
SC	clayey sand
CL	lean clay
CH	fat clay
bgs	below ground surface
cm/sec	centimeters per second
ID	identification
pcf	pounds per cubic foot
NP	nonplastic
GWDP	groundwater discharge permit

sample collected from the Upper Aquifer Zone
sample collected from the Deeper Silty Clay Unit
sample collected from the Lower Aquifer Zone

Laboratory methods used:

ASTM D2487	Classification of Soils for Engineering Purposes
ASTM D422	Particle Size Analysis with Hydrometer
ASTM D4318	Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D5084	Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

TABLE 3-2
MAIN DITCH AND BASELINE GROUNDWATER QUALITY
US MAGNESIUM, ROWLEY, UTAH

Analyte	Units	MCL[a]	Main Ditch (Surface Water)			MW-13B (9-19)[1]				MW-15B (9-19)[1]				
			6/29/2017	9/14/2017	11/20/2017	2/4/2014	8/9/2017	9/14/2017	11/2/2017	2/5/2014	8/9/2017	9/14/2017	11/2/2017	11/2/2017 (DUP)
Total Aluminum	ug/L	50 to 200	**1,800**	**3,400**	**1,400**	**5,400**	<1000	<1000	<1000	**6,200**	**6,300**	**7,100**	**6,100**	**6,100**
Dissolved Aluminum	ug/L		**1,600**	--	--	**5,600**	<1000	--	--	**6,000**	**6,000**	--	--	--
Total Antimony	ug/L	6	<2.0	<100	<100	0.9 J	<100	<100	<100	0.78 J	<100	<100	<100	<100
Dissolved Antimony	ug/L		<2.0	--	--	0.75 J	<100	--	--	0.73 J	<100	--	--	--
Total Arsenic	ug/L	10	**150**	**84**	**110**	**30**	<50	<50	<50	**42**	**68**	**66**	**95**	**96**
Dissolved Arsenic	ug/L		**120**	--	--	**28**	<50	--	--	**43**	**50**	--	--	--
Total Barium	ug/L	2,000	<5.0	<250	<250	350	<250	<250	<250	330	630	730	820	830
Dissolved Barium	ug/L		<5.0	--	--	330	<250	--	--	320	620	--	--	--
Total Cadmium	ug/L	5	<1.0	<50	<50	1.9 J	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cadmium	ug/L		<1.0	--	--	1.5 J	<50	--	--	<1.0	<50	--	--	--
Total Calcium	mg/L	NA	918	257 D	303	7,500	4,570 D	3,970 D	3,560 D	7,500	13,300 D	13,400 D	13,800 D	14,500 D
Dissolved Calcium	mg/L		917	--	--	7,300	4,780 D	--	--	7,400	13,400 D	--	--	--
Total Chromium	ug/L	100	**300**	<100	<100	<2.0	<100	<100	<100	2.9 J	<100	<100	<100	<100
Dissolved Chromium	ug/L		**290**	--	--	<2.0	<100	--	--	2.7 J	<100	--	--	--
Total Cobalt	ug/L	NA	<1.0	<50	<50	47 J	<50	<50	<50	85	120	180	190	190
Dissolved Cobalt	ug/L		<1.0	--	--	52 J	<50	--	--	84	120	--	--	--
Total Copper	ug/L	1,300	<2.0	120	<100	<2.0	<100	<100	<100	3.5 J	<100	130	<100	<100
Dissolved Copper	ug/L		<2.0	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Iron	ug/L	300	**420,000**	**200,000**	**160,000**	**67,000 J**	**5,500**	**8,400**	**16,000**	**93,000**	**190,000**	**210,000**	**310,000**	**310,000**
Dissolved Iron	ug/L		**370,000**	--	--	**69,000 J**	**4,700**	--	--	**91,000**	**180,000**	--	--	--
Total Lead	ug/L	15	<1.0	<50	<50	<1.0	<50	<50	<50	<1.0	**130**	<50	60	63
Dissolved Lead	ug/L		<1.0	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Magnesium	mg/L	NA	943	3970 D	3180 D	4,100	4,150 D	3,860 D	3,300 D	3,500	6,300 D	6,480 D	7,750 D	8,200 D
Dissolved Magnesium	mg/L		865	--	--	3,800	4,260 D	--	--	3,400	6,350 D	--	--	--
Total Manganese	ug/L	50	**290**	**560**	**320**	**8,000**	**310**	**230**	**250**	**11,000**	**15,000**	**16,000**	**21,000**	**21,000**
Dissolved Manganese	ug/L		**300**	--	--	**8,200**	**320**	--	--	**11,000**	**15,000**	--	--	--
Total Mercury	ug/L	2	<0.1	0.2	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	ug/L		<0.1	--	--	<0.1	<0.1	--	--	<0.1	<0.1	--	--	--
Total Molybdenum	ug/L	NA	<2.0	<100	<100	23	<100	<100	<100	50	<100	<100	<100	<100
Dissolved Molybdenum	ug/L		<2.0	--	--	17	<100	--	--	44	<100	--	--	--
Total Nickel	ug/L	NA	150	<50	60	160 J	<50	<50	59	260	500	700	660	670
Dissolved Nickel	ug/L		130	--	--	180 J	<50	--	--	250	480	--	--	--
Total Potassium	mg/L	NA	55	88.1 D	65	340	970 D	1130 D	836 D	150	313 D	348 D	319 D	339 D
Dissolved Potassium	mg/L		52	--	--	320	962 D	--	--	150	313 D	--	--	--
Total Selenium	ug/L	50	<5.0	<250	<250	2.7 J	<250	<250	<250	2.4 J	<250	<250	<250	<250
Dissolved Selenium	ug/L		<5.0	--	--	2.8 J	<250	--	--	<5.0	<250	--	--	--
Total Silver	ug/L	100	<1.0	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Silver	ug/L		<1.0	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Sodium	mg/L	NA	1,140	1160 DJ+	1190 D	4,800 J	11,300 D	12,800 DJ+	10,500 D	1,600	2,700 D	2,750 DJ+	2,700 D	2,840 D
Dissolved Sodium	mg/L		1,090	--	--	4,500	11,100 D	--	--	1,600	2,650 D	--	--	--
Total Thallium	ug/L	2	<1.0	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Thallium	ug/L		<1.0	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Vanadium	ug/L	NA	900	<100	140	7.3 J	<100	<100	<100	8.5 J	<100	<100	<100	<100
Dissolved Vanadium	ug/L		740	--	--	<2.0	<100	--	--	8.2 J	<100	--	--	--
Total Zinc	ug/L	5,000	320	110	260	350 J	170	<100	<100	370	560	650	910	930
Dissolved Zinc	ug/L		320	--	--	350 J	<100	--	--	360	370	--	--	--
Bromide	mg/L	NA	-	<100 D	40 D	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	100 D
Chloride	mg/L	250	-	**15,000 D**	**14,000 D**	**33,000**	**41,000 D**	**43,000 D**	**40,000 D**	**29,000**	**45,000 D**	**53,000 D**	**59,000 D**	**59,000 D**
Cyanide	ug/L	200	20	<10	<10	30	<25 D	<10	<10	47 J	44 D	19	<10	<10
Fluoride	mg/L	4	-	<100 D	<10 D	**18**	<100 D	<100 D	<100 D	**20**	<100 D	<100 D	<100 D	<100 D
Nitrate Ion	mg/L	NA	-	110 D	<10 D	--	<100 D	120 D	<100 D	--	<100 D	110 D	<100 D	<100 D
Nitrate-N	mg/L	10	-	**25 D**	<2.3 D	0.29 J	<23 D	**28 D**	<23 D	0.36 J	<23 D	**24 D**	<23 D	<23 D
Nitrite Ion	mg/L	NA	-	<100 D	<10 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Nitrite-N	mg/L	1	-	<31 D	<3.1 D	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<31 D
Perchlorate	ug/L	NA	1.8	2.4 D	--	490 J	280 D	1.2 FD	<5 D	0.6	<200 D	1.2 FD	<5 D	<5 D
Phosphorus, Total (as P)	mg/L	NA	-	<100 D	<10 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Phosphate-P	mg/L	NA	-	<33 D	<3.3 D	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<33 D
Sulfate	mg/L	250	-	**400 D**	**300 D**	**1,900**	**2,800 D**	**2,600 DJ+**	**2,800 D**	**1,300**	**1,100 D**	**950 D**	**840 D**	**890 D**
Total Alkalinity	mg/L	NA	ND	<20	--	760	210	160	180	830	680	280	470	400
Total Dissolved Solids	mg/L	2,000	**9,400**	**17,000**	**14,000**	**64,000**	**53,000**	**63,000**	**38,000**	**58,000**	**60,000**	**73,000**	**64,000**	**63,000**
Hexavalent Chromium	ug/L	100	--	--	--	0.377 J	--	--	--	0.634	<1.0 U	--	--	--
pH		NA	0.0	2.4	0.5	5.9	6.4	7.4	6.3	5.3	5.4	6.1	5.1	5.1
Conductivity	mS/cm	NA	--	35.6	63.2	69.5	87.6	77.5	88.7	56.0	87.3	90.7	72.6	72.6
DO	mg/L	NA	3.1	4.6	5.0	0.0	0.2	0.1	0.7	0.0	0.2	0.0	0.3	0.3
ORP	mV	NA	--	1015.7	--	26.0	-235.2	-263.8	-238.0	-12.0	-50.1	-130.3	-42.1	-42.1
Turbidity	NTU	NA	110.0	340.5	--	206.0	5.5	20.7	0.5	130.0	45.0	326.0	0.5	0.5
Chlorine	mg/L	NA	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0
Temperature	C	NA	33.5	23.0	15.3	10.2	21.5	18.0	17.0	9.2	20.0	20.1	19.3	19.3

[a]MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.

Bold Concentration above MCL; for comparative purpose only, MCLs are not applicable to Class IV groundwater.

'--' Not Analyzed

C Degrees Celcius

ug/L micrograms per liter

bgs below ground surface

D Sample dilution required for analysis: reported values reflect the dilution.

F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.

J Data are estimated due to associated quality control data.

J- Data are estimated and are potentially biased low due to associated quality control data.

J+ Data are estimated and are potentially biased high due to associated quality control data.

MCL drinking water maximum contaminant level

mg/L milligrams per liter

mS/cm microsiemens per centimeter

mV millivolts

NA No MCL established

NTU Nephelometric Turbidity Unit

UJ Potential low bias, possible false negative.

TABLE 3-2
MAIN DITCH AND BASELINE GROUNDWATER QUALITY
US MAGNESIUM, ROWLEY, UTAH

Analyte	Units	MCL[(a)]	MW-21 (50-60)[1]				MW-22A (24-34)[1]				MW-22B (54-64)[1]				
			7/13/2017	8/9/2017	9/13/2017	11/1/2017	7/12/2017	8/8/2017	9/13/2017	11/1/2017	7/12/2017	8/8/2017	9/13/2017	9/13/2017 (DUP)	11/1/2017
Total Aluminum	ug/L	50 to 200	<20	<1000	<1000	<1000	<20	<1000	<1000	<1000	<20	<1000	<1000	<1000	<1000
Dissolved Aluminum	ug/L		<20	<1000	--	--	<20	<1000	--	--	<20	<1000	--	--	--
Total Antimony	ug/L	6	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Antimony	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Arsenic	ug/L	10	39 J	<50	<50	<50	**34 J**	**57**	<50	<50	**45 J**	<50	<50	<50	<50
Dissolved Arsenic	ug/L		<1.0	<50	--	--	**42 J**	**55**	--	--	**35 J**	<50	--	--	--
Total Barium	ug/L	2,000	46	<250	<250	<250	42	<250	<250	<250	28	<250	<250	<250	<250
Dissolved Barium	ug/L		27	<250	--	--	51	<250	--	--	24 J	<250	--	--	--
Total Cadmium	ug/L	5	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cadmium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Calcium	mg/L	NA	390	661 D	721 D	698 D	470	785 D	713 D	662 D	370	718 D	708 D	698 D	673 D
Dissolved Calcium	mg/L		440	708 D	--	--	420	732 D	--	--	290	696 D	--	--	--
Total Chromium	ug/L	100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Chromium	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Cobalt	ug/L	NA	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cobalt	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Copper	ug/L	1,300	<2.0	<100	<100	170	<2.0	<100	<100	150	<2.0	<100	<100	<100	130
Dissolved Copper	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Iron	ug/L	300	<50	<2500	**2,500**	**3,800**	<50	<2500	<2500	3,100	<50	<2500	**2,500**	<2500	3,700
Dissolved Iron	ug/L		<50	<2500	--	--	<50	<2500	--	--	<50	<2500	--	--	--
Total Lead	ug/L	15	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Lead	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Magnesium	mg/L	NA	1,300	2,210 D	2,370 D	2,230 D	1,700	2,560 D	2,360 D	2,070 D	1,200	2,360 D	2,400 D	2,360 D	2,210 D
Dissolved Magnesium	mg/L		1,400	2,400 D	--	--	1,500	2,380 D	--	--	950	2,270 D	--	--	--
Total Manganese	ug/L	50	**93**	**53**	<50	<50	**210**	**250**	**72**	**99**	<1.0	<50	<50	<50	<50
Dissolved Manganese	ug/L		49 J	**56**	--	--	**250**	**240**	--	--	<1.0	<50	--	--	--
Total Mercury	ug/L	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	ug/L		<0.1	<0.1	--	--	<0.1	<0.1	--	--	<0.1	<0.1	--	--	--
Total Molybdenum	ug/L	NA	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Molybdenum	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Nickel	ug/L	NA	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Nickel	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Potassium	mg/L	NA	930	1,760 D	1,890 D	1,640 D	1,100	1,820 D	1,820 D	1,480 D	920	1,840 D	1,970 D	1,960 D	1,700 D
Dissolved Potassium	mg/L		1,000	1,850 D	--	--	970	1,700 D	--	--	740	1,800 D	--	--	--
Total Selenium	ug/L	50	<5.0	<250 UJ	<250 UJ	<250	<5.0	<250	<250	<250	<5.0	<250	<250	<250	<250
Dissolved Selenium	ug/L		<5.0	<250 UJ	--	--	<5.0	<250 UJ	--	--	<5.0	<250	--	--	--
Total Silver	ug/L	100	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Silver	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Sodium	mg/L	NA	26,000	32,200 D	34,400 D	33,800 D	23,000	32,200 D	32,500 D	29,700 D	26,000	35,000 D	35,200 D	33,100 D	33,800 D
Dissolved Sodium	mg/L		26,000	33,300 D	--	--	22,000	29,700 D	--	--	22,000	33,500 D	--	--	--
Total Thallium	ug/L	2	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Thallium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Vanadium	ug/L	NA	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Vanadium	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Zinc	ug/L	5,000	<2.0	160	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Zinc	ug/L		<2.0	110	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Bromide	mg/L	NA	28J	<100 D	<100 D	<100 D	<1.0	<100 D	<100 D	<100 D	34 J	<100 D	<100 D	<100 D	<100 D
Chloride	mg/L	250	**61,000**	**54,000 D**	**48,000 D**	**54,000 D**	**54,000**	**50,000 D**	**56,000 D**	**51,000 D**	**60,000**	**56,000 D**	**57,000 D**	**60,000 D**	**56,000 D**
Cyanide	ug/L	200	<10	140 DJ-	120 D	180 D	<10	<25 D	56 D	<25 D	57 J	**250 D**	190 DJ	100 DJ	45 D
Fluoride	mg/L	4	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	<100 D
Nitrate Ion	mg/L	NA	--	<100 D	110 D	<100 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Nitrate-N	mg/L	10	<0.0226	<23 D	**25 D**	<23 D	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	<23 D	<23 D	<23 D
Nitrite Ion	mg/L	NA	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Nitrite-N	mg/L	1	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<31 D
Perchlorate	ug/L	NA	0.1J	<200 D	2 D	<5 D	<0.2	<200 D	0.91 FD	<5 D	<0.2	<200 D	<2 D	1.5 FD	<5 D
Phosphorus, Total (as P)	mg/L	NA	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Phosphate-P	mg/L	NA	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<33 D
Sulfate	mg/L	250	**7,100**	**6,500 D**	**5,200 D**	**6,300 D**	**9,000**	**7,700 DJ-**	**6,900 D**	**7,400 D**	**6,600**	**6,000 D**	**5,600 D**	**5,700 D**	**6,000 D**
Total Alkalinity	mg/L	NA	410	370 J+	380	380	280	210	240	150	370	380	380	360	370
Total Dissolved Solids	mg/L	2,000	**110,000**	**85,000**	**110,000**	**74,000**	**100,000**	**90,000**	**100,000**	**62,000**	**110,000**	**96,000**	**110,000**	**110,000**	**56,000**
Hexavalent Chromium	ug/L	100	<0.275 U	<1.0 U	--	--	<0.275 R	<1.0 U	--	--	<2.2 R	<1.0 U	--	--	--
pH		NA	7.0	6.9	6.8	6.7	7.2	7.1	7.8	7.0	7.1	7.0	7.1	7.1	6.8
Conductivity	mS/cm	NA	163.0	131.8	12.7	122.3	152.0	124.5	18.3	113.5	169.0	131.9	17.4	17.4	120.7
DO	mg/L	NA	0.0	0.4	0.2	0.7	2.6	0.5	0.2	0.3	0.0	0.2	0.2	0.2	0.4
ORP	mV	NA	-418.0	-345.9	-372.8	-384.7	-399.0	-332.2	-361.0	-395.5	-422.0	-346.1	-381.0	-381.0	-396.1
Turbidity	NTU	NA	1.9	2.2	1.7	2.2	1.1	0.5	0.6	3.7	0.0	1.1	2.5	2.5	0.9
Chlorine	mg/L	NA	0.1	0.0	0.1	0.2	0.2	0.0	0.6	0.1	0.0	0.2	0.8	0.8	0.3
Temperature	C	NA	19.7	18.7	21.5	16.9	21.9	23.8	18.3	16.0	18.0	20.6	22.0	22.0	16.2

[(a)]MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.
Bold Concentration above MCL; for comparative purpose only, MCLs are not applicable to Class IV groundwater.
'--' Not Analyzed
C Degrees Celcius
ug/L micrograms per liter
bgs below ground surface
D Sample dilution required for analysis: reported values reflect the dilution.

F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.
J Data are estimated due to associated quality control data.
J- Data are estimated and are potentially biased low due to associated quality control data.
J+ Data are estimated and are potentially biased high due to associated quality control data.
MCL drinking water maximum contaminant level
mg/L milligrams per liter
mS/cm microsiemens per centimeter
mV millivolts
NA No MCL established
NTU Nephelometric Turbidity Unit
UJ Potential low bias, possible false negative.

TABLE 3-2
MAIN DITCH AND BASELINE GROUNDWATER QUALITY
US MAGNESIUM, ROWLEY, UTAH

Analyte	Units	MCL[a]	MW-23 Screened Interval 56-66 feet bgs				PZ-10 Screened Interval 4-14 feet bgs				PZ-12 Screened Interval 4-14 feet bgs			
			7/13/2017	8/8/2017	9/13/2017	11/1/2017	2/4/2014	8/8/2017	9/13/2017	11/1/2017	2/4/2014	8/8/2017	9/13/2017	11/1/2017
Total Aluminum	ug/L	50 to 200	<20	<1000	<1000	<1000	**51 J**	<1000	<1000	<1000	**3,600**	**4,000**	**2,300**	**1,600**
Dissolved Aluminum	ug/L		<20	<1000	--	--	<20	<1000	--	--	**3,600**	1,400	--	--
Total Antimony	ug/L	6	<2.0	<100	<100	<100	<2.0	<100	<100	<100	0.85J	<100	<100	<100
Dissolved Antimony	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	0.76J	<100	--	--
Total Arsenic	ug/L	10	**31 J**	<50	<50	55	**53**	**54**	**64**	**79**	**49**	**53**	**62**	**64**
Dissolved Arsenic	ug/L		<1.0	<50	--	--	**53**	**58**	--	--	**46**	<50	--	--
Total Barium	ug/L	2,000	37	<250	<250	<250	110	<250	<250	<250	210	400	360	380
Dissolved Barium	ug/L		23 J	<250	--	--	110	<250	--	--	200	300	--	--
Total Cadmium	ug/L	5	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Cadmium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--
Total Calcium	mg/L	NA	370	857 D	879 D	836 D	7,000	8,900 D	8,840 D	8,130 D	7,600	10,700 D	11,000 D	10,300 D
Dissolved Calcium	mg/L		670	897 D	--	--	7,800	8,770 D	--	--	7,700	10,700 D	--	--
Total Chromium	ug/L	100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Chromium	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--
Total Cobalt	ug/L	NA	<1.0	<50	<50	<50	28 J	<50	<50	<50	81J	94	100	100
Dissolved Cobalt	ug/L		<1.0	<50	--	--	29 J	<50	--	--	81J	97	--	--
Total Copper	ug/L	1,300	<2.0	<100	<100	200	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Copper	ug/L		<2.0	<100	--	--	2.1 J	<100	--	--	<2.0	<100	--	--
Total Iron	ug/L	300	<50	<2500	<2500	3,100	**240,000 J**	**300,000**	**310,000**	**320,000**	**160,000 J**	**180,000**	**200,000**	**240,000**
Dissolved Iron	ug/L		<50	<2500	--	--	**240,000 J**	**310,000**	--	--	**160,000 J**	180,000	--	--
Total Lead	ug/L	15	<1.0	**59**	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Lead	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--
Total Magnesium	mg/L	NA	1,200	3,060 D	3,040 D	2,850 D	3,800	5,400 D	5,190 D	4,760 D	3,400	3,980 D	4,310 D	4,640 D
Dissolved Magnesium	mg/L		2,300	3,020 D	--	--	4,200	5,340 D	--	--	3,300	3,950 D	--	--
Total Manganese	ug/L	50	**170**	**180**	**170**	**160**	**16,000**	**22,000**	**22,000**	**22,000**	**12,000**	**15,000**	**15,000**	**17,000**
Dissolved Manganese	ug/L		**72**	**170**	--	--	**16,000**	**22,000**	--	--	**12,000**	**15,000**	--	--
Total Mercury	ug/L	2	<0.1	<0.1 UJ	<0.1 UJ	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	ug/L		<0.1	<0.1	--	--	<0.1	<0.1	--	--	<0.1	<0.1	--	--
Total Molybdenum	ug/L	NA	<2.0	<100	<100	<100	2.4 J	<100	<100	<100	13	<100	<100	<100
Dissolved Molybdenum	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	8.4	<100	--	--
Total Nickel	ug/L	NA	<1.0	<50	<50	<50	45 J	140	140	150	200 J	310	330	370
Dissolved Nickel	ug/L		<1.0	130	--	--	46 J	140	--	--	190 J	310	--	--
Total Potassium	mg/L	NA	950	2,400 D	2,510 D	2,140 D	320	567 D	591 D	538 D	160	208 D	229 D	229 D
Dissolved Potassium	mg/L		1,700	2,410 D	--	--	360	572 D	--	--	160	220 D	--	--
Total Selenium	ug/L	50	<5.0	<250	<250	<250	<5.0	<250	<250	<250	2.6 J	<250	<250	<250
Dissolved Selenium	ug/L		<5.0	<250	--	--	4.4 J	<250	--	--	3.2 J	<250	--	--
Total Silver	ug/L	100	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Silver	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--
Total Sodium	mg/L	NA	26,000	48,700 D	48,100 D	49,600 D	2,400 J	3,680 D	3,580 DJ+	3,370 J+ D	1,700	1,810 D	1,940 DJ+	2,020 J+ D
Dissolved Sodium	mg/L		43,000	49,200 D	--	--	2,700	3,600 D	--	--	1,700	1,860 D	--	--
Total Thallium	ug/L	2	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Thallium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--
Total Vanadium	ug/L	NA	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Vanadium	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--
Total Zinc	ug/L	5,000	<2.0	190	<100	<100	11 J	<100	<100	<100	69 J	140	130	150
Dissolved Zinc	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	70 J	140	--	--
Bromide	mg/L	NA	53 J	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D
Chloride	mg/L	250	**84,000**	**73,000 D**	**89,000 D**	**77,000 D**	**28,000**	**34,000 D**	**34,000 D**	**38,000 D**	**26,000**	**32,000 D**	**34,000 D**	**40,000 D**
Cyanide	ug/L	200	<10	<25 D	<25 D	<25 D	23	30 D	<10	13	0.0095 J	38 D	21	10
Fluoride	mg/L	4	<0.1	<100 D	<100 D	<100 D	16	<100 D	<100 D	<100 D	**15**	<100 D	<100 D	<100 D
Nitrate Ion	mg/L	NA	--	<100 D	<100 D	<100 D		<100 D	100 D	100 D		<100 D	<100 D	<100 D
Nitrate-N	mg/L	10	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	**24 D**	**24 D**	<0.0226	<23 D	<23 D	<23 D
Nitrite Ion	mg/L	NA	--	<100 D	<100 D	<100 D		<100 D	<100 D	<100 D		<100 D	<100 D	<100 D
Nitrite-N	mg/L	1	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D
Perchlorate	ug/L	NA	<0.2	<200 D	1.1 FD	<5 D	<0.2	<200 D	0.99 FD	<5 D	0.42 J	<200 D	<2 D	<5 D
Phosphorus, Total (as P)	mg/L	NA	--	<100 D	<100 D	<100 D		<100 D	<100 D	<100 D		<100 D	<100 D	<100 D
Phosphate-P	mg/L	NA	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D
Sulfate	mg/L	250	**14,000**	**14,000 D**	**14,000 DJ+**	**14,000 D**	**1,500**	**1,400 D**	**1,400 D**	**1,200 D**	**1,300**	**1,100 D**	**1,100 D**	**920 D**
Total Alkalinity	mg/L	NA	290	270	300	270	790	840	690	560	800	840	690	600
Total Dissolved Solids	mg/L	2,000	**160,000**	**140,000**	**160,000**	**110,000**	**56,000**	**45,000**	**58,000**	**40,000**	**190,000**	**45,000**	**58,000**	**46,000**
Hexavalent Chromium	ug/L	100	<0.275 R	<1.0 U	--	--	0.159 J	<1.0 U	--	--	0.251J	<1.0 U	--	--
pH		NA	6.9	6.9	7.5	7.4	6.2	5.7	5.8	5.5	5.9	5.5	5.7	5.4
Conductivity	mS/cm	NA	895.0	162.6	122.5	157.3	52.2	69.3	36.8	72.2	48.3	73.9	30.8	76.0
DO	mg/L	NA	0.0	0.8	1.7	0.5	0.0	0.3	0.0	0.4	0.0	0.3	0.0	0.4
ORP	mV	NA	-395.0	-303.2	-356.0	-388.6	-125.0	-45.2	-128.1	-145.1	-58.0	-22.6	-61.2	-135.1
Turbidity	NTU	NA	0.5	2.6	0.1	1.1	0.0	3.5	1394.0	0.5	0.0	86.4	6126.0	53.0
Chlorine	mg/L	NA	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	2.2	2.1
Temperature	C	NA	19.0	22.1	22.5	13.0	13.6	19.2	20.5	16.8	12.9	20.0	19.6	16.4

[a]MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.

Bold Concentration above MCL; for comparative purpose only, MCLs are not applicable to Class IV groundwater

'--' Not Analyzed

C Degrees Celcius

ug/L micrograms per liter

bgs below ground surface

D Sample dilution required for analysis: reported values reflect the dilution.

F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.

J Data are estimated due to associated quality control data.

J- Data are estimated and are potentially biased low due to associated quality control data.

J+ Data are estimated and are potentially biased high due to associated quality control data.

MCL drinking water maximum contaminant level

mg/L milligrams per liter

mS/cm microsiemens per centimeter

mV millivolts

NA No MCL established

NTU Nephelometric Turbidity Unit

UJ Potential low bias, possible false negative.

TABLE 3-2
MAIN DITCH AND BASELINE GROUNDWATER QUALITY
US MAGNESIUM, ROWLEY, UTAH

Analyte	Units	MCL[a]	PZ-13 Screened Interval 7.5-17.5 feet bgs				PZ-8 Screened Interval 3.5-13.5 feet bgs			
			7/13/2017	8/8/2017	9/13/2017	11/1/2017	2/5/2014	8/9/2017	9/13/2017	11/1/2017
Total Aluminum	ug/L	50 to 200	<20	<1000	<1000	<1000	56J	<1000	<1000	<1000
Dissolved Aluminum	ug/L		<20	<1000	--	--	<20	<1000	--	--
Total Antimony	ug/L	6	<2.0	<100	<100	<100	0.70J	<100	<100	<100
Dissolved Antimony	ug/L		<2.0	<100	--	--	0.67J	<100	--	--
Total Arsenic	ug/L	10	**25**	<50	<50	<50	**130**	**70**	**72**	77
Dissolved Arsenic	ug/L		**24**	<50	--	--	**120**	**67**	--	--
Total Barium	ug/L	2,000	150	<250	<250	<250	160	260	290	300
Dissolved Barium	ug/L		130	<250	--	--	160	250	--	--
Total Cadmium	ug/L	5	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Cadmium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--
Total Calcium	mg/L	NA	8,100	7,530 D	7,910 D	7,150 D	6,800	12,400 D	13,000 D	11,500 D
Dissolved Calcium	mg/L		6,700	7,670 D	--	--	6,800	13,100 D	--	--
Total Chromium	ug/L	100	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Chromium	ug/L		<2.0	<100	--	--	<2.0	<100	--	--
Total Cobalt	ug/L	NA	<1.0	<50	<50	<50	65	120	140	120
Dissolved Cobalt	ug/L		<1.0	<50	--	--	60	120	--	--
Total Copper	ug/L	1,300	<2.0	<100	<100	<100	2.70	<100	<100	<100
Dissolved Copper	ug/L		<2.0	<100	--	--	2.50	<100	--	--
Total Iron	ug/L	300	**99,000**	**39,000**	**89,000**	**57,000**	**83,000**	**230,000**	**270,000**	**300,000**
Dissolved Iron	ug/L		**100,000**	**44,000**	--	--	**80,000**	**230,000**	--	--
Total Lead	ug/L	15	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Lead	ug/L		<1.0	<50	--	--	<1.0	<50	--	--
Total Magnesium	mg/L	NA	4,600	4,290 D	4,280 D	3,960 D	2,900	5,310 D	5,660 D	5,200 D
Dissolved Magnesium	mg/L		3,900	4,340 D	--	--	2,900	5,770 D	--	--
Total Manganese	ug/L	50	**13,000**	**4,200**	**8,400**	**3,700**	**9,500**	**18,000**	**17,000**	**19,000**
Dissolved Manganese	ug/L		**13,000**	**4,700**	--	--	**9,000**	**18,000**	--	--
Total Mercury	ug/L	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	ug/L		<0.1	<0.1	--	--	<0.1	<0.1	--	--
Total Molybdenum	ug/L	NA	17 J	<100	<100	<100	8.40	<100	<100	<100
Dissolved Molybdenum	ug/L		11 J	<100	--	--	5.40	<100	--	--
Total Nickel	ug/L	NA	50	94	84	110	180	**370**	420	410
Dissolved Nickel	ug/L		41	97	--	--	160	360	--	--
Total Potassium	mg/L	NA	380	418 D	401 D	407 D	100	**271 D**	291 D	255 D
Dissolved Potassium	mg/L		300	417 D	--	--	100	283 D	--	--
Total Selenium	ug/L	50	<5.0	<250	<250	<250	6.20	<250	<250	<250
Dissolved Selenium	ug/L		<5.0	<250	--	--	6.40	<250	--	--
Total Silver	ug/L	100	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Silver	ug/L		<1.0	<50	--	--	<1.0	<50	--	--
Total Sodium	mg/L	NA	2,600	2,540 D	2,490 DJ+	2,530 J+ D	1,300	2,350 D	2,350 DJ+	2,200 J+ D
Dissolved Sodium	mg/L		2,300	2,610 D	--	--	1,300	2,450 D	--	--
Total Thallium	ug/L	2	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Thallium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--
Total Vanadium	ug/L	NA	<2.0	<100	<100	<100	6.5J	<100	<100	<100
Dissolved Vanadium	ug/L		<2.0	<100	--	--	6.7J	<100	--	--
Total Zinc	ug/L	5,000	<2.0	<100	<100	<100	15	<100	<100	<100
Dissolved Zinc	ug/L		<2.0	<100	--	--	19	<100	--	--
Bromide	mg/L	NA	23 J	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D
Chloride	mg/L	250	**29,000**	**25,000 D**	**28,000 D**	**29,000 D**	**25,000**	**43,000 D**	**37,000 D**	**43,000 D**
Cyanide	ug/L	200	46 J	<25 D	<10	<10	29	33 D	<10	25
Fluoride	mg/L	4	**12**	<100 D	<100 D	<100 D	**13**	<100 D	<100 D	<100 D
Nitrate Ion	mg/L	NA	--	<100 D	<100 D	<100 D		<100 D	100 D	<100 D
Nitrate-N	mg/L	10	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	**23 D**	<23 D
Nitrite Ion	mg/L	NA	--	<100 D	<100 D	<100 D		<100 D	<100 D	<100 D
Nitrite-N	mg/L	1	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D
Perchlorate	ug/L	NA	<0.2	<200 D	<2 D	<5 D	0.55	<200 D	<2 D	<5 D
Phosphorus, Total (as P)	mg/L	NA	#N/A	<100 D	<100 D	<100 D		<100 D	<100 D	<100 D
Phosphate-P	mg/L	NA	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D
Sulfate	mg/L	250	**1,300**	**3,700 D**	**1,200 D**	**1,100 D**	**1,300**	**1,200 D**	**1,100 D**	**850 D**
Total Alkalinity	mg/L	NA	710	420	430	400	1,000	760	640	580
Total Dissolved Solids	mg/L	2,000	**61,000**	**40,000**	**48,000**	**32,000**	**51,000**	**53,000**	**65,000**	**43,000**
Hexavalent Chromium	ug/L	100	<0.27 U	<1.0 U	--	--	0.671	<1.0 U	--	--
pH		NA	5.9	6.2	6.2	6.3	5.7	5.6	6.0	5.3
Conductivity	mS/cm	NA	57.6	60.9	41.6	37.7	44.4	77.3	13.6	75.2
DO	mg/L	NA	2.6	2.4	4.4	3.6	0.0	0.2	0.0	0.3
ORP	mV	NA	4.0	-49.0	-114.7	-225.4	-25.0	-158.2	-210.6	-221.4
Turbidity	NTU	NA	0.0	32.1	3.0	3.7	0.0	7.1	37.6	1.5
Chlorine	mg/L	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature	C	NA	20.0	19.2	22.0	16.4	12.1	21.9	21.0	18.8

[a] MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.

Bold Concentration above MCL; for comparative purpose only, MCLs are not applicable to Class IV groundwater

'--' Not Analyzed

C Degrees Celcius

ug/L micrograms per liter

bgs below ground surface

D Sample dilution required for analysis: reported values reflect the dilution.

F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.

J Data are estimated due to associated quality control data.

J- Data are estimated and are potentially biased low due to associated quality control data.

J+ Data are estimated and are potentially biased high due to associated quality control data.

MCL drinking water maximum contaminant level

mg/L milligrams per liter

mS/cm microsiemens per centimeter

mV millivolts

NA No MCL established

NTU Nephelometric Turbidity Unit

UJ Potential low bias, possible false negative.

TABLE 3-3
ESTIMATES OF HYDRAULIC PARAMETERS
FROM PNEUMATIC SLUG TESTS
US MAGNESIUM, ROWLEY, UTAH

Well ID	Test Type	Screened Interval (ft bgs)	Lithological Description at Well Screen	Aquifer	Mathematical Solution for Hydraulic Conductivity (m/day)	Hydraulic Conductivity (m/day)				
						Individual Well		Hydrogeological Unit		
						Range	Median	Range	Geometric Mean	Median
MW-13B	Bouwer-Rice	9.0 - 19	Oolitic Sands (SP) and Silt Sand (SM)	Shallow	0.5	0.3 - 1.0	0.7	0.2 - 4.9	1.0	0.8
	Hvorslev				0.7					
MW-15B	Bouwer-Rice	9.0 - 19	Oolitic Sands (SP) and Silt Sand (SM)		1.4	1.2 - 2.3	1.6			
	Hvorslev				1.9					
PZ-3	Bouwer-Rice	10 - 20	Sand (SP) and Silt Sand (SM)		2.1	1.2 - 4.9	2.8			
	Hvorslev				3.2					
PZ-10	Bouwer-Rice	4 - 14	Silty Clay (CL) and Oolitic Sand (SP)		0.5	0.2 - 1.0	0.5			
	Hvorslev				0.7					
MW-22A	Bouwer-Rice	24 - 34	Silty Sand (SM) and Clayey Silt (SM/ML)		0.6	0.5 - 1.2	0.6			
	Hvorslev				0.7					
PMW-1D	Bouwer-Rice	30 - 40	Silty Clay (CL) Fine Sand (SM)		0.8	0.2 - 3.1	1.2			
	Hvorslev				1.0					
MW-21	Bouwer-Rice	50 - 60	Silty Sand (SM) Silty Clay (CL)		0.6	0.4 - 1.0	0.8			
	Hvorslev				0.9					
MW-22B	Bouwer-Rice	54 - 64	Silty Sand (SM) Clay (CL)	Deep	0.8	0.6 - 1.7	1.0	0.2 - 3.2	0.9	0.8
	Hvorslev				1.2					
MW-23	Bouwer-Rice	56.1 - 66.1	Silty Sand (SM) Silty Clay (CL)		0.5	0.4 - 0.9	0.7			
	Hvorslev				0.8					
PZ-28	Bouwer-Rice	65 - 75	Clay (CL) Silty Sand (SM)		0.9	0.3 - 3.2	1.1			
	Hvorslev				1.4					

-- No value recorded or no drawdown measured parameter value could not be calculated
ft feet
bgs below ground surface
m/day meters per day

TABLE 3-4
ESTIMATES OF HYDRAULIC PARAMETERS
FROM 2017 AND HISTORICAL PUMPING TESTS
US MAGNESIUM, ROWLEY, UTAH

Pumping Well	Test Date	Test Type	Hydrogeologic Unit Tested	Pumping Rate (gpm)	Aquifer Thickness (ft)	Water-level Measurement Location	Distance from Pumped Well (ft)	Screened Interval (ft bgs)	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)	Storativity	Analysis Method and Comments
MW-22B	June 2017	Constant Rate	Lower Aquifer Zone	3	16	MW-22B	0.5	54-64	60.1	3.8	1.8E-07	Cooper and Jacob (1946) CRT
				5.4	16	MW-22B	0.5	54-64	66.9	4	1.3E-08	Cooper and Jacob (1946) CRT
		Recovery			16	MW-22B	0.5	54-64	39.6	--	--	Theis (1935) Recovery
					30	MW-22A	12	24-34	--	--	--	Negligible drawdown at MW-22A, could not analyze.
					8	PZ-8	1503	3.5-13.5	--	--	--	PZ-8, PZ-10, PZ-11 and PZ-13 screened in Upper Aquifer Zone
					8	PZ-10		4-14	--	--	--	had negligible observed drawdown during CRT test.
					7	PZ-11	809	4-14	--	--	--	
					10	PZ-13	2435	7.5-17.5	--	--	--	
					9	PZ-28	5367	65-75	--	--	--	PZ-28, MW-10, MW-21 and MW-23 screened in Lower Aquifer
					6	MW-10	6228	68-78	--	--	--	Zone had negligible observed drawdown during constant
					10	MW-21	1522	50-60	--	--	--	rate test.
					7	MW-23	2468	56.1-66.1	--	--	--	
PZ-27	May 2004	Constant Rate	Upper Aquifer Zone	14.2	7	PZ-27	0.5	6.5-16.5	210	30	0.03	Hantush-Jacob
					7	PZ-04	64	6.5-16.5	--	--	--	Negligible drawdown at PZ-04 during PZ-27 constant rate test, could not analyze.
						PZ-28	65	65-75	--	--	--	Screened in deeper aquifer. No drawdown at PZ-28 during PZ-27 pumping.
		Recovery			7	PZ-27	0.5	6.5-16.5	108	15		Recovery
MW-02	May 2004	Constant Rate	Lower Aquifer Zone	8.0	20	MW-02	0.5	57.5-67.5	14.4	0.72	0.02	Hantush-Jacob
						PZ-03	17	10-20	--	--	--	Screened in shallower aquifer. No drawdown at PZ-03 during MW-02 constant rate test.
		Recovery			20	MW-02	0.5	57.5-67.5	15.4	0.77	0.02	Recovery
PZ-30[a]	May 2004	Step Test	Upper Aquifer Zone	2.2	7	PZ-30	0.5	5.5-15.5	109	16	0.07	Hantush-Jacob
				3.0	7	PZ-30	0.5	5.5-15.5	98	14	0.03	Hantush-Jacob
					7	PZ-29	133	5.5-15.5	--	--	--	Not monitored during PZ-30 step test. Drawdown evident during constant rate test.
					20	MW-10	188	68-78	--	--	--	Not monitored during PZ-30 step test. No drawdown during constant rate test.
PZ-16		Step Test	Upper Aquifer Zone	1.25, 2.5, 4.0	7	PZ-16	0.5	4-14	150	21	0.06	Hantush-Jacob

(a) Due to geochemical characteristics of groundwater, a constant pumping rate could not be maintained at PZ-30 for an extended period. Salt and precipitate deposits continually clogged the pump intake, flow gauge, throttle controls, and discharge line; thus, the flow rate continually slowed and eventually stopped. Two independent step tests in which constant pumping rates were maintained were analyzed to determine the aquifer characteristics.

-- No value recorded or no drawdown measured parameter value could not be calculated
bgs below ground surface
ft feet
ft^2/day feet squared per day
ft/day feet per day
gpm gallon per minute

TABLE 3-5
GROUNDWATER ELEVATION MEASUREMENTS
US MAGNESIUM, ROWLEY, UTAH

Well Identification	Northing (feet)	Easting (feet)	Screen Interval (feet bgs)	Measuring Point Elevation (feet amsl)	June 2017 Groundwater Elevation (feet amsl)	Sept 2017 Groundwater Elevation (feet amsl)	Dec 2017 Groundwater Elevation (feet amsl)
MW-1	1299152.71	7502711.81	58-68	4223.33	--	--	--
MW-2	1296014.88	7505568.45	57.5-67.5	4226.88	4217.12	4217.19	4217.13
MW-3	1298818.82	7506525.58	5-15	4223.97	4216.25	4216.07	4216.16
MW-4A	1299041.75	7506525.91	4-14	4224.03	4216.08	4215.86	4215.94
MW-4B	1299047.06	7506525.56	22.5-32.5	4224.10	4216.42	4216.19	4216.27
MW-5A	1299919.06	7506530.52	8-18	4226.48	4215.81	4215.58	4215.78
MW-5B	1299924.32	7506530.56	27-37	4226.80	4216.34	4216.10	4216.30
MW-6	1299844.22	7506043.93	7-17	4225.77	4216.23	4215.88	4216.09
MW-7	1299851.62	7505711.25	7.5-17.5	4227.05	4216.25	4215.88	4216.15
MW-8A	1300401.17	7506516.03	6-21	--	4212.64	4215.37	4215.61
MW-8B	1300405.94	7506516.19	27-37	--	4212.69	4215.38	4215.61
MW-9	1303819.64	7512001.02	59-69	4213.87	4207.82	4208.22	4208.44
MW-10	1307700.25	7512136.87	68-78	4213.20	4202.58	4202.12	4202.06
MW-11	1308131.73	7512468.79	3-13	--	--	4199.70	4199.83
MW-12	1308652.00	7513480.34	3-13	--	--	--	4198.95
MW-13A	1299497.93	7511525.61	2.5-7.5	4221.96	4212.82	4211.89	4212.08
MW-13B	1299492.23	7511521.91	9-19	4221.88	4213.03	4212.46	4212.73
MW-14	1300042.47	7511068.68	5-15	4219.60	4212.39	4212.06	4213.16
MW-15A	1301048.84	7509689.63	2-7	4220.98	4213.20	4213.02	4213.31
MW-15B	1301052.94	7509687.14	9-19	4220.71	--	4213.12	4213.40
MW-16	1299514.62	7508801.24	0.5-1.5	NA	--	--	--
MW-17	1301539.14	7506829.02	7-17	4219.78	4214.67	4214.64	4214.91
MW-18	1298256.29	7504882.09	12-22	4229.29	--	--	--
MW-19A	1301865.58	7506319.20	7-17	4218.51	--	4214.40	4214.72
MW-19B	1301867.58	7506316.40	23-33	4218.35	--	4214.88	4215.19
MW-20A	1300410.93	7504086.58	12-17	4227.83	4214.77	4214.29	4214.34
MW-20A	1300410.93	7504086.58	12-17	4227.83	4214.77	4214.29	4214.34
MW-21	1302061.29	7508971.65	50-60	4218.18	4211.78	4211.61	4211.77
MW-22A	1303125.84	7507924.09	24-34	4218.32	4211.57	4211.35	4211.64
MW-22B	1303132.68	7507914.81	54-64	4218.15	4211.77	4211.36	4211.57
MW-23	1305159.33	7506505.51	56.1-66.1	4219.58	4209.30	4209.00	4209.16
PZ-01	1302370.97	7503751.92	9.17-19.17	4224.06	4210.73	4210.12	4210.28
PZ-02	1299175.56	7502709.28	8-16	4223.70	--	--	--
PZ-03	1296016.26	7505551.74	10-20	4226.47	4215.11	4214.93	4214.83
PZ-04	1297773.55	7507871.54	6.5-16.5	4224.40	4215.13	4214.88	4214.95
PZ-05	1303806.87	7512000.96	3.5-13.5	4214.46	4205.64	4205.45	4206.37
PZ-06	1307692.16	7512137.54	3.5-13.5	4214.22	4203.42	4201.61	4201.99
PZ-07	1307696.18	7508202.89	3.5-13.5	4212.33	4204.65	4203.74	4204.72
PZ-08	1302052.49	7508960.28	3.5-13.5	4218.71	4211.76	4211.71	4211.85
PZ-10	1303140.57	7507905.62	4-14	4218.72	4212.22	4211.86	4212.22
PZ-11	1303807.37	7507466.23	4-14	4218.27	4211.44	4211.29	4212.15
PZ-12	1304462.71	7507038.16	4-14	4219.23	4210.44	4210.20	4210.32
PZ-13	1305136.04	7506525.40	7.5-17.5	4220.50	4209.87	4209.54	4209.91
PZ-14	1305167.51	7505854.11	4.5-14.5	4219.94	4211.76	4211.17	4211.60
PZ-16	1304711.89	7505172.54	4-14	4218.44	--	4212.06	4213.08
PZ-18	1303882.51	7504494.51	3.25-13.25	4217.96	--	4211.17	4211.49
PZ-20	1302747.21	7505038.78	3-13	--	--	4210.86	4211.36
PZ-22	1302067.25	7505822.25	3-13	--	4211.48	4214.23	4214.58
PZ-24	1301343.15	7507152.83	3-13	--	4212.28	4214.85	4215.19
PZ-26	1302170.80	7508114.31	3.5-13.5	4220.85	4214.16	4213.98	4214.29
PZ-27	1297728.69	7507917.75	6.5-16.5	4223.57	4214.72	4215.73	4214.88
PZ-28	1297760.31	7507860.22	65-75	4223.52	4215.70	4214.76	4215.63
PZ-29	1307712.36	7512083.15	5.5-15.5	4213.99	4202.95	4201.50	4202.09
PZ-30	1307716.42	7511949.76	5.5-15.5	4213.39	4202.88	4201.43	4202.05
LF-01	1300634.03	7505771.44	5.4-15.4	4224.10	4215.63	--	4215.85
LF-02	1300003.51	7506434.76	3-13	4224.89	4215.98	4215.80	4216.01
LF-03	1300940.45	7506605.67	2-12	4220.06	4215.33	--	--
SC-PZ-1	--	--	5-10	--	--	--	--
SC-PZ-2	--	--	2-7	--	--	--	--
PMW-1D	1291919.88	7508152.38	30-40	--	4218.14	4217.45	4217.95
PMW-1S	1291899.46	7508162.58	15-25	--	4217.26	4217.26	4216.12

amsl above mean sea level

bgs below ground surface

Horizontal coordinates in NAD83 UTM Zone 12 (US foot); vertical coordinates are NAVD 88 (US foot)

TABLE 3-6
VERTICAL HYDRAULIC GRADIENTS ACROSS THE DEEPER SILTY CLAY UNIT
US MAGNESIUM, ROWLEY, UTAH

Monitoring Point Construction Info						June 2017								August 2017							
Monitoring Point ID	Ground Surface (ft amsl)	TOC (ft amsl)	Screen Top (ft amsl)	Screen Bottom (ft amsl)	Delta L (ft)	GW Elev. (ft amsl)	Corrected GW Elev (ft amsl)	Delta H (ft)	Corrected Delta H (ft)	Vertical Gradient	Corrected Vertical Gradient	Induced Vertical Flow Direction	Corrected Induced Vertical Flow Direction	GW Elev. (ft amsl)	Corrected GW Elev. (ft amsl)	Delta H (ft)	Corrected Delta H (ft)	Vertical Gradient	Corrected Vertical Gradient	Induced Vertical Flow Direction	Corrected Induced Vertical Flow Direction
PZ-08	4215.90	4218.71	4212.40	4202.40	46.90	4211.76	4209.22	-0.02	-0.63	-0.0004	-0.0133	Upward	Upward	4211.46	4208.97	-0.07	-0.66	-0.0015	-0.0141	Upward	Upward
MW-21	4215.50	4218.18	4165.50	4155.50		4211.78	4209.85							4211.53	4209.63						
MW-22A	4215.69	4218.32	4191.69	4181.69	30.01	4211.57	4209.58	-0.20	-0.26	-0.0066	-0.0086	Upward	Upward	4211.27	4209.32	0.02	-0.06	0.0007	-0.0020	Downward	Upward
MW-22B	4215.68	4218.15	4161.68	4151.68		4211.77	4209.84							4211.25	4209.38						
PZ-13	4217.63	4220.50	4213.63	4203.63	52.75	4209.87	4207.25	0.57	-0.69	0.0108	-0.0131	Downward	Upward	4209.60	4207.03	0.42	-0.80	0.0079	-0.0152	Downward	Upward
MW-23	4216.98	4219.58	4160.88	4150.88		4209.30	4207.94							4209.18	4207.83						
PZ-05	4211	4214.46	4207.5	4197.5	55.21	4205.64	4204.11	-2.18	-2.31	-0.0395	-0.0419	Upward	Upward								
MW-9	4211.29	4213.87	4152.29	4142.29		4207.82	4206.42														
PZ-06	4210.54	4214.22	4207.04	4197.04	64.43	4203.42	4202.19	0.84	0.08	0.0130	0.0013	Downward	Downward								
MW-10	4210.61	4213.2	4142.61	4132.61		4202.58	4202.10														
PZ-03	4223.68	4226.47	4213.68	4203.68	46.92	4215.11	4212.03	-2.01	-0.95	-0.0428	-0.0203	Upward	Upward								
MW-2	4224.26	4226.88	4166.76	4156.76		4217.12	4212.98														
PMW-1S	4232.09	4234.87	4217.09	4207.09	15.02	4217.26	4212.94	-0.88	-0.68	-0.0586	-0.0456	Upward	Upward								
PMW-1D	4232.07	4234.88	4202.07	4192.07		4218.14	4213.62														

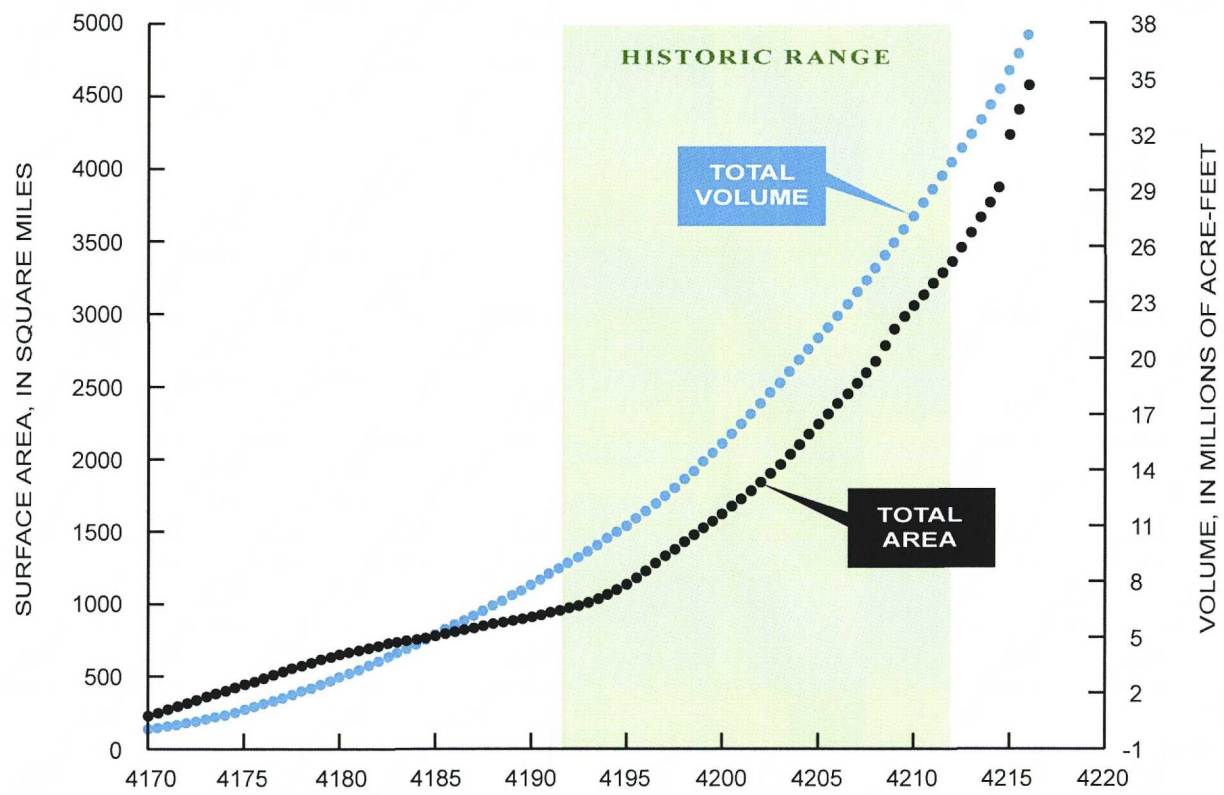
Monitoring Point Construction Info						September 2017								December 2017							
Monitoring Point ID	Ground Surface (ft amsl)	TOC (ft amsl)	Screen Top (ft amsl)	Screen Bottom (ft amsl)	Delta L (ft)	GW Elev. (ft amsl)	Corrected GW Elev. (ft amsl)	Delta H (ft)	Corrected Delta H (ft)	Vertical Gradient	Corrected Vertical Gradient	Induced Vertical Flow Direction	Corrected Induced Vertical Flow Direction	GW Elev. (ft amsl)	Corrected GW Elev. (ft amsl)	Delta H (ft)	Corrected Delta H (ft)	Vertical Gradient	Corrected Vertical Gradient	Induced Vertical Flow Direction	Corrected Induced Vertical Flow Direction
PZ-08	4215.90	4218.71	4212.40	4202.40	46.90	4211.71	4209.18	0.10	-0.52	0.0021	-0.0110	Downward	Upward	4211.85	4209.30	0.08	-0.5402	0.0017	-0.0115	Downward	Upward
MW-21	4215.50	4218.18	4165.50	4155.50		4211.61	4209.70							4211.77	4209.84						
MW-22A	4215.69	4218.32	4191.69	4181.69	30.01	4211.35	4209.39	-0.01	-0.09	-0.0003	-0.0029	Upward	Upward	4211.64	4209.65	0.071	-0.0187	0.0024	-0.0006	Downward	Upward
MW-22B	4215.68	4218.15	4161.68	4151.68		4211.36	4209.48							4211.57	4209.66						
PZ-13	4217.63	4220.50	4213.63	4203.63	52.75	4209.54	4206.98	0.54	-0.69	0.0102	-0.0131	Downward	Upward	4209.91	4207.28	0.748	-0.5285	0.0142	-0.0100	Downward	Upward
MW-23	4216.98	4219.58	4160.88	4150.88		4209.00	4207.67							4209.16	4207.81						
PZ-05	4211	4214.46	4207.5	4197.5	55.21	4205.45	4203.94	-2.77	-2.84	-0.0502	-0.0514	Upward	Upward	4206.37	4204.74	-2.07	-2.2387	-0.0375	-0.0405	Upward	Upward
MW-9	4211.29	4213.87	4152.29	4142.29		4208.22	4206.78							4208.44	4206.98						
PZ-06	4210.54	4214.22	4207.04	4197.04	64.43	4201.61	4200.62	-0.51	-1.05	-0.0079	-0.0163	Upward	Upward	4201.99	4200.95	-0.07	-0.6625	-0.0011	-0.0103	Upward	Upward
MW-10	4210.61	4213.2	4142.61	4132.61		4202.12	4201.67							4202.06	4201.61						
PZ-03	4223.68	4226.47	4213.68	4203.68	46.92	4214.93	4211.88	-2.26	-1.16	-0.0482	-0.0248	Upward	Upward	4214.83	4211.79	-2.3	-1.2002	-0.0490	-0.0256	Upward	Upward
MW-2	4224.26	4226.88	4166.76	4156.76		4217.19	4213.04							4217.13	4212.99						
PMW-1S	4232.09	4234.87	4217.09	4207.09	15.02	4216.69	4212.48	-0.76	-0.59	-0.0506	-0.0392	Upward	Upward	4216.12	4212.01	-1.83	-1.4561	-0.1218	-0.0969	Upward	Upward
PMW-1D	4232.07	4234.88	4202.07	4192.07		4217.45	4213.06							4217.95	4213.47						

FIGURES

DRAWN BY D. Severson

19 Sep 2017

C:\Data\MWH\PB&L &US Magnesium\USMAG_Hydrogeologic Report_Sep2017\FIGURES\Figure 1-1_USMAG_Location Map_19Sep2017.mxd



USGS 2017

1 Nov 2017

C:\Data\WWH\PB&L &US Magnesium\Fig 2-1_Surf Area and Volume of Great Salt Lake.ai

USMag®

SURFACE AREA AND VOLUME OF GREAT SALT LAKE AS A FUNCTION OF LAKE ELEVATION AS OBSERVED AT GILBERT BAY (SOUTH ARM)

Figure 2-1

DRAWN BY D. Severson

2 Nov 2017

C:\Data\MWH\PB&L &US Magnesium\For Dave S 10-31-17\Figure 2-2\Fig 2-2_General Soils Map_2Nov2017.mxd

US MAGNESIUM LLC PROPERTY

Flood Control Structures

ATI Property

Flood Elevation 4216 ft amsl

Lakeside Mountains

Well Pass

Monarch Canyon

Monarch Mine

Mountain Sheep Canyon

Deepstone Canyon

Rowley

Mud Flat

Marblehead Quarry

Bridger Canyon

Cranes Peak

Carter Can

Table Mtn

Marblehead Plant

Black Mtn

Radio Towers

Black Knoll

Dead Cow Point

Well

1286

1284

1329

1289

1512

1303

1421

1655

T.3 N.

T.2 N.

T.1 N.

36

31

6

1

EXPLANATION

- Federal Land
- State Land
- Private Land

NOTE:

Flood elevation represents the 100-year flood for the Great Salt Lake (Flood Plain Management Services, US Army Corp of Engineers)

N

W E

S

0 1

Miles

Stantec

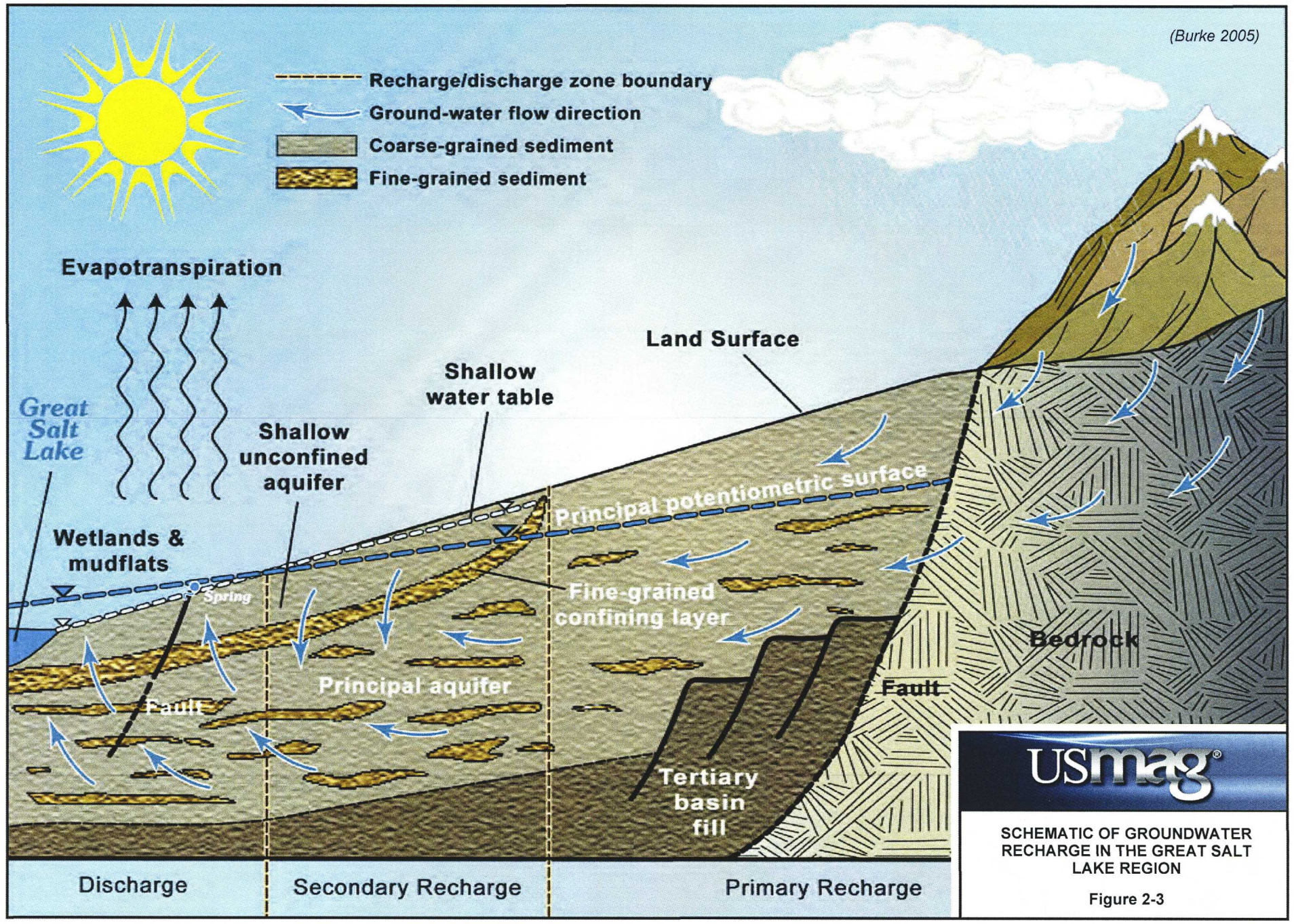
USmag®

US MAGNESIUM

USGS TOPOGRAPHIC MAP OF THE US MAGNESIUM SITE AREA

Figure 2-2

C:\Data\MWH\PB&L &US Magnesium\Fig 2-3_Schem of GW Recharge in the Great Salt Lake Region.ai 1 Nov 2017



USmag®

SCHEMATIC OF GROUNDWATER RECHARGE IN THE GREAT SALT LAKE REGION

Figure 2-3

DRAWN BY D. Severson

19 Oct 2017

EXPLANATION

- Monitoring well
- Off-site well
- Monitoring well (Jun 2017)
- Bench mark - brass cap
- Angled borehole (Jun 2017)
- Vertical borehole (Jun 2017)
- Piezometer
- Soil boring (Apr 2015)
- Test pit (Apr 2015)

Historical Locations

- Boring (Jun 1969)
- Boring (May 1969)
- Boring (Dec 1969)
- Boring (Oct 1973)
- Temporary monitoring well (Jul 1972)
- Test pit (Jan 1970)
- Test pit (Feb 1970)
- Test pit (Apr 1972)
- Test pit (Jul 1972)
- Test pit (Sep 1973)

N W E S

0 2000

Feet

BM 144
FMK_USGS1966Brass Cap

Stantec

USmag®

US MAGNESIUM

SITE MAP AND CROSS SECTION LOCATIONS

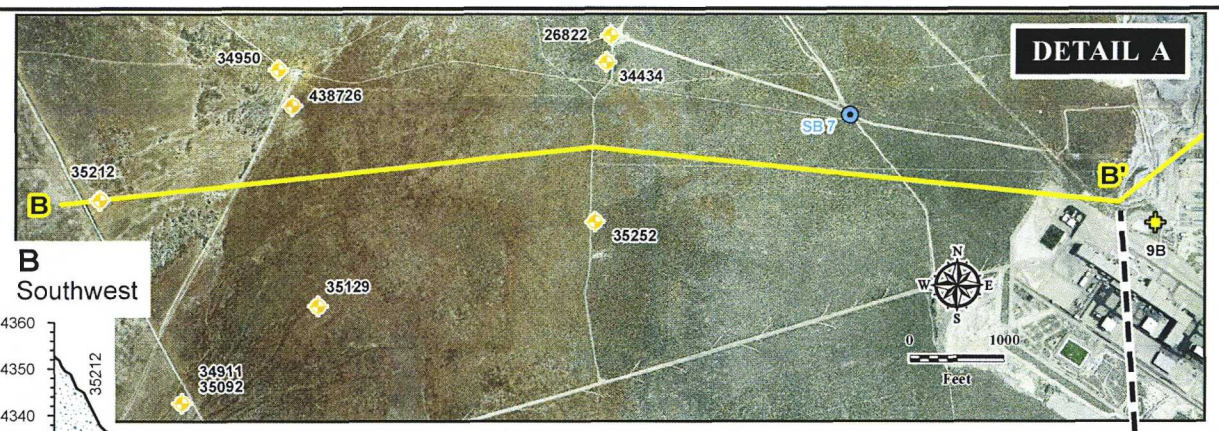
Figure 3-1a

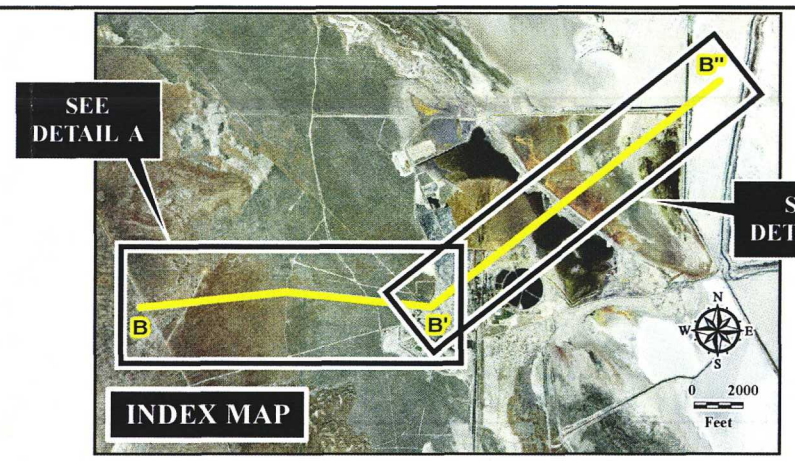
C:\Data\MWH\PB&L &US Magnesium\FIGURES\Fig 3-1a_Site Map and Cross Section Locations_19Oct2017.mxd

DRAWN BY: D. Severson

19 Oct 2017

C:\Data\MW-HPB&L &US Magnesium\FIGURES\Fig 3-1b_Cross Section B_B_B_19Oct2017_11x17.ai





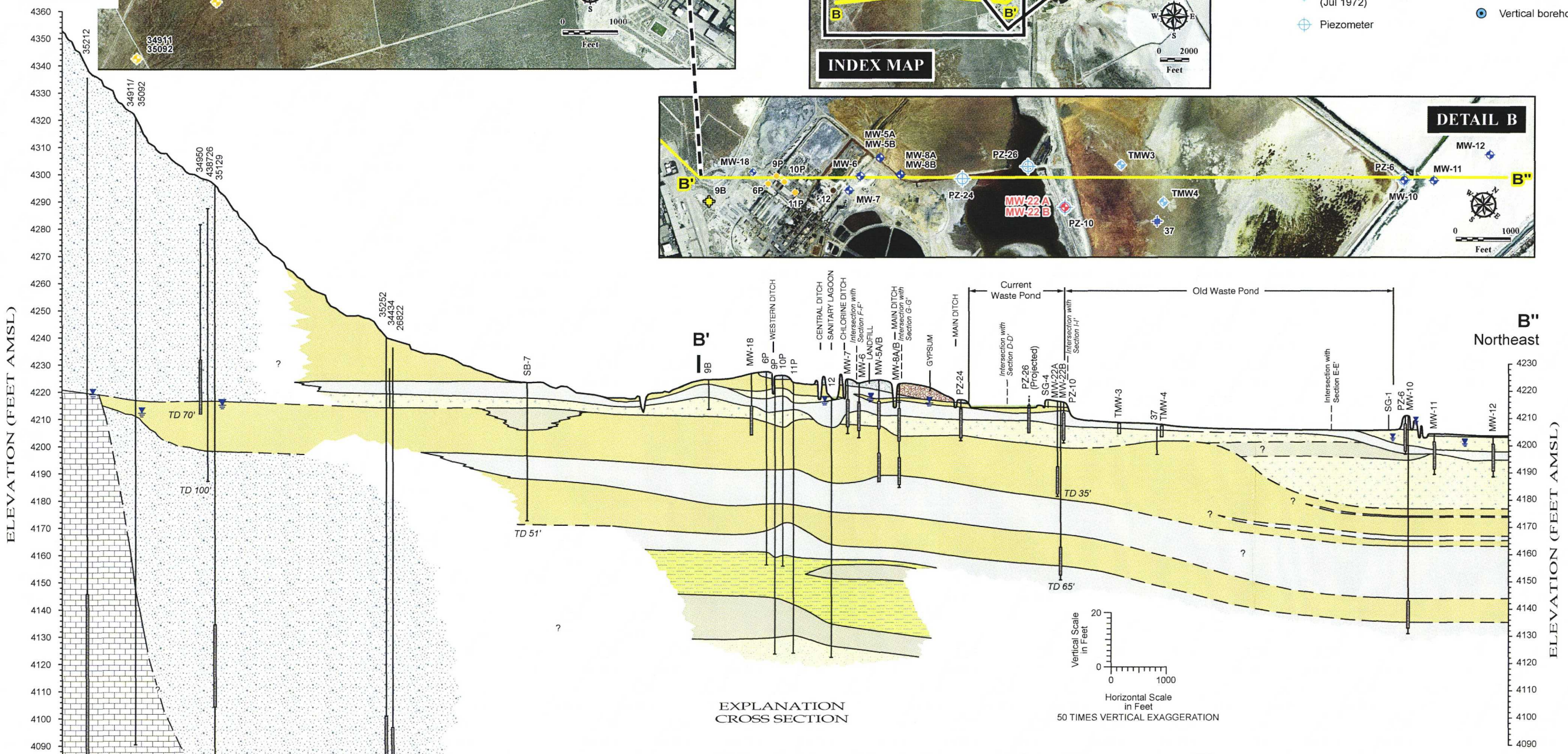
EXPLANATION
DETAIL A AND DETAIL B

- Monitoring well
- Off-site well
- Monitoring well (Jun 2017)
- Temporary monitoring well (Jul 1972)
- Piezometer
- Test pit (Jan 1970)
- Test pit (Feb 1970)
- Boring (Jun 1969)
- Boring (Dec 1969)
- Vertical borehole (Jul 2017)

B
Southwest

B'

B"
Northeast



EXPLANATION
CROSS SECTION

- Fill/landfill material
- Gypsum talus pile
- Clay/silty clay, low to medium plasticity
- Silt/sandy silt/clayey silt
- Silty sand/fine-grained sand, oolitic in part
- Fine-grained sand interbedded with silt and clay
- Fine-grained sand, oolitic in part
- Well-graded sand, oolitic in part, some gravel, cemented in part
- Pond/ditch water
- Shale
- Limestone
- Shaley limestone
- Silty sand/gravel
- TD Total depth
- Geological contact; dashed where inferred
- AMSL Above mean sea level
- Test pit or soil boring
- Temporary monitoring well
- Measured static water level (Sep 2017)
- Screened interval

Notes:

1. *Ground surface elevations derived from Nov 2015 lidar survey.*
2. *Section B'-B" modified after ERM, 2016*

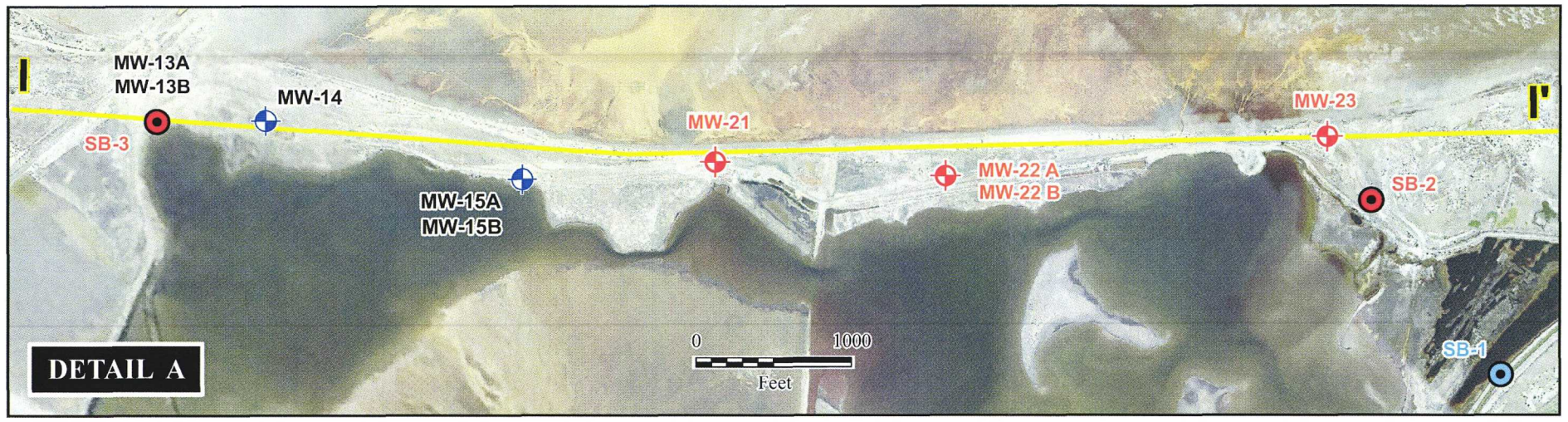
USmag®

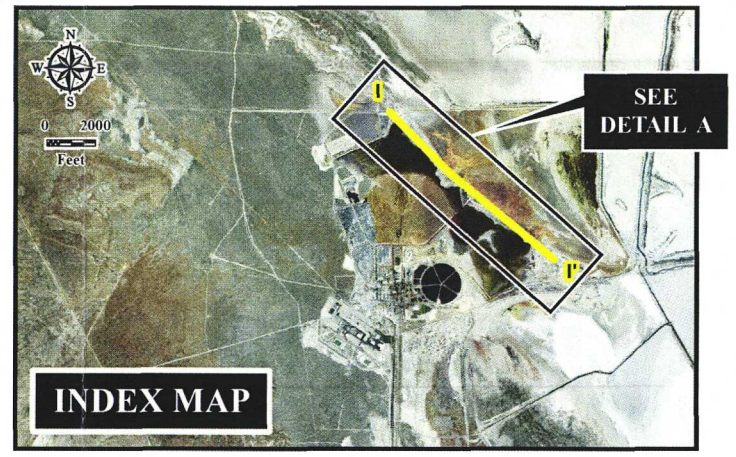
CROSS SECTION B-B'-B"

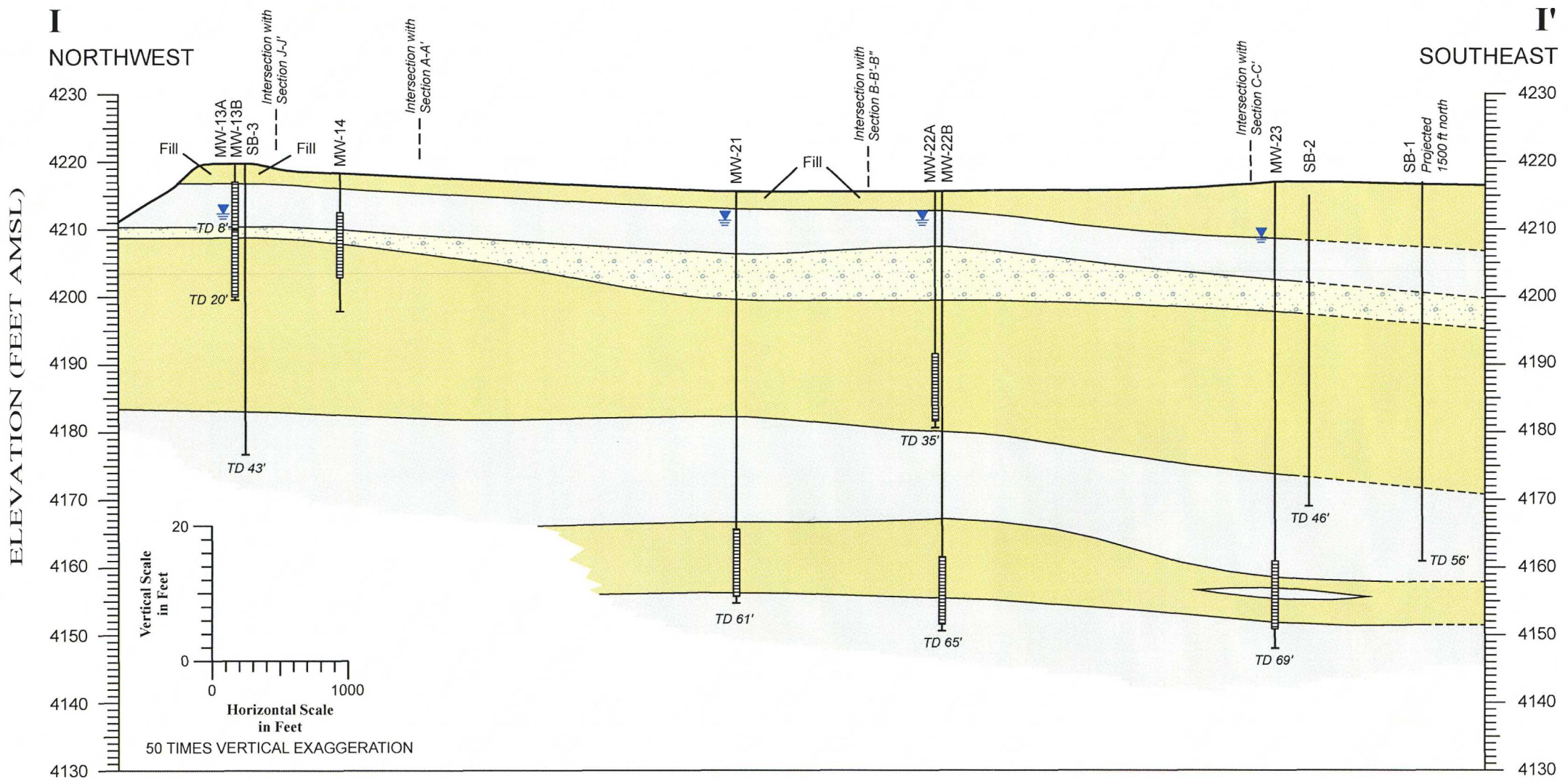
Figure 3-1b

DRAWN BY D. Severson

25 Oct 2017







EXPLANATION

- Monitoring well
- Monitoring well (Jun 2017)
- Angled borehole (Jun 2017)
- Vertical borehole (Jun 2017)
- Clay/silty clay, low to medium plasticity
- Silt/sandy silt/clayey silt
- Silty sand/fine-grained sand, oolitic in part
- Fine-grained sand interbedded with silt and clay
- Fine-grained sand, oolitic in part
- Well-graded sand, oolitic in part, some gravel, cemented in part
- Geological contact; dashed where inferred
- TD — Total depth
- AMSL — Above mean sea level
- Test pit or soil boring
- Measured static water level (Sep 2017)
- Screened interval

USmag®

Stantec

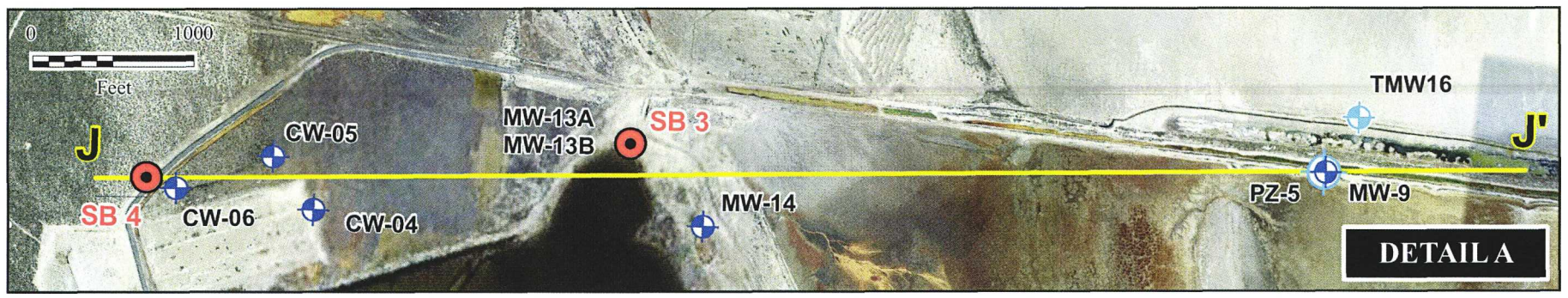
CROSS SECTION I-I'

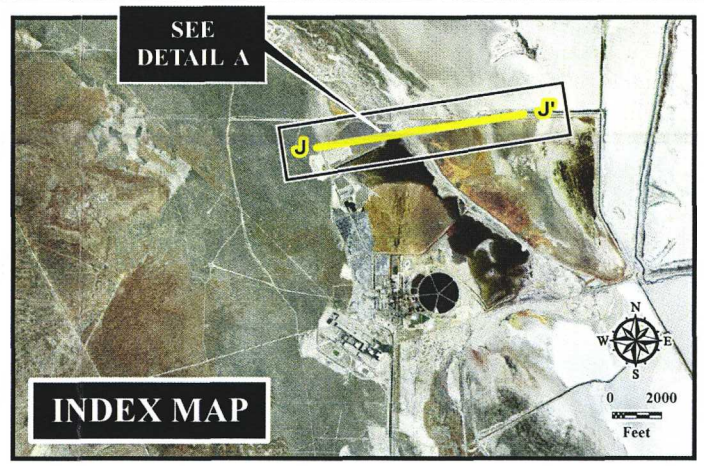
Figure 3-1c

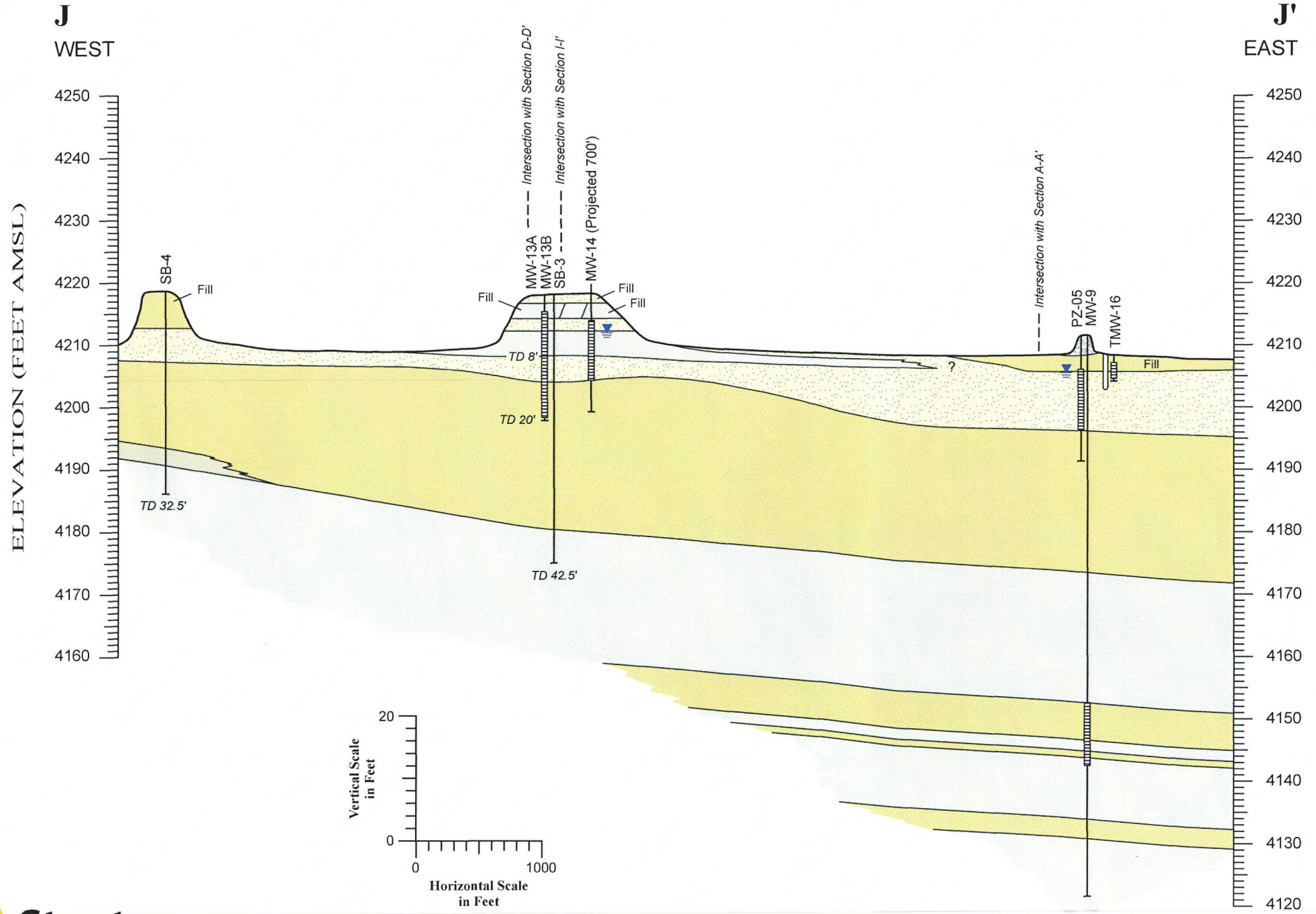
C:\Data\WWHPB&L &US Magnesium\FIGURES\Fig 3-1c_Cross Section I_I_21Oct2017.ai

DRAWN BY: D. Severson

25 Oct 2017 2017







EXPLANATION

- Monitoring well
- Temporary monitoring well (Jul 1972)
- Piezometer
- Angled borehole (Jun 2017)
- Clay/silty clay, low to medium plasticity
- Silt/sandy silt/clayey silt
- Silty sand/fine-grained sand, oolitic in part
- Fine-grained sand interbedded with silt and clay
- Fine-grained sand, oolitic in part
- Well-graded sand, oolitic in part, some gravel, cemented in part
- Geological contact; dashed where inferred
- TD — Total depth
- AMSL — Above mean sea level
- Test pit or soil boring
- Measured static water level (Sep 2017)
- Screened interval

Stantec

USmag®

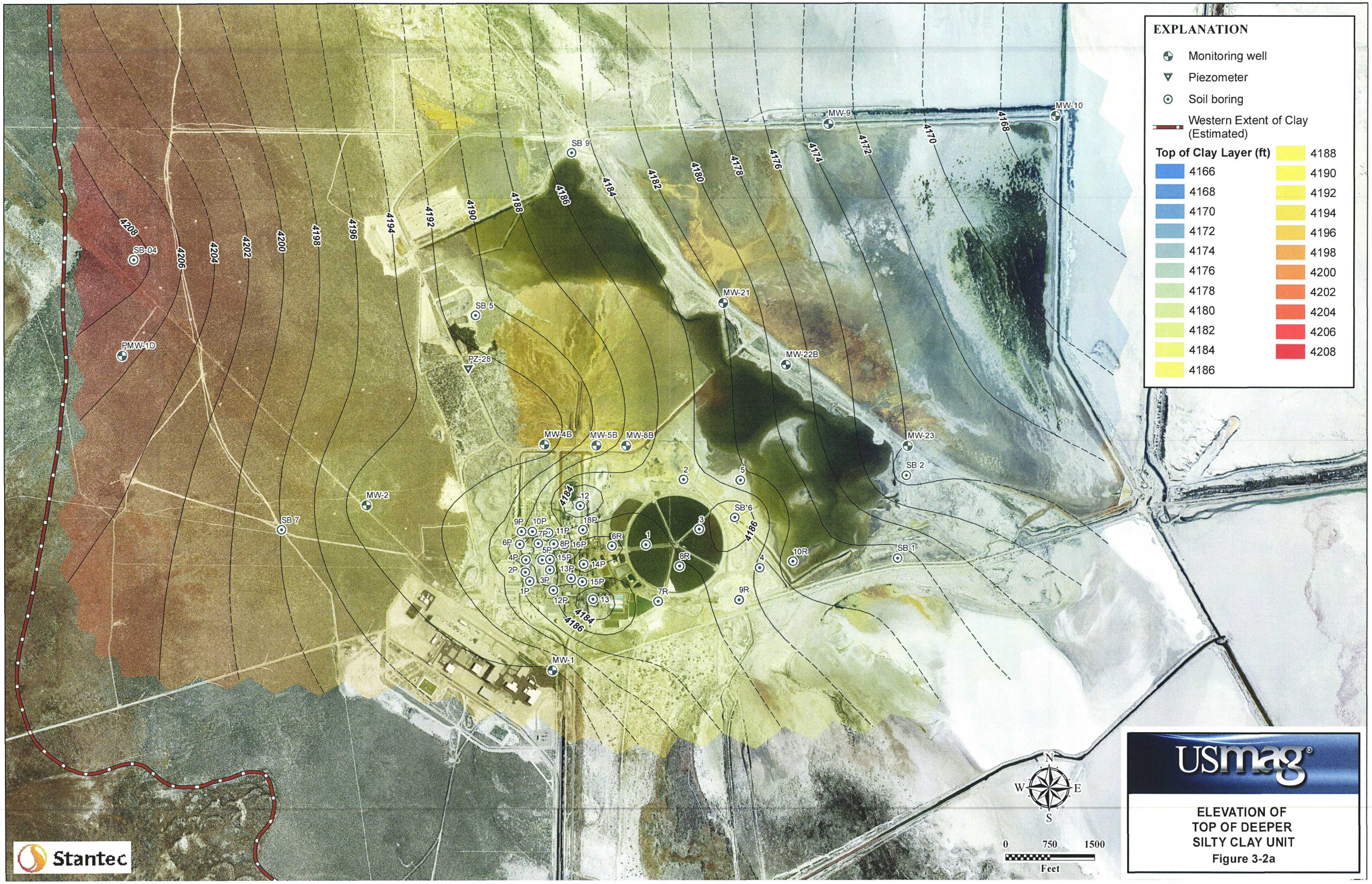
CROSS SECTION J-J'

Figure 3-1d

C:\Data\WWHVPB&L &US Magnesium\FIGURES\Fig 3-1d_Cross Section J_J'_21Oct2017.ai

Drawn by C Gallegos

Date: 9/27/2017



Stantec

USmag®

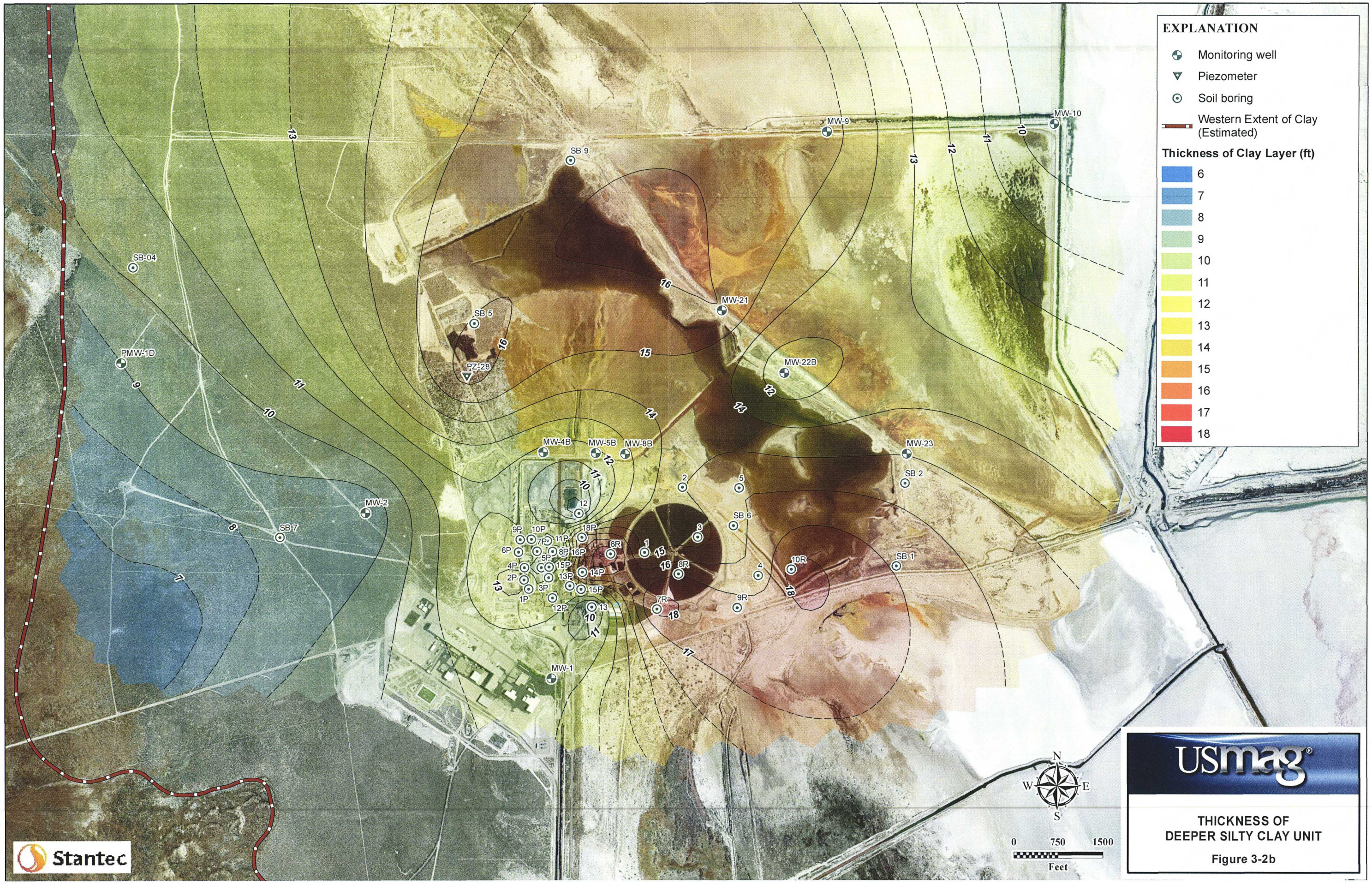
ELEVATION OF TOP OF DEEPER SILTY CLAY UNIT

Figure 3-2a

E:\PB&L &US Magnesium\FIGURES\Fig 3_2a_ELEVATION OF TOP OF DEEPER SILTY CLAY UNIT_20170927.mxd

Drawn by C Gallegos

Date: 9/27/2017



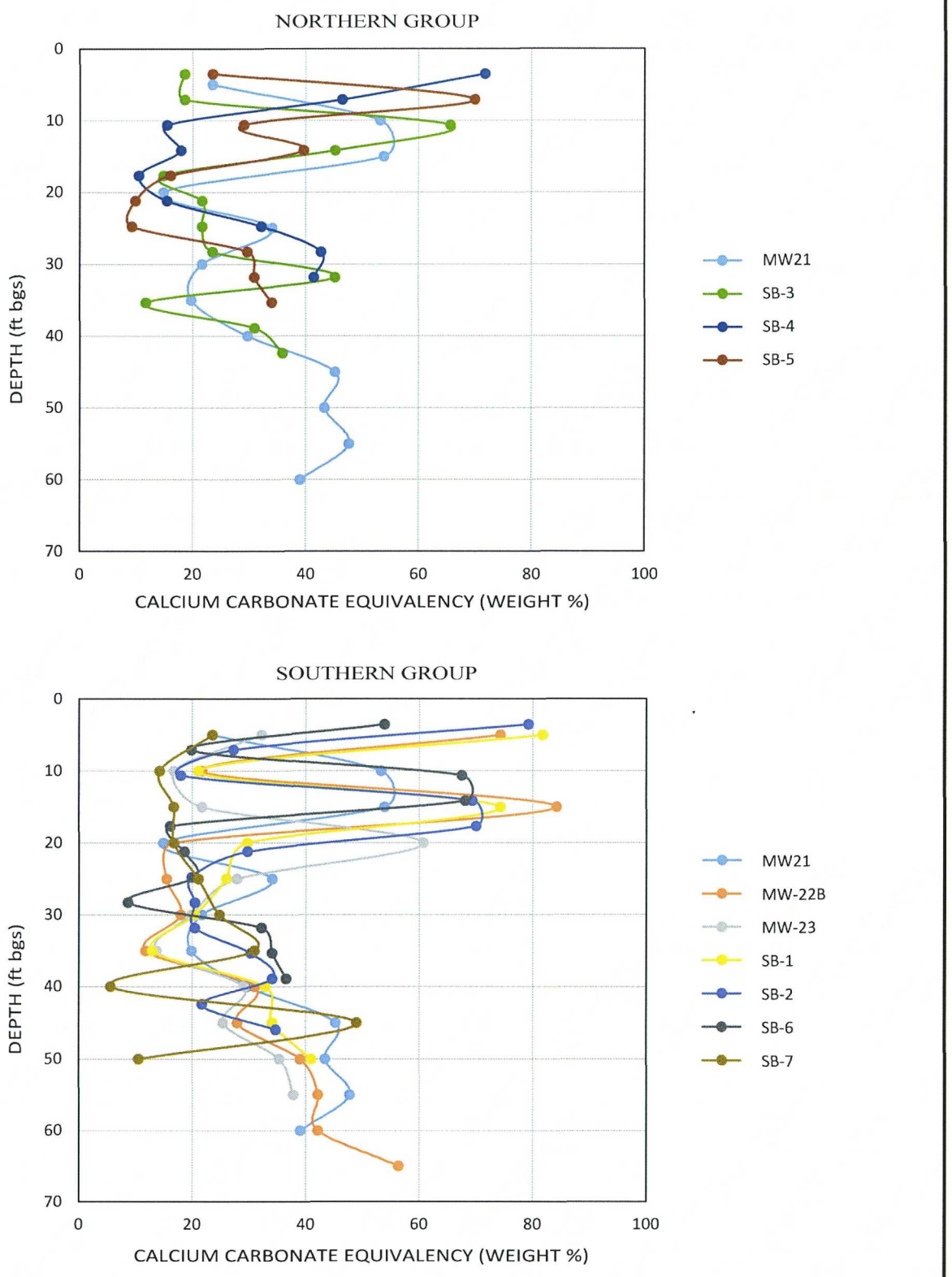
Stantec

USmag®

THICKNESS OF
DEEPER SILTY CLAY UNIT

Figure 3-2b

E:\PB&L &US Magnesium\FIGURES\Fig 3_2b Thickness of Deeper Silty Clay Unit_20170927.mxd



1 Nov 2017

C:\Data\MWH\PB&L &US Magnesium\Fig 3-3_Calc Carb Content of Soils Beneath the CWP.ai

USmag®

CALCIUM CARBONATE CONTENT OF SOILS BENEATH THE CWP

(boring and well locations shown in Figure 3-1a)

Figure 3-3

J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Shallow Aquifer\FIGURES\Fig 3-4a_USMAG_SEPT_Pot Surf of Shall Aq Zn_No Corr_27Nov2017.mxd 27 Nov 2017 DRAWN BY D. Severson

1292000 1296000 1300000 1304000 1308000

7512000 7508000 7504000

PMW-1S 4216.69
PZ-03 4214.93
PZ-27 4215.73
PZ-04 4214.88
MW-13A 4211.89
MW-13B 4212.46
MW-14 4212.06
MW-15A 4213.02
MW-15B 4213.12
PZ-05 4205.45
PZ-6 4201.61
MW-11 4199.7
PZ-29 4201.5
PZ-30 4201.43
PZ-08 4211.71
PZ-26 4213.98
MW-22A 4211.35
PZ-10 4211.86
PZ-07 4203.74
PZ-24 4214.85
MW-5A 4215.58
MW-8A 4215.37
MW-17 4214.64
PZ-11 4211.29
PZ-12 4210.2
MW-4A 4215.86
MW-5B 4216.1
MW-8B 4215.38
MW-3 4216.07
PZ-19A 4214.4
PZ-13 4209.54
MW-4B 4216.19
LF-02 4215.8
PZ-19B 4214.88
MW-6 4215.88
PZ-22 4214.23
PZ-14 4211.17
MW-7 4215.88
PZ-16 4212.06
PZ-20 4210.86
PZ-18 4211.17
MW-20A 4214.29
PZ-01 4210.12

4216 4214 4212 4210 4208 4206 4204 4202 4203 4205 4209 4211 4207 4211 4213 4215 4216

EXPLANATION

MW-14 4212.06 — Well ID; September 2017 measured groundwater elevation in feet below ground surface

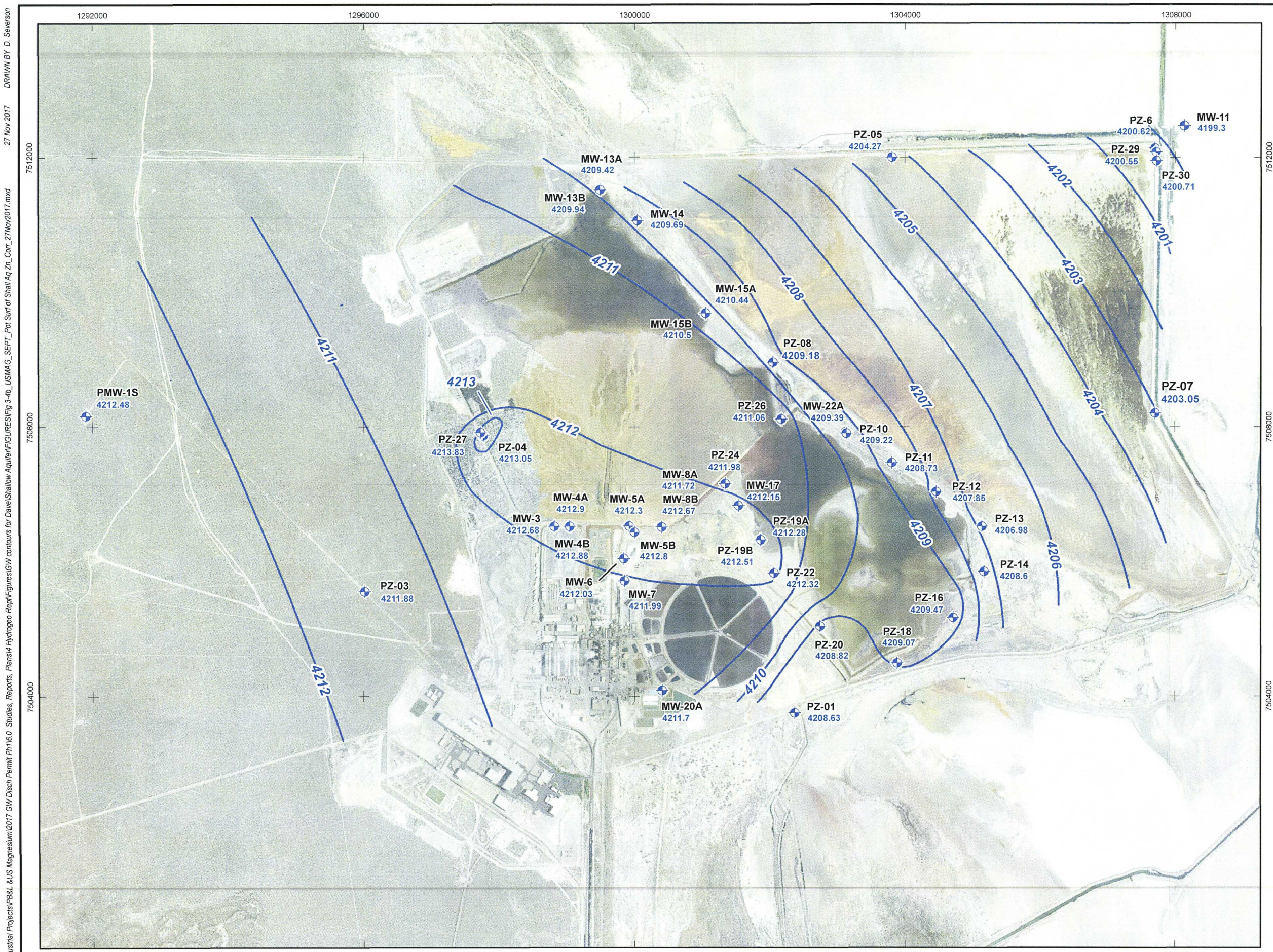
—4208— Potentiometric surface in feet (no correction) 1' contour interval

N W E S

0 700 1400
Feet

USmag®

US MAGNESIUM
POTENTIOMETRIC SURFACE OF THE UPPER AQUIFER ZONE (NO DENSITY CORRECTION APPLIED)
Figure 3-4a



EXPLANATION

MW-14 4209.69 — Well ID; September 2017 measured groundwater elevation in feet below ground surface

—4208— Potentiometric surface in feet (density correction) 1' contour interval

N
W E
S

0 700 1400
Feet

USmag®

US MAGNESIUM

POTENTIOMETRIC SURFACE OF THE UPPER AQUIFER ZONE (DENSITY CORRECTION APPLIED)

Figure 3-4b

DRAWN BY D. Severson 27 Nov 2017

J:\Industrial Projects\P&L & US Magnesium\2017 GW Disch Permit Ph116.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Shallow Aquifer\FIGURES\Fig 3-4b_USMAG_SEPT_Pot Surf of Shall Aq Zn_Corr_27Nov2017.mxd

EXPLANATION

MW-21 4211.61 — Well ID; September 2017 measured groundwater elevation in feet below ground surface

—4208— Potentiometric surface in feet (no correction) 1' contour interval

N
W E
S

0 700 1400
Feet

USmag®

US MAGNESIUM

POTENTIOMETRIC SURFACE OF THE LOWER AQUIFER ZONE (NO DENSITY CORRECTION APPLIED)

Figure 3-4c

DRAWN BY D. Severson 27 Nov 2017

J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Deep Aquifer\FIGURES\Fig 3-4c_USMAG_SEPT_Pot Surf of Lower Aq Zn_No Corr_27Nov2017.mxd

EXPLANATION

MW-21 4209.7 — Well ID; September 2017 measured groundwater elevation in feet below ground surface

—4208— Potentiometric surface in feet (density correction) 1' contour interval

N
W E
S

0 700 1400
Feet

USmag®

US MAGNESIUM

POTENTIOMETRIC SURFACE OF THE LOWER AQUIFER ZONE (DENSITY CORRECTION APPLIED)

Figure 3-4d

J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph1\6.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Deep AquiferFIGURES\Fig 3-4d_USMAG_SEPT_Pot Surf of Lower Aq Zn_Corr_27Nov2017.mxd 27 Nov 2017 DRAWN BY D. Severson

J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Shallow Aquifer\FIGURES\Fig 3-4a_USMAG_DEC_PotSurfShall Aq Zn_NoCorr_10Dec2017.mxd 10 Dec 2017 DRAWN BY D. Severson

1292000 1296000 1300000 1304000 1308000

7512000 7508000 7504000

MW-12 4198.95
MW-11 4199.83
PZ-06 4201.99
PZ-29 4202.09
PZ-30 4202.05
PZ-05 4206.37
MW-13A 4212.08
MW-13B 4212.73
MW-14 4213.16
MW-15A 4213.31
MW-15B 4213.4
PZ-08 4211.85
PZ-07 4204.72
PMW-1S 4216.12
PZ-26 4214.29
PZ-10 4212.22
PZ-27 4214.88
PZ-04 4214.95
MW-22A 4211.64
PZ-24 4215.19
PZ-11 4212.15
MW-5A 4215.78
MW-8A 4215.61
MW-17 4214.91
PZ-12 4210.32
MW-4A 4215.94
MW-5B 4216.3
MW-8B 4215.61
MW-3 4216.16
MW-19A 4214.72
PZ-13 4209.91
MW-4B 4216.27
LF-02 4216.01
MW-19B 4215.19
PZ-14 4211.6
MW-6 4216.09
PZ-22 4214.58
PZ-03 4214.83
LF-01 4215.85
MW-7 4216.15
PZ-16 4213.08
PZ-20 4211.36
PZ-18 4211.49
MW-20A 4214.34
PZ-01 4210.28

4201 4202 4203 4204 4205 4206 4207 4208 4209 4210 4211 4212 4213 4214 4215 4216

EXPLANATION

MW-14 4212.06 — Well ID
December 2017 measured groundwater elevation in feet below ground surface

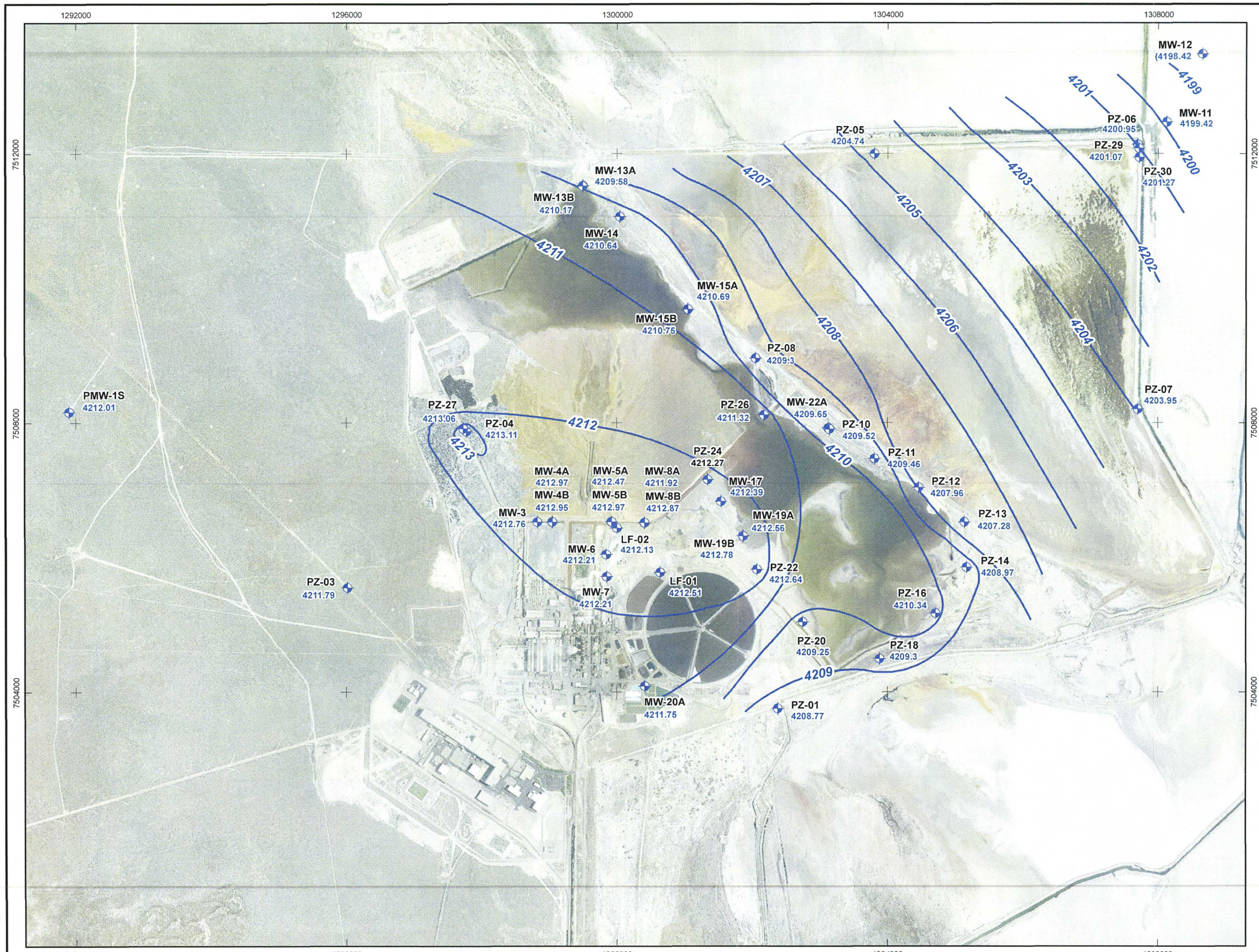
—4208— Potentiometric surface in feet (no correction)
1' contour interval

N W E S

0 700 1400
Feet

USmag®

US MAGNESIUM
POTENTIOMETRIC SURFACE OF THE UPPER AQUIFER ZONE (NO DENSITY CORRECTION APPLIED)
Figure 3-4e



EXPLANATION

MW-14
4212.06
Well ID
December 2017 measured groundwater elevation in feet below ground surface

—4208—
Potentiometric surface in feet (density correction)
1' contour interval

N
W
E
S

0 700 1400
Feet

USmag®

US MAGNESIUM
POTENTIOMETRIC SURFACE OF THE UPPER AQUIFER ZONE (DENSITY CORRECTION APPLIED)
Figure 3-4f

DRAWN BY D. Severson
10 Dec 2017
J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Shallow Aquifer\FIGURES\Fig 3-4b_USMAG_DEC_PotSurfShall Aq Zn_Corr_10Dec2017.mxd

EXPLANATION

MW-21 Well ID
4211.61 December 2017 measured groundwater elevation in feet below ground surface

—4208— Potentiometric surface in feet (no correction) 1' contour interval

N
W E
S

0 700 1400
Feet

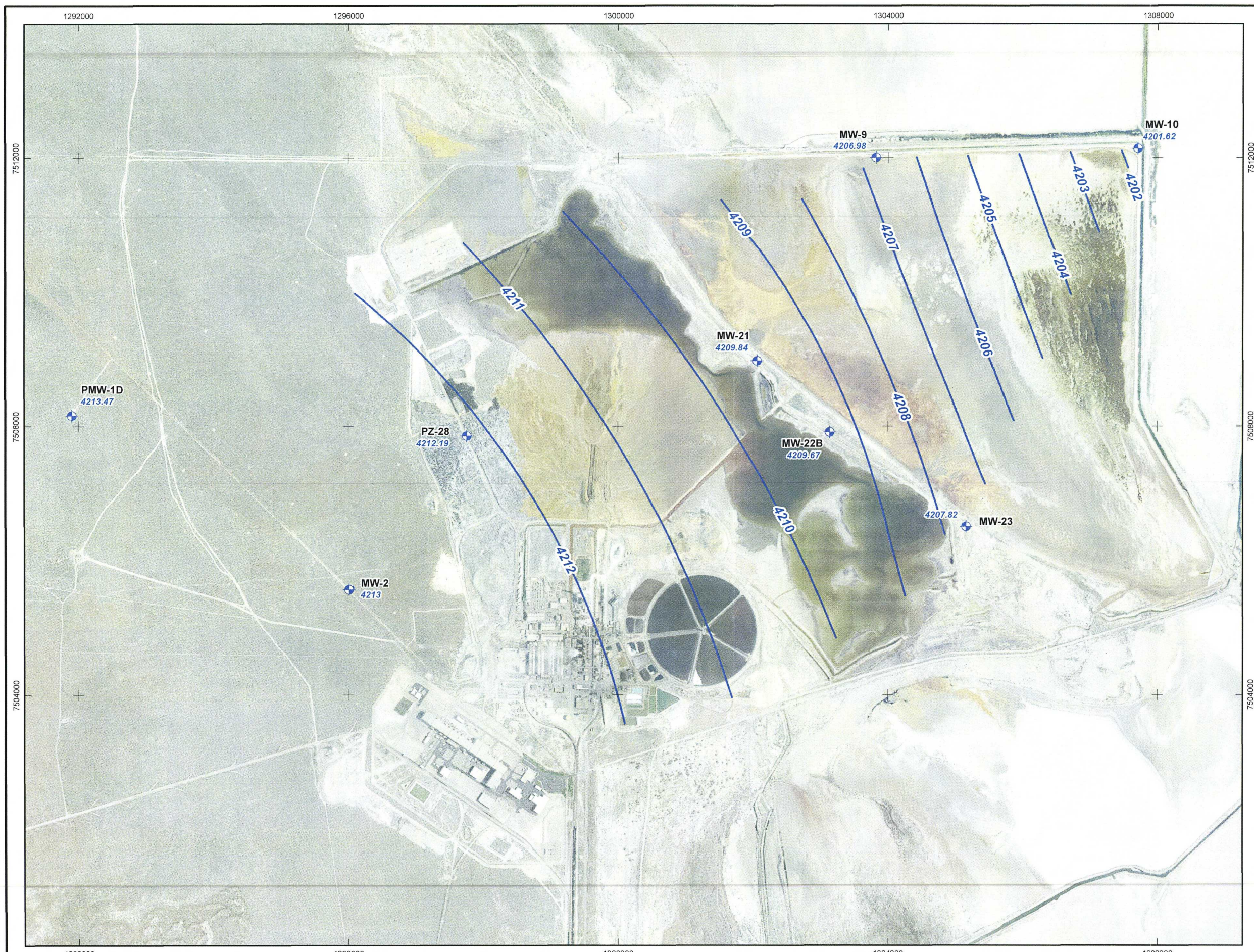
USmag®

US MAGNESIUM

POTENTIOMETRIC SURFACE OF THE LOWER AQUIFER ZONE (NO DENSITY CORRECTION APPLIED)

Figure 3-4g

DRAWN BY D. Severson
11 Dec 2017
J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Deep Aquifer\FIGURES\Fig 3-4c_USMAG_DEC_PotSurf of Lower_Aq Zn_NoCorr_11Dec2017.mxd



EXPLANATION

MW-21 Well ID
4211.61 December 2017 measured groundwater elevation in feet below ground surface

—4208— Potentiometric surface in feet (density correction) 1' contour interval

N
W E
S

0 700 1400
Feet

USmag®

US MAGNESIUM

POTENTIOMETRIC SURFACE OF THE LOWER AQUIFER ZONE (DENSITY CORRECTION APPLIED)

Figure 3-4h

DRAWN BY D. Severson
11 Dec 2017
J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Deep Aquifer\FIGURES\Fig 3-4d_USMAG_DEC_PotSurf of Lower_Aq Zn_Corr_11Dec2017.mxd

DRAWN BY D. Severson

1 Dec 2017

J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rep\Figures\TDS Contours for Dave SI\Fig 3-5_USMAG_Total Dissolved Solids Iso Map_1Dec2017.mxd

1292000 1296000 1300000 1304000 1308000

7512000 7508000 7504000

PMW-1S 6,600 (a)
PMW-1D 5,200 (a)
MW-13B 63,000 (c)
MW-13A 53,000 (b)
MW-14 64,000 (b)
MW-15A 53,000 (b)
PZ-08 65,000 (c)
MW-21 110,000 (c)
PZ-26 63,000 (b)
MW-22B 110,000 (c)
PZ-04 130,000 (b)
PZ-10 58,000 (c)
PZ-12 58,000 (c)
PZ-24 77,000 (b)
PZ-06 82,000 (b)
MW-4A 54,000 (b)
MW-5A 78,000 (b)
MW-8A 57,000 (b)
PZ-13 48,000 (c)
MW-23 160,000 (c)
MW-19A 130,000 (b)
LF-03 77,000 (b)
MW-6 29,000 (b)
PZ-22 180,000 (b)
MW-7 39,000 (b)
LF-01 33,000 (b)
PZ-16 60,000 (b)
PZ-18 92,000 (b)
MW-20A 70,000 (b)
PZ-01 300,000 (b)

10000 50000 100000 200000

EXPLANATION

- Lower aquifer zone monitoring well
- Upper aquifer zone monitoring well
- 110,000 TDS (mg/L) - Lower aquifer zone
- 110,000 TDS (mg/L) - Upper aquifer zone
- –4208– Lower aquifer zone TDS isocontour (mg/L)
- –4208– Upper aquifer zone TDS isocontour (mg/L)
- mg/L Micrograms per liter
- TDS Total dissolved solids

(a) July 2015 (MWH, 2015)
(b) February 2014 (ERM, 2016)
(c) September 2017

N W E S

0 700 1400
Feet

USmag®

US MAGNESIUM

TOTAL DISSOLVED SOLIDS ISOCONTOUR MAP

Figure 3-5

APPENDIX A – GEOLOGY AND LITHOLOGY DATA

Stantec

Table of Contents

1.0 INTRODUCTION 1
2.0 WELL DRILLING SUMMARY 3
2.1 GEOTECHNICAL AND GEOCHEMICAL SAMPLES 3
3.0 REFERENCES 5
ATTACHMENT A.1: BORING LOGS 6
ATTACHMENT A.2 – HISTORICAL CROSS SECTIONS 7
ATTACHMENT A.3 – 2017 CARBONATE AND XRD LAB RESULTS 8
ATTACHMENT A.4 – 2017 GEOTECHNICAL LAB RESULTS 9

1.0 INTRODUCTION

In preparation for submission of the Groundwater Discharge Permit (GWDP) application for the US Magnesium facility a series of field investigations were performed for the purpose of filling data gaps. The scope of work for the field investigations was proposed in two documents submitted to the Utah Department of Water Quality, the *Data Gaps Investigation* and *Work Plan* (Stantec, 2017a&b)
The field investigations consisted of:

- Drilling seven (7) boreholes to obtain lithological and geochemical data of the soils adjacent to and beneath the current waste ponds (CWP)

- Installation of four (4) new monitoring wells with the purpose of:
    - Obtaining lithological and geochemical data of soils downgradient/adjacent to the CWP
    - Allow performance of a pumping test to define aquifer parameters of the deep confined aquifer zone and to observe response in wells in the shallow aquifer zone
    - Provide data for baseline monitoring and future use as compliance wells

- Performing a pumping test at MW-22B in order to characterize the deeper aquifer zone and to observe potential response in shallow aquifer zone wells (See Appendix B)

- Performing pneumatic slug tests at ten wells throughout the site to obtain hydraulic conductivity data for use in the groundwater model (See Appendix B)

- Collect depth to water measurements (seasonally) to understand seasonal variability of aquifer and aid in groundwater modeling (See Appendix B)

- Collect and analyze groundwater samples from ten wells along the eastern dike to characterize the baseline groundwater quality (See Appendix C)

- Collect and analyze water samples from the waste water ditch to characterize the waste stream discharging from the US Magnesium facility (See Appendix C)

Included as part of this appendix are historical soil borings (Attachment A.1), historical cross sections (Attachment A.2) and lab reports from the 2017 soil borings (Attachments A.3 and A.4).

2.0 WELL DRILLING SUMMARY

From June 8th to June 21st, 2017 Cascade Drilling advanced seven (7) boreholes and installed four (4) monitoring wells at the US Magnesium site utilizing a sonic drilling rig (Rig GP24-300).

Six boreholes (SB-01 through SB-06) were advanced around the perimeter of the CWP in order to collect soil samples adjacent to and beneath the CWP. Two borings were advanced vertically and four were installed at a 45 degrees angle below the CWP. Borings were advanced into the deeper silty clay unit, but were terminated once this layer was encountered in order to preserve the integrity of the confining unit. One additional vertical soil boring (SB-07) was advanced up gradient of the CWP (outside of the area of historical impacts) to provide background lithological data and samples for geochemical analyses. A professional geologist (William Bragdon) was on-site during the drilling of all wells in order to record lithological data and collect geochemical and geotechnical samples (See **Attachment A.1** for drilling logs).

Four monitoring wells were installed along the eastern edge of the CWP the collection of lithological, hydraulic conductivity, water-level data, and to support a pump test of the confined lower aquifer zone. Drilling logs and lithology are presented in **Attachment A.1**. Three wells (MW-21, MW-22B and MW-23) are screened below the deeper silty clay unit and one well (MW-22A) was installed adjacent to MW-22B with the screened interval above the deeper silty clay unit at the bottom of the shallow aquifer zone.

The four monitoring wells were constructed with four-inch schedule 40 Polyvinyl chloride (PVC) casing and screen. Well screen intervals were ten feet in length with a slotted aperture or perforation of 0.01 inches. Following well installation, the outer annulus between the well screen and borehole wall was gravel packed with 20/40 silica sand to several feet above the top of the screen interval. Above the sand pack, the outer annulus was completed with a bentonite and grout sanitary seal to the surface. The above ground well casing was protected with the installation of a well monument cover. All monitoring wells top of casing and ground elevations were surveyed on June 28, 2017, by Robinson, Biehn & Biehn, Inc., Professional Land Surveyors. Wells were subsequently developed from June 13 to June 20, 2017, to remove fines accumulated in the wells during construction. Well development forms are presented in **Attachment A.2**.

2.1 GEOTECHNICAL AND GEOCHEMICAL SAMPLES

Undisturbed soil samples were collected from three monitoring well borings and seven soil borings and analyzed in a geotechnical laboratory for particle size distribution, Atterberg Limits, hydraulic conductivity (flexible wall permeameter), and water content as listed in attached Table 3-2.

Thirty-four (34) four samples were collected for particle distribution analysis with nine collected from the shallow aquifer, nineteen (19) from the silty clay layer and six from the deeper aquifer. Within each borehole two samples were collected from the top of the clay layer and another at a deeper interval or just above the deep aquifer. From the nineteen samples collected from the silty clay layer there was no gravels identified in the samples. Fines with in the silty clay

layer generally dominated the sample matrix with a geometric mean of 90% fines overall. Samples collected in the deeper interval of the silty clays generally increased in fines. The fines ranged in fractionation between samples from 76% to 97% in all samples collected from the silty clays. Geotechnical results suggest that all samples collected from the silty clay layer are a clay or fat clay.

A total of thirteen (13) Samples were collected for hydraulic conductivity analysis from the bottom of the shallow silty aquifer, confining silty clays and the deeper silty aquifer.

3.0 REFERENCES

Stantec, 2017a. *Technical Memo: Groundwater Discharge Permit Application Preparation – Data Gaps Summary and Proposed Data Collection Activities Revision 1.* Submitted to Utah Division of Environmental Quality: Division of Water Quality April 10, 2017.

Stantec, 2017b. *Technical Memo: US Magnesium Groundwater Discharge Permit Application Preparation – Field Data Collection Work Plan.* Submitted to Utah Division of Environmental Quality: Division of Water Quality May 2, 2017.

APPENDIX A: TABLE OF CONTENTS

ATTACHMENT A.1 – BORING LOGS

Section A.1-1 2017 Boring Logs and Well Construction Diagrams
Section A.1-2 2015 Boring Logs and Well Construction Diagrams
Section A.1-3 2004 Boring Logs and Well Construction Diagrams
Section A.1-4 1969 Boring Logs and Well Construction Diagrams
Section A.1-5 Desert Power Well Information

ATTACHMENT A.2 – HISTORICAL CROSS SECTIONS

Section A.2-1 Historical Cross Sections from Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model report (ERM, June 2016)
Section A.2-2 Historical Cross Sections from: Draft Preliminary Design Basis and Feasibility Evaluation Report – Proposed New Evaporation Pond (MWH, September 2015)
Section A.2-3 Historical Cross Sections from: Groundwater Characterization and First Quarter Groundwater Monitoring Report (MWH, September 2004)
Section A.2-4 1969 Historical Cross Sections (Dames and Moore, 1972)

ATTACHMENT A.3 – 2017 CALCIUM CARBONATE AND XRD LAB RESULTS

Section A.3-1 Calcium Carbonate Laboratory Results
Section A.3-2 X-Ray Diffraction Laboratory Results

ATTACHMENT A.4 – 2017 GEOTECHNICAL LAB RESULTS

Stantec

ATTACHMENT A.1
BORING LOGS (PRE-2017 BORING LOGS INCLUDED IN ELECTRONIC SUBMITTAL)

Stantec

MONITORNG WELL ID: **MW-21**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 12

EASTING: 1302098.55 NORTHING: 3499731.09

ELEVATION: 4218.18 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 60.5 GROUNDWATER LEVEL (ft btoc): 6.4

DATE STARTED: 6/17/2017 DATE FINISHED: 6/17/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		FILL-POORLY GRADED SAND (SP): with fine grained oolitic sand and some silt and fine gravel (cemented oolitic), pale brown (10YR						
5		SILTY CLAY (CL): with trace fine sand, greenish gray (GLEY 5/1), medium plasticity with low plasticity where fine grained sands						
		Estimated depth to groundwater in field.						
10		POORLY GRADED SAND WITH GRAVEL (SP): cemented oolitic sand, greenish gray (GLEY 5/1). POORLY GRADED SAND (SP): fine to coarse oolitic sand, with some silt and some fine gravel, greenish gray (GLEY 5/1) to very dar						
15		Cemented oolitic sand. SILTY SAND (SM): fine grained sand, dark gray (GLEY 4/1) to greenish gray (GLEY 5/1), wet, nonplastic, generally loose with som	0	79.2	20.8	SM		
20								
25			0.1	74.6	25.3	SM		
							16.3	1.7E-6
30		Grades to very dense, wet, greenish gray (GLEY 5/1), with thin 0.125 inch to 0.0625 inch silty clay wide stringers.						

WELL CONSTUCTION DIAGRAM

- Above ground protective casing
- Groundwater Level at 6.4 ft btoc in June 2017
- Aqua Grout 0 to 43 ft bgs
- 0 of 50 ft bgs, 4 in dia, Sch 40 PVC solid riser
- Borehole dia, 10 inches from 0 to 35 ft bgs

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-21**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 12

EASTING: 1302098.55 NORTHING: 3499731.09

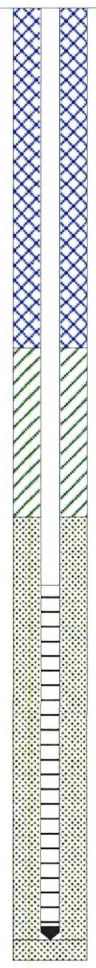
ELEVATION: 4218.18 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 60.5 GROUNDWATER LEVEL (ft btoc): 6.4

DATE STARTED: 6/17/2017 DATE FINISHED: 6/17/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS						WELL CONSTUCTION DIAGRAM
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)	
35		SILTY CLAY (CL): with trace fine grained sand, greenish gray (GLEY 6/1), medium plasticity, low plasticity where sandy, soft gr	0	21	79	CL	26.4	4.8E-8	
40		CLAY SAND (SC): with fine grained sand, greenish gray (GLEY 6/1), low plasticity, stiff, wet. SILTY CLAY (CL): with trace fine sand, greenish gray (GLEY 5/1), medium plasticity, soft to medium stiff, wet, strong sulfur od					31.1	2.8E-8	
45			0	2.4	97.6	CL			
50		SILTY SAND (SM): fine grained sand, with thinly interbedded clays, dark greenish gray (GLEY 4/1) to greenish gray (GLEY 6/1), n	0	27.3	72.7	CL			
55		SILTY CLAY (CL): greenish gray (GLEY 6/1), medium plasticity, stiff, wet. SILTY SAND (SM): fine grained sand, dark greenish gray (GLEY 4/1) to dark gray (GLEY 4/1), wet, medium dense, nonplastic.	0	73.1	26.9	SM			
60		CLAY(CL): with trace silt, greenish gray (GLEY 5/1), wet, low to medium plasticity, soft, moderate sulfur odor.					22.7	5.7E-5	
65		End of borehole at 63 ft below ground surface in clays.							



Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-22A**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 13

EASTING: 1303162.57 NORTHING: 3498683.21

ELEVATION: 4218.324 BOREHOLE ANGLE: 90 degrees

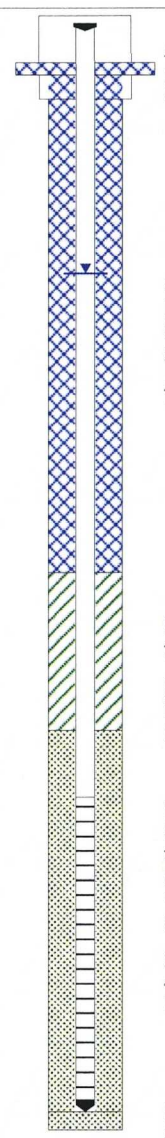
TOTAL DEPTH (ft): 35 GROUNDWATER LEVEL (ft btoc): 6.75

DATE STARTED: 6/9/2017 DATE FINISHED: 6/9/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		FILL SILTY SAND (SM): fine to medium grained sand, brown (10 YR 5/1), nonplastic, dry grading to slightly moist, loose.						
5		CLAY (CL): light brownish gray (2.5 Y 6/2), slight to low plasticity, wet, medium stiff, grading to soft at 7 ft, slightly mois						
10		POORLY GRADED GRAVEL (GP): cemented oolitic sands broke into angular sand and gravel size material.						
15		POORLY GRADED SAND (SP): fine to medium grained oolitic sand with trace silt, gray (10YR 6/1) grades to light brownish gray (2. With fine and coarse gravel size material of cemented oolitic sand.						
20		SILTY SAND (SM): fine grained sand with trace silt, gray (GLEY 5/1) to greenish gray (GLEY 6/1), wet, nonplastic, weak sulfur o With thin bedded silty clay, light olive gray (5Y 6/2), slight to low plasticity, medium dense, moist to wet.						
25		Same as previous.						
30		Increase in silt to 40%, gray (2.5Y 5/1), medium dense to dense, moderate sulfur odor. With thin bedded silty clay. With thinly interbedded silt (ML) from 35 to 36.2 ft, grades to dry to slightly moist at 35 ft, light greenish gray (GLEY 7/1).						
35		End of borehole at 35 ft below ground surface. Install shallow monitoring well.						

WELL CONSTUCTION DIAGRAM



Above ground protective casing

Groundwater Level at 6.75 ft btoc in June 2017

Aqua Grout 0 to 16.8 ft bgs

Bentonite 16.8 to 21.10 ft bgs

0 of 24 ft bgs, 4 in dia, Sch 40 PVC solid riser

Filter Pack Sand 24 to 35 ft bgs

Borehole dia, 10 inches from 0 to 35 ft bgs

24 to 34 ft bgs, 4 in dia, Sch 40 PVC screen

End Cap at 34.4 ft bgs

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-22B**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 14

EASTING: 1303169.4 NORTHING: 3498673.93

ELEVATION: 4218.15 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 65.2 GROUNDWATER LEVEL (ft btoc): 6.38

DATE STARTED: 6/8/2017 DATE FINISHED: 6/8/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS						WELL CONSTUCTION DIAGRAM
		Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)	
0	FILL SILTY SAND (SM): fine to medium grained sand, brown (10 YR 5/1), nonplastic, dry grading to slightly moist, loose.							Above ground protective casing
5	CLAY (CL): light brownish gray (2.5 Y 6/2), slight to low plasticity, wet, medium stiff, grading to soft at 7 ft, slightly mois							Groundwater Level at 6.38 ft btoc in June 2017
10	POORLY GRADED GRAVEL (GP): cemented oolitic sands broke into angular sand and gravel size material.							Aqua Grout 0 to 46.8 ft bgs.
15	POORLY GRADED SAND (SP): fine to medium grained oolitic sand with trace silt, gray (10YR 6/1) grades to light brownish gray (2. With fine and coarse gravel size material of cemented oolitic sand.	12.4	68.6	19	SM			
20	SILTY SAND (SM): fine grained sand with trace silt, gray (GLEY 5/1) to greenish gray (GLEY 6/1), wet, nonplastic, weak sulfur o With thin bedded silty clay, light olive gray (5Y 6/2), slight to low plasticity, medium dense, moist to wet.							0 of 54 ft bgs, 4 in dia, Sch 40 PVC solid riser
25	Same as previous.	0	72.8	27.2	SM			Borehole Diameter 10 inches from 0 to 39 ft bgs.
30	Increase in silt to 40%, gray (2.5Y 5/1), medium dense to dense, moderate sulfur odor. With thin bedded silty clay. With thinly interbedded silt (ML) from 35 to 36.2 ft, grades to dry to slightly moist at 35 ft, light greenish					28.6	7.3E-8	

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-22B**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 14

EASTING: 1303169.4 NORTHING: 3498673.93

ELEVATION: 4218.15 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 65.2 GROUNDWATER LEVEL (ft btoc): 6.38

DATE STARTED: 6/8/2017 DATE FINISHED: 6/8/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
		gray (GLEY 7/1).						
35		CLAY (CL): with trace fine sand, greenish gray (GLEY 5/1), medium plasticity, moist to wet, stiff.	0	6	94	CL	44.1	1.1E-7
40								
45		Note: Sonic core interval from 47 to 60 ft fell out of sampler and was retrieved with 15 foot recovery. Lithological interpreta	0	8.9	91.1	CL	53.7	6.2E-8
50		SILTY SAND (SM/ML): fine grained sand with silt, with some clay, greenish gray (GLEY 6/1), wet, low plasticity, soft to medium						
55							50.4	2E-7
60		CLAY (CL): with trace silt and few thin sand stringers, greenish gray (GLEY 6/1), wet, low to medium plasticity, medium stiff,	0	56.2	43.8	SC		
		POORLY GRADED SAND (SP): very dark greenish gray (GLEY 3/1), wet, nonplastic, very loose.						
65		CLAY (CL): with trace silt and fine grained sand, medium plasticity, medium stiff to stiff, moist, strong sulfur odor.	0	79.2	20.8	SM		
		End of borehole at 65.2 ft below ground surface. Stopped drilling in observed clay.						

WELL CONSTUCTION DIAGRAM

Borehole Diameter 8 inches from 39 to 65.2 ft bgs.

Bentonite 46.8 to 52 ft bgs.

Filter Pack Sand 52 to 65.2 ft bgs.

54 of 64 ft bgs, 4 in dia, Sch 40 PVC screen

End Cap at 64.4 ft bgs

Notes:

K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing

ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe

PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-23**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 15

EASTING: 1305195.27 NORTHING: 3497263.97

ELEVATION: 4219.582 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 67.3 GROUNDWATER LEVEL (ft btoc): 10.28

DATE STARTED: 6/16/2017 DATE FINISHED: 6/16/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)	WELL CONSTUCTION DIAGRAM
0		SILT WITH SAND (ML): fine grained oolitic sand, light brown gray (10 YR 6/2), low plasticity, soft, slightly moist, few organic							Above ground protective casing
10		SILTY CLAY (CL): gray (2.5 YR 6/1), high plasticity, wet, stiff and grading to very stiff. very dark gray (10 YR 3/1), medium plasticity, wet, weak sulfur odor, banded or very thinly beds, beds are greenish gray (GLEY							Aqua Grout 0 to 49 ft bgs Groundwater Level at 10.28 ft btoc in June 2017
15		POORLY GRADED GRAVEL WITH SAND (GP): cemented oolitic sand, light olive brown (2.5 YR 7/1). POORLY GRADED SAND (SP): fine grained oolitic sand with silt, light gray (10YR 7/1) to light brownish gray (10YR 6/2), wet, non	0	3.5	96.5	CH			
20		POORLY GRADED GRAVEL WITH SAND (GP): cemented oolitic sand, light olive brown (2.5 YR 7/1). SILTY SAND (SM): fine grained sand, with some silt, dark greenish gray (GLEY 4/1) to dark gray (GLEY 4/1), wet, nonplastic.							0 of 56.1 ft bgs, 4 in dia, Sch 40 PVC solid riser
25		Dark gray (GLEY 3/1), to dark greenish gray (GLEY 4/1), wet, nonplastic, medium dense.	0	74.7	25.3	SM	34.9	2.1E-6	Borehole dia, 10 inches from 0 to 67.3 ft bgs
30									
35		With interbedded silty clay, greenish gray (GLEY							

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-23**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 15

EASTING: 1305195.27 NORTHING: 3497263.97

ELEVATION: 4219.582 BOREHOLE ANGLE: 90 degrees

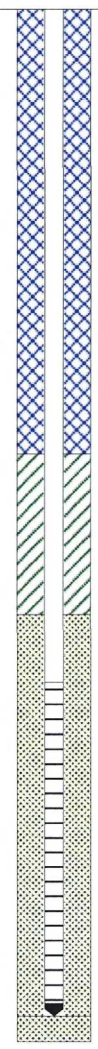
TOTAL DEPTH (ft): 67.3 GROUNDWATER LEVEL (ft btoc): 10.28

DATE STARTED: 6/16/2017 DATE FINISHED: 6/16/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
		5/1), slightly to low plasticity, moist.						
		Low sample recovery in silty sand.						
40		Same as previous.						
		CLAY (CL): with trace silt, greenish gray (GLEY 5/1), medium plasticity, wet, very stiff, sulfur odor.	0	5.1	94.9	CH	49.8	3.4E-8
45								
50			0	5.7	94.3	CL	50.7	4.1E-8
55		CLAY (CL): with silt and interbedded thin fine to medium grained sand, greenish gray (GLEY 6/1) to dark greenish gray (GLEY 4/1						
		SILTY SAND (SM): with trace silt, gray (5Y 5/1), wet, nonplastic, sulfur odor, loose.						
60		SILTY CLAY (CL): greenish gray (GLEY 5/1), slightly to low plasticity, wet.						
		SILTY SAND (SM): with trace silt, dark greenish gray (GLEY 3/1), fine to medium grained, wet, nonplastic, sulfur odor, loose.	0	70.4	29.6	SM		
65		CLAY (CL): with trace silt, dark greenish gray (GLEY 4/1), medium plasticity, stiff to very stiff, sulfur odor.	0	10.9	89.1	CL		
							47.7	8.2E-8
70		End of borehole at 69 ft below ground surface in clays.						

WELL CONSTUCTION DIAGRAM



Bentonite 49 to 54 ft bgs.
Filter Pack Sand 54 to 63.7 ft bgs

56.1 to 66.1 ft bgs, 4 in dia, Sch 40 PVC screen

End Cap at 69.4 ft bgs

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID: **SB-1**
CLIENT: US Magnesium LLC
PROJECT: Groundwater Discharge Permit Application
SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling
DRILLING METHOD: Sonic
DRILLING EQUIPMENT: GP24-300 RS
SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 17
EASTING: 1305030.77 NORTHING: 3495366.41
ELEVATION: 4216.718 BOREHOLE ANGLE: 90 degrees
TOTAL DEPTH (ft): 56
DATE STARTED: 6/19/2017 DATE FINISHED: 6/19/2017
LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0								
		SILTY SAND (SM): fine to medium grained oolitic sand, grayish brown (10YR 5/2), gadding to very pale brown (10YR 7/3), slightly						
5								
		SILT (ML): with trace clay and fine sand, greenish gray (GLEY 6/2), nonplastic, slight to low plasticity, weak ferrous oxide od						
10		Grades to greenish black (GLEY 2.5/1), organics odor.						
		POORLY GRADED SAND (SP): fine to medium grained oolitic sand with trace silt, some cemented oolitic sand at contact with ML, li						
15								
		SILTY SAND (SM): dark gray (GLEY 4/1), wet, nonplastic, loose to medium dense, strong sulfur odor.						
20								
25								
		With trace silty clay.						
30								

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-1**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 17
DRILLING METHOD:	Sonic	EASTING: 1305030.77	NORTHING: 3495366.41
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4216.718	BOREHOLE ANGLE: 90 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 56	
		DATE STARTED: 6/19/2017	DATE FINISHED: 6/19/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
35		CLAY (CL): greenish gray (GLEY 6/1), medium plasticity, medium dense, strong sulfur odor, wet, clay is very sticky when wet.	0	10.1	89.9	CL		
40			0	7.1	92.9	CL		
45								
50								
55		As above with trace silt interbedded, 0.25 to 0.5 inches.						
		End of borehole at 56 ft below ground surface in clays.						
60								
65								

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID: **SB-2**
CLIENT: US Magnesium LLC
PROJECT: Groundwater Discharge Permit Application
SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling
DRILLING METHOD: Sonic
DRILLING EQUIPMENT: GP24-300 RS
SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 18
EASTING: 1305140.29 NORTHING: 3496766.03
ELEVATION: 4215.087 BOREHOLE ANGLE: 45 degrees
TOTAL DEPTH (ft): 65
DATE STARTED: 6/19/2017 DATE FINISHED: 6/19/2017
LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		POORLY GRADED SAND (SP): oolitic sand, fine to medium grained, very pale brown (10YR 7/4), loose, subrounded to rounded, surfac						
		Grades to light gray (5Y 7/1), slightly moist to wet.						
		SILTY SAND (SM): fine to medium sand, some fine to medium oolitic sands, gray (5Y 6/1), oolitic sand are subrounded to rounded,						
5		SILT (ML): gray (5Y 6/1), wet, non to slightly plastic, medium stiff to stiff where clayey.						
		CLAY (CL): greenish gray (GLEY 6/1), moist stiff to very stiff, medium plasticity, trace silt.						
		CLAYEY SILT (ML): greenish gray (GLEY 6/1), moist to wet, slight plasticity to low plasticity where clayey, medium stiff, trace						
10		POORLY GRADED SAND WITH GRAVEL (SP): light green gray (GLEY 8/1), fine to coarse sand, fine to coarse gravel, cemented oolitic						
		POORLY GRADED SAND (SP): oolitic sand, light olive gray (5Y 6/2), wet, nonplastic, very loose to loose.						
15								
		POORLY GRADED SAND WITH GRAVEL (SP): cemented oolitic sand, light green gray (GLEY 8/1), fine to coarse sand, fine to coarse gr						
		POORLY GRADED SAND WITH SILT (SP-SM): fine sand, dark gray (GLEY 4/1), wet, nonplastic, weak sulfur odor.						
20								
		SILTY SAND (SM): dark gray (GLEY 3/1), grades to silty fine sand, with increase in silt to 30%, wet, nonplastic, with some inte						
25								
30		With interbedded silty clays.						

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft. = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-2**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 18
DRILLING METHOD:	Sonic	EASTING: 1305140.29	NORTHING: 3496766.03
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4215.087	BOREHOLE ANGLE: 45 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 65	
		DATE STARTED: 6/19/2017	DATE FINISHED: 6/19/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS					
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
35		SILT WITH SAND (ML): greenish gray (GLEY 6/1), wet, slight plasticity, soft to medium stiff, strong sulfur odor.						
40		CLAY (CL): with trace silt, greenish gray (GLEY 6/1), medium plasticity, medium stiff to stiff, strong sulfur odor.	0	13.8	86.2	CL		
45			0	4.8	95.2	CL		
		End of 45 degree angled borehole at a length of 65 ft, approximately 46 ft below ground surface.						
50								
55								
60								
65								

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft. = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-3**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 19
DRILLING METHOD:	Sonic	EASTING: 1299550.42	NORTHING: 3502274.05
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4218.746	BOREHOLE ANGLE: 45 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 60	
		DATE STARTED: 6/20/2017	DATE FINISHED: 6/20/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		FILL-SILTY SAND (SM): grayish brown (10YR 7/3), nonplastic, loose to medium dense, moist.						
		CLAYEY SILT (ML): with trace fine sand, pale brown (10 YR 6/3), slightly to high plasticity locally, medium stiff, slight moist						
5		Grading to wet at 7 ft. below ground level.						
		SILTY SAND (SM): light brownish gray (2.5Y 6/2), fine to medium grained sand, nonplastic, loose, wet, grades to red 2.5 YR 4/8)						
10		POORLY GRADED SAND WITH GRAVEL (SP): cemented oolitic sand, fine to medium grained sand, fine and coarse gravel.						
		POORLY GRADED SAND (SP): fine medium grained oolitic sand, subrounded to rounded, nonplastic, wet, strong chemical odor.						
		Grades to red (2.5 YR 4/8), with strong ferrous oxide staining, pH = 5.0, strong chemical odor, wet, nonplastic.						
15		SILTY SAND (SM): gray (GLEY 5/1), loose to medium dense, nonplastic, wet, weak sulfur and chemical odor.						
20		Decrease in chemical odor.						
25								
30		With interbedded clayey silt (ML) olive gray (5Y 4/2), low plasticity, wet, weak sulfur odor.						

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-3**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 19
DRILLING METHOD:	Sonic	EASTING: 1299550.42	NORTHING: 3502274.05
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4218.746	BOREHOLE ANGLE: 45 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 60	
		DATE STARTED: 6/20/2017	DATE FINISHED: 6/20/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS					
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
35		SILTY SAND (SM): gray (GLEY 5/1), loose to medium dense, nonplastic, wet, weak sulfur and chemical odor.						
		CLAY (CL): with trace silt, greenish gray (GLEY 6/1), medium plasticity, medium stiff, moist grading to wet, moderate to strong	0	12	88	CL		
40			0	5.1	94.9	CL		
		End of 45 degree angled borehole at a length of 60 ft, approximately 42.5 ft below ground surface.						
45								
50								
55								
60								
65								

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-4**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 20
DRILLING METHOD:	Sonic	EASTING: 1296610.3	NORTHING: 3501603.33
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4219.344	BOREHOLE ANGLE: 45 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 46	
		DATE STARTED: 6/20/2017	DATE FINISHED: 6/20/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS					
		Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0	Fill material.						
	SILTY SAND (SM): yellowish brown (10YR 5/4), fine to medium grained sand, nonplastic, slight moist. Fill.						
	POORLY GRADED SAND (SP): fine medium grained oolitic sand, with trace silt, pale brown (10 YR 5/4), wet, nonplastic, slightly m						
5	Weak chemical odor and trace ferrous oxide.						
	SILTY SAND (SM): fine grained sand, gray (GLEY 5/1), wet, nonplastic, weak sulfur and chemical odor, rounded oolitic sand, mixi						
10	SILT (ML): greenish gray (GLEY 6/1), interbedded.						
	SILTY SAND (SM): fine sand, gray (GLEY 5/1), wet, nonplastic, weak sulfur and chemical odor, some fine sand, rounded, mixing of						
15	SILT (ML): 3 inch of silt, light greenish gray (GLEY 7/1), non to slightly plastic, medium stiff.						
	SILTY SAND (SM): same as previous.						
	SILT (ML): less than 2 inch of silt. Same as previous.						
20	SILTY SAND (SM): same as previous.						
25	CLAYEY SAND (SC): fine grained sands, dark greenish gray (GLEY 4/1), slightly moist, low to medium plasticity, medium stiff to						
	CLAY (CL): with trace silt, greenish gray (GLEY 5/1) to light greenish gray (GLEY 7/1), medium plasticity, medium stiff to hard	0	7.2	92.8	CL		
30	With interbedded sand silt (ML), beds are less than 0.5 inches, dark greenish gray (GLEY 4/1), wet, slightly plastic, strong su	0	3	97	CL		
	End of borehole at a length of 46 ft, approximately 35.3 ft below ground surface.						
35							

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-5**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 21
DRILLING METHOD:	Sonic	EASTING: 1297900.42	NORTHING: 3499496.31
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4219.44	BOREHOLE ANGLE: 45 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 50	
		DATE STARTED: 6/21/2017	DATE FINISHED: 6/21/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0	SILTY CLAY (CL): light gray (10YR 7/2) to light olive brown (2.5 Y 5/3), moist, low to medium plasticity, some roots an organic						
	CLAYEY SILT (ML): generally light gray (10YR 7/2), with some light olive brown (2.5 Y 5/3), slightly to low plasticity, medium						
5	POORLY GRADED SAND (SP): fine to medium grained oolitic sand, very pale brown (10 YR 8/2), to white (10 YR 8/1), wet, nonplasti						
	Cemented from oolitic fragments up to 3 inches.						
	POORLY GRADED SAND (SP): fine sand with trace silt dark gray (GLEY 4/1), nonplastic, loose, wet, weak sulfur odor.						
10	Cemented oolitic sand, light gray.						
	SILTY SAND (SM): fine sand with trace silt, dark gray (GLEY 4/1), wet nonplastic, loose, weak sulfur odor.						
	Grades to fine to medium sand with trace silt, light gray (GLEY 7/1), wet.						
	CLAY (CL): dark greenish gray (GLEY 4/1), medium plasticity, soft to medium stiff.						
15	POORLY GRADED SAND SILTY SAND (SP/SM): fine to medium grained sand, with trace silt, dark gray (GLEY 4/1), wet, nonplastic, wea						
20							
	Grades to fine sand with trace silt, dark gray (GLEY 4/1), nonplastic, loose, wet, weak to moderate sulfur odor.						
25							
	With thin beds of silty clay (CL), light greenish gray (GLEY 7/1), wet, low plasticity, medium stiff, weak sulfur odor.						
	Same as previous.						
30	CLAYEY SILT (ML): greenish gray (GLEY 6/1), wet, slightly plastic, soft, weak sulfur odor.						
	CLAY (CL): greenish gray (GLEY 6/1), moist, medium plasticity, stiff, moderate to strong sulfur odor.	0	8.1	91.9	CL		
		0	10.6	89.4	CL		
35	End of 45 degree angled borehole at a length of 50 ft, approximately 35.4 ft below ground surface.						

Notes: K = Hydraulic conductivity; cm/sec = centimeters per second; ft btoc = feet below top of casing; ft = feet; UTM = Universal Transverse Mercator; Sch = schedule of a pipe; PVC = polyvinyl chloride pipe; dia = diameter; bgs = below ground surface

Stantec

BOREHOLE ID: **SB-6**
CLIENT: US Magnesium LLC
PROJECT: Groundwater Discharge Permit Application
SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling
DRILLING METHOD: Sonic
DRILLING EQUIPMENT: GP24-300 RS
SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 22
EASTING: 1302302.73 NORTHING: 3496078.35
ELEVATION: 4217.798 BOREHOLE ANGLE: 45 degrees
TOTAL DEPTH (ft): 55
DATE STARTED: 6/22/2017 DATE FINISHED: 6/22/2017
LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS					
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		FILL: sand and silt fill material.						
		SILTY SAND (SM): fine to medium grained oolitic sands, very pale brown (10YR 8/2) to white (10 YR 8/1), subrounded to rounded s						
		SILT (ML): with trace fine sand and clay, very pale brown (10 YR 8/2), slightly low plasticity, moist, trace roots and organics						
5		Grades to light brownish gray (2.5 Y 6/2), low plasticity, moist, weak ferrous oxide.						
		Grades to grayish brown (2.5 Y 5/2), moist to wet, low to medium plasticity.						
		SILTY SAND (SM): fine to medium grained sands, light greenish gray (GLEY 6/1), nonplastic, wet.						
10		SILT (ML): with trace fine sand, greenish gray (GLEY 6/1), low plasticity, moist to wet.						
		POORLY GRADED SAND (SP): fine to medium grained sand with trace silt, some oolitic sand, light greenish gray (GLEY 7/1), nonpla						
		Grades to greenish gray (GLEY 5/1).						
15		POORLY GRADED SAND WITH GRAVEL (SP): cemented oolitic sand, fine and coarse gravel fragments to 3 inches, grades to light yello						
		SILTY SAND (SM): gray (GLEY 6/1), nonplastic, loose, wet, weak sulfur odor.						
20								
25		With few thin interbedded silt (ML), light greenish gray (GLEY 8/1), low plasticity, medium stiff, wet.						
		SILTY SAND (SM): as previous.						
30		CLAY (CL): with trace silt, greenish gray (GLEY 5/1), medium plasticity, medium stiff, strong sulfur odor.	0	23.2	76.8	CL		
		SILT (ML): with sand, greenish gray (GLEY 5/1), low plasticity, soft, moist to wet, strong sulfur odor.						
		CLAY (CL): as previous.						
		SILT (ML): as previous.						
35		CLAY (CL): as previous.	0	15.3	84.7	CL		
		SILT (ML): as previous.						
		CLAY (CL): as previous.	0	11.1	88.9	CL		
40		End of 45 degree angled borehole at a length of 55 ft, approximately 39 ft below ground surface.						

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-7**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 23
DRILLING METHOD:	Sonic	EASTING: 1294618.03	NORTHING: 3495924.73
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4224.563	BOREHOLE ANGLE: 90 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 51	
		DATE STARTED: 6/21/2017	DATE FINISHED: 6/21/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS					
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		SILTY CLAY (CL): with trace fine sand, light brownish gray (10YR 6/2) to grayish brown (10YR 5/2), medium plasticity, soft to m						
5		Grading to moist.						
		POORLY GRADED SAND WITH GRAVEL (SP): fine to medium grained oolitic sand, very pale brown (10 YR 8/2), angular cemented gravels Same as previous, loose, not cemented.						
10		Same as previous, grading to light greenish gray (GLEY 8/1), cemented. SILT (ML): with fine sand, greenish gray (GLEY 5/1), nonplastic, wet, weak sulfur odor.						
		Grades to greenish black (GLEY 2.5/1).						
15								
		SILTY SAND (SM): fine sand grained, greenish gray (GLEY 5/1) to gray (GLEY 5/1), nonplastic, loose, wet.						
20			0	73.1	26.9	SM		
25								
		SILTY CLAY (CL): greenish gray (GLEY 6/1), low to medium plasticity, medium stiff, wet, weak sulfur odor.					45.3	8.7E-8
30		SILTY SAND (SM): fine grained sand with some silt, greenish gray (GLEY 6/1) nonplastic, loose, wet. SILTY CLAY (CL): as previous.						

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

BOREHOLE ID:	**SB-7**
CLIENT:	US Magnesium LLC
PROJECT:	Groundwater Discharge Permit Application
SITE LOCATION:	US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR:	Cascade Drilling	COORDINATE SYSTEM:	NAD 1983 UTM Zone 23
DRILLING METHOD:	Sonic	EASTING: 1294618.03	NORTHING: 3495924.73
DRILLING EQUIPMENT:	GP24-300 RS	ELEVATION: 4224.563	BOREHOLE ANGLE: 90 degrees
SAMPLING METHOD:	Sonic Core Barrel	TOTAL DEPTH (ft): 51	
		DATE STARTED: 6/21/2017	DATE FINISHED: 6/21/2017
		LOGGED BY: Bill Bragdon	

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS					
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
35		POORLY GRADED SAND (SP): fine grained sand with trace silt, greenish gray (GLEY 6/1), nonplastic, loose, wet, strong sulfur odo	0	12.5	87.5	CL		
40		Grades to dark gray (GLEY 4/1).	0	86.4	13.6	SM		
45		With 3 inch gravel or cobble. Same as previous.						
50		End of borehole at 51 ft below ground surface.						
55								
60								
65								

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

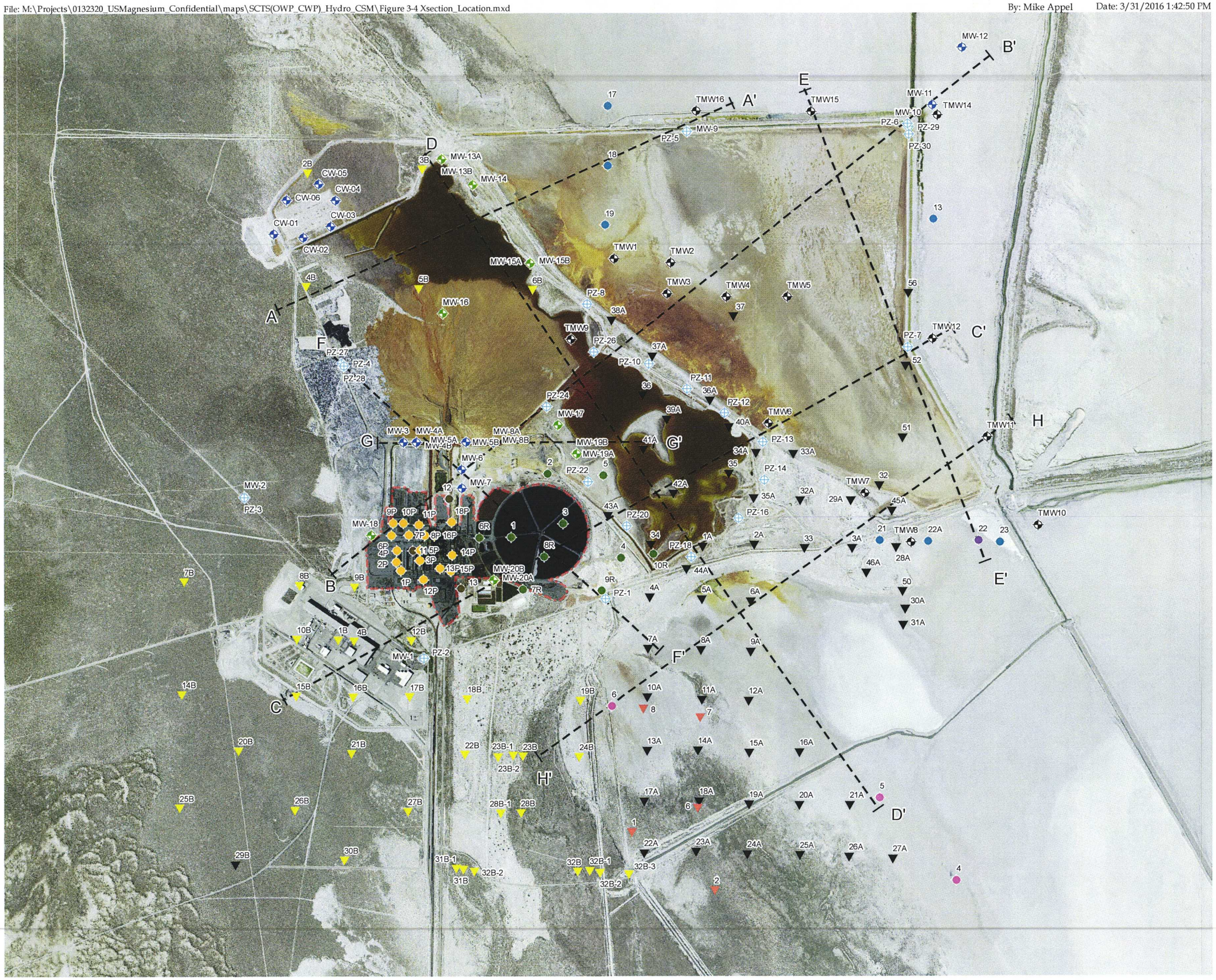
ATTACHMENT A.2

HISTORICAL CROSS SECTIONS

File: M:\Projects\0132320_USMagnesium_Confidential\maps\SCTS(OWP_CWP)_Hydro_CSM\Figure 3-4 Xsection_Location.mxd

By: Mike Appel

Date: 3/31/2016 1:42:50 PM



Legend

- Newly Installed Monitoring Well
- Monitoring Well
- Piezometer

Historical D&M Locations

- Boring - 5/27/1969
- Boring - 8/8/1969
- Boring - 12/4/1969
- Boring - 9/26/1973
- Boring - 4/18/1972
- Boring - 7/18/1972
- Temporary Monitoring Well - 7/18/1972
- Test Pit - 1/23/1970
- Test Pit - 2/5/1970
- Test Pit - 9/26/1973
- Cross Section Location Line
- Operating Facility

Notes:
Aerial Photo: NAIP (Utah.gov) 2014.

N

0 1,700 3,400 Feet

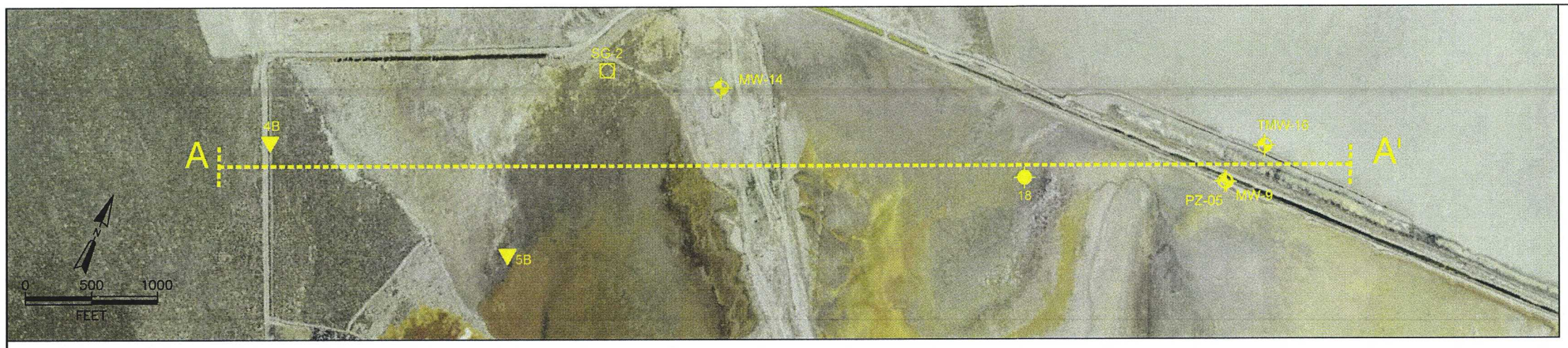
Figure 3-4

Cross-Section Location Map
OWP/CWP Hydrologic Conceptual Site Model
US Magnesium LLC
Tooele County, Utah

USmag®

Environmental Resources Management
7272 East Indian School Road, Suite 108
Scottsdale, Arizona 85251

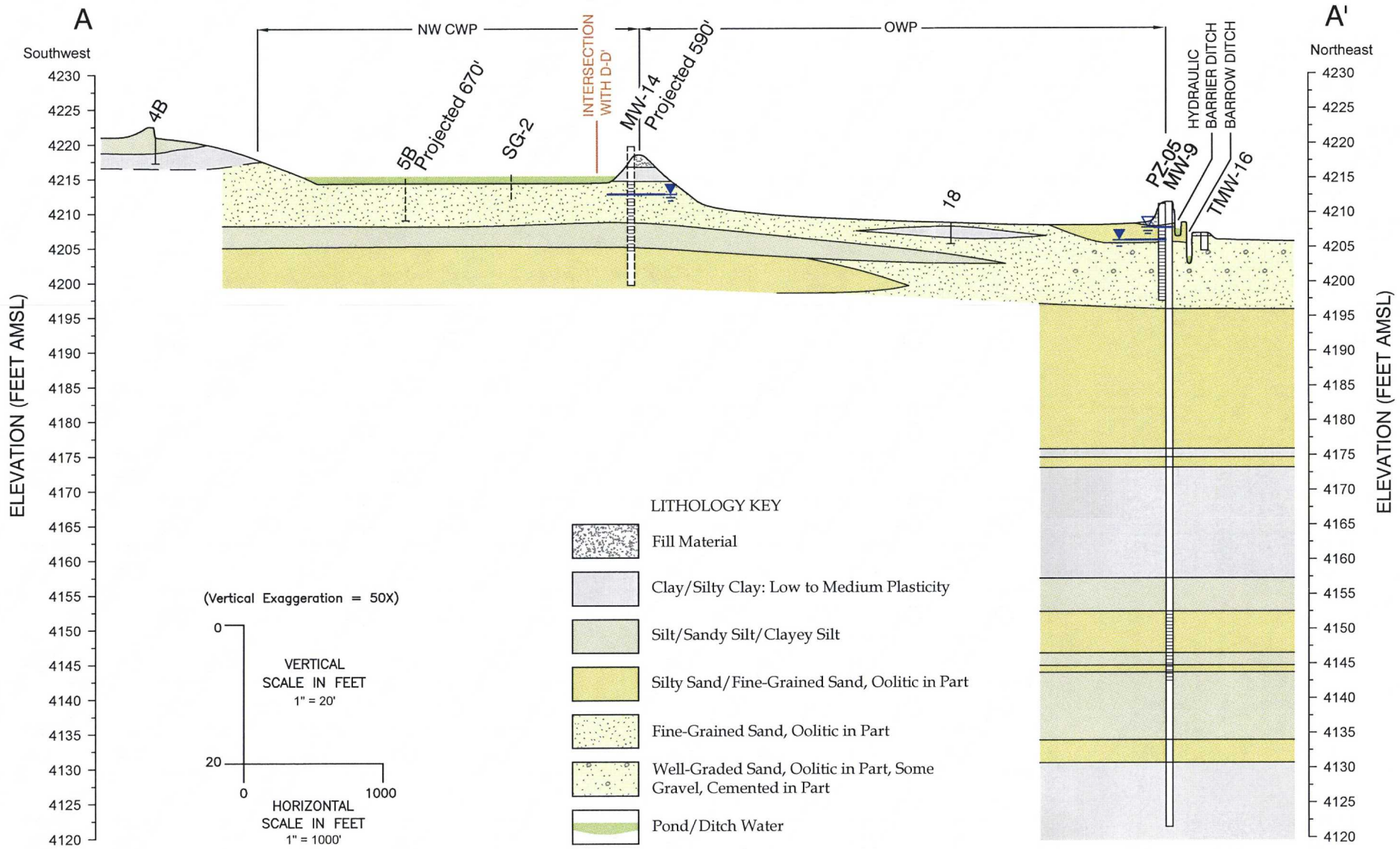
ERM



LEGEND

- Monitoring Well
- Piezometer
- Soil Boring
- Test Pit
- Staff Gauge
- A — A' Cross Section Location Line

Aerial: 2006



LITHOLOGY KEY

- Fill Material
- Clay/Silty Clay: Low to Medium Plasticity
- Silt/Sandy Silt/Clayey Silt
- Silty Sand/Fine-Grained Sand, Oolitic in Part
- Fine-Grained Sand, Oolitic in Part
- Well-Graded Sand, Oolitic in Part, Some Gravel, Cemented in Part
- Pond/Ditch Water

LEGEND

- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 18 — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- TMW-16 — Temporary Monitoring Well Identifier
- Temporary Monitoring Well
- PZ-05 — Piezometer or Monitoring Well Identifier
- Piezometer or Monitoring Well
- Piezometer or Monitoring Well Screen Interval
- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015
- Deep Zone Groundwater Elevation (Feet Above Mean Sea Level); November 2015

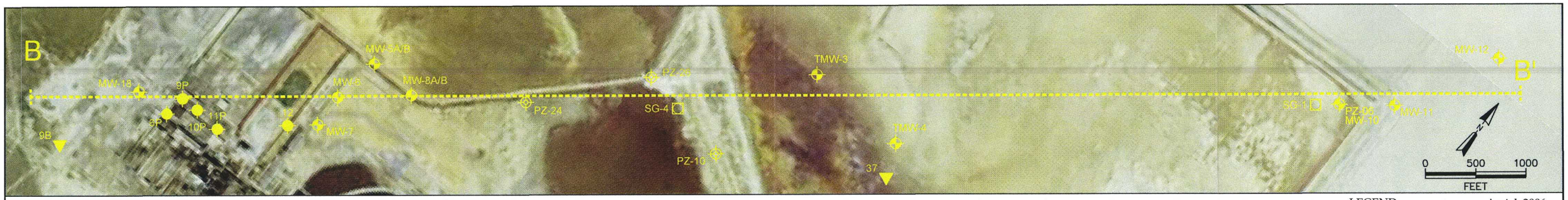
Note: Ground surface elevations derived from November 2015 Lidar Survey.

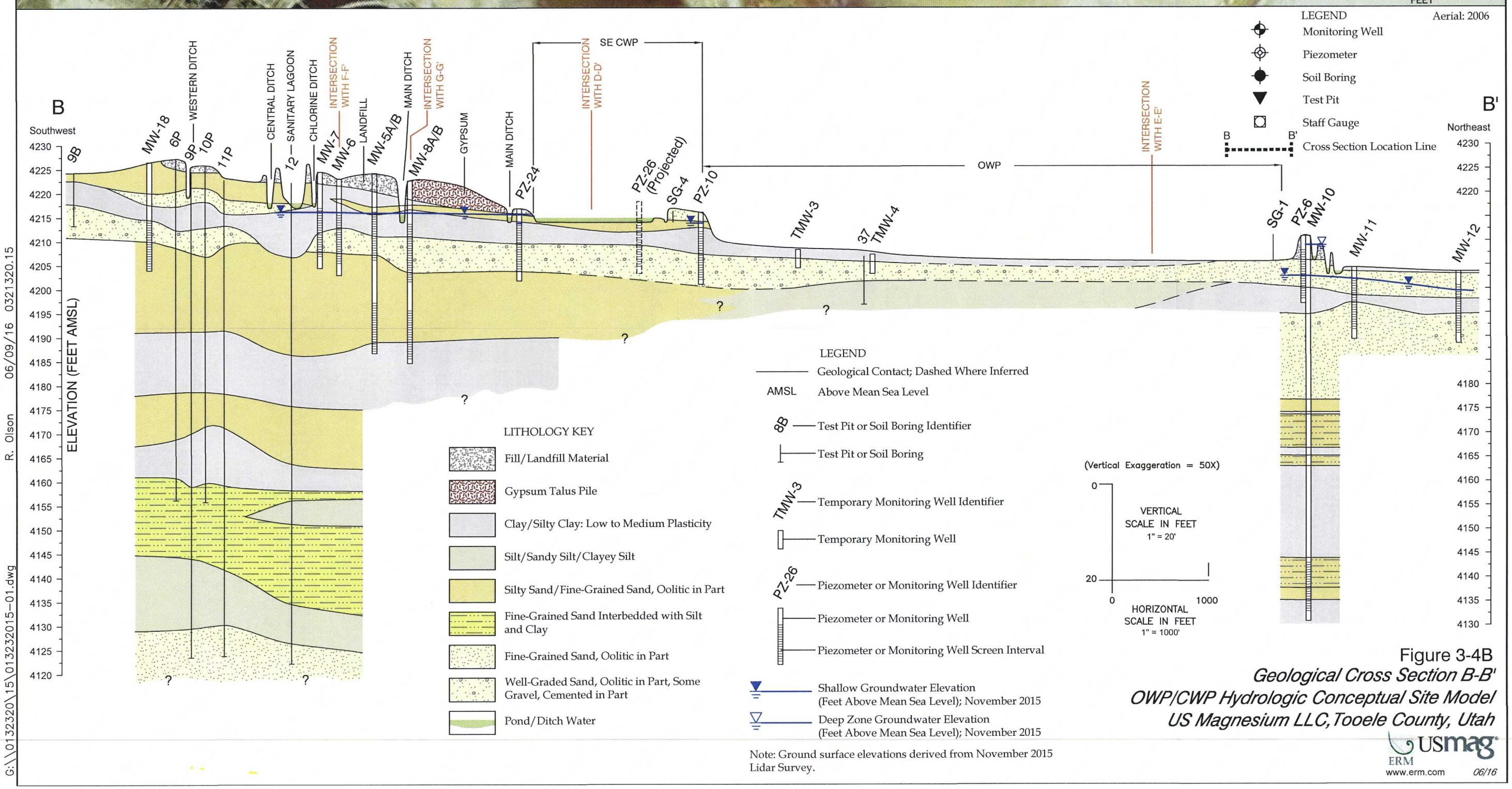
Figure 3-4A

Geological Cross Section A-A'
OWP/CWP Hydrologic Conceptual Site Model
US Magnesium LLC
Tooele County, Utah

ERM
www.erm.com
05/16

G:\0132320\15\0132320150-01.dwg R. Olson 05/25/16 0321320.15





LEGEND

Aerial: 2006

- Monitoring Well
- Piezometer
- Soil Boring
- Test Pit
- Staff Gauge
- Cross Section Location Line

LITHOLOGY KEY

- Fill/Landfill Material
- Gypsum Talus Pile
- Clay/Silty Clay: Low to Medium Plasticity
- Silt/Sandy Silt/Clayey Silt
- Silty Sand/Fine-Grained Sand, Oolitic in Part
- Fine-Grained Sand Interbedded with Silt and Clay
- Fine-Grained Sand, Oolitic in Part
- Well-Graded Sand, Oolitic in Part, Some Gravel, Cemented in Part
- Pond/Ditch Water

LEGEND

- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 8B — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- TMW-3 — Temporary Monitoring Well Identifier
- Temporary Monitoring Well
- PZ-26 — Piezometer or Monitoring Well Identifier
- Piezometer or Monitoring Well
- Piezometer or Monitoring Well Screen Interval
- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015
- Deep Zone Groundwater Elevation (Feet Above Mean Sea Level); November 2015

(Vertical Exaggeration = 50X)

VERTICAL SCALE IN FEET
1" = 20'

0
20

0
1000

HORIZONTAL SCALE IN FEET
1" = 1000'

Note: Ground surface elevations derived from November 2015 Lidar Survey.

G:\0132320\15\0132320150321320.15 06/09/16 R. Olson G:\0132320\15\0132320150321320.15-01.dwg

Figure 3-4B

Geological Cross Section B-B'

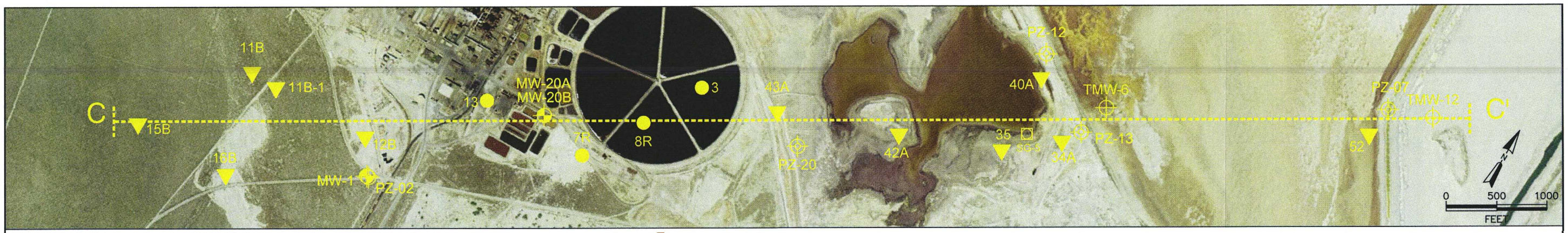
OWP/CWP Hydrologic Conceptual Site Model

US Magnesium LLC, Tooele County, Utah

USmag

ERM

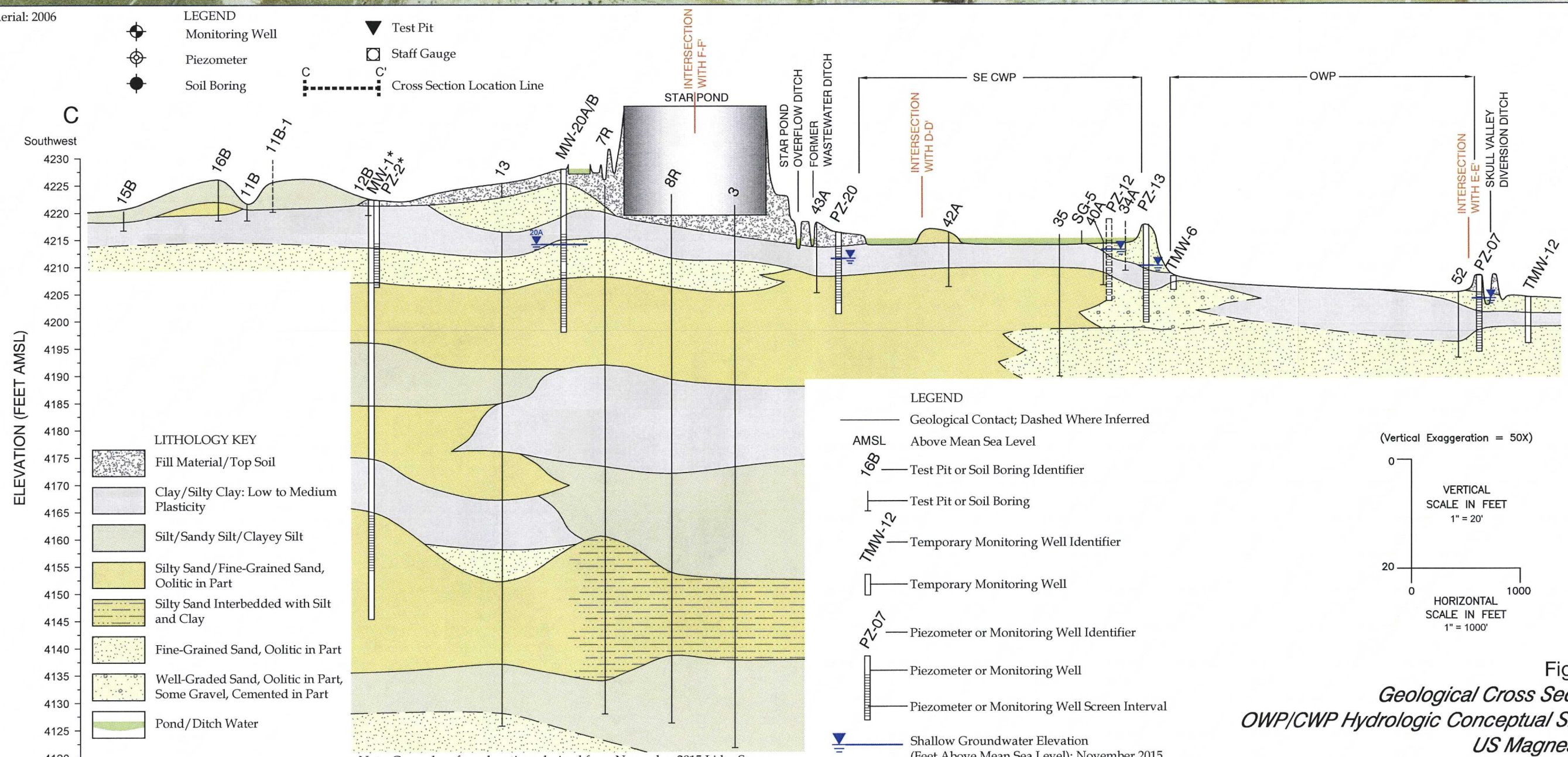
www.erm.com 06/16



Aerial: 2006

LEGEND

- Monitoring Well
- Piezometer
- Soil Boring
- Test Pit
- Staff Gauge
- C — C' Cross Section Location Line



LITHOLOGY KEY

- Fill Material/Top Soil
- Clay/Silty Clay: Low to Medium Plasticity
- Silt/Sandy Silt/Clayey Silt
- Silty Sand/Fine-Grained Sand, Oolitic in Part
- Silty Sand Interbedded with Silt and Clay
- Fine-Grained Sand, Oolitic in Part
- Well-Graded Sand, Oolitic in Part, Some Gravel, Cemented in Part
- Pond/Ditch Water

Note: Ground surface elevations derived from November 2015 Lidar Survey.

LEGEND

- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 16B — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- TMW-12 — Temporary Monitoring Well Identifier
- Temporary Monitoring Well
- PZ-07 — Piezometer or Monitoring Well Identifier
- Piezometer or Monitoring Well
- Piezometer or Monitoring Well Screen Interval
- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015
- Deep Zone Groundwater Elevation (Feet Above Mean Sea Level); November 2015
- MW-1* — Water Level Not Recorded for November 2015

(Vertical Exaggeration = 50X)

VERTICAL SCALE IN FEET
1" = 20'

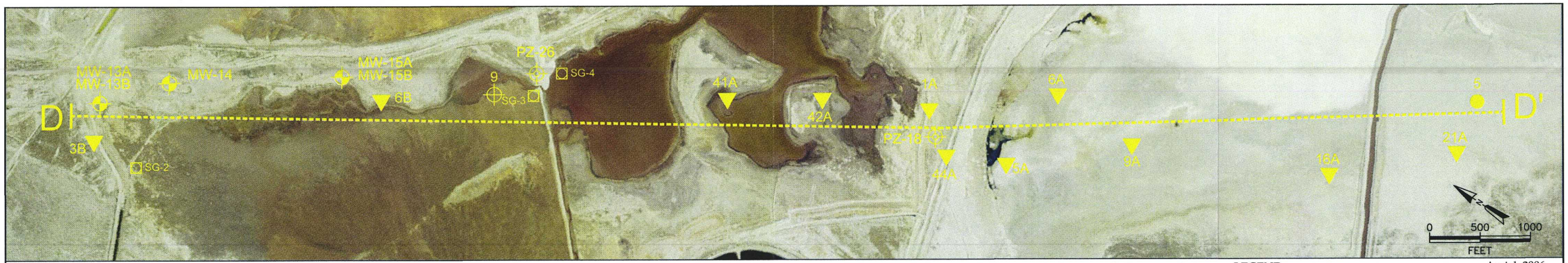
HORIZONTAL SCALE IN FEET
1" = 1000'

Figure 3-4C

Geological Cross Section C-C'
OWP/CWP Hydrologic Conceptual Site Model
US Magnesium LLC
Tooele County, Utah

USmag
ERM
www.erm.com
06/16

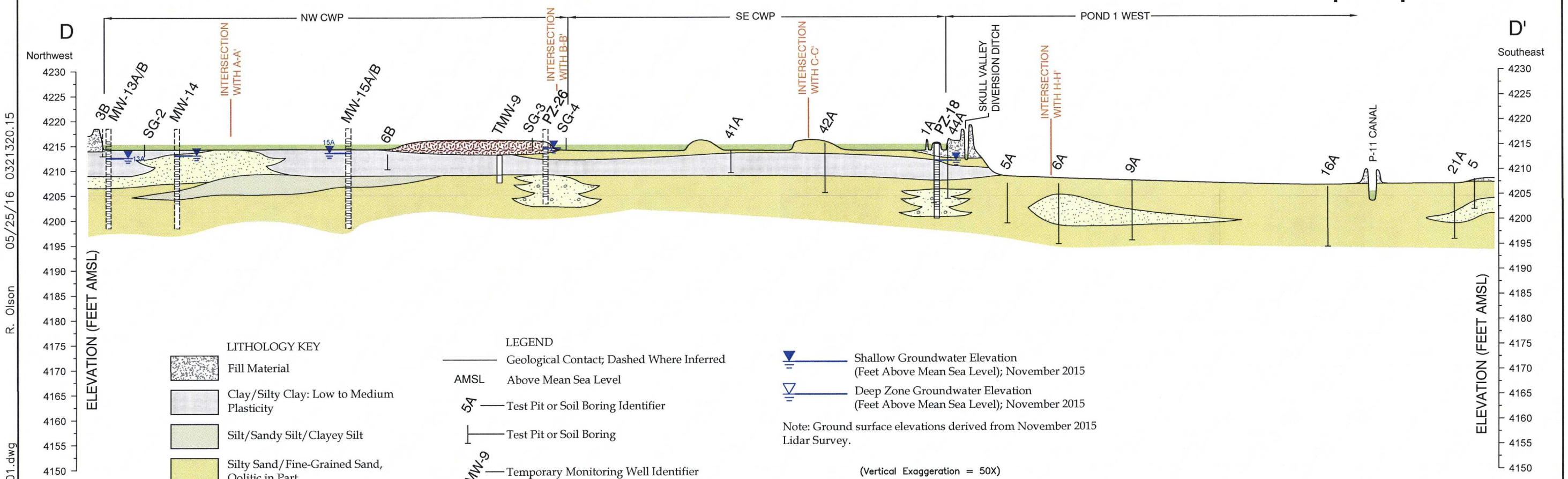
G:\0132320\15\0132320150-01.dwg R. Olson 06/09/16 0321320.15



Aerial: 2006

LEGEND

- Monitoring Well
- Piezometer
- Soil Boring
- Test Pit
- Staff Gauge
- D — D' Cross Section Location Line



LITHOLOGY KEY

- Fill Material
- Clay/Silty Clay: Low to Medium Plasticity
- Silt/Sandy Silt/Clayey Silt
- Silty Sand/Fine-Grained Sand, Oolitic in Part
- Fine-Grained Sand, Oolitic in Part
- Well-Graded Sand, Oolitic in Part, Some Gravel, Cemented in Part
- Gypsum
- Pond/Ditch Water

LEGEND

- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 5A — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- TMW-9 — Temporary Monitoring Well Identifier
- Temporary Monitoring Well
- PZ-18 — Piezometer or Monitoring Well Identifier
- Piezometer or Monitoring Well
- Piezometer or Monitoring Well Screen Interval

- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015
- Deep Zone Groundwater Elevation (Feet Above Mean Sea Level); November 2015

Note: Ground surface elevations derived from November 2015 Lidar Survey.

(Vertical Exaggeration = 50X)

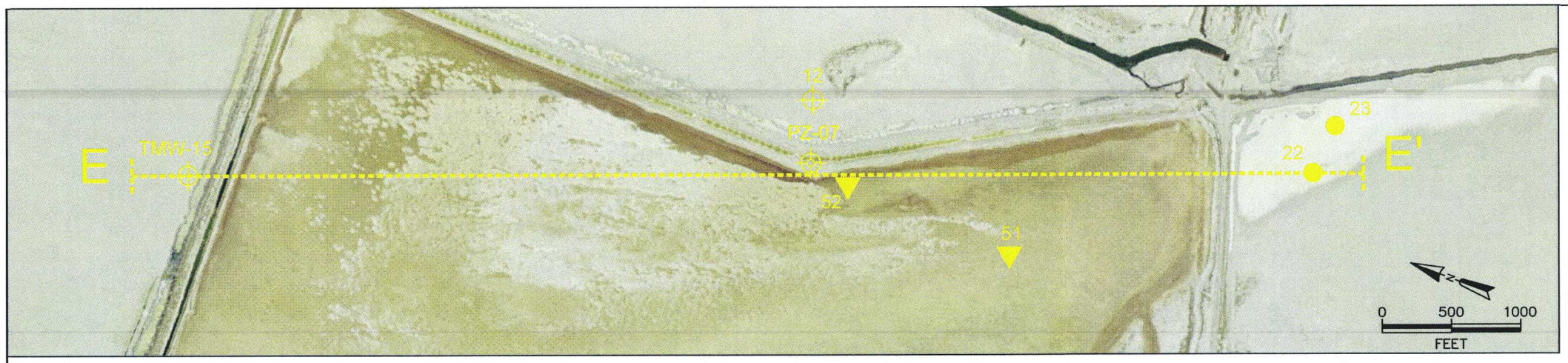
VERTICAL SCALE IN FEET
1" = 20'

HORIZONTAL SCALE IN FEET
1" = 1000'

Figure 3-4D
Geological Cross Section D-D'
OWP/CWP Hydrologic Conceptual Site Model
US Magnesium LLC
Tooele County, Utah

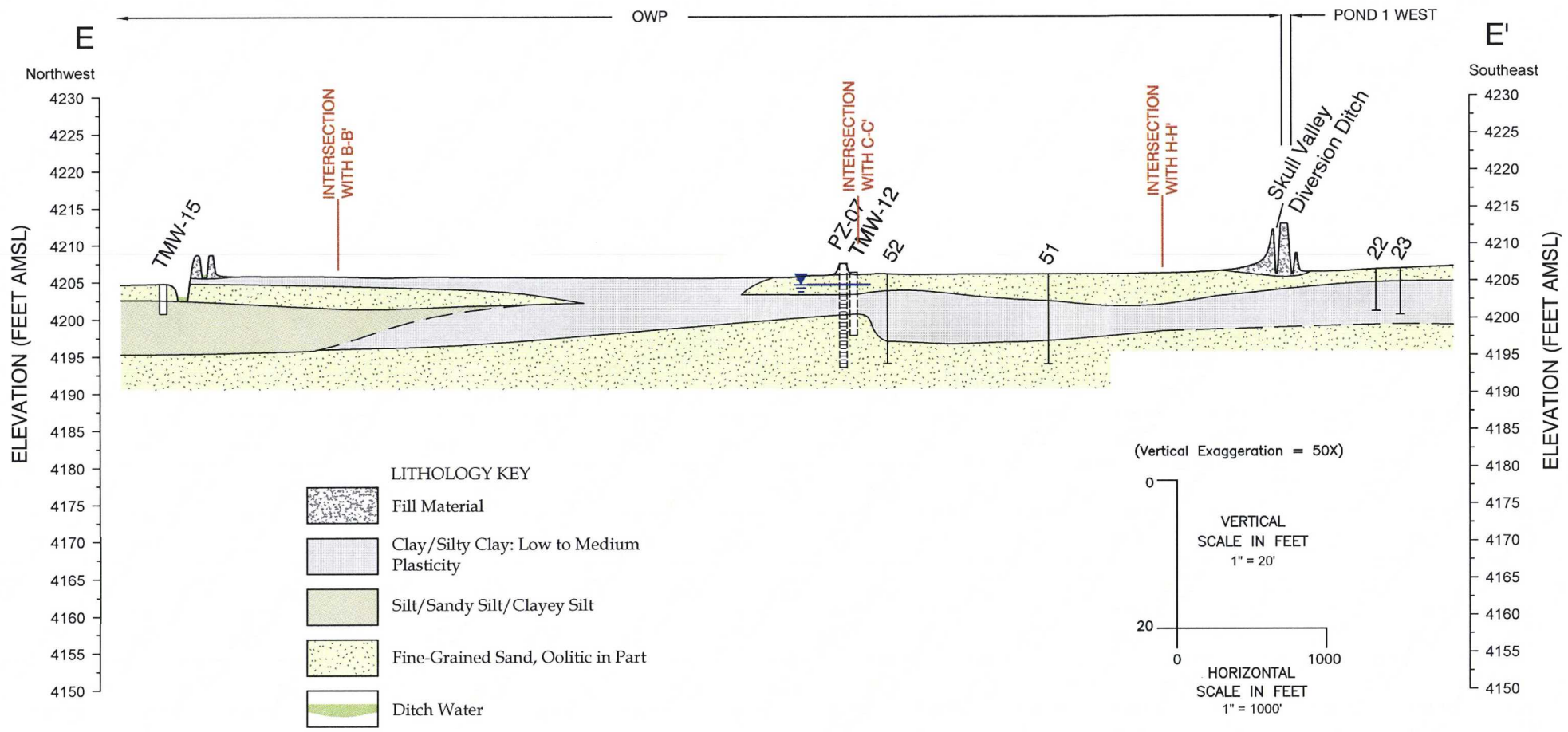
ERM
www.erm.com
05/16

G:\\0132320\15\013232015-01.dwg R. Olson 05/25/16 0321320.15



LEGEND
- Temporary Monitoring Well
- Piezometer
- Soil Boring
- Test Pit
- E — E' Cross Section Location Line

Aerial: 2006



LEGEND
- Geological Contact; Dashed Where Inferred
- AMSL Above Mean Sea Level
- 51 — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- TMW-12 — Temporary Monitoring Well Identifier
- Temporary Monitoring Well
- PZ-07 — Piezometer or Monitoring Well Identifier
- Piezometer or Monitoring Well
- Piezometer or Monitoring Well Screen Interval
- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015

Note: Ground surface elevations derived from November 2015 Lidar Survey.

Figure 3-4E

Geological Cross Section E-E'

OWP/CWP Hydrologic Conceptual Site Model

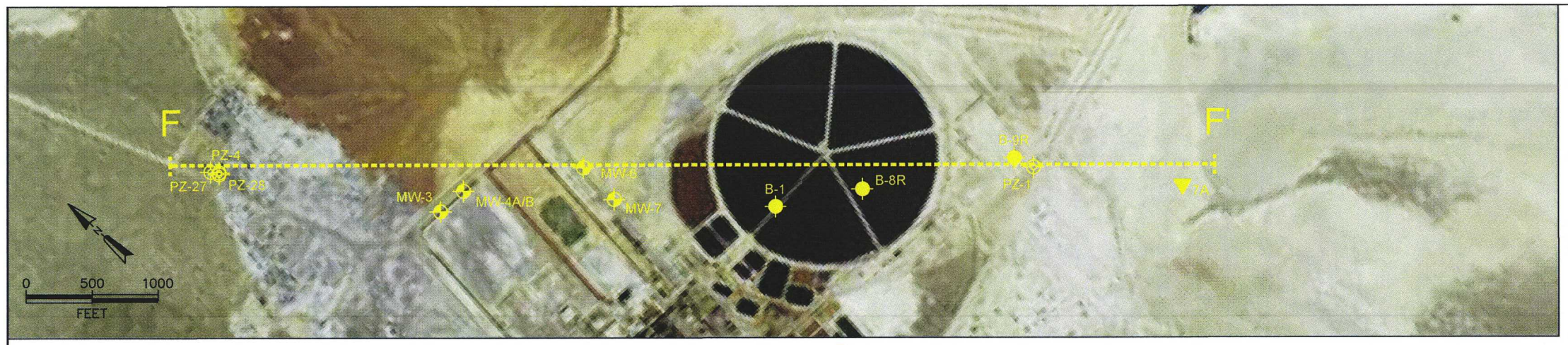
US Magnesium LLC

Tooele County, Utah

ERM

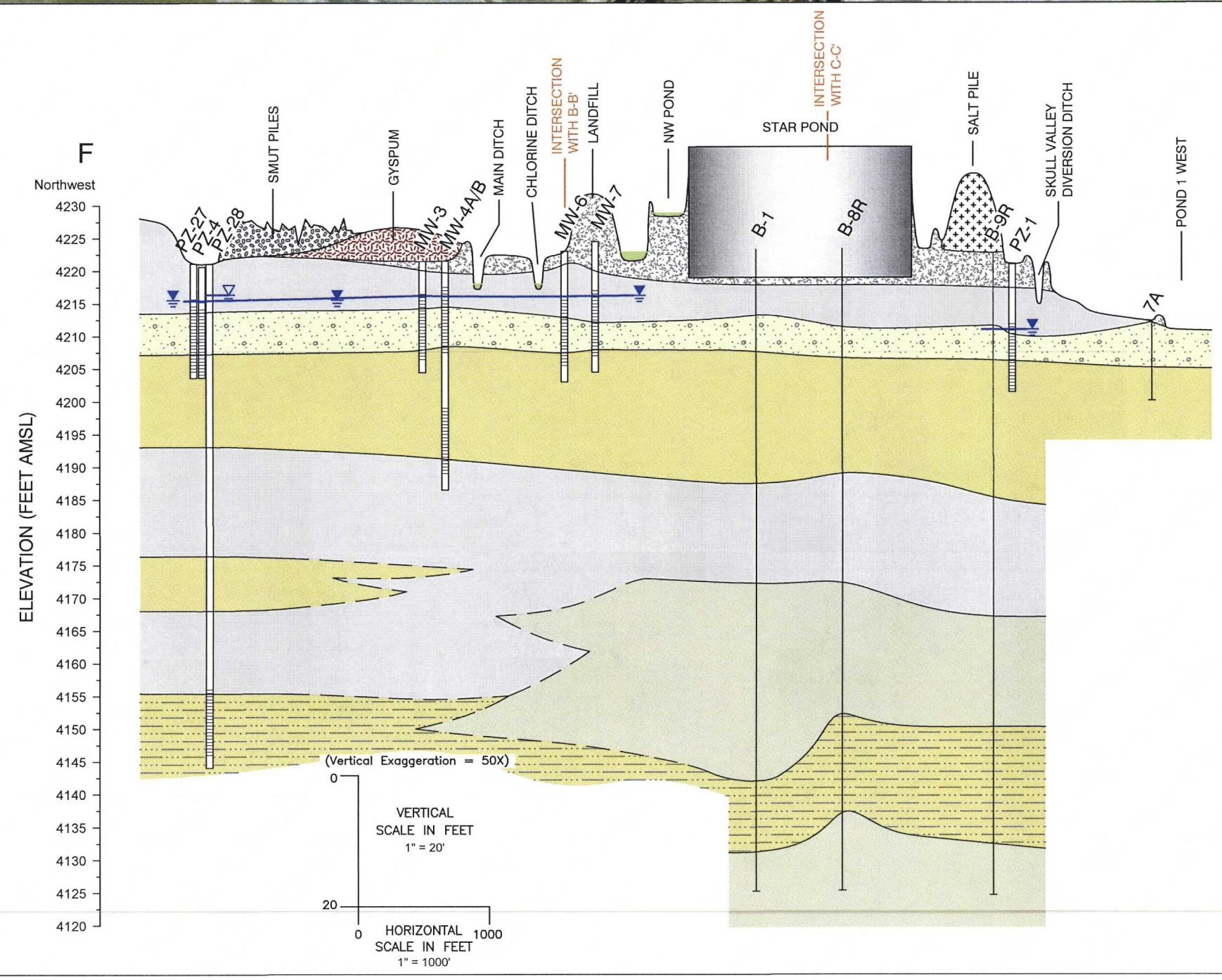
www.erm.com 06/16

G:\0132320\15\013232015-01.dwg R. Olson 06/09/16 0321320.15



LEGEND

- Monitoring Well
- Piezometer
- Soil Boring
- Test Pit
- F — F' Cross Section Location Line
- Aerial: 2006



LEGEND

- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 7A — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- PZ-26 — Piezometer or Monitoring Well Identifier
- Piezometer or Monitoring Well
- Piezometer or Monitoring Well Screen Interval
- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015
- Deep Zone Groundwater Elevation (Feet Above Mean Sea Level); November 2015

Note: Ground surface elevations derived from November 2015 Lidar Survey.

- Clay/Silty Clay: Low to Medium Plasticity
- Silt/Sandy Silt/Clayey Silt
- Silty Sand/Fine-Grained Sand, Oolitic in Part
- Fine-Grained Sand Interbedded with Silt and Clay
- Well-Graded Sand, Oolitic in Part, Some Gravel, Cemented in Part
- Fill Material/Top Soil
- Gypsum
- Smut Piles
- Salt Pile
- Pond/Ditch Water

Figure 3-4F

Geological Cross Section F-F'

OWP/CWP Hydrologic Conceptual Site Model

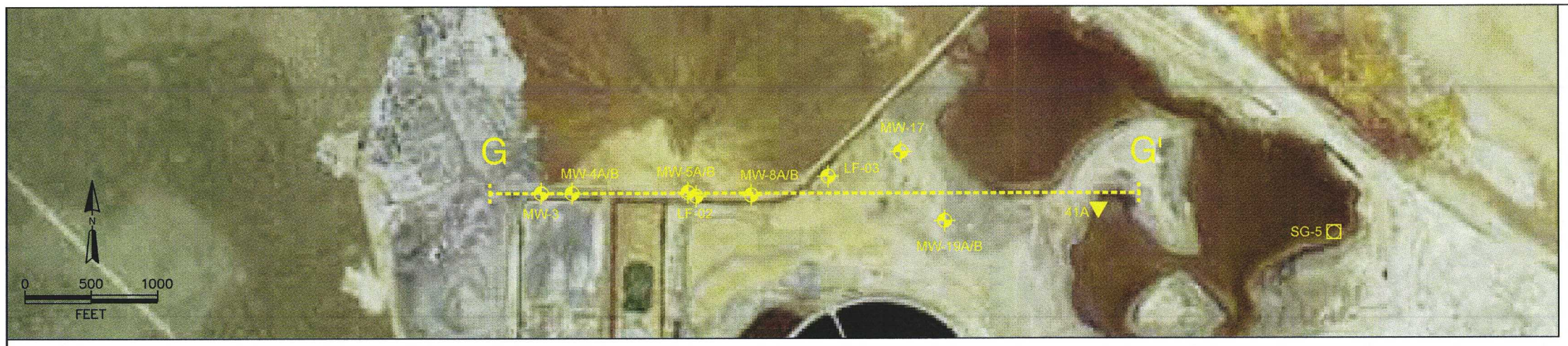
US Magnesium LLC

Tooele County, Utah

ERM

www.erm.com 06/16

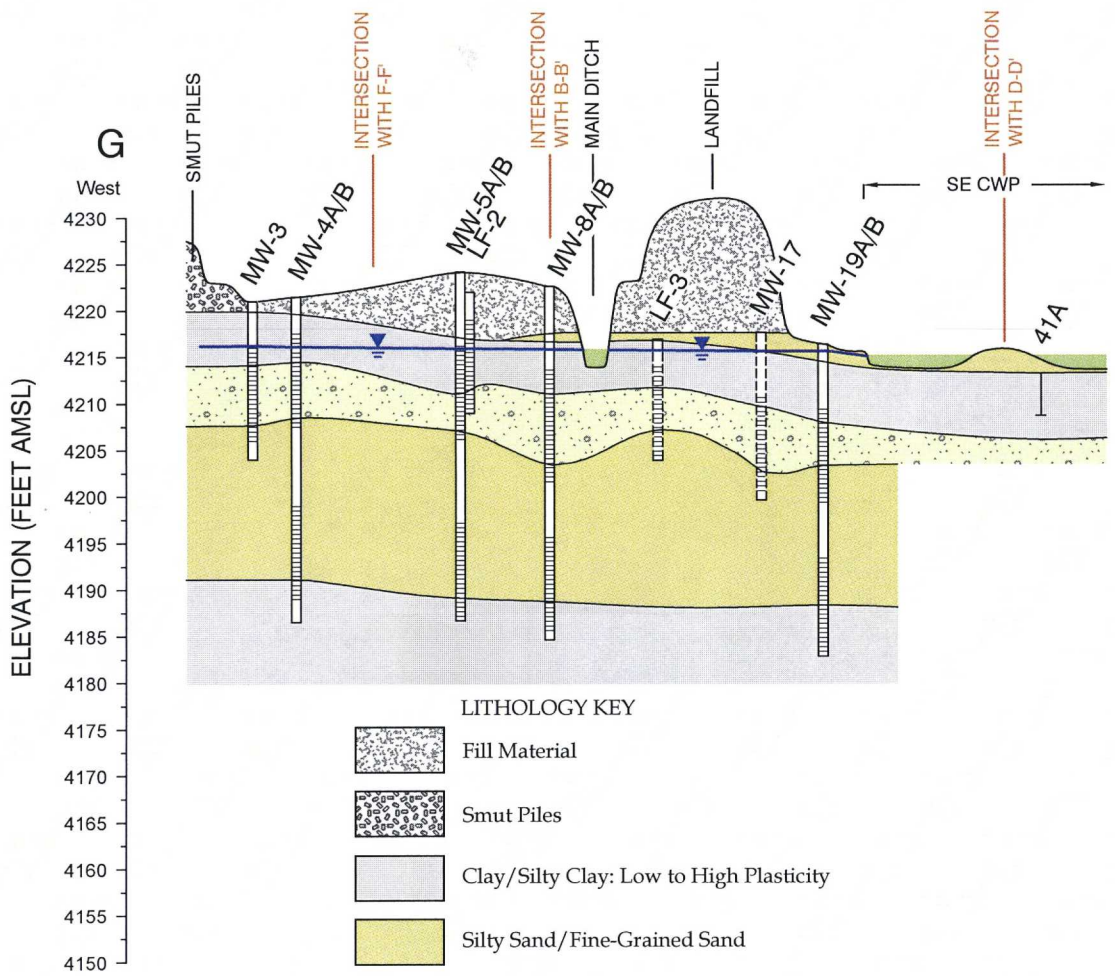
G:\0132320\15\0132320150-01.dwg 06/09/16 R. Olson 0321320.15



LEGEND

- Monitoring Well
- Test Pit
- Staff Gauge
- G — G' Cross Section Location Line

Aerial: 2006



LITHOLOGY KEY

- Fill Material
- Smut Piles
- Clay/Silty Clay: Low to High Plasticity
- Silty Sand/Fine-Grained Sand
- Well-Graded Sand, Oolitic in Part, Some Gravel, Cemented in Part
- Pond/Ditch Water

(Vertical Exaggeration = 50X)

VERTICAL SCALE IN FEET
1" = 20'
0
20

HORIZONTAL SCALE IN FEET
1" = 1000'
0
1000

LEGEND

- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 41A — Test Pit Identifier
- Test Pit
- MW-3 — Monitoring Well Identifier
- Monitoring Well
- Monitoring Well Screen Interval
- Shallow Groundwater Elevation (Feet Above Mean Sea Level); November 2015

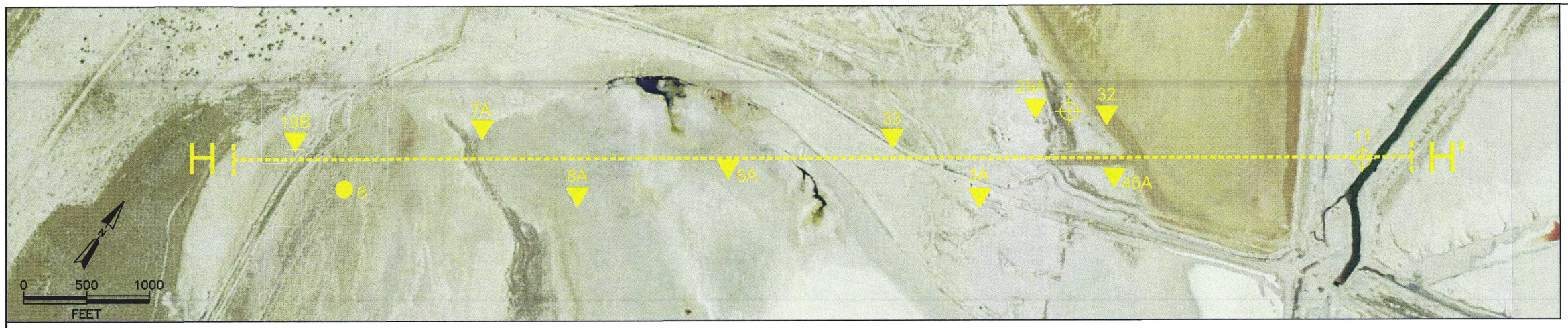
Note: Ground surface elevations derived from November 2015 Lidar Survey.

Figure 3-4G

Geological Cross Section G-G'
OWP/CWP Hydrologic Conceptual Site Model
US Magnesium LLC
Tooele County, Utah

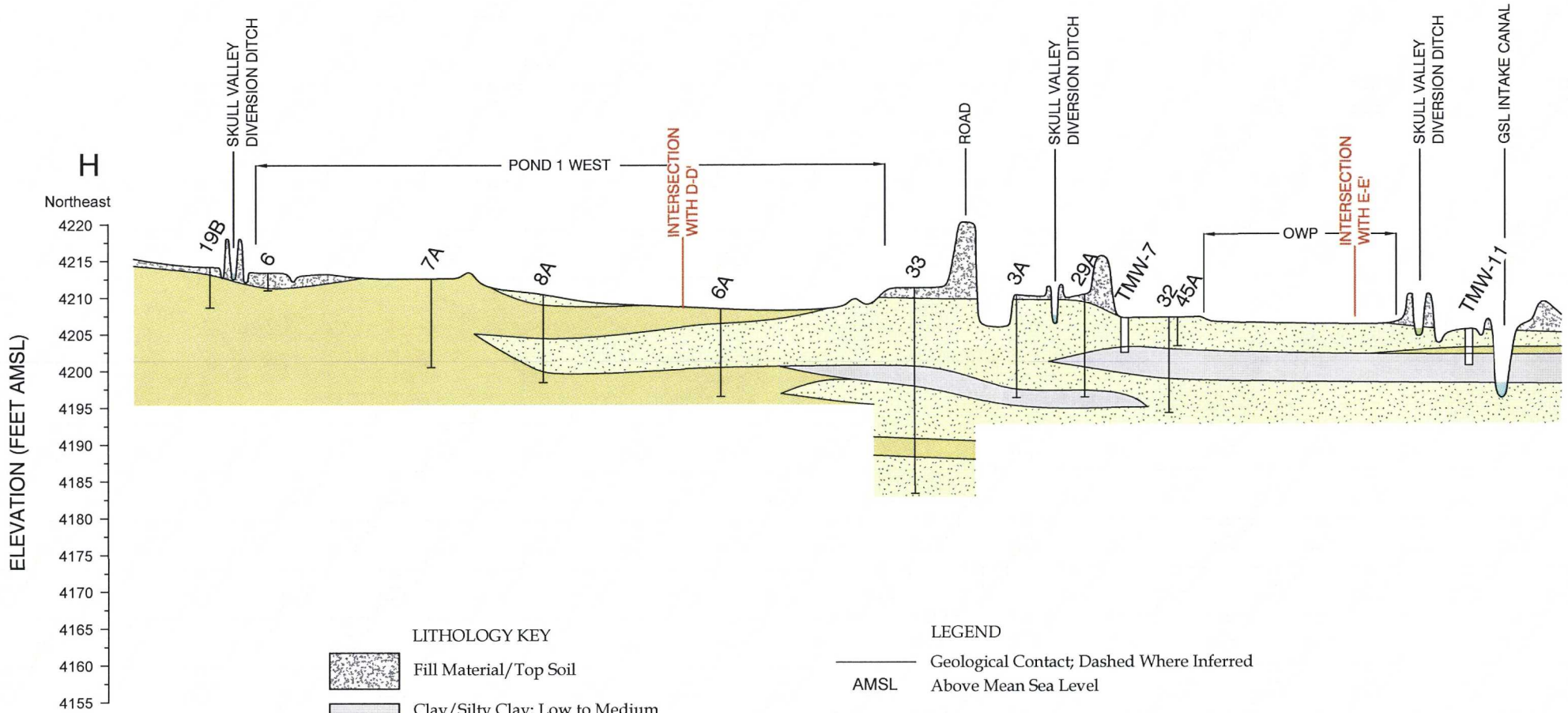
ERM
www.erm.com
06/16

G:\0132320\15\0132320150-01.dwg 06/09/16 R. Olson 0321320.15



LEGEND
- Monitoring Well
- Piezometer
- Temporary Monitoring Well
- Soil Boring
- Test Pit
- Staff Gauge
- H — H' Cross Section Location Line

Aerial: 2006



(Vertical Exaggeration = 50X)

VERTICAL SCALE IN FEET
1" = 20'

0
20

0
1000

HORIZONTAL SCALE IN FEET
1" = 1000'

LITHOLOGY KEY
- Fill Material/Top Soil
- Clay/Silty Clay: Low to Medium Plasticity
- Silty Sand/Fine-Grained Sand, Oolitic in Part
- Fine-Grained Sand, Oolitic in Part
- Ditch Water (Skull Valley Diversion Ditch and GSC Intake Canal)

LEGEND
- Geological Contact; Dashed Where Inferred
- AMSL — Above Mean Sea Level
- 7A — Test Pit or Soil Boring Identifier
- Test Pit or Soil Boring
- TMW-11 — Temporary Monitoring Well Identifier
- Temporary Monitoring Well

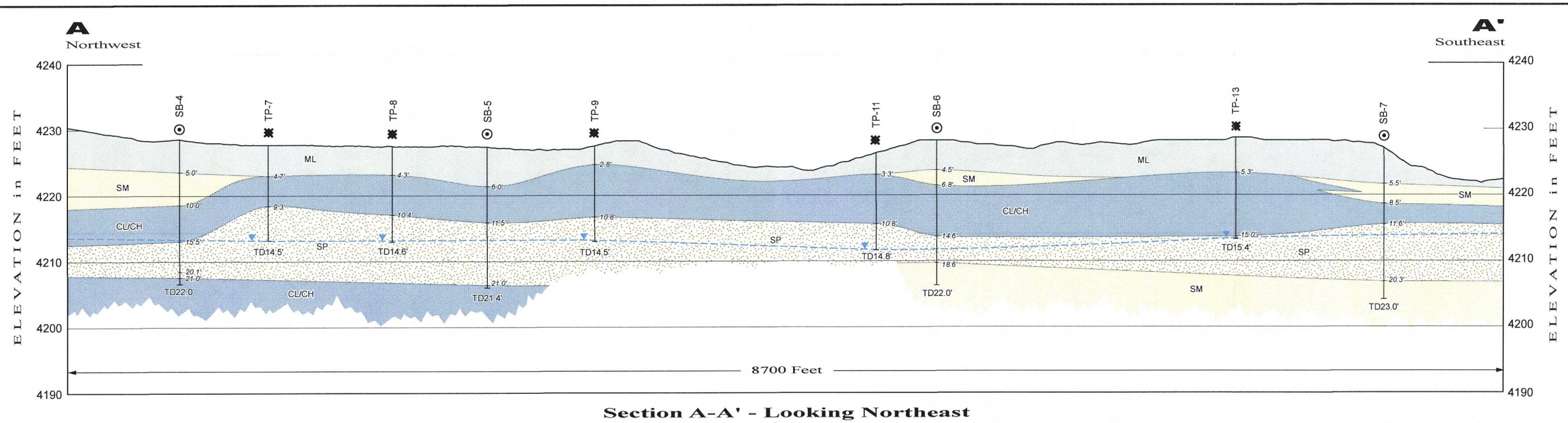
Note: Ground surface elevations derived from November 2015 Lidar Survey.

Figure 3-4H

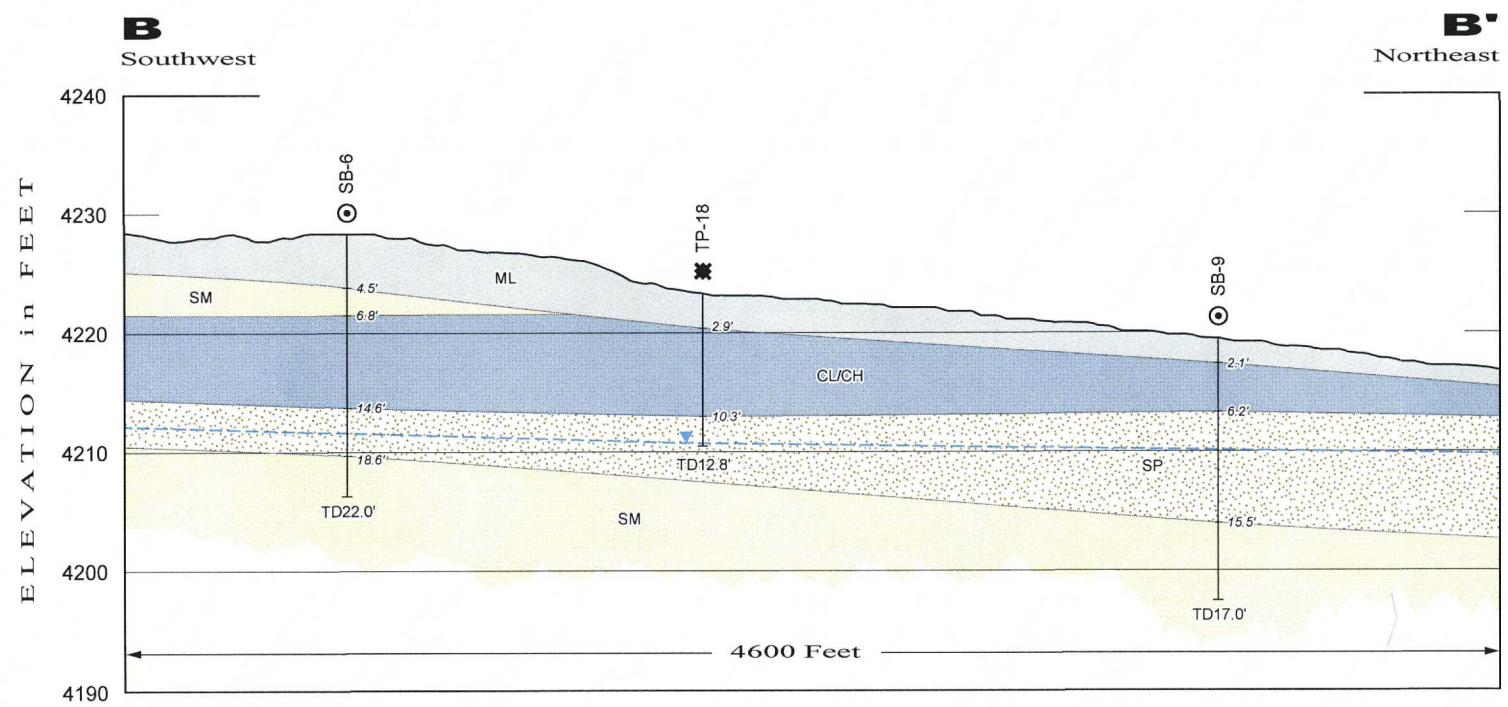
Geological Cross Section H-H'
OWP/CWP Hydrologic Conceptual Site Model
US Magnesium LLC
Tooele County, Utah

USmag
ERM
www.erm.com 06/16

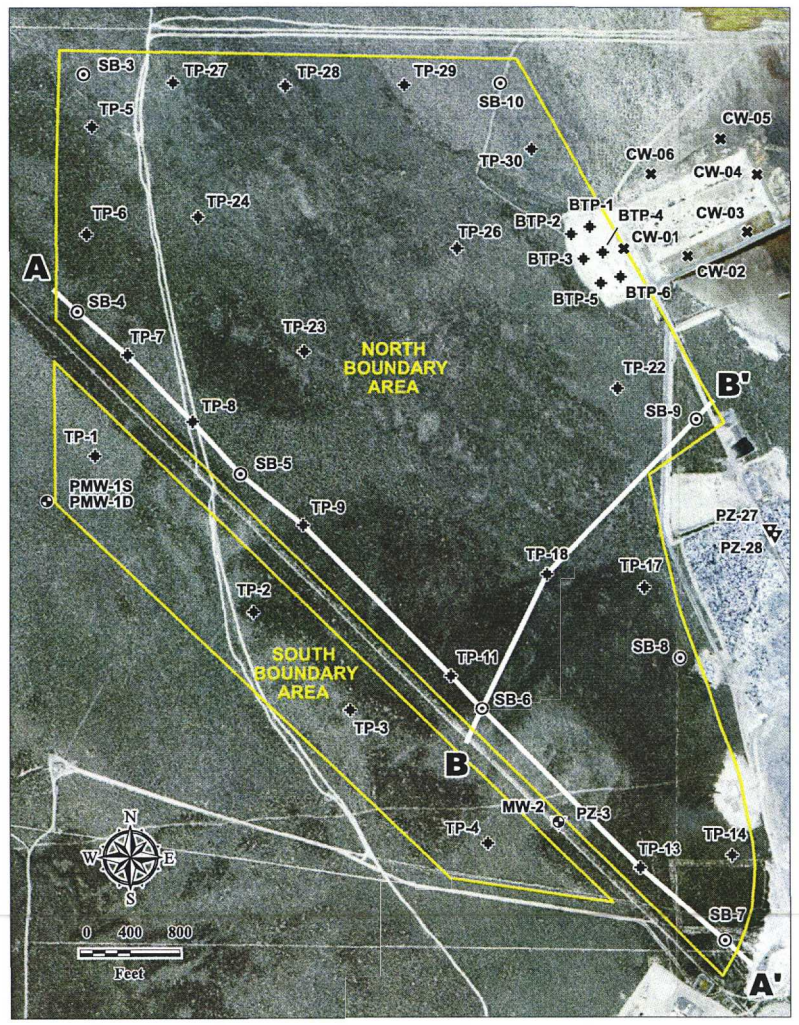
G:\0132320\15\013232015-01.dwg R. Olson 06/09/16 0321320.15



Section A-A' - Looking Northeast

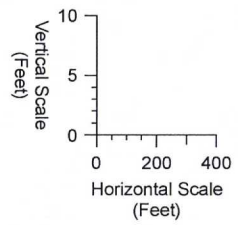


Section B-B' - Looking Northwest



ML Silt/clayey silt
CL/CH Silty clay
SM Silty sand
SP Oolitic sand

Soil boring
Test pit
Monitoring well
Piezometer
Reported static water level (April 27-28, 2015)



40 Times Vertical Exaggeration

Surface elevations are approximate, based on United States Elevation Data (NED) 10 meter resolution grid model
Lithology data collected April 27-28, 2015

USmag®

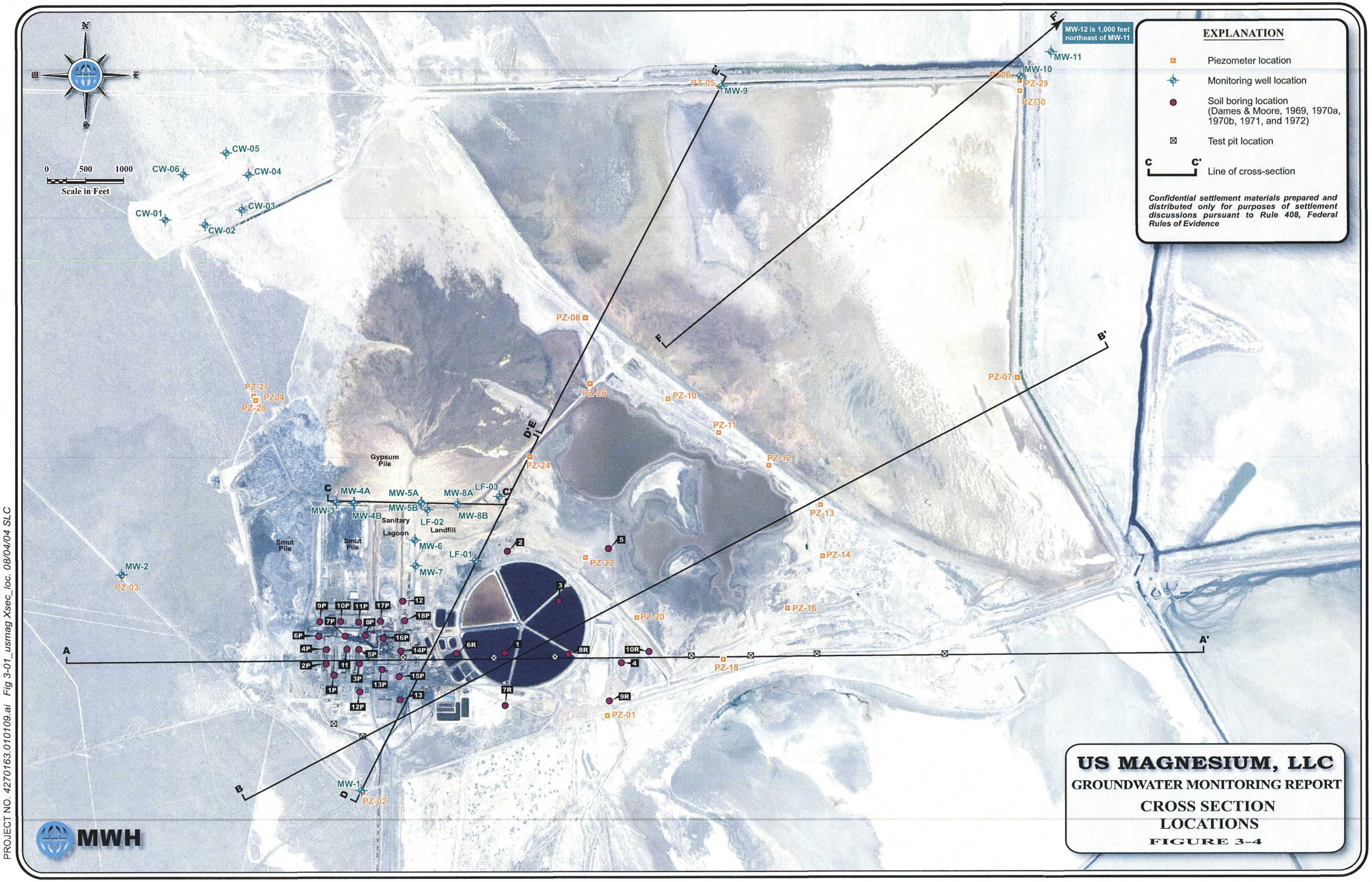
CROSS SECTIONS A-A' AND B-B'

FIGURE 2-1

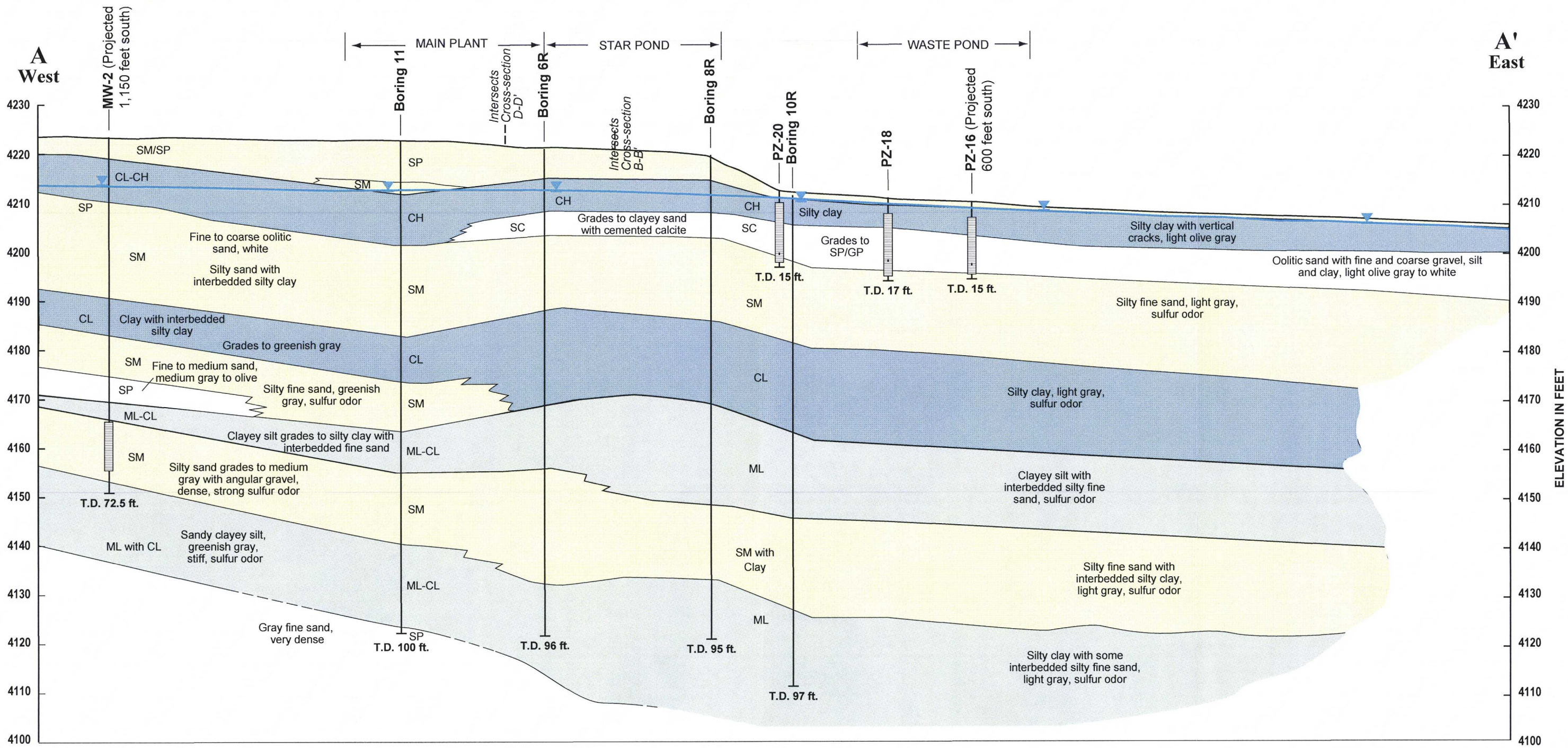
DRAWN BY D. Severson

28 July 2015

C:\MWH\USMAG\FIGURES\Figure 2-1_USMag_CrossSectionA-A_B-B_Jul2015.ai



PROJECT NO. 4270163.010109.ai Fig 3-01_usmag Xsec_loc. 08/04/04 SLC



20
0
1000
Scale in Feet
Vertical exaggeration = 50x

EXPLANATION

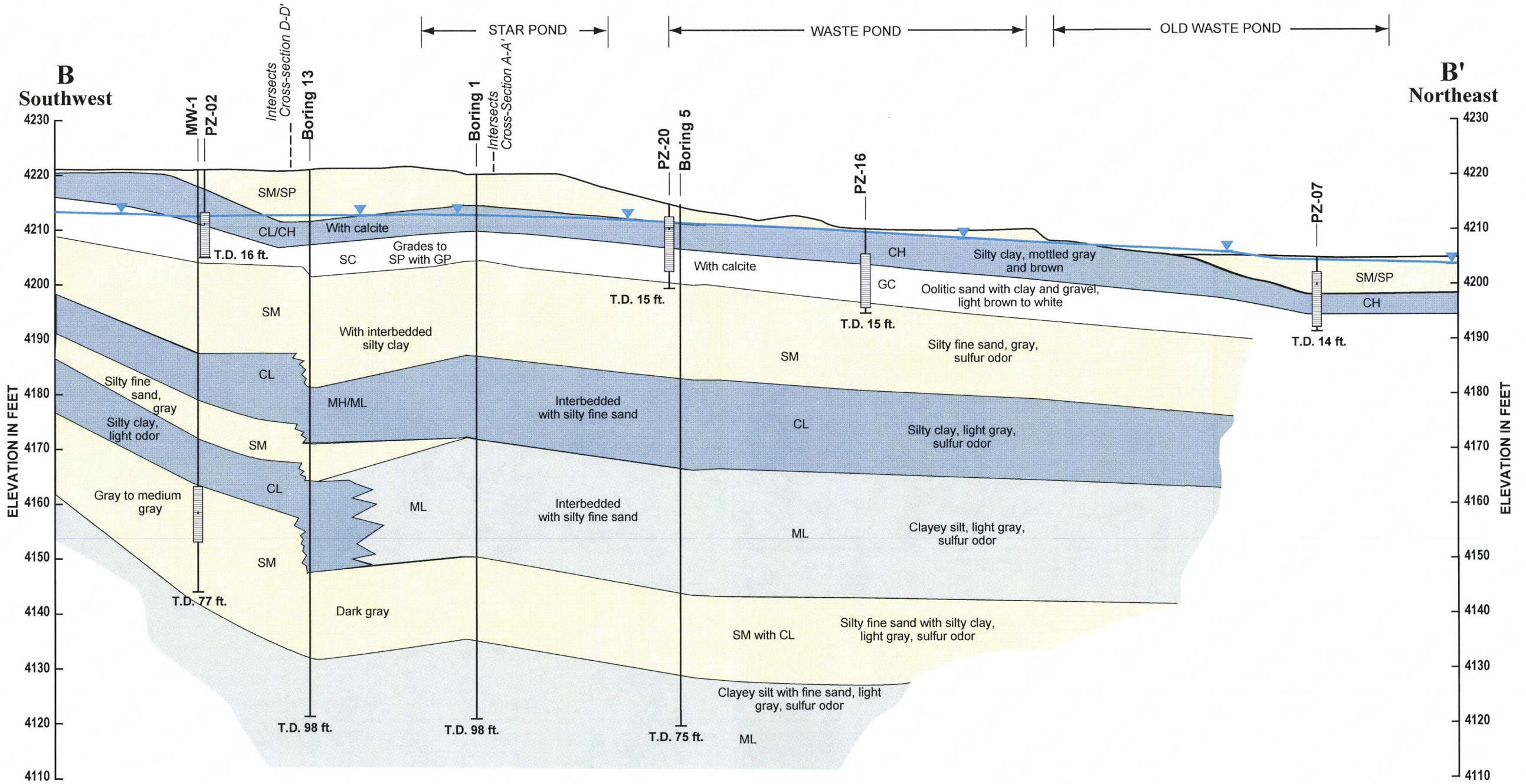
- CL/CH — Silty clay
- ML — Clayey silt
- SM — Silty sand
- SP — Oolitic sand
- Reported static water level
- Reported perforated interval

Confidential settlement materials prepared and distributed only for purposes of settlement discussions pursuant to Rule 408, Federal Rules of Evidence

MWH

PROJECT NO. 4270163.010109.ai 07/22/04 SLC

US MAGNESIUM, LLC
GROUNDWATER MONITORING REPORT
HYDROGEOLOGIC CROSS SECTION A-A'
FIGURE 3-5



20
0
1000
Scale in Feet
Vertical exaggeration = 50x

EXPLANATION

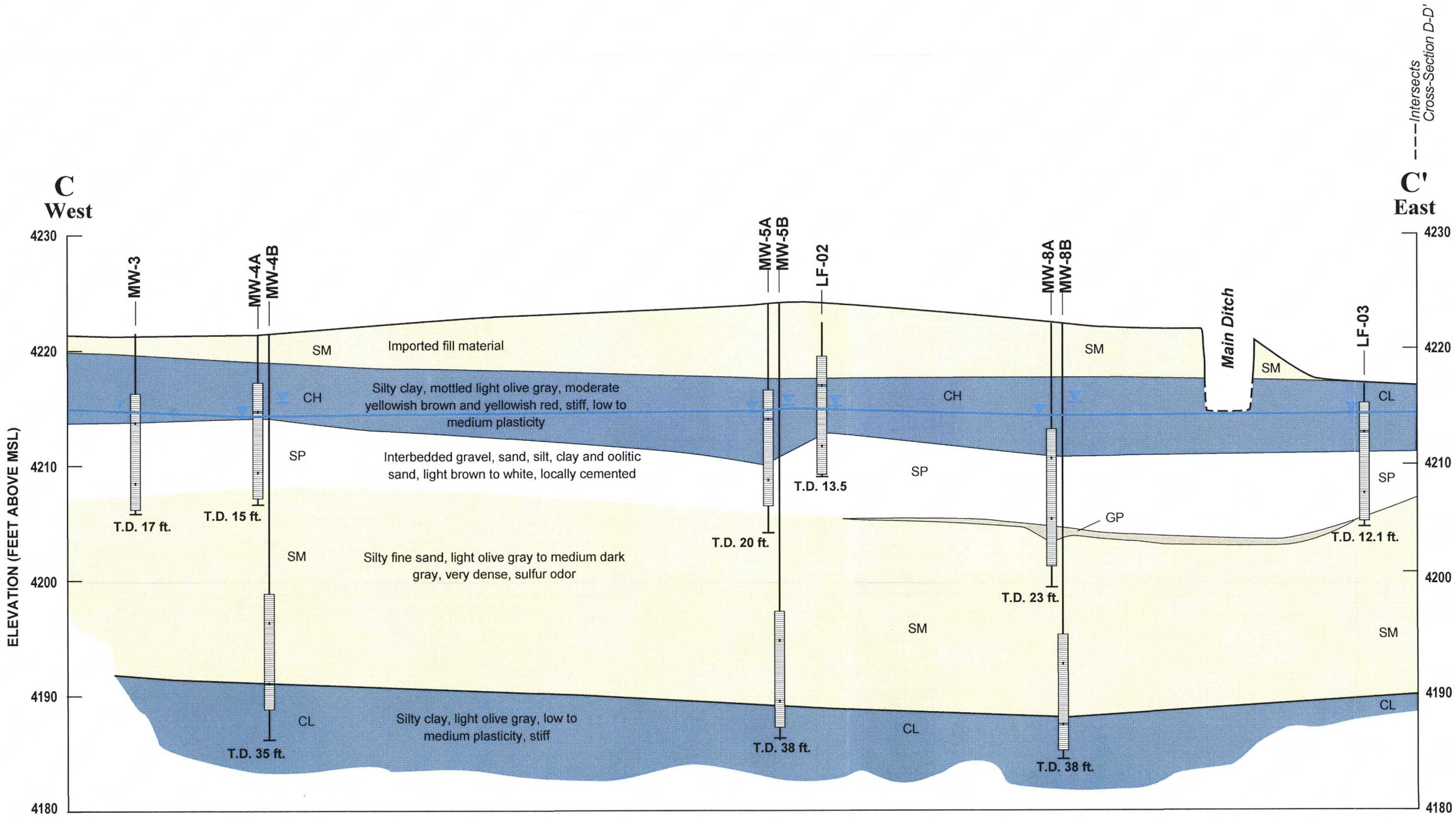
- CL/CH — Silty clay
- ML — Clayey silt
- SM — Silty sand
- SP — Oolitic sand
- Reported static water level
- Reported perforated interval

Confidential settlement materials prepared and distributed only for purposes of settlement discussions pursuant to Rule 408, Federal Rules of Evidence

US MAGNESIUM, LLC
GROUNDWATER MONITORING REPORT
HYDROGEOLOGIC CROSS SECTION B-B'
FIGURE 3-6

MWH

PROJECT NO. 4270163.010109.ai 08/04/04 SLC



Confidential settlement materials prepared and distributed only for purposes of settlement discussions pursuant to Rule 408, Federal Rules of Evidence

PROJECT NO. 4270163.010109.ai 08/04/04 SLC

MWH

US MAGNESIUM, LLC

GROUNDWATER MONITORING REPORT

HYDROGEOLOGIC CROSS SECTION C-C'

FIGURE 3-7

D
Southwest

D'
Northeast

Continues as Cross-section E-E'

Intersects Cross-section B-B'

Intersects Cross-section A-A'

MW-1 / PZ-02

D&M 15P

LF-01

D&M 2

MW-8A/B

Solid Waste Landfill

LF-03

PZ-24

Main Ditch

ELEVATION (FEET ABOVE MSL)

4230 — 4220 — 4210 — 4200 — 4190 — 4180 — 4170 — 4160 — 4150 — 4140

CL/CH
Silty clay, mottled light olive gray, moderate yellowish brown and yellowish red, stiff, low to medium plasticity

SM

CH

SP Interbedded gravel, sand, silt, clay and oolitic sand, light brown to white, locally cemented

SM With sand and gravel

T.D. 16.3 ft.

T.D. 15.8 ft.

SP

SM

ML/CL

8A

GP

T.D. 12 ft.

ML

SM

SP

T.D. 15 ft.

Silty fine sand, light olive gray to medium dark gray, very dense, sulfur odor

SM

With cemented layers and silty sand

With calcite

SM

8B

T.D. 38 ft.

Silty clay, light olive gray, low to medium plasticity, stiff

CL

Grades to light gray

With interbedded silty fine sand

CL

Silty fine sand with thin interbedded silty clay, dense, sulfur odor

CL with SM

Silty clay, light olive gray, medium plasticity, strong sulfur odor

CL

Grades to light gray

ML

ML

Clayey silt with interbedded silty fine sand, light gray, sulfur odor

Silty fine sand with some interbedded silty clay, medium gray, very dense, sulfur odor

SP/SM

T.D. 70.5 ft.

SP/SM

With interbedded silty clay

T.D. 77 ft.

T.D. 97 ft.

10
0 500
Scale in Feet
Vertical exaggeration = 50x

EXPLANATION

CL/CH	Silty clay
ML	Clayey silt
SM	Silty sand
SP/SM	Silty sand with interbedded clay layers
SP	Oolitic sand
GP	Gravel
▼	Reported static water level
▯	Reported perforated interval

Confidential settlement materials prepared and distributed only for purposes of settlement discussions pursuant to Rule 408, Federal Rules of Evidence

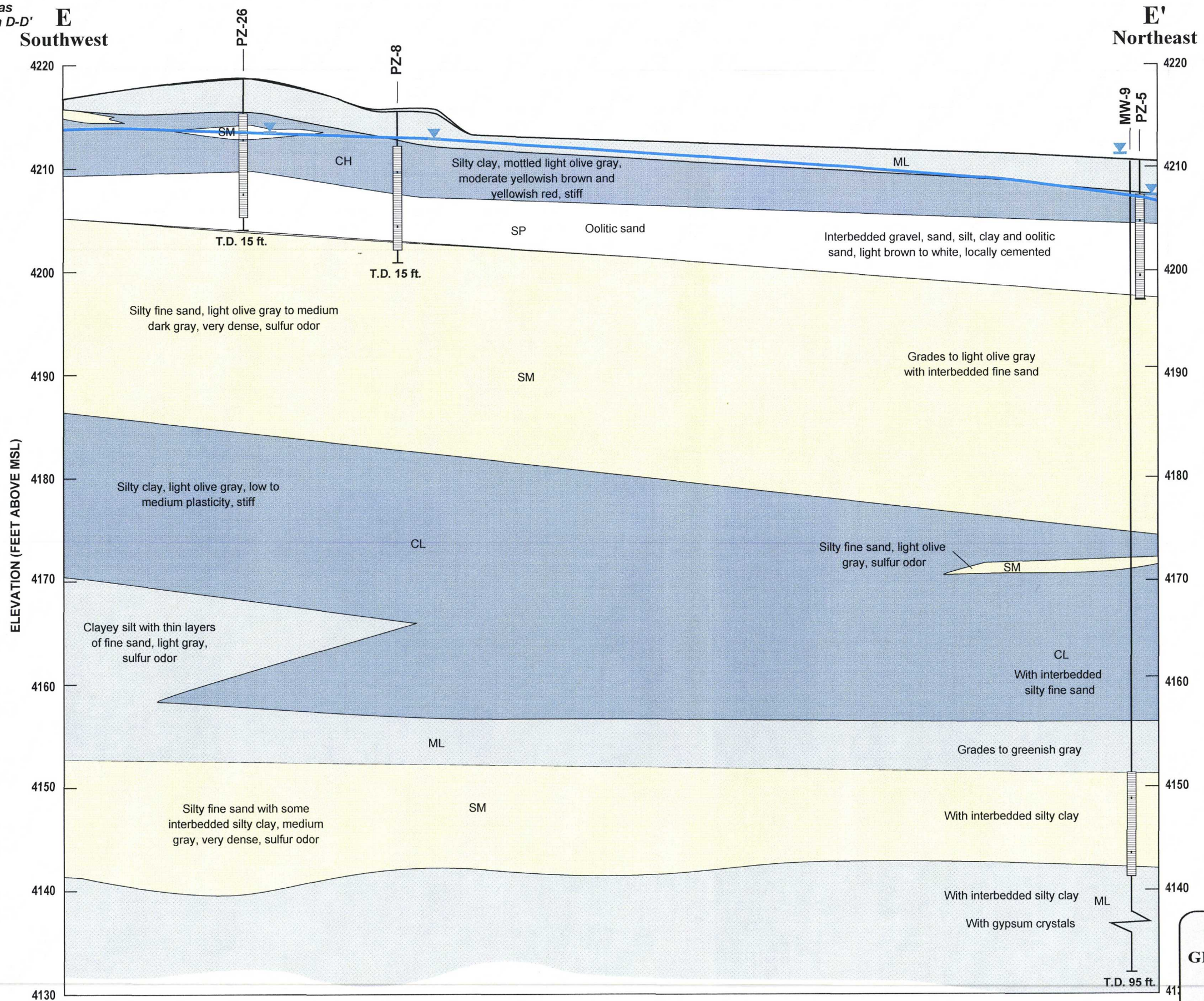
US MAGNESIUM, LLC
GROUNDWATER MONITORING REPORT
HYDROGEOLOGIC CROSS SECTION D-D'
FIGURE 3-8

MWH

PROJECT NO. 4270163.010109.ai 08/04/04 SLC

Continues as Cross-section D-D'

E Southwest — E' Northeast



10
0
500
Scale in Feet
Vertical exaggeration = 50x

EXPLANATION

- CL/CH — Silty clay
- ML — Clayey silt
- SM — Silty sand
- SP — Oolitic sand
- GP — Gravel
- Reported static water level
- Reported perforated interval

Confidential settlement materials prepared and distributed only for purposes of settlement discussions pursuant to Rule 408, Federal Rules of Evidence

US MAGNESIUM, LLC
GROUNDWATER MONITORING REPORT
HYDROGEOLOGIC CROSS SECTION E-E'
FIGURE 3-9

MWH

PROJECT NO. 4270163.010109.ai 08/04/04 SLC

F'
Southwest

F'
Northeast

PZ-24 is 2268 feet to the southwest and PZ-26 is 1107 feet to the west

OLD WASTE POND

Old Waste Pond berm

PZ-29

PZ-6

MW-10

MW-11

MW-12

ELEVATION (FEET ABOVE MSL)

4220
4210
4200
4190
4180
4170
4160
4150
4140
4130

SM
SP
Silty clay, light olive gray, stiff to very stiff
CH/CL
Fill
GP
GM
Interbedded gravel, sand, silt, clay and oolitic sand, light brown to white, locally cemented
SP/GP
T.D. 17 ft.
T.D. 14 ft.
CL
Fine oolitic sand
T.D. 13.2
T.D. 13.3
Oolitic sand
Silty fine sand, light olive gray to medium dark gray, very dense, sulfur odor
Fine to medium, oolitic sand, light olive gray to white, dense
Fine to coarse sand and coarse gravel, light olive gray, oolitic sand with coarse gravel, sulfur odor
Silty clay, light olive gray, low to medium plasticity, stiff
ML
Grades to greenish gray
Silty fine sand, olive gray, dense, sufur odor
Silty clay with gypsum crystals
Clayey silt with thin layers of fine sand, light gray, sulfur odor
SM with CL
Silty fine sand with some interbedded silty clay, medium gray, very dense, sulfur odor
Silty fine sand, greenish gray, dense, sufur odor
Silty clay
T.D. 80 ft.

10
0
500
Scale in Feet
Vertical exaggeration = 50x

EXPLANATION

CL/CH	Silty clay
ML	Clayey silt
SM	Silty sand
SP/SM	Silty sand with interbedded clay layers
SP	Oolitic sand and gravel
GP	Gravel
GM	Silty gravel
▼	Reported static water level
▯	Reported perforated interval

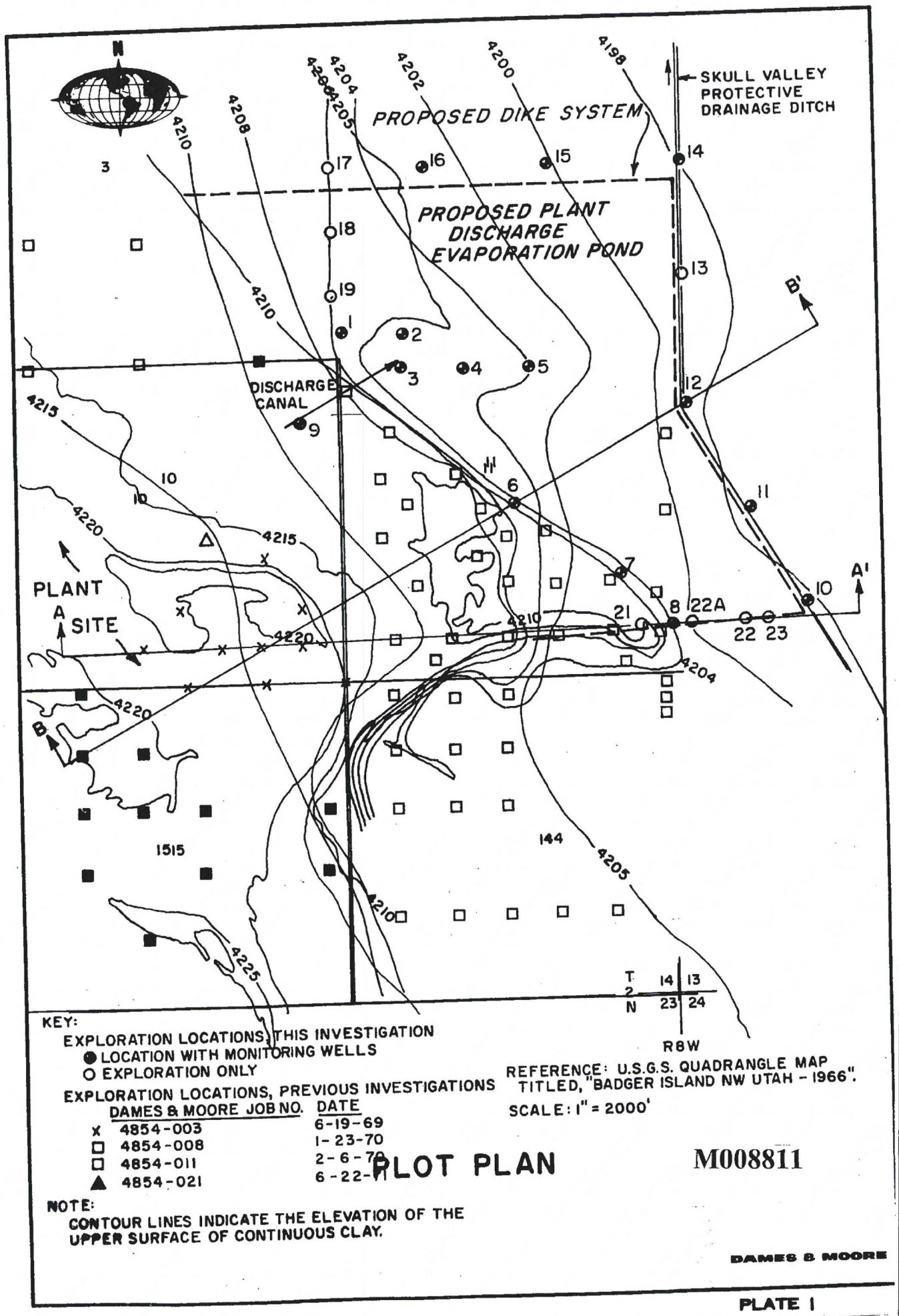
Confidential settlement materials prepared and distributed only for purposes of settlement discussions pursuant to Rule 408, Federal Rules of Evidence

PROJECT NO. 4270163.010109.ai 08/04/04 SLC

MWH

US MAGNESIUM, LLC

GROUNDWATER MONITORING REPORT
HYDROGEOLOGIC CROSS SECTION F-F'
FIGURE 3-10



KEY:

EXPLORATION LOCATIONS, THIS INVESTIGATION
- ● LOCATION WITH MONITORING WELLS
- ○ EXPLORATION ONLY

EXPLORATION LOCATIONS, PREVIOUS INVESTIGATIONS

	DAMES & MOORE JOB NO.	DATE
x	4854-003	6-19-69
□	4854-008	1-23-70
□	4854-011	2-6-70
▲	4854-021	6-22-71

REFERENCE: U.S.G.S. QUADRANGLE MAP TITLED, "BADGER ISLAND NW UTAH - 1966".

SCALE: 1" = 2000'

NOTE:
CONTOUR LINES INDICATE THE ELEVATION OF THE UPPER SURFACE OF CONTINUOUS CLAY.

PLOT PLAN

M008811

DAMES & MOORE

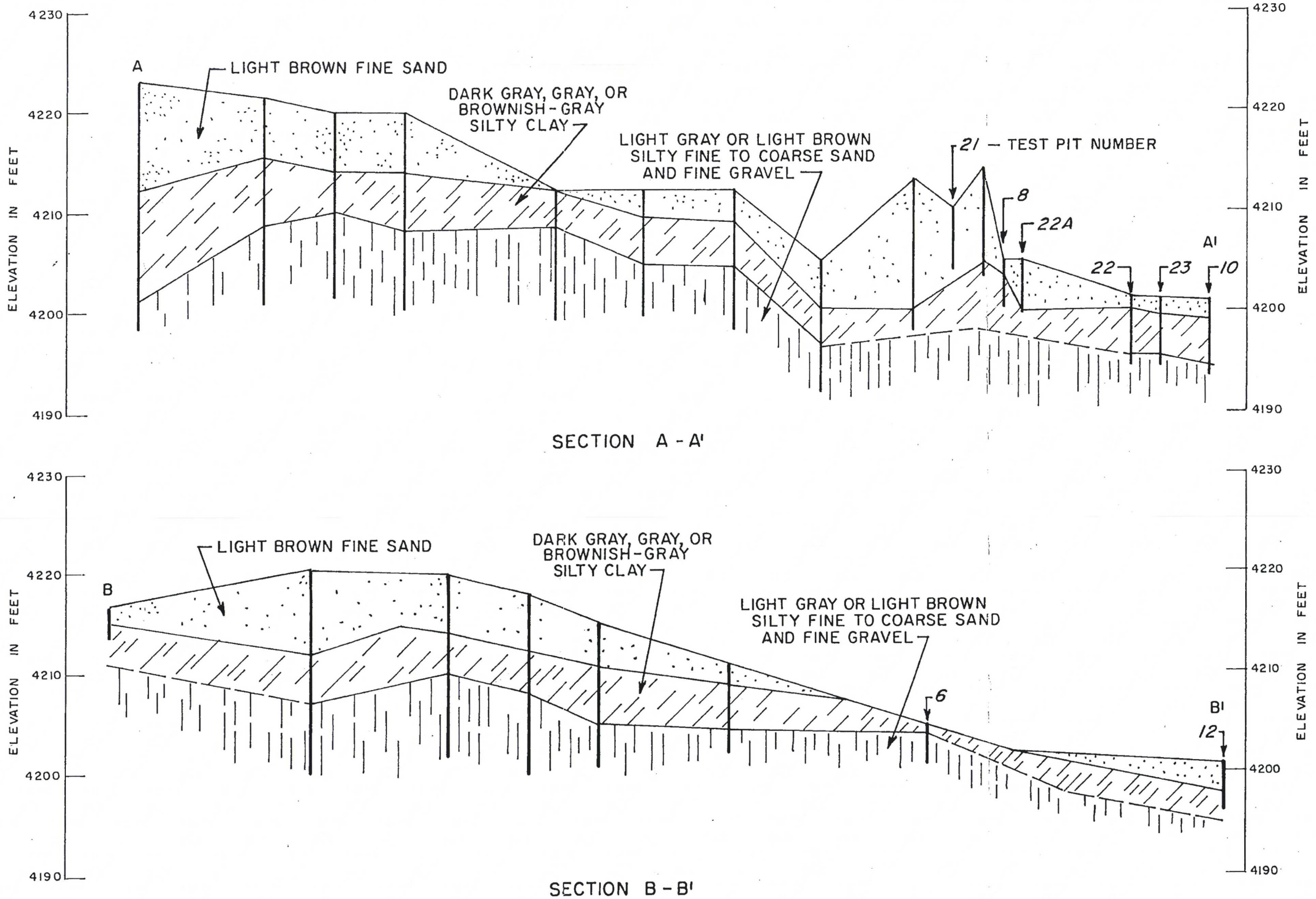
PLATE 1

REVISIONS BY DATE

946.7 (REV. 6-

BY KBF DATE 7-18-72
CHECKED BY JCK 7-19-72

FILE 4854-050 NL



NOTE: LOCATIONS WITH A NUMBER ARE THIS INVESTIGATION.
UNNUMBERED LOCATIONS ARE DATA FROM PREVIOUS INVESTIGATIONS.

SCALE: HORIZONTAL SCALE: 1" = 1000'
VERTICAL SCALE: 1" = 10'

SUBSURFACE SECTIONS

M008812

DAMES & MOORE

PLATE 2

Stantec

ATTACHMENT A.3

2017 CARBONATE AND XRD LAB RESULTS

UtahStateUniversity
USU ANALYTICAL LABORATORIES

Physical Address: 1541 North 800 East, North Logan
Mailing Address: 9400 Old Main Hill, Logan, UT 84322 – 9400
Phone: (435) 797– 2217 • Fax: (435) 797 – 2117
Web: usual.usu.edu

7/6/2017

Stantec
Attn: Susan Eyzaguirre
2890 East Cottonwood Parkway, Suite 300
Salt Lake City, UT 84121

Samples Received: 6/23/2017

USU ID	Identification	Calcium Carbonate %
1505	MW21-5	23.5
1506	MW21-10	53.3
1507	MW21-15	53.9
1508	MW21-20	14.9
1509	MW21-25	34.1
1510	MW21-30	21.7
1511	MW21-35	19.8
1512	MW21-40	29.7
1513	MW21-45	45.2
1514	MW21-50	43.3
1515	MW21-55	47.7
1516	MW21-60	39.0

UtahStateUniversity
USU ANALYTICAL LABORATORIES

Physical Address: 1541 North 800 East, North Logan
Mailing Address: 9400 Old Main Hill, Logan, UT 84322 – 9400
Phone: (435) 797– 2217 • Fax: (435) 797 – 2117
Web: usual.usu.edu

7/6/2017

Stantec
Attn: Susan Eyzaguirre
2890 East Cottonwood Parkway, Suite 300
Salt Lake City, UT 84121

Samples Received: 6/23/2017

USU ID	Identification	Calcium Carbonate %
1517	MW23-5	32.2
1518	MW23-10	16.7
1519	MW23-15	21.7
1520	MW23-20	60.7
1521	MW23-25	27.9
1522	MW23-30	19.8
1523	MW23-35	13.6
1524	MW23-40	29.1
1525	MW23-45	25.4
1526	MW23-50	35.3
1527	MW23-55	37.8

UtahStateUniversity
USU ANALYTICAL LABORATORIES

Physical Address: 1541 North 800 East, North Logan
Mailing Address: 9400 Old Main Hill, Logan, UT 84322 – 9400
Phone: (435) 797– 2217 • Fax: (435) 797 – 2117
Web: usual.usu.edu

7/6/2017

Stantec
Attn: Susan Eyzaguirre
2890 East Cottonwood Parkway, Suite 300
Salt Lake City, UT 84121

Samples Received: 6/23/2017

USU ID	Identification	Calcium Carbonate %
1528	SB1-5	81.7
1529	SB1-10	21.1
1530	SB1-15	74.3
1531	SB1-20	29.7
1532	SB1-25	26.0
1533	SB1-30	20.4
1534	SB1-35	13.0
1535	SB1-40	32.8
1536	SB1-45	34.1
1537	SB1-50	40.9

UtahStateUniversity
USU ANALYTICAL LABORATORIES

Physical Address: 1541 North 800 East, North Logan
Mailing Address: 9400 Old Main Hill, Logan, UT 84322 – 9400
Phone: (435) 797– 2217 • Fax: (435) 797 – 2117
Web: usual.usu.edu

7/6/2017

Stantec
Attn: Susan Eyzaguirre
2890 East Cottonwood Parkway, Suite 300
Salt Lake City, UT 84121

Samples Received: 6/23/2017

USU ID	Identification	Calcium Carbonate %
1538	SB2-5	79.3
1539	SB2-10	27.2
1540	SB2-15	18.0
1541	SB2-20	69.3
1542	SB2-25	70.0
1543	SB2-30	29.7
1544	SB2-35	19.8
1545	SB2-40	20.4
1546	SB2-45	20.4
1547	SB2-50	30.3
1548	SB2-55	34.1
1549	SB2-60	21.7
1550	SB2-65	34.7

UtahStateUniversity
USU ANALYTICAL LABORATORIES

Physical Address: 1541 North 800 East, North Logan
Mailing Address: 9400 Old Main Hill, Logan, UT 84322 – 9400
Phone: (435) 797– 2217 • Fax: (435) 797 – 2117
Web: usual.usu.edu

7/13/2017

Stantec
Attn: Susan Eyzaguirre
2890 East Cottonwood Parkway, Suite 300
Salt Lake City, UT 84121

Samples Received: 6/23/2017

USU ID	Identification	Calcium Carbonate %
1551	SB3-5	18.6
1552	SB3-10	18.6
1553	SB3-15	65.6
1554	SB3-20	45.2
1555	SB3-25	14.9
1556	SB3-30	21.7
1557	SB3-35	21.7
1558	SB3-40	23.5
1559	SB3-45	45.2
1560	SB3-50	11.8
1561	SB3-55	31.0
1562	SB3-60	35.9

TE

July 21, 2017
Lab no. 217225

Ms. Susan Eyzaguirre
Stantec Consulting Services, Inc
2890 East Cottonwood Parkway, Suite 300
Salt Lake City, Utah 84121

Dear Ms. Eyzaguirre:

Enclosed are the x-ray diffraction (XRD) results for "US Magnesium" samples received with PO no P30152-N. This report will be mailed and emailed to you. The signed acknowledgment of the "New Client Credit Application" will be mailed with this report.

The samples were wet as received so were air-dried before grinding and analysis. Each dry sample was crushed by hand. A representative portion of each dry, crushed sample was ground to approximately -400 mesh in a steel swing mill, packed into a well-type plastic holder (bulk mount) and then scanned with the diffractometer over the range, 3-61° 2θ using Cu-Kα radiation. The ground samples were also prepared as oriented mounts by mixing ground sample with distilled water, drawing the mixture onto a cellulose acetate filter and then rolling the deposited material onto a glass disk. The oriented mounts were scanned over the range 2-30°; treated with glycol and then re-scanned over the range 2-22°. Analysis of oriented mounts aids in the identification of clay minerals. The results of the scans are summarized as approximate mineral weight percent concentrations on the enclosed table. Estimates of mineral concentrations were made using our XRF-determined elemental compositions and the relative peak areas on the XRD scans of the "bulk" mounts. The detection limit for an average mineral in these samples is ~1-3% and the analytical reproducibility is approximately equal to the square root of the amount. "Unidentified" accounts for that portion of the XRD scan which could not be resolved and a "?" indicates doubt in both mineral identification and amount.

Thank you for the opportunity to be of service to Stantec Consulting Services.

Sincerely,

Peggy Dalheim

July 21, 2017
Lab no. 217225

Mineral Name	Chemical Formula	Approx. Wt % MW-21-40	MW-21-45	MW-22B-40	MW-22B-50
Quartz	SiO_2	19	10	16	14
Calcite	$CaCO_3$	13	14	11	14
Aragonite	$CaCO_3$	12	29	13	23
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	18	16	13	15
Halite	NaCl	5	<5	5	<5
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	9	5	9	7
K-feldspar	$KAlSi_3O_8$	<5	<5	<5	—
Mica/illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	8	6	8	10
Smectite	$(Ca,Na)_x(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH,F)_4 \bullet nH_2O$	<10	<10	16	<10
Chlorite	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)$	<3?	—	—	<3
Kaolinite	$Al_2Si_2O_5(OH)_4$	—	<5	<3	<3?
Clinoamphibole	$(Na,K)(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$	<1?	—	—	<2?
Unidentified	?	<5	<5	<5	<5

Initial _____

Date _____

Analysis performed by The Mineral Lab, Inc

Mineral Name	Chemical Formula	Approx. Wt % MW-23-40	MW-23-50	SB-1-40	SB-1-45
Quartz	SiO_2	22	13	15	16
Calcite	$CaCO_3$	12	13	15	13
Aragonite	$CaCO_3$	5	26	16	11
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	28	13	13	20
Halite	NaCl	6	16	5	5
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	11	5	7	8
K-feldspar	$KAlSi_3O_8$	<3?	<3?	<5?	<5
Mica/illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	7	5	7	9
Smectite	$(Ca,Na)_x(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH,F)_4 \bullet nH_2O$	<5?	<5	15	10
Chlorite	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)$	<3?	—	—	<5
Kaolinite	$Al_2Si_2O_5(OH)_4$	—	—	<3?	—
Clinoamphibole	$(Na,K)(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$	<3	<2?	<2?	<2?
Unidentified	?	<5	<5	<5	<5

Initial _____

Date _____

Analysis performed by The Mineral Lab, Inc

July 21, 2017
Lab no. 217225

Mineral Name	Chemical Formula	Approx. Wt % SB-2-60/42	SB-2-65/46	SB-3-55/39	SB-3-60/42
Quartz	SiO_2	30	9	22	10
Calcite	$CaCO_3$	11	13	11	16
Aragonite	$CaCO_3$	—	18	8	18
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	23	10	24	15
Halite	NaCl	5	22	<5	<5
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	16	<5	11	10
K-feldspar	$KAlSi_3O_8$	<5	<5	<3	<3?
Mica/illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	5	<5	9	8
Smectite	$(Ca,Na)_x(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH,F)_4 \bullet nH_2O$	<5	13	<10	10
Chlorite	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)$	<3?	<3?	<3?	<3
Kaolinite	$Al_2Si_2O_5(OH)_4$	—	—	—	<3?
Clinoamphibole	$(Na,K)(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$	<2?	—	<3	<2?
Unidentified	?	<5	<5	<5	<5

Initial _____

Date _____

Analysis performed by The Mineral Lab, Inc

		Approx. Wt %			
Mineral Name	**Chemical Formula**	**SB-4-40**	**SB-4-45**	**SB-5-45/32**	**SB-5-50/35**
Quartz	SiO_2	14	14	24	19
Calcite	$CaCO_3$	15	15	12	14
Aragonite	$CaCO_3$	20	25	<5	13
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	17	16	29	18
Halite	NaCl	<2	<2?	<3	<3
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	8	8	10	10
K-feldspar	$KAlSi_3O_8$	<5	<3	<3	<3
Mica/illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	8	9	10	9
Smectite	$(Ca,Na)_x(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH,F)_4 \bullet nH_2O$	<10	<5	<5	10
Chlorite	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)$	—	<3	<3?	<3
Kaolinite	$Al_2Si_2O_5(OH)_4$	<3?	—	—	—
Clinoamphibole	$(Na,K)(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$	<2?	<2?	—	<2?
Unidentified	?	<5	<5	<5	<5

Initial _____

Date _____

Analysis performed by The Mineral Lab, Inc

July 21, 2017
Lab no. 217225

Mineral Name	Chemical Formula	Approx. Wt % SB-6-50/35	SB-6-55/39	SB-7-30	SB-7-35
Quartz	SiO_2	19	15	24	23
Calcite	$CaCO_3$	11	17	22	18
Aragonite	$CaCO_3$	6	15	—	6
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	29	14	22	18
Halite	NaCl	<2	<2	—	—
Plagioclase feldspar	$(Na,Ca)Al(Si,Al)_3O_8$	13	9	9	10
K-feldspar	$KAlSi_3O_8$	<5	<3	5	5
Mica/illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	10	9	13	9
Smectite	$(Ca,Na)_x(Al,Mg,Fe)_4(Si,Al)_8O_{20}(OH,F)_4 \bullet nH_2O$	<5	14	<5	<10
Chlorite	$(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)$	—	—	<3	<3
Kaolinite	$Al_2Si_2O_5(OH)_4$	—	—	—	—
Clinoamphibole	$(Na,K)(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$	<2?	<2	<2?	<2?
Unidentified	?	<5	<5	<5	<5

Initial _____

Date _____

Analysis performed by The Mineral Lab, Inc

Stantec

ATTACHMENT A.4

2017 GEOTECHNICAL LAB RESULTS

(INCLUDED IN ELECTRONIC SUBMISSION)

Stantec

ATTACHMENT A.4

2017 GEOTECHNICAL LAB RESULTS

(INCLUDED IN ELECTRONIC SUBMISSION)

APPENDIX B – AQUIFER PROPERTIES RESULTS AND DATA

US MAGNESIUM 2017 AQUIFER PROPERTY TEST REPORT

Table of Contents

1.0 INTRODUCTION 1
2.0 PNEUMATIC SLUG TESTS 1
2.1 PNEUMATIC SLUG TESTS ANALYSIS 2
2.2 PNEUMATIC SLUG TESTS ANALYSIS AND RESULTS 2
3.0 PUMPING TEST – LOWER AQUIFER ZONE 3
3.1 PUMPING TEST ANALYSIS METHODS 3
3.2 PUMPING TEST RESULTS 4
5.0 REFERENCES 5
ATTACHMENT B.1 - PNEUMATIC SLUG TEST DATA, RESULTS AND ANALYSIS 6
ATTACHMENT B.2 - PUMPING TESTS DATA, RESULTS AND ANALYSIS 7

1.0 INTRODUCTION

Aquifer tests were conducted at the US Magnesium facility in June 2017 to provide data to support the Groundwater Discharge Permit application for a proposed Retrofitted Waste Pond designed to receive production wastewater. During the June 2017 field effort pneumatic slug tests and a pumping test were performed at the site to characterizing aquifer properties in both the Upper and Lower Aquifer Zones of the regional shallow aquifer. Sections 2, 3 and 4 below summarize these efforts.

2.0 PNEUMATIC SLUG TESTS

Stantec personnel conducted pneumatic slug tests on June 19th and 20th, 2017 at ten locations throughout the site in accordance with Standard Operating Procedures (SOPs) as described in the May 2017 work plan (Stantec, 2017). The original work plan identified 15 wells/piezometers for testing, however 5 locations were not tested due to the inability to hold pressure because the static groundwater level was below the top of the well screen interval, or the casing was not sufficiently air tight to hold pressure/vacuum. Pneumatic slug tests were conducted in five wells with screened intervals in the shallow aquifer Upper Aquifer Zone, and five wells screened in the Lower Aquifer Zone (Figure B-1).

A minimum of three pneumatic slug tests were completed at each monitoring well. Positive pressure tests on all wells/piezometers were completed first, followed by a round of negative pressure tests at all wells/piezometers. Positive pressure tests consisted of delivering between 12 and 55 inches of water to create groundwater displacement within the well. Negative (vacuum) pressure tests consisted of applying negative pressure to the water column to create a positive displacement of water (increase in water column). The displacement of

groundwater was monitored using a transducer submerged below the groundwater which collected water-level readings every 0.25 seconds.

2.1 PNEUMATIC SLUG TESTS ANALYSIS

Pneumatic slug test data were analyzed using the software package AQTESOLV, version 4.0 Professional (Duffield, 2007). The hydraulic head data measured during the selected pneumatic slug tests were evaluated using two different mathematical models: Bouwer-Rice (Bouwer and Rice, 1976) and Hvorslev (Hvorslev, 1951). The following assumptions have been applied for these analysis methods (Duffield, 2007):

- Aquifer has infinite areal extent and is homogeneous and of uniform thickness,
- Aquifer potentiometric surface is initially horizontal,
- Control well is fully or partially penetrating,
- A volume of water is injected or discharged instantaneously from the control well,
- Aquifer is confined or unconfined and flow is steady.

2.2 PNEUMATIC SLUG TESTS ANALYSIS AND RESULTS

Pneumatic slug test analysis reports are presented in **Attachment B.1**.

2.2.1 Upper Aquifer Zone Results

Data from five tests conducted in wells/piezometers completed to shallower depths were used to interpret the hydraulic conductivity of the Upper Aquifer Zone. Calculated hydraulic conductivity values for this zone ranged from 0.2 to 4.9 meters per day (m/day) and had a median of 0.8 m/day. Generally, the Upper Aquifer Zone is composed of fine-grained sands, including oolitic sands with some interbedded silts and clays. Published literature from Domenico and Schwartz (1990) suggest sedimentary deposits including fine sand have a range of potential hydraulic conductivity between 1.7×10^{-2} and 17 m/day. The overall calculated hydraulic conductivity of 0.8 m/day for Upper Aquifer Zone is considered at the higher end of this range.

2.2.2 Lower Aquifer Zone Results

Data from five wells completed at deeper depths were used to evaluate hydraulic conductivity of the Lower Aquifer Zone, which is composed of finer-grained silty clays. Hydraulic conductivity interpreted from five wells from the Lower Aquifer Zone range between 0.2 to 3.2 m/day with a median of 0.8 m/day. Published literature from Domenico and Schwartz (Domenico and

Schwartz, 1990) suggest a range for silts between 8.6×10^{-5} and 1.7 m/day and clays between 8.6×10^{-7} and 4×10^{-4} m/day. The calculated hydraulic conductivity in the Lower Aquifer Zone is considered on the higher end of the typical range for a silty aquifer.

3.0 PUMPING TEST – LOWER AQUIFER ZONE

A 48-hour pumping test was conducted at MW-22B, a new well completed in the Lower Aquifer Zone. Responses in both the Upper and Lower Aquifer Zones were recorded and analyzed.

The pumping test was performed in accordance with Standard Operating Procedures presented in the May 2017 Work Plan (Stantec, 2017). Water was pumped from the aquifer using a Grundfos X submersible pump with a 150 kW Franklin electric motor. The pump was powered by a 300 KVA generator. The pump inlet was lowered to approximately the midway point of the screen interval to draw groundwater from the deep aquifer and obtain maximum groundwater head above the pump. Water levels were measured both manually and with a transducer in MW-22B during the preliminary, constant-rate, and recovery tests.

Groundwater levels were monitored with transducers in nine observation wells/piezometers to record groundwater-level drawdown responses during the aquifer test (five completed in the Upper Aquifer Zone and four completed in the Lower Aquifer Zone). Table 3-4 in the Hydrogeologic Report summarizes the water-level monitoring point screen interval, aquifer type and proximity to MW-22B for each observation well/piezometer during the aquifer tests. Figure B-2 presents the location of the nearby monitoring wells used to monitor the constant rate and recovery tests.

Following test setup and preliminary tests, the constant rate test was started on June 17, 2017 and conducted for approximately 24 hours at a rate of 3 gallons per minute (gpm). On June 18, 2017, the flow rate was increased to 5.4 gpm and the constant rate test continued for an additional 24 hours. The pumping rate was increased for the constant rate test after a 24-hour period due to the relatively low drawdowns observed in the pumping during the first 24 hours. Therefore, the second half of the pumping test was able to stress the Lower Aquifer Zone with a higher pumping rate and a larger drawdown in the pumping well was observed. After 48 hours of constant rate test, the pump was stopped and the recovery test began on June 19, 2017.

3.1 PUMPING TEST ANALYSIS METHODS

The hydraulic head data measured during the pumping test at MW-22B was evaluated using two different mathematical models including Cooper-Jacob (1946) for the pumping period and Theis (1935) for the recovery test. The

following assumptions were applied for these analysis methods (Kruseman, 1994):

- The aquifer is confined and infinite areal extent,
- The aquifer is homogeneous, isotropic and of uniform thickness over the area influenced by the test,
- Prior to pumping the piezometric surface is horizontal over the area that will be influenced by the test,
- The aquifer is pumped at a constant discharge rate
- The pumping wells penetrate the entire thickness of the aquifer and receive water by horizontal flow.

3.2 PUMPING TEST RESULTS

The resulting analysis and interpretation reports for aquifer and recovery tests at the pumping well, MW-22B, are presented in **Attachment B.2**. Results from the pumping test analyses indicate that hydraulic conductivity estimates for MW-22B range from 3.8 to 4 ft/day ($1.3x10^{-03}$ to $8.4x10^{-04}$ centimeters per second [cm/s]). These results are consistent with literature values for silty sands and fine sand unconsolidated sediments (Fetter, 2001). The storage coefficient or storativity values calculated for the constant rate test (CRT) suggest they are consistent within an order of magnitude of values expected for confined aquifers.

With the exception of observation well MW-22A, water levels in eight of the nine observation monitoring wells/piezometers did not change during the 48-hour pumping test at pumping rates of 3 to 5.4 gpm. MW-22A is located 12 feet from MW-22B and screened from 24 to 34 feet below ground surface (bgs) in the silty sand Upper Aquifer Zone. The maximum drawdown of 1.6 feet was observed during the preliminary setup and prior to the test when the well was pumped at 10 gpm for seventy five minutes. During the pump test period the maximum drawdown observed was 0.27 feet in MW-22A. These results may suggest the clay confining unit (Deeper Silty Clay Unit) between the Upper and Lower Aquifer Zones may be leaky under stressed conditions. However, negligible change in water level was observed at the other during the stressed condition of the preliminary tests and the CRT.

5.0 REFERENCES

Bouwer, H., 1989. *The Bouwer and Rice slug test--an update,* Ground Water, vol. 27, no. 3.

Bouwer, H. and R.C. Rice, 1976. *A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells*, Water Resources Research, vol. 12, no. 3.

Cooper, H.H. and C.E. Jacob, 1946. *A generalized graphical method for evaluating formation constants and summarizing well field history*, Am. Geophys. Union Trans., vol. 27, pp. 526-534.

Domenico, P.A. and F.W. Schwartz, 1990. *Physical and Chemical Hydrogeology*, John Wiley & Sons, New York.

Duffield, G.M., 2007. *AQTESOLV for Windows Version 4.5*, HydroSOLVE, Inc., Reston, VA.

Fetter, C. W., 2001. *Applied hydrogeology. Upper Saddle River, N.J: Prentice Hall.*
Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi.

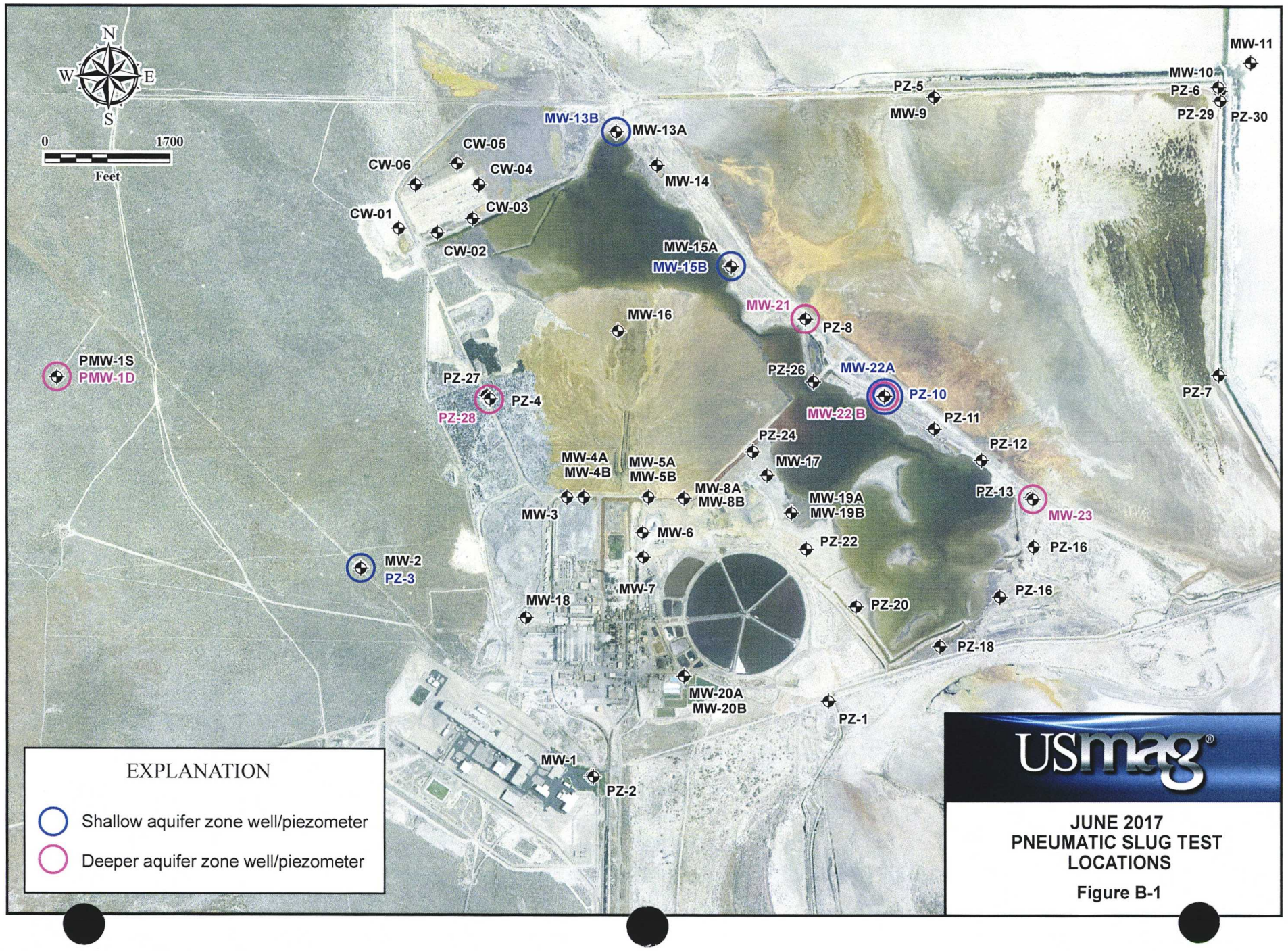
Kruseman, G.P. and N.A. de Ridder, 1994. *Analysis and Evaluation of Pumping Test Data (2nd ed.),* Publication 47, Intern. Inst. for Land Reclamation and Improvement, Wageningen, The Netherlands.

MWH Americas Inc. (MWH). 2004. *Groundwater Characterization and First Quarter Groundwater Monitoring Report*. US Magnesium LLC.

Stantec, 2017. *Technical Memo: US Magnesium Groundwater Discharge Permit Application Preparation – Field Data Collection Work Plan.* Submitted to Utah Division of Environmental Quality: Division of Water Quality May 2, 2017.

Theis, C.V., 1935. *The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage*, Am. Geophys. Union Trans., vol. 16.

C:\Data\MWH\PB&L &US Magnesium\FIGURES\DATA GAPS TECH MEMO\FIGURES\Figure 3-1_Pneumatic Slug Test Locs_27Sep2017.mxd 27 Sep 2017 DRAWN BY D. Severson



USmag®

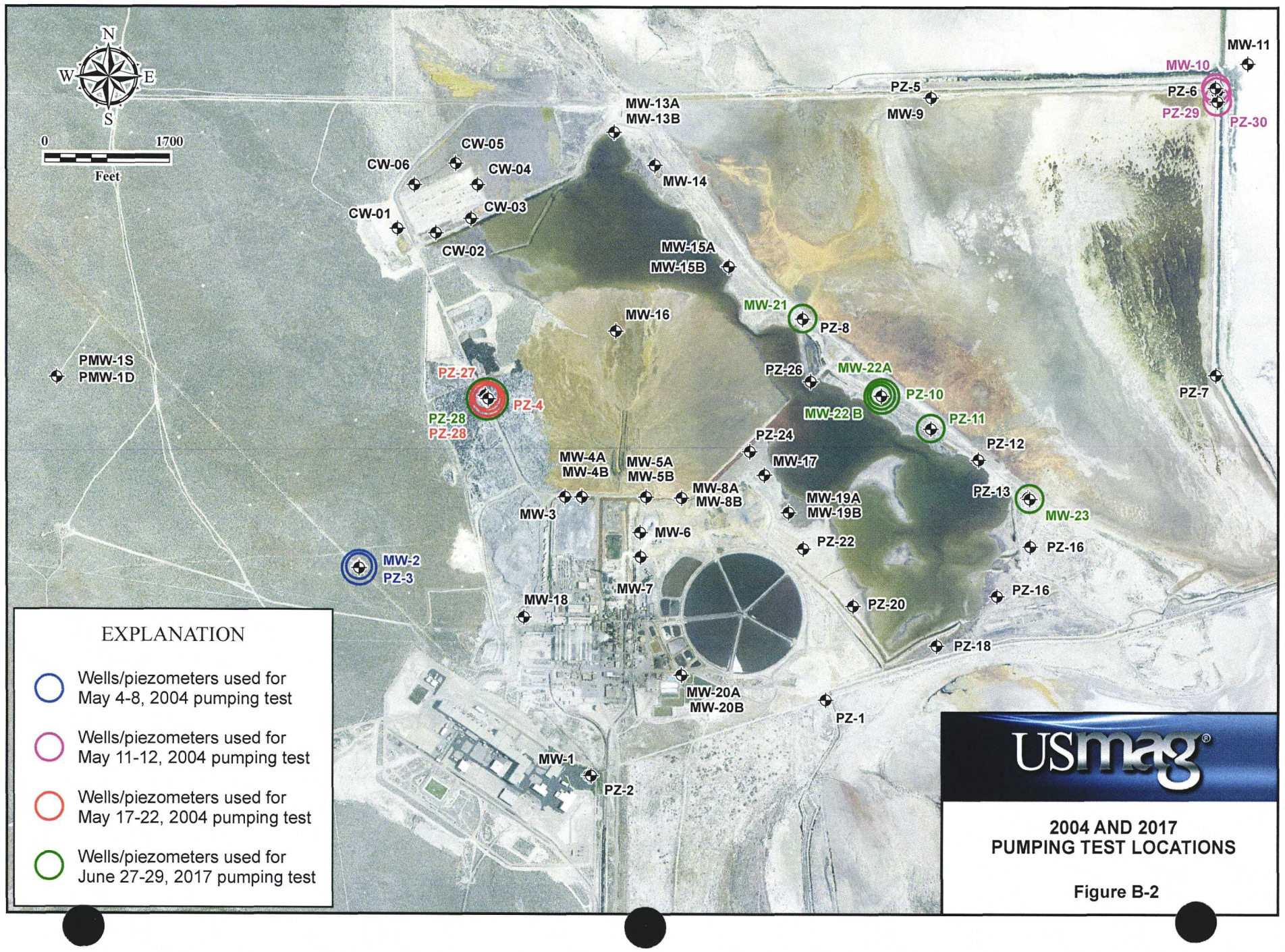
JUNE 2017
PNEUMATIC SLUG TEST LOCATIONS

Figure B-1

C:\Data\MWH\PB&L &US Magnesium\FIGURES\DATA GAPS TECH MEMO\FIGURES\Figure 3-2_Pumping Test Locs_27Sep2017.mxd

27 Sep 2017

DRAWN BY D. Severson



USmag®

2004 AND 2017 PUMPING TEST LOCATIONS

Figure B-2

Stantec

ATTACHMENT B.1

PNEUMATIC SLUG TEST DATA, RESULTS AND ANALYSIS

(Included in Electronic Submission)

Stantec

ATTACHMENT B.2

PUMPING TESTS DATA, RESULTS AND ANALYSIS

Aquifer Test Data Form

Test: US Mag	By:						Test Date:			Page 1 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	06	27	2017	10	20	00		6.44		3 gpm	Flow initially ≈6gpm for ≈10-15 sec
				10	22	40		15.34		3.1 *	* Flow meter
				10	24	00		17.41			
				10	25	45		19.11			
				10	27	10		19.98			
				10	28	15		20.49		2.8	Adjust valve
				10	29	40		21.38			
				10	30	03				2.5*/3.0	
				10	31	16		22.92			
				10	31	36				3.7*	
				10	32	40		23.57			
				10	33	01				3.0*/30	
				10	34	10		23.78		~~2.9*30~~	
				10	36	00				2.9	
				10	36	25		23.84			
				10	37	50				3.0	
				10	38	40		24.00			

MINNESOTA MDH DEPARTMENT OF HEALTH
Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES: * Flow meter totalizer measurement

IC #140-0523

Aquifer Test Data Form

Test: Constant-rate	By: A. Pettley / J. Pierson						Test Date: 6/27/17			Page 2 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge gpm	Remarks
MW-22B	6	27	2017	10	40	30				2.9*/3.0	
				10	40	50		24.20	~~24.20~~ 20		
				10	43	40				3.0	
				10	44	35		24.38	~~24.38~~ 39		
				10	46	41		24.58			
				10	47	18				2.9*/3.0	
				~~10~~ 20				24.76/24.78			check sounders
				10	55	01				2.9*	
				10	56	?		24.91			
				10	57	50				3.0	
				10	58	16		25.00			
				11	00	30		25.18		3.0	
				11	06	35		25.31		3.0	
				11	09	35		25.36		3.0	
				11	24	40		25.63		~~3.0~~ 2.9	Adjust value @ 1128
				11	30	20				3.5	
				11	32	40				2.5*	

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES: * Flow meter measurement; all others bucket test
1 Soj. ust sounder

IC #140-0523

Aquifer Test Data Form

Test:	By:						Test Date:			Page 3 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge 9 Dec	Remarks
MW-22B				11	34	10		27.02	~~27~~	3.3*	
				11	38	00				3.3	
				11	40	30		27.05		3.0*/3.0	
				11	46	30		26.46		3.0*	
				11	55	00				3.0*/3.0	3-min average on meter
				11	58	00		26.38			
				12	05	10		26.46			
				12	10	00		26.49		2.9*	
				12	20	00	120	26.61		2.9*	
				12	47	13		26.83		2.9*	
				13	12	00		26.98		3.0	
				13	35	?		27.13		3.0	
				14	10	20		27.30			
				14	31	?		27.34		2.9	
				14	50	-		27.46			
				15	06	-		27.52		3.0	
				15	34	-		27.63		3.0	

MINNESOTA MDH DEPARTMENT OF HEALTH
Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

Aquifer Test Data Form

Test:	By:						Test Date:			Page 4 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	6	27	2017	15	58	—		27.71		3.0 gpm	
				17	19	—		27.91		3.0	
				18	15	—		28.11		3.0	
				19	06	10		28.21			
				20.	02	40		28.26		2.9	
				20	45	-		28.33		3.0	
				21	12	—		28.36		—	
	6	28	2017	07	50	-		29.10		3.0 / 2.8*	
				11	00	00					Increase flow rate
				11	01					3.5	
				11	03					4.0 / 3.8*	
				11	04					4.5	
				11	06	—				5.2 / 5.1*	
				11	08	~				5.5	
				11	09	30		40.25			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

Aquifer Test Data Form

Test: US MAG	By: Joel Pierson			Test Date: 6-28-17			Page 5 of 9	
LOCATION (Unique Well Number)	DATE Month Day Year	TIME Hour Minute Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	6 28 2017	11 12 30		~~41.67~~		5.3*/5.6	
MW-22B	6 28 2017	11 13 30		41.75			
MW-22B	6 28 2017	11 19 -		~~43.~~		5.1*/5.5	
MW-22B	6 28 2017	11 21 -		42.70			
MW-22B	6 28 2017	11 23 -		42.86			
MW-22B	6 28 2017	11 27 -		43.02			
MW-22B	6 28 2017	11 30 -				5.1*/5.5	
MW-22B	6 28 2017	11 31 -		43.19			
MW-22B	6 28 2017	11 40 -		43.40			
MW-22B	6 28 2017	11 41 -				5.0*/5.4	
		12 02 -		43.72			
		12 05 -				5.0*/5.4	
		12 11 -		43.82			
		12 48 -				5.0*/5.4	
		12 50 -		44.13			
		13 42 -		44.47			
		13 44 -				5.2*/5.4	

MINNESOTA MDH DEPARTMENT of HEALTH
Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By:						Test Date:			Page 6 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	6	28	17	14	21	–		44.61			
				14	23	–				4.9* gpm	Meter
				15	37	–		44.81		5.4 gpm	bucket test
				17	05			45.04		4.2* gpm	meter
				19	19	–		45.26		5.0* gpm	meter
				21	17			45.44			
	6	29	17	08	18	–		46.20		5.4 gpm	bucket
				10	04	–		46.30			
				10	48	-		46.35			
				10	58			46.38		5.3/4.9	
				11	02	18	:18	44			
						32		42			
						46		~~55.04~~ 41			
~~Hi pp shut down~~				11	01	04	.	39			
				11	01	15	.	38			
				11	01	27	.	37			
				11	01	40	.	36			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By:						Test Date:			Page 7 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	6	29	2017	11	01	52		~~335.00~~			
				11	02	34		34			
				11	~~02~~	~~38~~		~~33.00~~			
				11	02	38		32			
				11	02	56		31			
				11	03	14		30			
				11	3	35		25			
				11	3	55		28			
				11	04	25		27			
				11	04	53		26			
				11	05	26		25			
				11	06	~~48~~ 53		23			
				11	07	40		22			
				11	10	06		20			
				11	11	49		19			
				11	14	16		18			
				11	17	50		17			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By:						Test Date: 6/29/17			Page 8 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	6	29	2017	11	23	25		16.00			
				11	~~18~~ 33	19		~~16~~ 15.00			
				11	35	00		14.85			
				11	40	00		14.55			
				11	45	00		14.29			
				11	50	00		14.05			
				11	55	00		13.84			
				12	00	00		13.65			
				12	05	-		13.49			
				12	10	-		13.34			
				12	15	-		13.19			
				12	20	-		13.08			
				12	41	-		12.63			
				13	43	-		11.78			
				14	29	-		11.27			
				15	26	-		10.85			
				15	55	-		10.68			

MINNESOTA MDH DEPARTMENT OF HEALTH
Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By:						Test Date:			Page 9 of 9	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22B	6	30	2009	09	25	–		8.51			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test: US Mag	By: A. Pettley						Test Date: 6/27/17			Page 1 of 2	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22A	06	27	2017					6.77			
				10	49	20		6.701			
				11	08	?		6.71[1]			
				11	51	00		6.71[1]			
				12	12	30		6.71[1]			
				13	17	00		6.72'			
				13	36	00		6.72'			
				14	33	00		6.73'			
				15	37	-		6.75'			
				16	00	-		6.74'			
				17	23	-		6.73'			
				18	16	-		6.73'			
				19	05			6.73'			
				20	09	-		6.74'			
				21	08	-		6.73			
MW-22A	6	28	2017	11	25	-		6.75'			
				12	09	-		6.75'			

MINNESOTA MDH DEPARTMENT OF HEALTH
Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES: 1 Solnist sounder

IC #140-0523

Aquifer Test Data Form

Test:	By:						Test Date:			Page 2 of 2	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-22A	06	28	2017	12	53	-		6.75			
				15	43	-		6.76			
				17	07	-		6.76			
				19	22	-		6.76			
				21	20	-		6.77			
	06	29	2017	08	23	-		6.82			
				10	06	-		6.83			
				10	46			6.83			
				11	59			6.96			
				12	16	-		6.96			
				13	45	-		6.94			
				14	27	-		6.93			
				15	30	-		6.93			
	6	30	2017	9	30	-		6.95			

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test: US Mag	By: A. Puttley						Test Date: 6/27/17			Page 1 of 2	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
PZ-10	6	27	2017					6.50			
				10	50	35		6.51			
				10	53	20		6.68			
				11	08	20		6.51			
				11	51	40		6.51			
				12	12	00		6.51			
				13	15	00		6.51'			
				13	35	00		6.51'			
				13	34	—		6.51'			
				15	36	-		6.51'			
				16	01	-		6.50'			
				17	22	-		6.50'			
				18	20	-		6.48'			
				19	04	-		6.50'			
				20	08	-		6.48'			
				20	10	-		6.49'			
PZ-10	6	28	17	11	25	-		6.48'			

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES: 2 Solinst sounder

Aquifer Test Data Form

Test:	By:						Test Date:			Page 2 of 2	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
PZ-10	06	28	2017	12	08	-		6.47			
				12	52	-		6.47			
				15	41	-		6.46			
				17	07	-		6.46			
				19	21	-		6.45			
				21	19	-		6.45			
	06	29	2017	08	21	-		6.43			
				10	05	-		6.43			
				10	44	-		6.43			
				11	58	-		6.43			
				12	15	-		6.43			
				13	46	-		6.43			
				14	30			6.43			
				15	24			6.44			
	6	30	2017	9	29	-		6.51			

MINNESOTA MDH DEPARTMENT of HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By: A Pettley J Pierson						Test Date: 6/27/17			Page 1 of 1	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
PZ-6	6	26	2017	8	50	-		10.80			
	6	27	2017	13	15	-		10.91			
	6	28	2017	10	10	-		10.93			
	6	28	2017	20	37	-		10.94			
	6	29	2017	09	09	-		10.87			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By: A Pettley J Pierson							Test Date: 6/27/17				Page 1 of 1
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks	
MW-10	6	26	17	8	50	-		10.62'				
	6	27	17	9	08	-		10.83'				
	6	27	17	13	15	-		10.60'				
	6	27	17	20	55	-		10.58'				
	6	28	17	10	10	-		10.61				
	6	28	17	16	33	-		10.60				
	6	28	17	20	35	-		10.60				
	6	29	17	09	08	-		10.61				

MINNESOTA MDH DEPARTMENT of HEALTH
Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By: A Pettley J Pierson						Test Date: 6/27/17 1020			Page 1 of 1	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-9	6	26	2017	9	40	-		6.05			
	6	27	2017	13	03	-		5.96			
	6	27	2017	16	40	-		5.95			
	6	27	2017	20	50	-		5.95			
	6	28 27	2017	9	52	-		5.95			
	6	28	2017	16	28	-		5.93			
	6	28	2017	20	40	-		5.91			
	6	29	2017	09	01	-		5.92			

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By: A Pettley J Pierson						Test Date: 6/27/17			Page 1 of 1	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-13A	6	26	2017	10	04	-		9.14			
	6	27	2017	9	00	-		9.59			
	6	27	2017	20	32	-		9.15			
	6	28	2017	16	08	-		9.17			
	6	28	2017	20	44	-		9.18			
	6	29	2017	9	16	-		9.25			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By: A Bethke J Pierson						Test Date: 6/27/17 1020			Page 1 of 1	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-21	6	26	2017	10	25	-		6.40'			
	6	27	2017	~~16~~ 04 12	~~57~~ 30	-		6.42'			
	6	27	2017	16	57	-		6.40			
	6	27	2017	20	25	-		6.38			
	6	28	2017	4	14	-		6.41			
	6	28	2017	16	56	-		6.43			
	6	28	2017	20	52			6.43			
	6	29	2017	8	43	-		6.47			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

Test:	By: A Bethley J Pierson						Test Date: 6/27/17 1020			Page 1 of 1	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
MW-23	6	27	17	09	24	-		10.71			
	6	27	17	14	05	-		10.25			
	6	27	17	17	05			10.28			
	6	27	17	20	15			10.26			
	6	28	17	08	35			10.29			
	6	28	17	17	20	-		10.28			
	6	28	17	21	03	-		10.27			
	6	29	17	9	25	-		10.28			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523

Aquifer Test Data Form

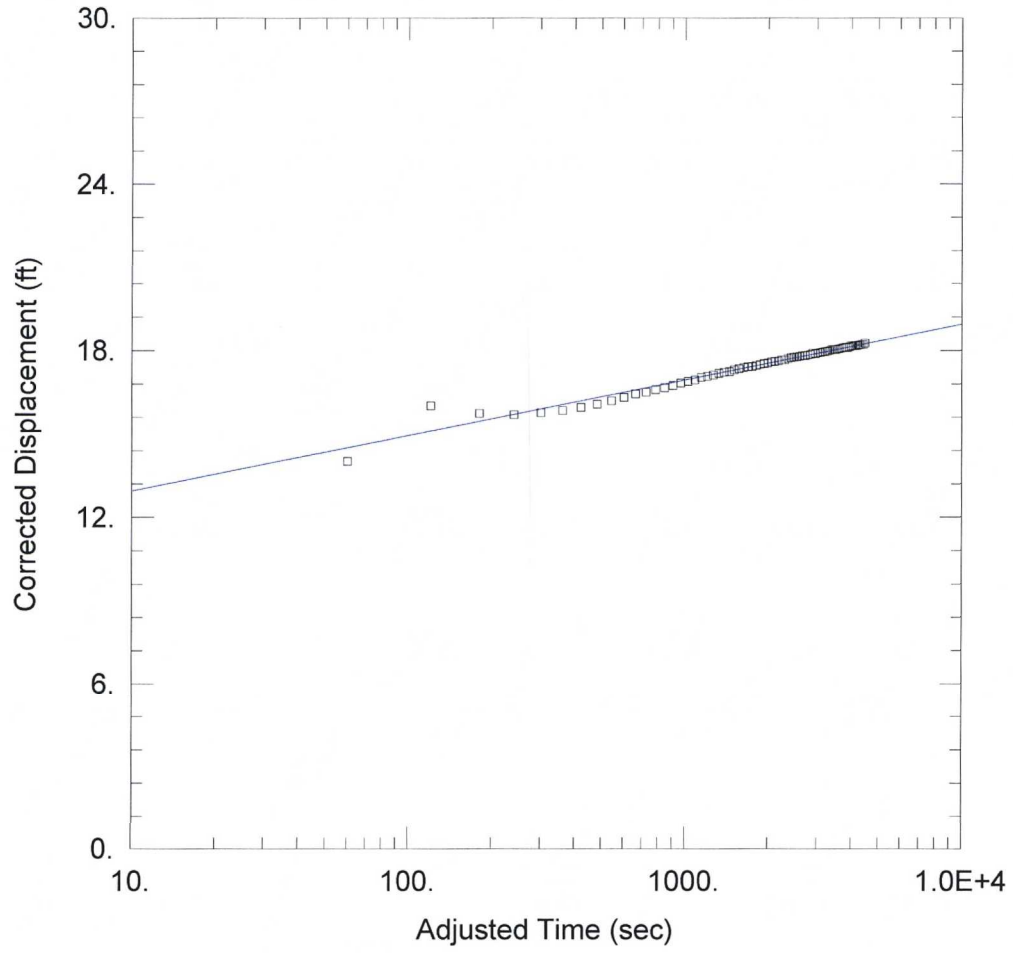
Test:	By: A Pettley J Pierson						Test Date: 6/27/17 1020			Page 1 of 1	
LOCATION (Unique Well Number)	DATE Month	Day	Year	TIME Hour	Minute	Sec.	Elapsed Time (Minutes)	Depth to Water	Drawdown/ Recovery	Discharge	Remarks
PZ-28	6	27	17	12	45	-		7.67			
	6	27	17	16	48	-		7.63			
	6	27	17	20	40	-		7.62			
	6	28	17	09	42	-		7.66			
	6	28	17	16	18	-		7.64			
	6	29	17	20	18	-		7.65			
	6	29	17	8	53	-		7.65			

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Source Water Protection Unit
Drinking Water Protection Section
P.O. Box 64975
St. Paul, Minnesota 55164-0975

NOTES:

IC #140-0523



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec
Client: U.S. Magnesium
Test Well: MW-22B
Test Date: 26 June 2017

AQUIFER DATA

Saturated Thickness: 60. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-22B	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
MW-22B	0	0

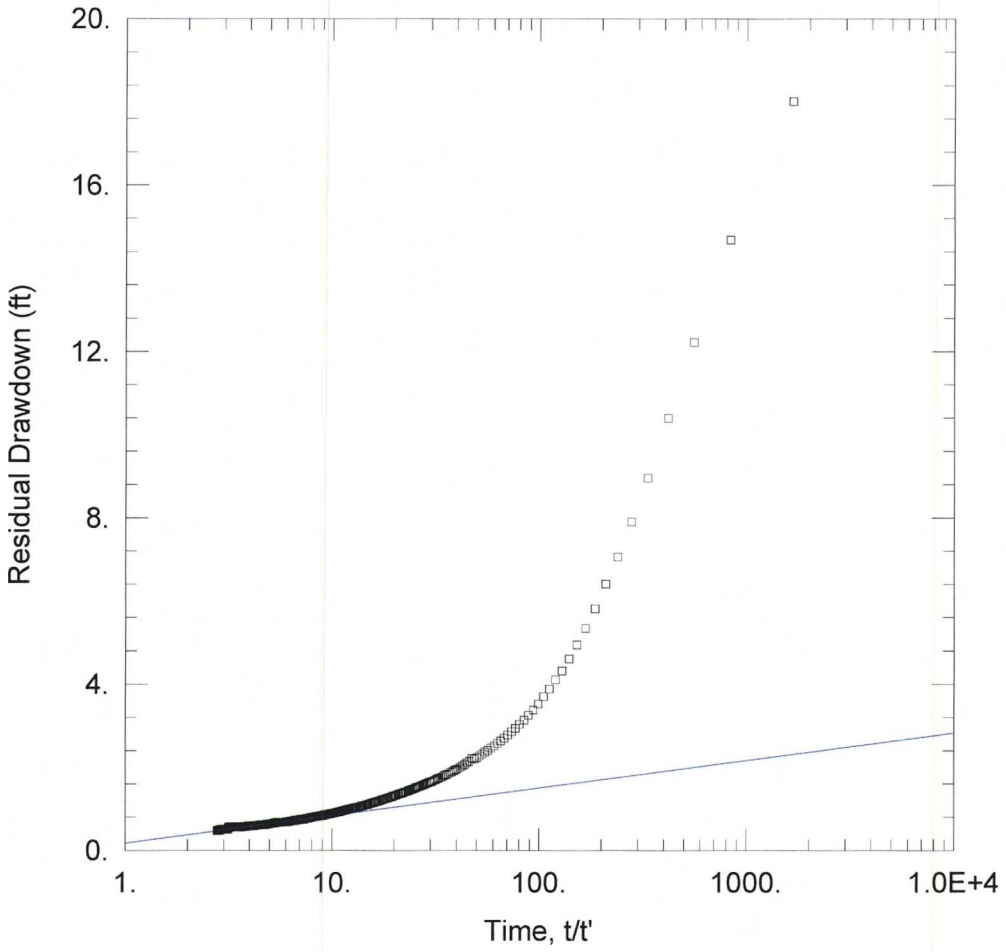
SOLUTION

Aquifer Model: Unconfined

Solution Method: Cooper-Jacob

T = 60.06 ft^2/day

S = 1.834E-7



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec
Client: U.S. Magnesium
Test Well: MW-22B
Test Date: 26 June 2017

AQUIFER DATA

Saturated Thickness: 60. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-22B	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-22B	0	0

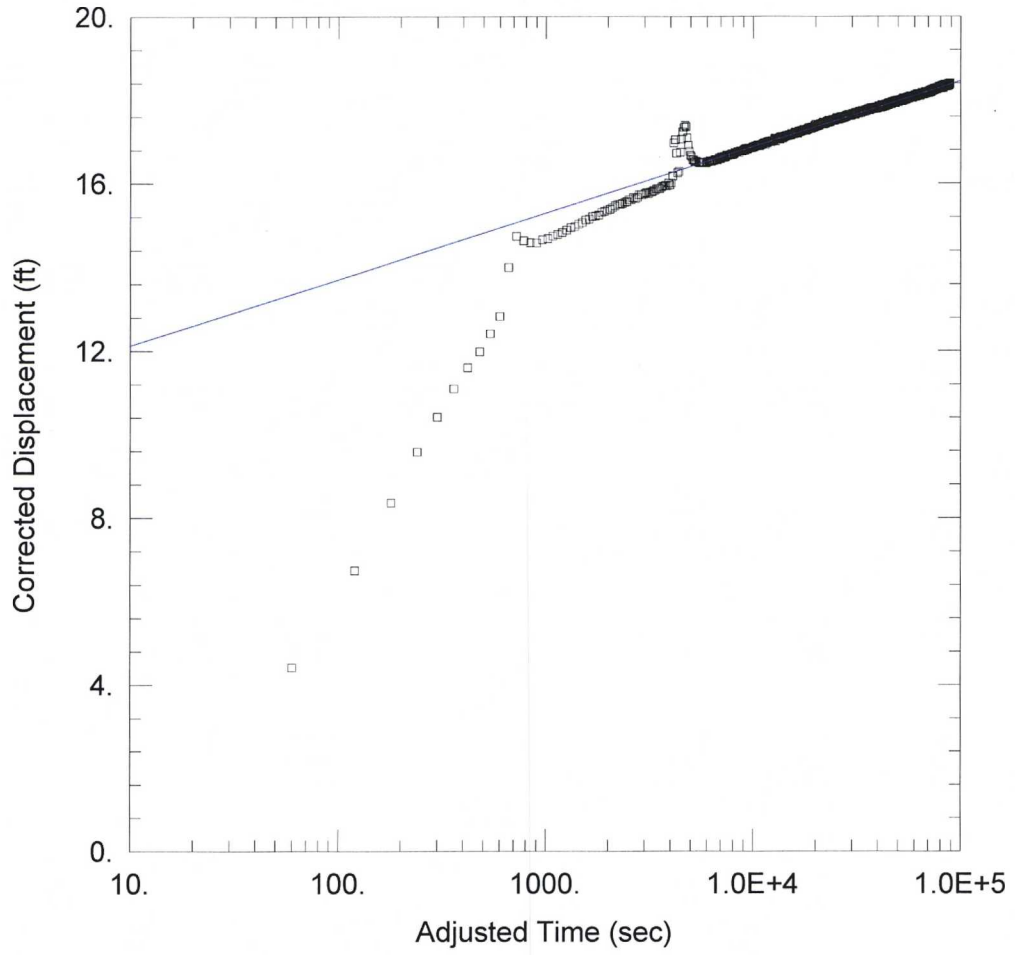
SOLUTION

Aquifer Model: Confined

Solution Method: Theis (Recovery)

T = 181.3 ft^2/day

S/S' = 0.534



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec
Client: U.S. Magnesium
Test Well: MW-22B
Test Date: 27 June 2017

AQUIFER DATA

Saturated Thickness: 60. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-22B	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-22B	0	0

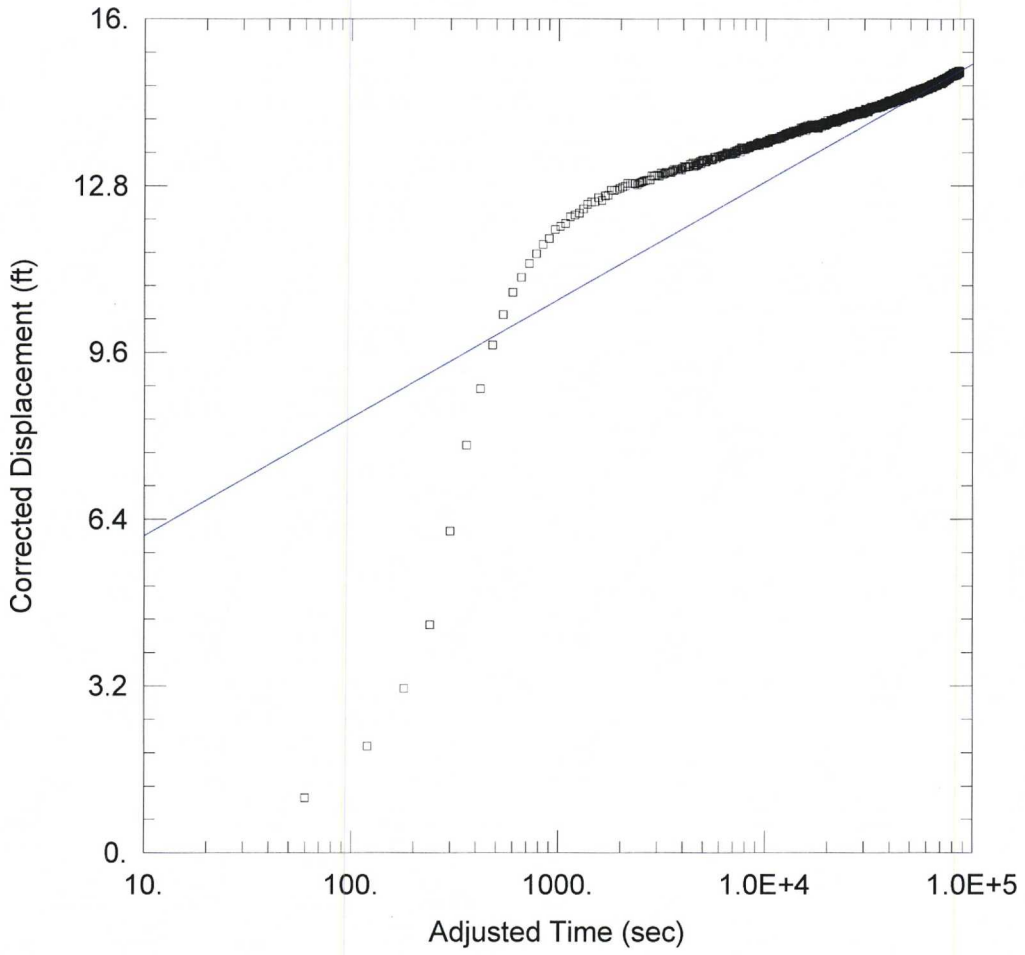
SOLUTION

Aquifer Model: Unconfined

Solution Method: Cooper-Jacob

T = 66.9 ft^2/day

S = 1.346E-8



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec
Client: U.S. Magnesium
Test Well: MW-22B
Test Date: 29 June 2017

AQUIFER DATA

Saturated Thickness: 60. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-22B	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-22B	0	0

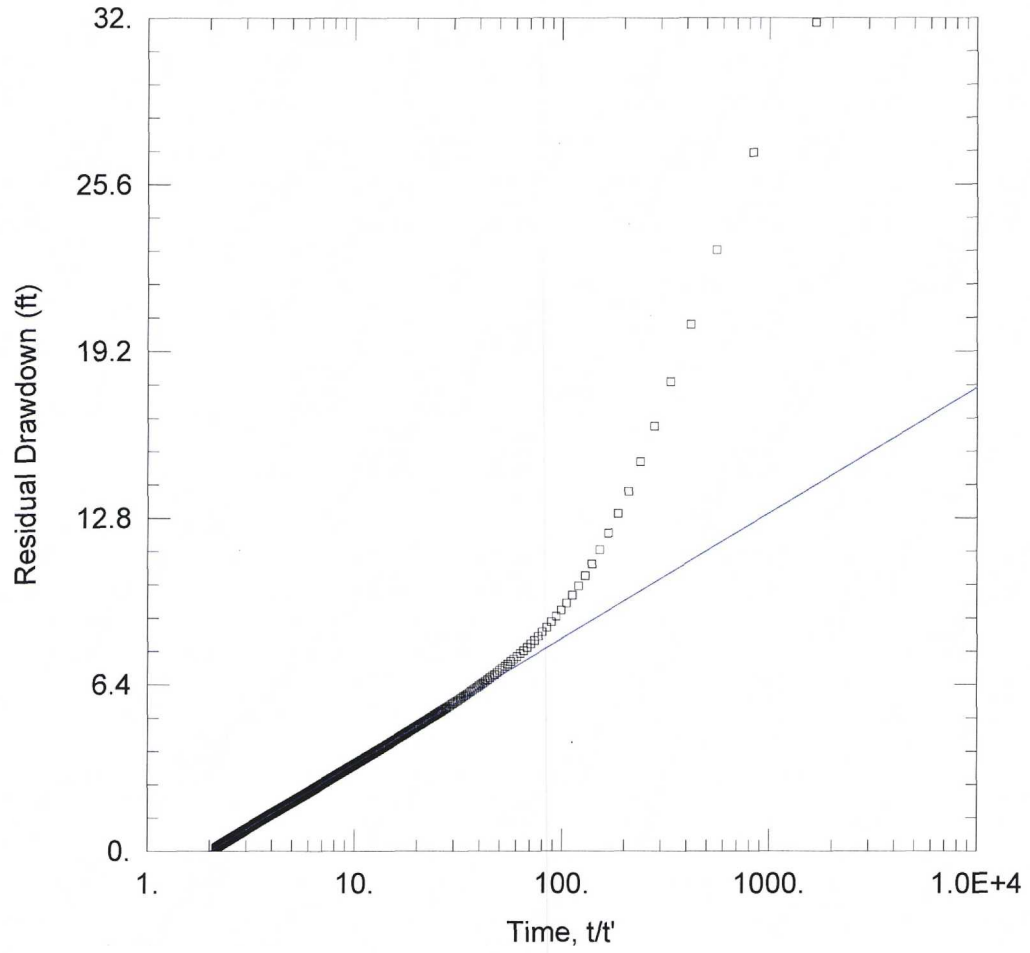
SOLUTION

Aquifer Model: Unconfined

Solution Method: Cooper-Jacob

T = 84.08 ft^2/day

S = 0.001624



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec
Client: U.S. Magnesium
Test Well: MW-22B
Test Date: 29 June 2017

AQUIFER DATA

Saturated Thickness: 60. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MW-22B	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-22B	0	0

SOLUTION

Aquifer Model: Confined

Solution Method: Theis (Recovery)

T = 39.56 ft^2/day

S/S' = 2.01

APPENDIX C – 2017 GROUNDWATER SAMPLING: DATA VALIDATION REPORTS, FIELD FORMS AND LAB RESULTS

Stantec

DATA VALIDATION REPORT

AUGUST AND SEPTEMBER 2017

DATA VERIFICATION
GROUNDWATER AND SURFACE WATER SAMPLING
AUGUST/SEPTEMBER 2017

Introduction. Groundwater samples were collected as listed in Table C-1 at the US Magnesium Rowley Facility August 8-9, 2017 and September 13-14, 2017. A summary of the analytical data is presented in Table C-2. The following paragraphs summarize the results of the data validation.

Sampling Procedures. All groundwater samples were collected as scheduled and in accordance with the *US Magnesium Groundwater Discharge Permit Application Preparation – Field Data Collection Work Plan* (Stantec, 2017).

Analytical Procedures and Detection Limits. All samples were analyzed in accordance with the methodology, detection limits, and quality control (QC) criteria in the appropriate United States Environmental Protection Agency (USEPA) methods and laboratory Standard Operating Procedures. ALS Laboratory, located in Salt Lake City, Utah, provided the analytical services.

Holding times were evaluated and are presented in Table C-3. All holding times met method criteria.

One field duplicate sample was collected at monitoring well MW-22B. A summary of the field duplicate results as compared with the normal sample results is presented in Table C-4. Requested matrix spike/matrix spike duplicate (MS/MSD) analyses were performed MW-21. Additional MS/MSD analyses were performed on MW-13B, MW-22A, and MW-23 for laboratory batch QC.

The following occurred during sample analysis resulting in flagged or qualified data; however, there was no impact to data usability:

- Dilutions were required during the analysis of anions, perchlorate, cyanide, and metals due to matrix interference or high concentrations of one or more constituents. The affected sample results are flagged with a "D" to indicate sample dilution in Table C-2.
- Sodium was detected in two method blanks associated with samples collected September 2017.
- MS/MSD recoveries and/or relative percent differences (RPDs) were outside the acceptance criteria for cyanide, mercury, total and dissolved selenium, sulfate, and total alkalinity.
- The field duplicate RPD calculated for cyanide exceeded the control limit for MW-22B.

Data that were qualified are listed in Table C-5 and discussed in more detail later in this section.

Data Verification Process. Data validation was performed using procedures outlined in the USEPA Contract Laboratory Program National Functional Guidelines (CLPNFG) for Inorganic (USEPA 2017a) and Organic (USEPA 2017b) Superfund Data Review. Where specific guidance was not available, the data were evaluated using professional experience and in a manner consistent with industry standards. The results of the data verification are summarized in the following tables:

- Table C-1, Summary of Groundwater Samples
- Table C-2, Sample Data Summary
- Table C-3, Holding Time Summary
- Table C-4, Field Duplicate Data Summary
- Table C-5, Qualified Data Summary

All holding times, reporting limits, accuracy, precision, and representativeness criteria were met, with the following exceptions.

- Sodium was detected in two method blanks associated with 12 samples collected in September. The sodium results for seven samples were qualified with a "J+" flag to indicate that the analyte was potentially biased high.

- Three method blanks had sodium, total dissolved solids, or calcium detected at concentrations greater than the reporting limits. Reported concentrations in the 14 associated groundwater samples were greater than ten-times the method blank concentrations and were not qualified.

- The MS/MSD percent recoveries for mercury were below the lower acceptance criterion in matrix spikes performed on groundwater samples collected from MW-23 in August and September. Mercury was qualified as an estimated non-detect (UJ) for both samples to indicate a possible false negative.

- MS percent recoveries were below lower acceptance criteria for sulfate and dissolved selenium in groundwater samples collected from MW-22A in August. Dissolved selenium was qualified as an estimated non-detected (UJ) and sulfate as a potentially biased low detection (J-) in the parent sample.

- MS/MSD recoveries and/or RPDs were outside laboratory-established control limits for total alkalinity, total and dissolved selenium, perchlorate, and cyanide in groundwater samples collected from MW-21 in August. Matrix spike recoveries indicated a potential positive bias for total alkalinity and perchlorate. Total alkalinity was qualified as estimated with a high bias (J+), perchlorate was non-detect and therefore was not qualified. MS/MSD percent recoveries were less than the lower control limit for the remaining constituents. Cyanide was qualified as estimated with a low bias (J-), total and dissolved selenium were qualified as estimated non-detects (UJ).

- The MS percent recovery was less than the lower control limit for total selenium in the groundwater sample collected from MW-21 in September. Total selenium was qualified as an estimated non-detect (UJ), indicating a potential false negative.

- MS and/or MSD percent recoveries were greater than the upper control limit for nitrite, nitrite as nitrogen (-N), and sulfate in samples collected from MW-23 and MW-13B in September. Detected sulfate results were qualified as estimated with a positive bias (J+) in both samples. The matrix spike recoveries for nitrite and nitrite-N were above the upper acceptance criterion, indicating a potentially high bias. Results in the parent sample were not qualified because both nitrite results were non-detect.

- The reporting limit requirements were met for all samples except those requiring dilution due to high concentrations or interference from non-target compounds. Associated reporting limits were elevated by the dilution factor.

Conclusions. Based on the results of the data verification, the data are considered precise, accurate, and representative. Sampling completeness for this project is 100 percent, and analytical completeness for this sampling round is 100 percent, which meets the completeness goal of 85 percent.

References.

Stantec, 2017. US Magnesium Groundwater Discharge Permit Application Preparation – Field Data Collection Work Plan. March.

USEPA, 2017a – CLPNFG for Inorganics Superfund Methods Data Review. EPA-540/R-2017-001. Office of Superfund Remediation and Technology Innovation United States Environmental Protection Agency. Washington, D.C. January.

USEPA, 2017b – CLPNFG for Organic Superfund Methods Data Review. EPA-540/R-2017-002. Office of Superfund Remediation and Technology Innovation United States Environmental Protection Agency. Washington, D.C. January.

TABLE C-1
SUMMARY OF SAMPLES COLLECTED
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 1 of 2)

Location Identification	Field Sample Identification	Date Collected	Sample Matrix	Sampling Technique	Sample Type	Total/ Dissolved	Metals SW-6020A	Metals SW-6010C	Mercury SW-7470A	Alkalinity E310.1	Anions E300	Hexachrome E218.6	Percholorate SW-6850	Cyanide SW-9012A	TDS E160.1
FLUME	FLUME	14-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
					LR	Total	--	--	--	--	--	--	--	--	X
MW-13B	MW-13B	9-Aug-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
					LR	Total	--	--	--	--	--	--	--	--	X
MW-13B	MW-13BF	9-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
MW-13B	MW-13B	14-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
					LR	Total	--	--	--	X	--	--	--	--	--
					MS	Total	--	--	--	X	X	--	--	--	--
					SD	Total	--	--	--	X	X	--	--	--	--
MW-15B	MW-15B	9-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
MW-15B	MW-15BF	9-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
MW-15B	MW-15B	14-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
MW-21	MW-21	9-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
					LR	Total	--	X	--	--	--	--	--	--	--
					MS	Total	X	--	X	X	X	--	X	X	--
					SD	Total	X	--	X	X	X	--	X	X	--
MW-21	MW-21F	9-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
					LR	Dissolved	--	X	--	--	--	--	--	--	--
					MS	Dissolved	X	--	X	--	--	--	--	--	--
					SD	Dissolved	X	--	X	--	--	--	--	--	--
MW-21	MW-21	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
					LR	Total	X	--	--	--	--	--	--	--	--
					MS	Total	X	--	--	--	--	--	--	--	--
MW-22A	MW-22A	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
					MS	Total	--	--	--	--	X	--	--	--	--
					SD	Total	--	--	--	--	X	--	--	--	--
MW-22A	MW-22A-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
					MS	Dissolved	X	--	--	--	--	--	--	--	--
					SD	Dissolved	X	--	--	--	--	--	--	--	--
MW-22A	MW-22A	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
					LR	Total	--	--	--	--	--	--	--	--	X
MW-22B	MW-22B	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
MW-22B	MW-22B-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
MW-22B	MW-22B	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
MW-22B	MW-22B-D	13-Sep-17	WS	G	FD	Total	X	X	X	X	X	--	X	X	X
MW-23	MW-23	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
					LR	Total	--	--	--	X	--	--	--	--	--
					MS	Total	--	--	X	--	--	--	--	--	--
					SD	Total	--	--	X	--	--	--	--	--	--
MW-23	MW-23-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
MW-23	MW-23	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
					MS	Total	--	--	X	--	X	--	--	X	--
					SD	Total	--	--	X	--	X	--	--	X	--
PZ-10	PZ-10	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
PZ-10	PZ-10-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
PZ-10	PZ-10	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
PZ-12	PZ-12	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
PZ-12	PZ-12-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
PZ-12	PZ-12	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
PZ-13	PZ-13	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
PZ-13	PZ-13	8-Aug-17	WS	G	LR	Total	--	X	--	--	--	--	--	--	--
PZ-13	PZ-13-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
PZ-13	PZ-13	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
PZ-8	PZ-8	9-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X

TABLE C-1
SUMMARY OF SAMPLES COLLECTED
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 2 of 2)

Location Identification	Field Sample Identification	Date Collected	Sample Matrix	Sampling Technique	Sample Type	Total/ Dissolved	Metals SW-6020A	Metals SW-6010C	Mercury SW-7470A	Alkalinity E310.1	Anions E300	Hexachrome E218.6	Percholorate SW-6850	Cyanide SW-9012A	TDS E160.1
PZ-8	PZ-8F	9-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--
PZ-8	PZ-8	13-Sep-17	WS	G	N	Total	X	X	X	X	X	--	X	X	X
SPZ-10	SPZ-10	8-Aug-17	WS	G	N	Total	X	X	X	X	X	X	X	X	X
SPZ-10	SPZ-10-F	8-Aug-17	WS	G	N	Dissolved	X	X	X	--	--	--	--	--	--

AB	Ambient blank	MSD	Matrix spike duplicate	TB	Trip blank
EB	Equipment rinseate blan	N	Compliance sample	VOCs	Volatile organic compounds
FD	Field Duplicate	NA	Not applicable	WG	Groundwater
G	Grab sample	NS	Not sampled	WQ	Reagent Grade water or distilled water
LR	Laboratory replicate	PCP	Pentachlorophenol	X	Sampled
MS	Matrix spike	TDS	Total Dissolved Solids	--	Not collected

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	MW-13B	MW-13B	MW-15B	MW-15B	MW-21	MW-21
Date Collected	9/14/2017	8/9/2017	9/14/2017	8/9/2017	9/14/2017	8/9/2017	9/13/2017
Analyte (Units)							
Chemistry Parameters							
Alkalinity, Total (as $CaCO_3$) (mg/L)	<20	**210**	**160**	**680**	**280**	**370 J+**	**380**
Bromide (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Chloride (as Cl) (mg/L)	**15000 D**	**41000 D**	**43000 D**	**45000 D**	**53000 D**	**54000 D**	**48000 D**
Cyanide (µg/L)	<10	<25 D	<10	**44 D**	**19**	**140 DJ-**	**120 D**
Fluoride (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrate Ion (mg/L)	**110 D**	<100 D	**120 D**	<100 D	**110 D**	<100 D	**110 D**
Nitrite Ion (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	**25 D**	<23 D	**28 D**	<23 D	**24 D**	<23 D	**25 D**
Nitrogen, Nitrite (mg/L)	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D
Perchlorate (µg/L)	**2.4 D**	**280 D**	**1.2 FD**	<200 D	**1.2 FD**	<200 D	**2 D**
Phosphate-P (mg/L)	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**400 D**	**2800 D**	**2600 DJ+**	**1100 D**	**950 D**	**6500 D**	**5200 D**
Total dissolved solids (mg/L)	**17000**	**53000**	**63000**	**60000**	**73000**	**85000**	**110000**

Metals	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**	**Total**
Aluminum (µg/L)	**3400**	<1000	<1000	<1000	**6300**	**6000**	**7100**	<1000	<1000	<1000
Antimony (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Arsenic (µg/L)	**84**	<50	<50	<50	**68**	**50**	**66**	<50	<50	<50
Barium (µg/L)	<250	<250	<250	<250	**630**	**620**	**730**	<250	<250	<250
Cadmium (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium (mg/L)	**257 D**	**4570 D**	**4780 D**	**3970 D**	**13300 D**	**13400 D**	**13400 D**	**661 D**	**708 D**	**721 D**
Chromium, Total (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cobalt (µg/L)	<50	<50	<50	<50	**120**	**120**	**180**	<50	<50	<50
Copper (µg/L)	**120**	<100	<100	<100	<100	<100	**130**	<100	<100	<100
Chromium, Hexavalent	--	--	--	--	<50 D	--	--	<50 D	--	--
Iron (µg/L)	**200000**	**5500**	**4700**	**8400**	**190000**	**180000**	**210000**	<2500	<2500	**2500**
Lead (µg/L)	<50	<50	<50	<50	**130**	<50	<50	<50	<50	<50
Magnesium (mg/L)	**3970 D**	**4150 D**	**4260 D**	**3860 D**	**6300 D**	**6350 D**	**6480 D**	**2210 D**	**2400 D**	**2370 D**

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	MW-13B	MW-13B	MW-15B	MW-15B	MW-21	MW-21
Date Collected	9/14/2017	8/9/2017	9/14/2017	8/9/2017	9/14/2017	8/9/2017	9/13/2017
Analyte (Units)							
Manganese (µg/L)	**560**	**310**	**320**	**230**	**15000**	**15000**	**16000**	**53**	**56**	<50
Mercury (µg/L)	**0.19**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Nickel (µg/L)	<50	<50	<50	<50	**500**	**480**	**700**	<50	<50	<50
Potassium (mg/L)	**88.1 D**	**970 D**	**962 D**	**1130 D**	**313 D**	**313 D**	**348 D**	**1760 D**	**1850 D**	**1890 D**
Selenium (µg/L)	<250	<250	<250	<250	<250	<250	<250	<250 UJ	<250 UJ	<250 UJ
Silver (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sodium (mg/L)	**1160 DJ+**	**11300 D**	**11100 D**	**12800 DJ+**	**2700 D**	**2650 D**	**2750 DJ+**	**32200 D**	**33300 D**	**34400 D**
Thallium (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Vanadium (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc (µg/L)	**110**	**170**	<100	<100	**560**	**370**	**650**	**160**	**110**	<100

µg/L	micrograms per liter.
mg/L	milligrams per liter.
Bold	Bolded result indicates positively identified compound.
D	Sample dilution required for analysis; reported values reflect the dilution.
F	Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.
J	Data are estimated due to associated quality control data.
J-	Data are estimated and are potentially biased low due to associated quality control data.
J+	Data are estimated and are potentially biased high due to associated quality control data.
UJ	Potential low bias, possible false negative.

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	MW-22A	MW-22A	MW-22B	MW-22B	MW-22B Dup	MW-23
Date Collected	9/14/2017	8/8/2017	9/13/2017	8/8/2017	9/13/2017	9/13/2017	8/8/2017
Analyte (Units)							
Chemistry Parameters							
Alkalinity, Total (as $CaCO_3$) (mg/L)	<20	**210**	**240**	**380**	**380**	**360**	**270**
Bromide (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Chloride (as Cl) (mg/L)	**15000 D**	**50000 D**	**56000 D**	**56000 D**	**57000 D**	**60000 D**	**73000 D**
Cyanide (µg/L)	<10	<25 D	**56 D**	**250 D**	**190 DJ**	**100 DJ**	<25 D
Fluoride (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrate Ion (mg/L)	**110 D**	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrite Ion (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	**25 D**	<23 D	<23 D	<23 D	<23 D	<23 D	<23 D
Nitrogen, Nitrite (mg/L)	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D
Perchlorate (µg/L)	**2.4 D**	<200 D	**0.91 FD**	<200 D	<2 D	**1.5 FD**	<200 D
Phosphate-P (mg/L)	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**400 D**	**7700 DJ-**	**6900 D**	**6000 D**	**5600 D**	**5700 D**	**14000 D**
Total dissolved solids (mg/L)	**17000**	**90000**	**100000**	**96000**	**110000**	**110000**	**140000**

Metals	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Total**	**Dissolved**
Aluminum (µg/L)	**3400**	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Antimony (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Arsenic (µg/L)	**84**	**57**	**55**	<50	<50	<50	<50	<50	<50	<50
Barium (µg/L)	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
Cadmium (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium (mg/L)	**257 D**	**785 D**	**732 D**	**713 D**	**718 D**	**696 D**	**708 D**	**698 D**	**857 D**	**897 D**
Chromium, Total (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cobalt (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Copper (µg/L)	**120**	<100	<100	<100	<100	<100	<100	<100	<100	<100
Chromium, Hexavalent	--	<50 D	--	--	<50 D	--	--	--	<50 D	--
Iron (µg/L)	**200000**	<2500	<2500	<2500	<2500	<2500	**2500**	<2500	<2500	<2500
Lead (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	**59**	<50
Magnesium (mg/L)	**3970 D**	**2560 D**	**2380 D**	**2360 D**	**2360 D**	**2270 D**	**2400 D**	**2360 D**	**3060 D**	**3020 D**

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	MW-22A	MW-22A	MW-22B	MW-22B	MW-22B Dup	MW-23	
Date Collected	9/14/2017	8/8/2017	9/13/2017	8/8/2017	9/13/2017	9/13/2017	8/8/2017	
Analyte (Units)								
Manganese (µg/L)	**560**	**250**	**240**	**72**	<50	<50	<50	<50	**180**	**170**
Mercury (µg/L)	**0.19**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1 UJ	<0.1
Molybdenum (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Nickel (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	**130**
Potassium (mg/L)	**88.1 D**	**1820 D**	**1700 D**	**1820 D**	**1840 D**	**1800 D**	**1970 D**	**1960 D**	**2400 D**	**2410 D**
Selenium (µg/L)	<250	<250	<250 UJ	<250	<250	<250	<250	<250	<250	<250
Silver (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sodium (mg/L)	**1160 DJ+**	**32200 D**	**29700 D**	**32500 D**	**35000 D**	**33500 D**	**35200 D**	**33100 D**	**48700 D**	**49200 D**
Thallium (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Vanadium (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc (µg/L)	**110**	<100	<100	<100	<100	<100	<100	<100	**190**	<100

µg/L micrograms per liter.
mg/L milligrams per liter.
Bold Bolded result indicates positively identifie
D Sample dilution required for analysis; rep
F Analyte was positively identified but the
than the reporting limit, but greater than
J Data are estimated due to associated q
J- Data are estimated and are potentially
J+ Data are estimated and are potentially
UJ Potential low bias, possible false negativ

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	MW-23	PZ-10	PZ-10	PZ-12	PZ-12	PZ-13
Date Collected	9/14/2017	9/13/2017	8/8/2017	9/13/2017	8/8/2017	9/13/2017	8/8/2017
Analyte (Units)							
Chemistry Parameters							
Alkalinity, Total (as $CaCO_3$) (mg/L)	<20	**300**	**840**	**690**	**840**	**690**	**420**
Bromide (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Chloride (as Cl) (mg/L)	**15000 D**	**89000 D**	**34000 D**	**34000 D**	**32000 D**	**34000 D**	**25000 D**
Cyanide (µg/L)	<10	<25 D	**30 D**	<10	**38 D**	**21**	<25 D
Fluoride (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrate Ion (mg/L)	**110 D**	<100 D	<100 D	**100 D**	<100 D	<100 D	<100 D
Nitrite Ion (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	**25 D**	<23 D	<23 D	**24 D**	<23 D	<23 D	<23 D
Nitrogen, Nitrite (mg/L)	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D
Perchlorate (µg/L)	**2.4 D**	**1.1 FD**	<200 D	**0.99 FD**	<200 D	<2 D	<200 D
Phosphate-P (mg/L)	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**400 D**	**14000 DJ+**	**1400 D**	**1400 D**	**1100 D**	**1100 D**	**3700 D**
Total dissolved solids (mg/L)	**17000**	**160000**	**45000**	**58000**	**45000**	**58000**	**40000**

Metals	**Total**	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**
Aluminum (µg/L)	**3400**	<1000	<1000	<1000	<1000	**4000**	**1400**	**2300**	<1000	<1000
Antimony (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Arsenic (µg/L)	**84**	<50	**54**	**58**	**64**	**53**	<50	**62**	<50	<50
Barium (µg/L)	<250	<250	<250	<250	<250	**400**	**300**	**360**	<250	<250
Cadmium (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Calcium (mg/L)	**257 D**	**879 D**	**8900 D**	**8770 D**	**8840 D**	**10700 D**	**10700 D**	**11000 D**	**7530 D**	**7670 D**
Chromium, Total (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cobalt (µg/L)	<50	<50	<50	<50	<50	**94**	**97**	**100**	<50	<50
Copper (µg/L)	**120**	<100	<100	<100	<100	<100	<100	<100	<100	<100
Chromium, Hexavalent	--	--	<50 D	--	--	<50 D	--	--	<50 D	--
Iron (µg/L)	**200000**	<2500	**300000**	**310000**	**310000**	**180000**	**180000**	**200000**	**39000**	**44000**
Lead (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Magnesium (mg/L)	**3970 D**	**3040 D**	**5400 D**	**5340 D**	**5190 D**	**3980 D**	**3950 D**	**4310 D**	**4290 D**	**4340 D**

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	MW-23	PZ-10	PZ-10	PZ-12	PZ-12	PZ-13		
Date Collected	9/14/2017	9/13/2017	8/8/2017	9/13/2017	8/8/2017	9/13/2017	8/8/2017		
Analyte (Units)									
Manganese (µg/L)	**560**	**170**	**22000**	**22000**	**22000**	**15000**	**15000**	**15000**	**4200**	**4700**
Mercury (µg/L)	**0.19**	<0.1 UJ	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Nickel (µg/L)	<50	<50	**140**	**140**	**140**	**310**	**310**	**330**	**94**	**97**
Potassium (mg/L)	**88.1 D**	**2510 D**	**567 D**	**572 D**	**591 D**	**208 D**	**220 D**	**229 D**	**418 D**	**417 D**
Selenium (µg/L)	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
Silver (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sodium (mg/L)	**1160 DJ+**	**48100 D**	**3680 D**	**3600 D**	**3580 DJ+**	**1810 D**	**1860 D**	**1940 DJ+**	**2540 D**	**2610 D**
Thallium (µg/L)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Vanadium (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Zinc (µg/L)	**110**	<100	<100	<100	<100	**140**	**140**	**130**	<100	<100

µg/L micrograms per liter.
mg/L milligrams per liter.
Bold Bolded result indicates positively identifie
D Sample dilution required for analysis; rep
F Analyte was positively identified but the
than the reporting limit, but greater than
J Data are estimated due to associated q
J- Data are estimated and are potentially
J+ Data are estimated and are potentially
UJ Potential low bias, possible false negativ

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	PZ-13	PZ-8	PZ-8	SPZ-10
Date Collected	9/14/2017	9/13/2017	8/9/2017	9/13/2017	8/8/2017
Analyte (Units)					
Chemistry Parameters					
Alkalinity, Total (as $CaCO_3$) (mg/L)	<20	**430**	**760**	**640**	**660**
Bromide (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D
Chloride (as Cl) (mg/L)	**15000 D**	**28000 D**	**43000 D**	**37000 D**	**35000 D**
Cyanide (µg/L)	<10	<10	**33 D**	<10	**25 D**
Fluoride (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrate Ion (mg/L)	**110 D**	<100 D	<100 D	**100 D**	<100 D
Nitrite Ion (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	**25 D**	<23 D	<23 D	**23 D**	<23 D
Nitrogen, Nitrite (mg/L)	<31 D	<31 D	<31 D	<31 D	<31 D
Perchlorate (µg/L)	**2.4 D**	<2 D	<200 D	<2 D	<200 D
Phosphate-P (mg/L)	<33 D	<33 D	<33 D	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**400 D**	**1200 D**	**1200 D**	**1100 D**	**1400 D**
Total dissolved solids (mg/L)	**17000**	**48000**	**53000**	**65000**	**45000**

Metals	**Total**	**Total**	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**
Aluminum (µg/L)	**3400**	<1000	<1000	<1000	<1000	<1000	<1000
Antimony (µg/L)	<100	<100	<100	<100	<100	<100	<100
Arsenic (µg/L)	**84**	<50	**70**	**67**	**72**	**59**	**56**
Barium (µg/L)	<250	<250	**260**	**250**	**290**	<250	<250
Cadmium (µg/L)	<50	<50	<50	<50	<50	<50	<50
Calcium (mg/L)	**257 D**	**7910 D**	**12400 D**	**13100 D**	**13000 D**	**8660 D**	**8610 D**
Chromium, Total (µg/L)	<100	<100	<100	<100	<100	<100	<100
Cobalt (µg/L)	<50	<50	**120**	**120**	**140**	<50	<50
Copper (µg/L)	**120**	<100	<100	<100	<100	<100	<100
Chromium, Hexavalent	--	--	<50 D	--	--	<50 D	--
Iron (µg/L)	**200000**	**89000**	**230000**	**230000**	**270000**	**300000**	**300000**
Lead (µg/L)	<50	<50	<50	<50	<50	<50	<50
Magnesium (mg/L)	**3970 D**	**4280 D**	**5310 D**	**5770 D**	**5660 D**	**5250 D**	**5160 D**

TABLE C-2
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	FLUME	PZ-13	PZ-8	PZ-8	PZ-8	SPZ-10	SPZ-10
Date Collected	9/14/2017	9/13/2017	8/9/2017	8/9/2017	9/13/2017	8/8/2017	8/8/2017
Analyte (Units)							
Manganese (µg/L)	**560**	**8400**	**18000**	**18000**	**17000**	**22000**	**22000**
Mercury (µg/L)	**0.19**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	<100	<100	<100	<100	<100	<100	<100
Nickel (µg/L)	<50	**84**	**370**	**360**	**420**	**140**	**140**
Potassium (mg/L)	**88.1 D**	**401 D**	**271 D**	**283 D**	**291 D**	**555 D**	**577 D**
Selenium (µg/L)	<250	<250	<250	<250	<250	<250	<250
Silver (µg/L)	<50	<50	<50	<50	<50	<50	<50
Sodium (mg/L)	**1160 DJ+**	**2490 DJ+**	**2350 D**	**2450 D**	**2350 DJ+**	**3570 D**	**3580 D**
Thallium (µg/L)	<50	<50	<50	<50	<50	<50	<50
Vanadium (µg/L)	<100	<100	<100	<100	<100	<100	<100
Zinc (µg/L)	**110**	<100	<100	<100	<100	<100	<100

µg/L micrograms per liter.
mg/L milligrams per liter.
Bold Bolded result indicates positively identifie
D Sample dilution required for analysis; rep
F Analyte was positively identified but the
than the reporting limit, but greater than
J Data are estimated due to associated q
J- Data are estimated and are potentially
J+ Data are estimated and are potentially
UJ Potential low bias, possible false negativ

TABLE 3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 1 of 8)

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
FLUME	14-Sep-17	1402	E160.1	19-Sep-17	1420	5	7
	14-Sep-17	1402	E300.0	15-Sep-17	1740	1	2
	14-Sep-17	1402	E310.1	28-Sep-17	1000	14	14
	14-Sep-17	1402	SW6010C	27-Sep-17	1453	13	180
	14-Sep-17	1402	SW6020A	26-Sep-17	1630	12	180
	14-Sep-17	1402	SW6850	19-Sep-17	1141	5	28
	14-Sep-17	1402	SW7470A	28-Sep-17	1410	14	28
	14-Sep-17	1402	SW9012A	26-Sep-17	1529	12	14
MW-13B	9-Aug-17	1355	E160.1	15-Aug-17	1545	6	7
	9-Aug-17	1355	E300.0	10-Aug-17	2033	1	2
	9-Aug-17	1355	E310.1	22-Aug-17	1019	13	14
	9-Aug-17	1355	SW6010C	23-Aug-17	1146	14	180
	9-Aug-17	1355	SW6010C	23-Aug-17	1208	14	180
	9-Aug-17	1355	SW6020A	15-Aug-17	1631	6	180
	9-Aug-17	1355	SW6020A	15-Aug-17	1552	6	180
	9-Aug-17	1355	SW6850	16-Aug-17	1659	7	28
	9-Aug-17	1355	SW7470A	23-Aug-17	1412	14	28
	9-Aug-17	1355	SW7470A	23-Aug-17	1422	14	28
	9-Aug-17	1355	SW9012A	15-Aug-17	1918	6	14
	14-Sep-17	1055	E160.1	19-Sep-17	1420	5	7
	14-Sep-17	1055	E300.0	15-Sep-17	1633	1	2
	14-Sep-17	1055	E300.0	15-Sep-17	1831	1	2
	14-Sep-17	1055	E310.1	28-Sep-17	1000	14	14
	14-Sep-17	1055	SW6010C	27-Sep-17	1456	13	180
	14-Sep-17	1055	SW6020A	26-Sep-17	1613	12	180
	14-Sep-17	1055	SW6850	19-Sep-17	1102	5	28
	14-Sep-17	1055	SW7470A	28-Sep-17	1408	14	28
	14-Sep-17	1055	SW9012A	26-Sep-17	1528	12	14

TABLE C-3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
MW-15B	9-Aug-17	1235	E160.1	15-Aug-17	1545	6	7
	9-Aug-17	1235	E218.6	8/28/2017	14:23	19	28
	9-Aug-17	1235	E300.0	10-Aug-17	2016	1	2
	9-Aug-17	1235	E310.1	22-Aug-17	1019	13	14
	9-Aug-17	1235	SW6010C	23-Aug-17	1205	14	180
	9-Aug-17	1235	SW6010C	23-Aug-17	1143	14	180
	9-Aug-17	1235	SW6020A	15-Aug-17	1548	6	180
	9-Aug-17	1235	SW6020A	15-Aug-17	1628	6	180
	9-Aug-17	1235	SW6850	16-Aug-17	1640	7	28
	9-Aug-17	1235	SW7470A	23-Aug-17	1410	14	28
	9-Aug-17	1235	SW7470A	23-Aug-17	1421	14	28
	9-Aug-17	1235	SW9012A	15-Aug-17	1915	6	14
	14-Sep-17	1219	E160.1	19-Sep-17	1420	5	7
	14-Sep-17	1219	E300.0	15-Sep-17	1921	1	2
	14-Sep-17	1219	E300.0	15-Sep-17	1723	1	2
	14-Sep-17	1219	E310.1	28-Sep-17	1000	14	14
	14-Sep-17	1219	SW6010C	27-Sep-17	1505	13	180
	14-Sep-17	1219	SW6020A	26-Sep-17	1627	12	180
	14-Sep-17	1219	SW6850	19-Sep-17	1121	5	28
	14-Sep-17	1219	SW7470A	28-Sep-17	1409	14	28
	14-Sep-17	1219	SW9012A	26-Sep-17	1528	12	14
MW-21	9-Aug-17	840	E160.1	15-Aug-17	1545	6	7
	9-Aug-17	840	E218.6	8/28/2017	14:48	19	28
	9-Aug-17	840	E300.0	10-Aug-17	2124	1	2
	9-Aug-17	840	E300.0	10-Aug-17	1909	1	2
	9-Aug-17	840	E310.1	22-Aug-17	1019	13	14
	9-Aug-17	840	SW6010C	23-Aug-17	1149	14	180
	9-Aug-17	840	SW6010C	23-Aug-17	1301	14	180
	9-Aug-17	840	SW6010C	23-Aug-17	1243	14	180

TABLE 3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
MW-21	9-Aug-17	840	SW6010C	23-Aug-17	1121	14	180
	9-Aug-17	840	SW6020A	15-Aug-17	1527	6	180
	9-Aug-17	840	SW6020A	15-Aug-17	1556	6	180
	9-Aug-17	840	SW6850	16-Aug-17	1523	7	28
	9-Aug-17	840	SW7470A	23-Aug-17	1405	14	28
	9-Aug-17	840	SW7470A	23-Aug-17	1415	14	28
	9-Aug-17	840	SW9012A	15-Aug-17	1911	6	14
	13-Sep-17	1918	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1918	E300.0	15-Sep-17	209	2	2
	13-Sep-17	1918	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1918	SW6010C	22-Sep-17	1023	9	180
	13-Sep-17	1918	SW6010C	22-Sep-17	1048	9	180
	13-Sep-17	1918	SW6020A	26-Sep-17	1555	13	180
	13-Sep-17	1918	SW6850	19-Sep-17	1457	6	28
	13-Sep-17	1918	SW7470A	28-Sep-17	1407	15	28
	13-Sep-17	1918	SW9012A	26-Sep-17	1121	13	14
MW-22A	8-Aug-17	1815	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1815	E218.6	8/28/2017	15:06	20	28
	8-Aug-17	1815	E300.0	10-Aug-17	1438	2	2
	8-Aug-17	1815	E300.0	10-Aug-17	1529	2	2
	8-Aug-17	1815	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1815	SW6010C	23-Aug-17	1039	15	180
	8-Aug-17	1815	SW6010C	23-Aug-17	1109	15	180
	8-Aug-17	1815	SW6020A	15-Aug-17	1409	7	180
	8-Aug-17	1815	SW6020A	15-Aug-17	1433	7	180
	8-Aug-17	1815	SW6850	16-Aug-17	1420	8	28
	8-Aug-17	1815	SW7470A	14-Aug-17	1437	6	28
	8-Aug-17	1815	SW7470A	14-Aug-17	1427	6	28
	8-Aug-17	1815	SW9012A	15-Aug-17	1911	7	14

TABLE C-3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
MW-22A	13-Sep-17	1655	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1655	E300.0	15-Sep-17	440	2	2
	13-Sep-17	1655	E300.0	15-Sep-17	102	2	2
	13-Sep-17	1655	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1655	SW6010C	22-Sep-17	1039	9	180
	13-Sep-17	1655	SW6010C	22-Sep-17	1011	9	180
	13-Sep-17	1655	SW6020A	26-Sep-17	1531	13	180
	13-Sep-17	1655	SW6850	19-Sep-17	1317	6	28
	13-Sep-17	1655	SW7470A	28-Sep-17	1403	15	28
	13-Sep-17	1655	SW9012A	26-Sep-17	1119	13	14
MW-22B	8-Aug-17	1720	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1720	E218.6	8/28/2017	15:14	20	28
	8-Aug-17	1720	E300.0	10-Aug-17	1405	2	2
	8-Aug-17	1720	E300.0	10-Aug-17	1422	2	2
	8-Aug-17	1720	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1720	SW6010C	23-Aug-17	1036	15	180
	8-Aug-17	1720	SW6010C	23-Aug-17	1106	15	180
	8-Aug-17	1720	SW6020A	15-Aug-17	1405	7	180
	8-Aug-17	1720	SW6020A	15-Aug-17	1430	7	180
	8-Aug-17	1720	SW6850	16-Aug-17	1401	8	28
	8-Aug-17	1720	SW7470A	14-Aug-17	1436	6	28
	8-Aug-17	1720	SW7470A	14-Aug-17	1425	6	28
	8-Aug-17	1720	SW9012A	15-Aug-17	1910	7	14
	13-Sep-17	1544	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1544	E300.0	15-Sep-17	457	2	2
	13-Sep-17	1544	E300.0	15-Sep-17	119	2	2
	13-Sep-17	1544	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1544	SW6010C	22-Sep-17	1042	9	180
	13-Sep-17	1544	SW6010C	22-Sep-17	1014	9	180

TABLE 3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 5 of 8)

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
MW-22B	13-Sep-17	1544	SW6020A	26-Sep-17	1545	13	180
	13-Sep-17	1544	SW6850	19-Sep-17	1336	6	28
	13-Sep-17	1544	SW7470A	28-Sep-17	1404	15	28
	13-Sep-17	1544	SW9012A	26-Sep-17	1120	13	14
MW-23	8-Aug-17	1100	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1100	E218.6	8/28/2017	15:23	20	28
	8-Aug-17	1100	E300.0	10-Aug-17	1042	2	2
	8-Aug-17	1100	E300.0	10-Aug-17	1026	2	2
	8-Aug-17	1100	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1100	SW6010C	23-Aug-17	1233	15	180
	8-Aug-17	1100	SW6010C	23-Aug-17	1000	15	180
	8-Aug-17	1100	SW6010C	23-Aug-17	1230	15	180
	8-Aug-17	1100	SW6010C	23-Aug-17	1042	15	180
	8-Aug-17	1100	SW6020A	15-Aug-17	1412	7	180
	8-Aug-17	1100	SW6020A	15-Aug-17	1337	7	180
	8-Aug-17	1100	SW6850	16-Aug-17	1719	8	28
	8-Aug-17	1100	SW7470A	14-Aug-17	1414	6	28
	8-Aug-17	1100	SW7470A	14-Aug-17	1428	6	28
	8-Aug-17	1100	SW9012A	15-Aug-17	1902	7	14
	13-Sep-17	1005	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1005	E300.0	14-Sep-17	2247	1	2
	13-Sep-17	1005	E300.0	15-Sep-17	226	2	2
	13-Sep-17	1005	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1005	SW6010C	22-Sep-17	959	9	180
	13-Sep-17	1005	SW6010C	22-Sep-17	1027	9	180
	13-Sep-17	1005	SW6020A	26-Sep-17	1517	13	180
	13-Sep-17	1005	SW6850	19-Sep-17	1200	6	28
	13-Sep-17	1005	SW7470A	28-Sep-17	1352	15	28
	13-Sep-17	1005	SW9012A	26-Sep-17	1115	13	14

TABLE C-3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
PZ-10	8-Aug-17	1600	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1600	E218.6	8/28/2017	15:31	20	28
	8-Aug-17	1600	E300.0	10-Aug-17	1223	2	2
	8-Aug-17	1600	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1600	SW6010C	23-Aug-17	1030	15	180
	8-Aug-17	1600	SW6010C	23-Aug-17	1052	15	180
	8-Aug-17	1600	SW6020A	15-Aug-17	1423	7	180
	8-Aug-17	1600	SW6020A	15-Aug-17	1347	7	180
	8-Aug-17	1600	SW6850	16-Aug-17	1322	8	28
	8-Aug-17	1600	SW7470A	14-Aug-17	1423	6	28
	8-Aug-17	1600	SW7470A	14-Aug-17	1431	6	28
	8-Aug-17	1600	SW9012A	15-Aug-17	1905	7	14
	13-Sep-17	1438	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1438	E300.0	15-Sep-17	45	2	2
	13-Sep-17	1438	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1438	SW6010C	22-Sep-17	1008	9	180
	13-Sep-17	1438	SW6020A	26-Sep-17	1527	13	180
	13-Sep-17	1438	SW6850	19-Sep-17	1258	6	28
	13-Sep-17	1438	SW7470A	28-Sep-17	1359	15	28
	13-Sep-17	1438	SW9012A	26-Sep-17	1524	13	14
PZ-12	8-Aug-17	1438	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1438	E218.6	8/28/2017	15:59	20	28
	8-Aug-17	1438	E300.0	10-Aug-17	1150	2	2
	8-Aug-17	1438	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1438	SW6010C	23-Aug-17	1027	15	180
	8-Aug-17	1438	SW6010C	23-Aug-17	1237	15	180
	8-Aug-17	1438	SW6020A	15-Aug-17	1344	7	180
	8-Aug-17	1438	SW6020A	15-Aug-17	1419	7	180
	8-Aug-17	1438	SW6850	16-Aug-17	1303	8	28

TABLE 3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 7 of 8)

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
PZ-12	8-Aug-17	1438	SW7470A	14-Aug-17	1430	6	28
	8-Aug-17	1438	SW7470A	14-Aug-17	1422	6	28
	8-Aug-17	1438	SW9012A	15-Aug-17	1905	7	14
	13-Sep-17	1253	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1253	E300.0	15-Sep-17	29	2	2
	13-Sep-17	1253	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1253	SW6010C	22-Sep-17	1005	9	180
	13-Sep-17	1253	SW6020A	26-Sep-17	1524	13	180
	13-Sep-17	1253	SW6850	19-Sep-17	1238	6	28
	13-Sep-17	1253	SW7470A	28-Sep-17	1358	15	28
	13-Sep-17	1253	SW9012A	26-Sep-17	1521	13	14
PZ-13	8-Aug-17	1235	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1235	E218.6	8/28/2017	16:07	20	28
	8-Aug-17	1235	E300.0	10-Aug-17	1116	2	2
	8-Aug-17	1235	E300.0	10-Aug-17	1133	2	2
	8-Aug-17	1235	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1235	SW6010C	23-Aug-17	1003	15	180
	8-Aug-17	1235	SW6010C	23-Aug-17	1046	15	180
	8-Aug-17	1235	SW6020A	15-Aug-17	1416	7	180
	8-Aug-17	1235	SW6020A	15-Aug-17	1340	7	180
	8-Aug-17	1235	SW6850	16-Aug-17	1244	8	28
	8-Aug-17	1235	SW7470A	14-Aug-17	1429	6	28
	8-Aug-17	1235	SW7470A	14-Aug-17	1419	6	28
	8-Aug-17	1235	SW9012A	15-Aug-17	1902	7	14
	13-Sep-17	1125	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1125	E300.0	15-Sep-17	12	2	2
	13-Sep-17	1125	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1125	SW6010C	22-Sep-17	1002	9	180
	13-Sep-17	1125	SW6020A	26-Sep-17	1520	13	180

TABLE C-3
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	Sample Collection Date	Sample Collection Time	Analytical Method	Sample Analysis Date	Sample Analysis Time	Analysis Holding Time (Days)	Maximum Holding Time (Days)
PZ-13	13-Sep-17	1125	SW6850	19-Sep-17	1219	6	28
	13-Sep-17	1125	SW7470A	28-Sep-17	1357	15	28
	13-Sep-17	1125	SW9012A	26-Sep-17	1521	13	14
PZ-8	9-Aug-17	1110	E160.1	15-Aug-17	1545	6	7
	9-Aug-17	1110	E218.6	8/28/2017	14:57	19	28
	9-Aug-17	1110	E300.0	10-Aug-17	2000	1	2
	9-Aug-17	1110	E310.1	22-Aug-17	1019	13	14
	9-Aug-17	1110	SW6010C	23-Aug-17	1134	14	180
	9-Aug-17	1110	SW6010C	23-Aug-17	1202	14	180
	9-Aug-17	1110	SW6020A	15-Aug-17	1545	6	180
	9-Aug-17	1110	SW6020A	15-Aug-17	1624	6	180
	9-Aug-17	1110	SW6850	16-Aug-17	1621	7	28
	9-Aug-17	1110	SW7470A	23-Aug-17	1419	14	28
	9-Aug-17	1110	SW7470A	23-Aug-17	1409	14	28
	9-Aug-17	1110	SW9012A	15-Aug-17	1915	6	14
	13-Sep-17	1823	E160.1	20-Sep-17	1000	7	7
	13-Sep-17	1823	E300.0	15-Sep-17	152	2	2
	13-Sep-17	1823	E310.1	27-Sep-17	1415	14	14
	13-Sep-17	1823	SW6010C	22-Sep-17	1020	9	180
	13-Sep-17	1823	SW6020A	26-Sep-17	1552	13	180
	13-Sep-17	1823	SW6850	19-Sep-17	1438	6	28
	13-Sep-17	1823	SW7470A	28-Sep-17	1406	15	28
	13-Sep-17	1823	SW9012A	26-Sep-17	1525	13	14
SPZ-10	8-Aug-17	1610	E160.1	15-Aug-17	1545	7	7
	8-Aug-17	1610	E218.6	8/28/2017	16:16	20	28
	8-Aug-17	1610	E300.0	10-Aug-17	1331	2	2
	8-Aug-17	1610	E310.1	22-Aug-17	1019	14	14
	8-Aug-17	1610	SW6010C	23-Aug-17	1033	15	180
	8-Aug-17	1610	SW6010C	23-Aug-17	1240	15	180
SPZ-10	8-Aug-17	1610	SW6020A	15-Aug-17	1351	7	180
	8-Aug-17	1610	SW6020A	15-Aug-17	1426	7	180
	8-Aug-17	1610	SW6850	16-Aug-17	1341	8	28
	8-Aug-17	1610	SW7470A	14-Aug-17	1424	6	28
	8-Aug-17	1610	SW7470A	14-Aug-17	1432	6	28
	8-Aug-17	1610	SW9012A	15-Aug-17	1909	7	14

TABLE C-4
FIELD DUPLICATE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	MW-22B	MW-22B Dup
Field Sample Identification	MW-22B	MW-22B-D
Sample Type	Normal	Field Duplicate
Date Collected	9/13/2017	9/13/2017
Analyte (Units)		
Chemistry Parameters		
Alkalinity, Total (as $CaCO_3$) (mg/L)	**380**	**360**
Bromide (mg/L)	<100 D	<100 D
Chloride (as Cl) (mg/L)	**57000 D**	**60000 D**
Cyanide (µg/L)	**190 DJ**	**100 DJ**
Fluoride (mg/L)	<100 D	<100 D
Nitrate Ion (mg/L)	<100 D	<100 D
Nitrite Ion (mg/L)	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	<23 D	<23 D
Nitrogen, Nitrite (mg/L)	<31 D	<31 D
Perchlorate (µg/L)	<2 D	**1.5 FD**
Phosphate-P (mg/L)	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**5600 D**	**5700 D**
Total dissolved solids (mg/L)	**110000**	**110000**
Metals	**Total**	**Total**
Aluminum (µg/L)	<1000	<1000
Antimony (µg/L)	<100	<100
Arsenic (µg/L)	<50	<50
Barium (µg/L)	<250	<250
Cadmium (µg/L)	<50	<50
Calcium (mg/L)	**708 D**	**698 D**
Chromium, Total (µg/L)	<100	<100
Cobalt (µg/L)	<50	<50
Copper (µg/L)	<100	<100
Chromium, Hexavalent	--	--
Iron (µg/L)	**2500**	<2500
Lead (µg/L)	<50	<50
Magnesium (mg/L)	**2400 D**	**2360 D**
Manganese (µg/L)	<50	<50
Mercury (µg/L)	<0.1	<0.1
Molybdenum (µg/L)	<100	<100
Nickel (µg/L)	<50	<50
Potassium (mg/L)	**1970 D**	**1960 D**
Selenium (µg/L)	<250	<250

TABLE C-4
FIELD DUPLICATE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 2 of 2)

Location Identification	MW-22B	MW-22B Dup
Field Sample Identification	MW-22B	MW-22B-D
Sample Type	Normal	Field Duplicate
Date Collected	9/13/2017	9/13/2017
Analyte (Units)		
Silver (µg/L)	<50	<50
Sodium (mg/L)	**35200 D**	**33100 D**
Thallium (µg/L)	<50	<50
Vanadium (µg/L)	<100	<100
Zinc (µg/L)	<100	<100

µg/L	micrograms per liter
mg/L	milligrams per liter
Bold	Bolded result indicates positively identified compound
D	Sample dilution required for analysis; reported values reflect the dilution
F	Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.
J	Data are estimated due to associated quality control data

TABLE C-5
QUALIFIED DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 1 of 2)

Sample Identification	Sample Date	Lab Identification	Analysis Method	Parameter	Sample Result	QC Type	QC Result	Qualifier	Reason Code
MW-23	8/8/2017	1722114-001	SW7470A	Mercury	< 0.10 µg/L	MS %R MSD %R	26.8 29.5	UJ	08a
MW-22A	8/8/2017	1722114-007	EPA 300.0	Sulfate	7,700 mg/L	MS %R	88.2	J-	08a
MW-22A-F	8/8/2017	1722114-014	SW6020A	Dissolved Selenium	< 250 µg/L	MS %R	36.9	UJ	08a
MW-21	8/9/2017	1722220-001	SW9012A	Cyanide	140 µg/L	MS %R MSD %R MS/MSD RPD	15.2 41.5 31.4	J-	08a; 09a
MW-21	8/9/2017	1722220-001	SW6020A	Selenium	< 250 µg/L	MS %R	18.5	UJ	08a
MW-21	8/9/2017	1722220-001	EPA 310.1	Total Alkalinity	370 mg/L	MS %R	182.0	J+	08b
MW-21F	8/9/2017	1722220-007	SW6020A	Dissolved Selenium	< 250 µg/L	MS %R	18.1	UJ	08a
MW-23	9/13/2017	1725702-001	EPA 300.0	Sulfate	14,000 mg/L	MS %R	124.0	J+	08b
MW-23	9/13/2017	1725702-001	SW7470A	Mercury	< 0.10 µg/L	MS %R MSD %R	37.1 42.7	UJ	08a
PZ-13	9/13/2017	1725702-002	SW6010C	Sodium	2,490 mg/L	MB	1,510 mg/L	J+	07a
PZ-12	9/13/2017	1725702-003	SW6010C	Sodium	1,940 mg/L	MB	1,510 mg/L	J+	07a
PZ-10	9/13/2017	1725702-004	SW6010C	Sodium	3,580 mg/L	MB	1,510 mg/L	J+	07a
MW-22B	9/13/2017	1725702-006	SW9012A	Cyanide	190 µg/L	FD RPD	62	J	14a
MW-22B-D (Field Duplicate)	9/13/2017	1725702-007	SW9012A	Cyanide	100 µg/L	FD RPD	62	J	14a
PZ-8	9/13/2017	1725702-008	SW6010C	Sodium	2,350 mg/L	MB	1,510 mg/L	J+	07a
MW-21	9/13/2017	1725702-009	SW6020A	Selenium	< 250 µg/L	MS %R	23	UJ	08a
MW-13B	9/14/2017	1725804-001	SW6010C	Sodium	12,800 mg/L	MB	1,440 mg/L	J+	07a
MW-13B	9/14/2017	1725804-001	EPA 300.0	Sulfate	2,600 mg/L	MSD %R	117	J+	08b

TABLE C-5
QUALIFIED DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 2 of 2)

Sample Identification	Sample Date	Lab Identification	Analysis Method	Parameter	Sample Result	QC Type	QC Result	Qualifier	Reason Code
MW-15B	9/14/2017	1725804-002	SW6010C	Sodium	2,750 mg/L	MB	1,440 mg/L	J+	07a
Flume	9/14/2017	1725804-003	SW6010C	Sodium	1,160 mg/L	MB	1,440 mg/L	J+	07a

Definitions:
µg/L - micrograms per liter
mg/L - milligrams per liter

%R - percent recovery
EPA - Environmental Protection Agency
FD - field duplicate
MB - method blank
MS/MSD - matrix spike/matrix spike duplicate
QC - quality control
RPD - relative percent difference

Reason Codes:
07a - Target parameter was detected in laboratory method blank sample or other preparatory blank sample.
08a - MS or MSD percent recovery was less than the lower control limit.
08b - MS or MSD percent recovery was greater than the upper control limit.
09a - MS/MSD RPD was greater than the control limit.
14a - Field duplicate RPD is greater than the control limit.

Data Validation Qualifiers:

J+ : The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying high bias, due to non-conformances discovered during data validation.

J- : The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying low bias, due to non-conformances discovered during data validation.

J : The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation. Bias is indeterminate.

UJ : The compound or analyte was reported as not detected by the laboratory; however the reported quantitation/detection limit is estimated due to non-conformances discovered during data validation.

Stantec

DATA VALIDATION REPORT

NOVEMBER 2017

DATA VERIFICATION
GROUNDWATER AND SURFACE WATER SAMPLING
NOVEMBER 2017

Introduction. Groundwater samples were collected as listed in Table C-6 at the US Magnesium Rowley Facility November 1st and 2nd 2017 and November 20, 2017. A summary of the analytical data is presented in Table C-7. The following paragraphs summarize the results of the data validation.

Sampling Procedures. All groundwater samples were collected as scheduled and in accordance with the *US Magnesium Groundwater Discharge Permit Application Preparation – Field Data Collection Work Plan* (Stantec, 2017).

Analytical Procedures and Detection Limits. All samples were analyzed in accordance with the methodology, detection limits, and quality control (QC) criteria in the appropriate United States Environmental Protection Agency (USEPA) methods and laboratory Standard Operating Procedures. ALS Laboratory, located in Salt Lake City, Utah, provided the analytical services.

Holding times were evaluated and are presented in Table C-8. All holding times met method criteria.

One field duplicate sample was collected at monitoring well MW-22B. A summary of the field duplicate results as compared with the normal sample results is presented in Table C-9.
Requested matrix spike/matrix spike duplicate (MS/MSD) analyses were performed on MW-13.
Additional MS/MSD analyses were performed MW-23 and Flume for laboratory batch QC.

The following occurred during sample analysis resulting in flagged or qualified data; however, there was no impact to data usability:

- Dilutions were required during the analysis of anions, perchlorate, cyanide, and metals due to matrix interference or high concentrations of one or more constituents. The affected sample results are flagged with a "D" to indicate sample dilution in Table C-7.

- Sodium was detected one method blank associated with samples collected November 1, 2017.

Data that were qualified are listed in Table C-10 and discussed in more detail later in this section.

Data Verification Process. Data validation was performed using procedures outlined in the USEPA Contract Laboratory Program National Functional Guidelines (CLPNFG) for Inorganic Superfund Data Review (USEPA 2017). Where specific guidance was not available, the data were evaluated using professional experience and in a manner consistent with industry standards. The results of the data verification are summarized in the following tables:

- Table C-6, Summary of Groundwater Samples

- Table C-7, Sample Data Summary
- Table C-8, Holding Time Summary
- Table C-9, Field Duplicate Data Summary
- Table C-10, Qualified Data Summary

All holding times, reporting limits, accuracy, precision, and representativeness criteria were met, with the following exceptions.

- Sodium and magnesium were detected in one method blank associated with eight samples collected November 1, 2017. Sodium results in four samples were qualified with a "J+" flag to indicate that the analyte was potentially biased high. Magnesium was detected in the associated samples at concentrations that were greater than ten-times the method blank concentrations and were not qualified.

- The reporting limit requirements were met for all samples except those requiring dilution due to high concentrations or interference from non-target compounds. Associated reporting limits were elevated by the dilution factor.

Conclusions. Based on the results of the data verification, the data are considered precise, accurate, and representative. Sampling completeness for this project is 100 percent, and analytical completeness for this sampling round is 100 percent, which meets the completeness goal of 85 percent.

References.

Stantec, 2017. US Magnesium Groundwater Discharge Permit Application Preparation – Field Data Collection Work Plan. March.

USEPA, 2017 – CLPNFG for Inorganics Superfund Methods Data Review. EPA-540/R-2017-001. Office of Superfund Remediation and Technology Innovation United States Environmental Protection Agency. Washington, D.C. January.

TABLE C-6
SUMMARY OF SAMPLES COLLECTED
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification	Field Sample Identification	Date Collected	Sample Matrix	Sampling Technique	Sample Type	Total/ Dissolved	Metals SW-6020A	Metals SW-6010C	Mercury SW-7470A	Alkalinity E310.1	Anions E300	Percholorate SW-6850	Cyanide SW-9012A	TDS E160.1
FLUME	FLUME	20-Nov-17	WS	G	N	Total	X	X	X		X		X	X
FLUME	FLUME	20-Nov-17	WS	G	LR	Total	X	X						
FLUME	FLUME	20-Nov-17	WS	G	MS	Total	X				X			
FLUME	FLUME	20-Nov-17	WS	G	SD	Total					X			
MW-13B	MW-13B	2-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
MW-13B	MW-13B	2-Nov-17	WS	G	LR	Total		X						
MW-13B	MW-13BMS	2-Nov-17	WS	G	MS	Total	X	X	X	X	X	X	X	
MW-13B	MW-13BMSD	2-Nov-17	WS	G	SD	Total	X	X	X	X	X	X	X	
MW-15B	MW-15B	2-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
MW-15B	SW-15B	2-Nov-17	WS	G	FD	Total	X	X	X	X	X	X	X	X
MW-21	MW-21	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
MW-21	MW-21	1-Nov-17	WS	G	LR	Total								X
MW-22A	MW-22A	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
MW-22B	MW-22B	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
MW-23	MW-23	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
MW-23	MW-23	1-Nov-17	WS	G	LR	Total				X			X	
MW-23	MW-23	1-Nov-17	WS	G	MS	Total				X	X		X	
MW-23	MW-23	1-Nov-17	WS	G	SD	Total				X	X		X	
PZ-8	PZ-8	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
PZ-10	PZ-10	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
PZ-12	PZ-12	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X
PZ-13	PZ-13	1-Nov-17	WS	G	N	Total	X	X	X	X	X	X	X	X

AB	Ambient blank	MSD	Matrix spike duplicate	TB	Trip blank
EB	Equipment rinseate blank	N	Compliance sample	VOCs	Volatile organic compounds
FD	Field Duplicate	NA	Not applicable	WG	Groundwater
G	Grab sample	NS	Not sampled	WQ	Reagent Grade water or distilled water
LR	Laboratory replicate	PCP	Pentachlorophenol	X	Sampled
MS	Matrix spike	TDS	Total Dissolved Solids	--	Not collected

TABLE C-7
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification Date Collected Analyte (Units)	FLUME 11/20/2017	MW-13B 11/2/2017	MW-15B 11/2/2017	MW-15B Dup 11/2/2017	MW-21 11/1/2017	MW-22A 11/1/2017
Chemistry Parameters						
Alkalinity, Total (as $CaCO_3$) (mg/L)	--	**180**	**470**	**400**	**380**	**150**
Bromide (mg/L)	**40 D**	<100 D	<100 D	**100 D**	<100 D	<100 D
Chloride (as Cl) (mg/L)	**14000 D**	**40000 D**	**59000 D**	**59000 D**	**54000 D**	**51000 D**
Cyanide (µg/L)	<10	<10	<10	<10	**180 D**	<25 D
Fluoride (mg/L)	<10 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrate Ion (mg/L)	<10 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrite Ion (mg/L)	<10 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	<2.3 D	<23 D	<23 D	<23 D	<23 D	<23 D
Nitrogen, Nitrite (mg/L)	<3.1 D	<31 D	<31 D	<31 D	<31 D	<31 D
Perchlorate (µg/L)	--	<5 D	<5 D	<5 D	<5 D	<5 D
Phosphate-P (mg/L)	<3.3 D	<33 D	<33 D	<33 D	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<10 D	<100 D	<100 D	<100 D	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**300 D**	**2800 D**	**840 D**	**890 D**	**6300 D**	**7400 D**
Total dissolved solids (mg/L)	**14000**	**38000**	**64000**	**63000**	**74000**	**62000**
Metals						
Aluminum (µg/L)	**1400**	<1000	**6100**	**6100**	<1000	<1000
Antimony (µg/L)	<100	<100	<100	<100	<100	<100
Arsenic (µg/L)	**110**	<50	**95**	**96**	<50	<50
Barium (µg/L)	<250	<250	**820**	**830**	<250	<250
Cadmium (µg/L)	<50	<50	<50	<50	<50	<50
Calcium (mg/L)	**303**	**3560 D**	**13800 D**	**14500 D**	**698 D**	**662 D**
Chromium, Total (µg/L)	<100	<100	<100	<100	<100	<100
Cobalt (µg/L)	<50	<50	**190**	**190**	<50	<50
Copper (µg/L)	<100	<100	<100	<100	**170**	**150**
Iron (µg/L)	**160000**	**16000**	**310000**	**310000**	**3800**	**3100**
Lead (µg/L)	<50	<50	**60**	**63**	<50	<50
Magnesium (mg/L)	**3180 D**	**3300 D**	**7750 D**	**8200 D**	**2230 D**	**2070 D**

TABLE C-7
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification Date Collected Analyte (Units)	FLUME 11/20/2017	MW-13B 11/2/2017	MW-15B 11/2/2017	MW-15B Dup 11/2/2017	MW-21 11/1/2017	MW-22A 11/1/2017
Manganese (µg/L)	**320**	**250**	**21000**	**21000**	<50	**99**
Mercury (µg/L)	**0.37**	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	<100	<100	<100	<100	<100	<100
Nickel (µg/L)	**60**	**59**	**660**	**670**	<50	<50
Potassium (mg/L)	**65**	**836 D**	**319 D**	**339 D**	**1640 D**	**1480 D**
Selenium (µg/L)	<250	<250	<250	<250	<250	<250
Silver (µg/L)	<50	<50	<50	<50	<50	<50
Sodium (mg/L)	**1190 D**	**10500 D**	**2700 D**	**2840 D**	**33800 D**	**29700 D**
Thallium (µg/L)	<50	<50	<50	<50	<50	<50
Vanadium (µg/L)	**140**	<100	<100	<100	<100	<100
Zinc (µg/L)	**260**	<100	**910**	**930**	<100	<100

µg/L micrograms per liter.
mg/L milligrams per liter.
Bold Bolded result indicates positively identified compound.
D Sample dilution required for analysis; reported values reflect the dilution.
J+ : The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying high bias, due to non-conformances discovered during data validation.

TABLE C-7
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification Date Collected Analyte (Units)	MW-22B 11/1/2017	MW-23 11/1/2017	PZ-10 11/1/2017	PZ-12 11/1/2017	PZ-13 11/1/2017	PZ-8 11/1/2017
Chemistry Parameters						
Alkalinity, Total (as $CaCO_3$) (mg/L)	**370**	**270**	**560**	**600**	**400**	**580**
Bromide (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Chloride (as Cl) (mg/L)	**56000 D**	**77000 D**	**38000 D**	**40000 D**	**29000 D**	**43000 D**
Cyanide (µg/L)	**45 D**	<25 D	**13**	**10**	<10	**25**
Fluoride (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrate Ion (mg/L)	<100 D	<100 D	**100 D**	<100 D	<100 D	<100 D
Nitrite Ion (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	<23 D	<23 D	**24 D**	<23 D	<23 D	<23 D
Nitrogen, Nitrite (mg/L)	<31 D	<31 D	<31 D	<31 D	<31 D	<31 D
Perchlorate (µg/L)	<5 D	<5 D	<5 D	<5 D	<5 D	<5 D
Phosphate-P (mg/L)	<33 D	<33 D	<33 D	<33 D	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D	<100 D	<100 D	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**6000 D**	**14000 D**	**1200 D**	**920 D**	**1100 D**	**850 D**
Total dissolved solids (mg/L)	**56000**	**110000**	**40000**	**46000**	**32000**	**43000**
Metals						
Aluminum (µg/L)	<1000	<1000	<1000	**1600**	<1000	<1000
Antimony (µg/L)	<100	<100	<100	<100	<100	<100
Arsenic (µg/L)	<50	**55**	**79**	**64**	<50	**77**
Barium (µg/L)	<250	<250	<250	**380**	<250	**300**
Cadmium (µg/L)	<50	<50	<50	<50	<50	<50
Calcium (mg/L)	**673 D**	**836 D**	**8130 D**	**10300 D**	**7150 D**	**11500 D**
Chromium, Total (µg/L)	<100	<100	<100	<100	<100	<100
Cobalt (µg/L)	<50	<50	<50	**100**	<50	**120**
Copper (µg/L)	**130**	**200**	<100	<100	<100	<100
Iron (µg/L)	**3700**	**3100**	**320000**	**240000**	**57000**	**300000**
Lead (µg/L)	<50	<50	<50	<50	<50	<50
Magnesium (mg/L)	**2210 D**	**2850 D**	**4760 D**	**4640 D**	**3960 D**	**5200 D**

TABLE C-7
SAMPLE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 4 of 4)

Location Identification Date Collected Analyte (Units)	MW-22B 11/1/2017	MW-23 11/1/2017	PZ-10 11/1/2017	PZ-12 11/1/2017	PZ-13 11/1/2017	PZ-8 11/1/2017
Manganese (µg/L)	<50	**160**	**22000**	**17000**	**3700**	**19000**
Mercury (µg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	<100	<100	<100	<100	<100	<100
Nickel (µg/L)	<50	<50	**150**	**370**	**110**	**410**
Potassium (mg/L)	**1700 D**	**2140 D**	**538 D**	**229 D**	**407 D**	**255 D**
Selenium (µg/L)	<250	<250	<250	<250	<250	<250
Silver (µg/L)	<50	<50	<50	<50	<50	<50
Sodium (mg/L)	**33800 D**	**49600 D**	**3370 J+ D**	**2020 J+ D**	**2530 J+ D**	**2200 J+ D**
Thallium (µg/L)	<50	<50	<50	<50	<50	<50
Vanadium (µg/L)	<100	<100	<100	<100	<100	<100
Zinc (µg/L)	<100	<100	<100	**150**	<100	<100

µg/L micrograms per liter.
mg/L milligrams per liter.
Bold Bolded result indicates positive
D Sample dilution required for ar
J+ : The compound or analyte was an
concentration is estimated, displaying

TABLE C-8
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 1 of 2)

Location Identification	Field Identification	Sample Date	Sample Time	Analysis Code	Analysis Date	Analysis Time	Analysis Holding Time (Days)	Method Holding Time (Days)
FLUME	FLUME	20-Nov-17	1130	E160.1	20-Nov-17	1330	0	7
				E300.0	21-Nov-17	1818	1	2
				E300.0	21-Nov-17	1728	1	2
				SW6010C	5-Dec-17	1223	5	180
				SW6010C	5-Dec-17	1200	5	180
				SW6010C	5-Dec-17	1226	5	180
				SW6020A	28-Nov-17	1454	1	180
				SW7470A	4-Dec-17	1355	0	28
				SW9012A	30-Nov-17	1703	10	14
MW-13B	MW-13B	2-Nov-17	1235	E160.1	9-Nov-17	1405	7	7
				E300.0	3-Nov-17	1429	1	2
				E310.1	16-Nov-17	900	14	14
				SW6010C	15-Nov-17	1052	1	180
				SW6020A	14-Nov-17	1914	1	180
				SW6850	6-Nov-17	1543	0	28
				SW7470A	6-Nov-17	1521	0	28
				SW9012A	10-Nov-17	1613	8	14
MW-15B	MW-15B	2-Nov-17	1100	E160.1	9-Nov-17	1405	7	7
				E300.0	3-Nov-17	1355	1	2
				E300.0	6-Nov-17	1452	4	2
				E310.1	16-Nov-17	900	14	14
				SW6010C	15-Nov-17	1046	1	180
				SW6020A	14-Nov-17	1855	1	180
				SW6850	6-Nov-17	1516	0	28
				SW7470A	6-Nov-17	1516	0	28
				SW9012A	10-Nov-17	1612	8	14
MW-21	MW-21	1-Nov-17	1725	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1951	1	2
				E300.0	3-Nov-17	1751	2	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1356	3	180
				SW6010C	6-Nov-17	1440	3	180
				SW6020A	14-Nov-17	1852	1	180
				SW6850	6-Nov-17	1436	0	28
				SW7470A	14-Nov-17	1356	0	28
				SW9012A	13-Nov-17	1335	12	14
MW-22A	MW-22A	1-Nov-17	1500	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1917	1	2
				E300.0	3-Nov-17	1734	2	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1437	3	180
				SW6010C	6-Nov-17	1351	3	180
				SW6020A	14-Nov-17	1844	1	180
				SW6850	6-Nov-17	1409	0	28
				SW7470A	14-Nov-17	1351	0	28
				SW9012A	13-Nov-17	1335	12	14
MW-22B	MW-22B	1-Nov-17	1400	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1826	1	2
				E300.0	3-Nov-17	1717	2	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1348	3	180
				SW6010C	6-Nov-17	1434	3	180
				SW6020A	14-Nov-17	1841	1	180
				SW6850	6-Nov-17	1355	0	28
				SW7470A	14-Nov-17	1350	0	28
				SW9012A	13-Nov-17	1334	12	14

TABLE C-8
HOLDING TIME SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH
(Page 2 of 2)

Location Identification	Field Identification	Sample Date	Sample Time	Analysis Code	Analysis Date	Analysis Time	Analysis Holding Time (Days)	Method Holding Time (Days)
MW-23	MW-23	1-Nov-17	1000	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1645	1	2
				E300.0	3-Nov-17	1627	2	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1431	3	180
				SW6010C	6-Nov-17	1328	3	180
				SW6020A	14-Nov-17	1826	1	180
				SW6850	6-Nov-17	1301	0	28
				SW7470A	14-Nov-17	1346	0	28
				SW9012A	13-Nov-17	1330	12	14
PZ-10	PZ-10	1-Nov-17	1315	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1809	1	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1345	3	180
				SW6020A	14-Nov-17	1837	1	180
				SW6850	6-Nov-17	1342	0	28
				SW7470A	14-Nov-17	1349	0	28
				SW9012A	10-Nov-17	1608	9	14
PZ-12	PZ-12	1-Nov-17	1205	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1753	1	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1342	3	180
				SW6020A	14-Nov-17	1833	1	180
				SW6850	6-Nov-17	1328	0	28
				SW7470A	14-Nov-17	1348	0	28
				SW9012A	10-Nov-17	1605	9	14
PZ-13	PZ-13	1-Nov-17	1105	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1736	1	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1339	3	180
				SW6020A	14-Nov-17	1830	1	180
				SW6850	6-Nov-17	1315	0	28
				SW7470A	14-Nov-17	1347	0	28
				SW9012A	10-Nov-17	1605	9	14
PZ-8	PZ-8	1-Nov-17	1620	E160.1	8-Nov-17	1110	7	7
				E300.0	2-Nov-17	1934	1	2
				E310.1	14-Nov-17	1446	13	14
				SW6010C	6-Nov-17	1354	3	180
				SW6020A	14-Nov-17	1848	1	180
				SW6850	6-Nov-17	1422	0	28
				SW7470A	14-Nov-17	1352	0	28
				SW9012A	10-Nov-17	1608	9	14

TABLE C-9
FIELD DUPLICATE DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, NOVEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Location Identification Date Collected Analyte (Units)	MW-15B 11/2/2017	MW-15B Dup 11/2/2017
Chemistry Parameters		
Alkalinity, Total (as $CaCO_3$) (mg/L)	**470**	**400**
Bromide (mg/L)	<100 D	**100 D**
Chloride (as Cl) (mg/L)	**59000 D**	**59000 D**
Cyanide (µg/L)	<10	<10
Fluoride (mg/L)	<100 D	<100 D
Nitrate Ion (mg/L)	<100 D	<100 D
Nitrite Ion (mg/L)	<100 D	<100 D
Nitrogen, Nitrate (as N) (mg/L)	<23 D	<23 D
Nitrogen, Nitrite (mg/L)	<31 D	<31 D
Perchlorate (µg/L)	<5 D	<5 D
Phosphate-P (mg/L)	<33 D	<33 D
Phosphorus, Total (as P) (mg/L)	<100 D	<100 D
Sulfate (as SO_4) (mg/L)	**840 D**	**890 D**
Total dissolved solids (mg/L)	**64000**	**63000**
Metals		
Aluminum (µg/L)	**6100**	**6100**
Antimony (µg/L)	<100	<100
Arsenic (µg/L)	**95**	**96**
Barium (µg/L)	**820**	**830**
Cadmium (µg/L)	<50	<50
Calcium (mg/L)	**14000 D**	**15000 D**
Chromium, Total (µg/L)	<100	<100
Cobalt (µg/L)	**190**	**190**
Copper (µg/L)	<100	<100
Iron (µg/L)	**310000**	**310000**
Lead (µg/L)	**60**	**63**
Magnesium (mg/L)	**7800 D**	**8200 D**
Manganese (µg/L)	**21000**	**21000**
Mercury (µg/L)	<0.1	<0.1
Molybdenum (µg/L)	<100	<100
Nickel (µg/L)	**660**	**670**
Potassium (mg/L)	**320 D**	**340 D**
Selenium (µg/L)	<250	<250
Silver (µg/L)	<50	<50
Sodium (mg/L)	**2700 D**	**2800 D**
Thallium (µg/L)	<50	<50
Vanadium (µg/L)	<100	<100
Zinc (µg/L)	**910**	**930**

µg/L micrograms per liter
mg/L milligrams per liter
Bold Bolded result indicates positively identified compound.
D Sample dilution required for analysis; reported values reflect the dilution.

TABLE C-10
QUALIFIED DATA SUMMARY
GROUNDWATER AND SURFACE WATER SAMPLING, AUGUST/SEPTEMBER 2017
US MAGNESIUM FACILITY, ROWLEY, UTAH

Sample Identification	Sample Date	Lab Identification	Analysis Method	Parameter	Sample Result	QC Type	QC Result	Qualifier	Reason Code
PZ-13	11/1/2017	1730607-002	SW6010C	Sodium	2,530 mg/L	MB	2,060 mg/L	J+	07a
PZ-12	11/1/2017	1730607-003	SW6010C	Sodium	2,020 mg/L	MB	2,060 mg/L	J+	07a
PZ-10	11/1/2017	1730607-004	SW6010C	Sodium	3,370 mg/L	MB	2,060 mg/L	J+	07a
PZ-8	11/1/2017	1730607-007	SW6010C	Sodium	2,200 mg/L	MB	2,060 mg/L	J+	07a

Definitions:
mg/L - milligrams per liter

MB - method blank

Reason Codes:
07a - Target parameter was detected in laboratory method blank sample or other preparatory blank sample.

Data Validation Qualifiers:
J+ : The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying high bias, due to non-conformances discovered during data validation.

APPENDIX D – 2017 GROUNDWATER LEVEL MEASUREMENT FIELD FORMS

US MAGNESIUM WATER-LEVEL MONITORING FIELD SHEET
JUNE 2017

Field Staff: _____

Well ID	Date and Time	Location Description	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Depth to Water Measurement (ft below TOC)	Comments
LF-01	6/26/17 1351	North of Landfill	15.8	5.4-15.4	4219.63	4224.10	8.47	TOC, N
LF-02	6/26/17 1333	North of Landfill	13.5	3-13	4221.99	4224.89	8.91	Could Not locate.
LF-03	6/26/17	North of Landfill	12.1	2-12	4216.92	4220.06	4.73	TOC, N
MW-1	6/26/17	South of Main Gate	77	58-68	4223.33	4223.33	—	Inside ATI Gate
MW-2	6/26/17	Wast of Facility	72.5	57.5-67.5	4224.26	4226.88	9.76	TOC, N
MW-3	6/26/17 1300	Main Ditch	17	5-15	4221.44	4223.97	7.72	TOC, N
MW-4A	6/26/17 1305	Main Ditch	15	4-14	4221.47	4224.03	7.95	TOC, N
MW-4B	6/26/17 1307	Main Ditch	35	22.5-32.5	4221.53	4224.10	7.68	TOC, N
MW-5A	6/26/17 1322	Main Ditch	20	8-18	4223.86	4226.48	10.67	TOC, N
MW-5B	6/26/17 1324	Main Ditch	38	27-37	4224.19	4226.80	10.46	TOC, N
MW-6	6/26/17 1348	South of Gypsum Pile	20	7-17	4222.98	4225.77	9.54	TOC, N
MW-7	6/26/17 1344	South of Gypsum Pile	20	7.5-17.5	4224.46	4227.05	10.80	TOC, N
MW-8A	6/26/17 1316	Main Ditch	23	6-21	4222.62	--	9.98	TOC, N
MW-8B	6/26/17 1317	Main Ditch	38	27-37	4222.44	--	9.75	TOC, N
MW-9	6/26/17 0910	Northern Bank of OWP	95	59-69	4211.29	4213.87	6.05	
MW-10	6/26/17 0850	NE Corner of OWP	80	68-78	4210.61	4213.20	10.62	
MW-11		NE of OWP	15	3-13	4204.02	--	—	Could Not Access
MW-12		NE of OWP	15	3-13	4203.57	--	—	Could Not Access
MW-13A	6/26/17 1004	NE of CWP	11.04	2.5-7.5	4221.96	4221.96	9.14	
MW-13B	6/26/17 1004	NE of CWP	21.34	9-19	4221.88	4221.88		Not available, cap stuck on PVC
MW-14	6/26/17 1645	NE of CWP	18.86	5-15	4219.6	4219.6	7.21	TOC, N
MW-15A	6/26/17 1634	East of CWP on Dike	10.98	2-7	4220.98	4220.98	7.78	TOC N
MW-15B	6/26/17	East of CWP on Dike	21.08	9-19	4220.71	4220.71	—	Could Not Remove cap
MW-16	—	Gypsum Pile	0	0.5-1.5	--	NA	—	Did Not Do
MW-17	6/26/17 1401	West of CWP	21.1	7-17	4219.78	4219.78	5.11	TOC, N
MW-18	6/26/17	West of Facility	24.38	12-22	4229.29	4229.29	—	Damage, No WL
MW-19A	6/26/17	West of CWP	19.48	7-17	4218.51	4218.51	—	No Access
MW-19B	6/26/17	West of CWP	35.9	23-33	4218.35	4218.35	—	No Access
MW-20A	6/26/17 1443	SE of Facility	20.24	12-17	4227.83	4227.83	13.06	TOC, N
MW-20B	6/26/17 1451	SE of Facility	32.26	19-29	4228.14	4228.14	13.71	TOC, N
PZ-01	6/26/17 1554	SE of Facility	19.5	9.17-19.17	4220.96	4224.06	13.33	TOC, N
PZ-02	—	Co-Located with MW-1	16.3	8-16	4220.64	4223.70	—	ATI Parking lot Locked
PZ-03	6/26/17 1511	Co-Located with MW-2	20.5	10-20	4223.68	4226.47	11.36	TOC, N
PZ-04	6/26/17 1243	West of Facility Co-Located with PZ-27 & 28	17	6.5-16.5	4220.65	4224.40	9.27	TOC, North
PZ-05	6/26/17; 0940	North Embankment of OWP	14	3.5-13.5	4211	4214.46	8.82	
PZ-06	6/26/17; 0950	NE Corner of OWP	14	3.5-13.5	4210.54	4214.22	10.80	Top of PVC casing; North

US MAGNESIUM WATER-LEVEL MONITORING FIELD SHEET
JUNE 2017

Field Staff: _____

Well ID	Date and Time	Location Description	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Depth to Water Measurement (ft below TOC)	Comments
PZ-07	6/26/17 910	East side of OWP	14	3.5-13.5	4205.36	4212.33	7.68	
PZ-08	6/26/17 1025	Between OWP and CWP	15	3.5-13.5	4215.9	4218.71	6.95	
PZ-10	6/26/17 1050	Between OWP and CWP	15	4-14	4215.99	4218.72	6.50	
PZ-11	6/26/17 1619	Between OWP and CWP	15	4-14	4215.46	4218.27	6.83	
PZ-12	6/26/17 1614	Between OWP and CWP	15	4-14	4216.64	4219.23	8.79	TOC, N
PZ-13	6/26/17 1609	Between OWP and CWP	18	7.5-17.5	4217.63	4220.50	10.63	TOC, N
PZ-14	6/26/17 1601	SE Corner of CWP	15	4.5-14.5	4216.83	4219.94	8.18	TOC, N
PZ-16	6/26/17	SE Corner of CWP	15	4-14	4215.55	4218.44	—	Could Not Access
PZ-18	6/26/17	Southern Side of CWP	17	3.25-13.25	4215.28	4217.96	—	Could Not Access
PZ-20	6/26/17	West of CWP	15	3-13	4216.58	--	—	Could Not Locate
PZ-22	6/26/17 1435	West of CWP	15	3-13	4217.44	-	5.96	TOC, N
PZ-24	6/26/17 1465	West of CWP along Main Ditch	15	3-13	4216.82	--	4.54	TOC, N
PZ-26	6/26/17 1037	Between OWP and CWP	15	3.5-13.5	4218.26	4220.85	6.69	TOC, N
PZ-27	6/26/17 1244	West of Facility Co-Located with PZ-4 & 28	17	6.5-16.5	4221.09	4223.57	8.85	TOC, North 4" well
PZ-28	6/26/17 1241	West of Facility Co-Located with PZ-4 & 27	77	65-75	4221.02	4223.52	7.82	Top of casing N
PZ-29	6/26/17 0900	NE Corner of OWP	17	5.5-15.5	4211.15	4213.99	11.04	
PZ-30	6/26/17 0900	NE Corner of OWP	17	5.5-15.5	4210.61	4213.39	10.51	
~~SC-PZ-1~~		SE Corner of OWP	--	5-10	4212.67			
~~SC-PZ-2~~		SE Corner of OWP		2-7	4210.9			
PMW-1D	6/26/17 1533	West of Facility	--	30-40	4234.88	~~46~~	16.74	TOC, N
PMW-1S	~~6/26/17 1035~~ (6/26/17 1521)	West of Facility	--	15-25	4234.87		17.61	TOC, N
MW-21[1]	6/26/17 1025	East Dike of CWP (near PZ-8)	TBD	TBD	TBD		6.40	
MW-22A[1]	6/26/17 1050	East Dike of CWP (near PZ-10)	TBD	TBD	TBD		6.75	
MW-22B[1]	6/26/17 1050	East Dike of CWP (near PZ-10)	TBD	TBD	TBD		6.38	
MW-23[1]	6/26/17 1606	East Dike of CWP (near PZ-13)	TBD	TBD	TBD		10.28	TOC, N
~~34911~~		~~West of Facility (BLM Well)~~	~~284~~	~~174-284~~	~~--~~			
34950		West of Facility (BLM Well)	70	50-70	--			
438726		West of Facility (BLM Well)	109	--	--			
35129		West of Facility (BLM Well)	323	170-200	4305			
35092		West of Facility (BLM Well)	274	173-274	4365			

bgs - below ground surface
amsl - above mean sea level
TBD - to be determined
CWP - Current waste ponds
OWP - Old waste pond
BLM - Bureau of Land Management
1 - Proposed well (not drilled)

PZ South of MW 5/8 6/26/17 1333 8.91

US MAGNESIUM WATER-LEVEL MONITORING FIELD SHEET

SEPTEMBER 2017

Well ID	Date and Time	Location Description	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Depth to Water Measurement (ft below TOC)	Comments
LF-01	9-12-17	North of Landfill	15.8	5.4-15.4	4219.63	4224.10		Can't Locate
LF-02		North of Landfill	13.5	3-13	4221.99	4224.89	9.09	
LF-03		North of Landfill	12.1	2-12	4216.92	4220.06		Can't Locate
MW-1		South of Main Gate	77	58-68	4223.33	4223.33		ATI - Property
MW-2		West of Facility	72.5	57.5-67.5	4224.26	4226.88	9.69	TOC, N
MW-3		Main Ditch	17	5-15	4221.44	4223.97	7.90	
MW-4A		Main Ditch	15	4-14	4221.47	4224.03	8.17	
MW-4B		Main Ditch	35	22.5-32.5	4221.53	4224.10	7.91	
MW-5A		Main Ditch	20	8-18	4223.86	4226.48	10.90	
MW-5B		Main Ditch	38	27-37	4224.19	4226.80	10.70	
MW-6		South of Gypsum Pile	20	7-17	4222.98	4225.77	9.89	
MW-7		South of Gypsum Pile	20	7.5-17.5	4224.46	4227.05	11.17	
MW-8A		Main Ditch	23	6-21	4222.62	--	10.25	
MW-8B		Main Ditch	38	27-37	4222.44	--	9.84	
MW-9		Northern Bank of OWP	95	59-69	4211.29	4213.87	5.65	
MW-10		NE Corner of OWP	80	68-78	4210.61	4213.20	11.08	
MW-11		NE of OWP	15	3-13	4204.02	--	7.05	
MW-12		NE of OWP	15	3-13	4203.57	--	N/A	Could not locate
MW-13A		NE of CWP	11.04	2.5-7.5	4221.96	4221.96	10.07	
MW-13B		NE of CWP	21.34	9-19	4221.88	4221.88	9.42	
MW-14		NE of CWP	18.86	5-15	4219.6	4219.6	7.54	
MW-15A		East of CWP on Dike	10.98	2-7	4220.98	4220.98	7.96	
MW-15B		East of CWP on Dike	21.08	9-19	4220.71	4220.71	7.59	
MW-16		Gypsum Pile	0	0.5-1.5	--	NA		
MW-17		West of CWP	21.1	7-17	4219.78	4219.78	5.14	
MW-18		West of Facility	24.38	12-22	4229.29	4229.29		
MW-19A		West of CWP	19.48	7-17	4218.51	4218.51	4.11	
MW-19B		West of CWP	35.9	23-33	4218.35	4218.35	3.47	
MW-20A		SE of Facility	20.24	12-17	4227.83	4227.83	13.54	
MW-20B		SE of Facility	32.26	19-29	4228.14	4228.14	14.19	
PZ-01		SE of Facility	19.5	9.17-19.17	4220.96	4224.06	13.94	
PZ-02		Co-Located with MW-1	16.3	8-16	4220.64	4223.70		ATI Property
PZ-03		Co-Located with MW-2	20.5	10-20	4223.68	4226.47	11.51	TOC, N
PZ-04		West of Facility Co-Located with PZ-27 & 28	17	6.5-16.5	4220.65	4224.40	9.52	
PZ-05		North Embankment of OWP	14	3.5-13.5	4211	4214.46	9.01	
PZ-06		NE Corner of OWP	14	3.5-13.5	4210.54	4214.22	12.61	
PZ-07		East side of OWP	14	3.5-13.5	4205.36	4212.33	8.59	
PZ-08		Between OWP and CWP	15	3.5-13.5	4215.9	4218.71	7.00	
PZ-10		Between OWP and CWP	15	4-14	4215.99	4218.72	6.86	
PZ-11		Between OWP and CWP	15	4-14	4215.46	4218.27	6.98	
PZ-12		Between OWP and CWP	15	4-14	4216.64	4219.23	9.03	
PZ-13		Between OWP and CWP	18	7.5-17.5	4217.63	4220.50	10.96	
PZ-14		SE Corner of CWP	15	4.5-14.5	4216.83	4219.94	8.77	
PZ-16		SE Corner of CWP	15	4-14	4215.55	4218.44	6.38	
PZ-18		Southern Side of CWP	17	3.25-13.25	4215.28	4217.96	6.79	
PZ-20		West of CWP	15	3-13	4216.58	--	5.72	
PZ-22		West of CWP	15	3-13	4217.44	--	6.03	
PZ-24		West of CWP along Main Ditch	15	3-13	4216.82	--	4.68	
PZ-26		Between OWP and CWP	15	3.5-13.5	4218.26	4220.85	6.87	

US MAGNESIUM WATER-LEVEL MONITORING FIELD SHEET

SEPTEMBER 2017

Well ID	Date and Time	Location Description	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Depth to Water Measurement (ft below TOC)	Comments
PZ-27	9-12-17	West of Facility Co-Located with PZ-4 & 28	17	6.5-16.5	4221.09	4223.57	7.84	
PZ-28		West of Facility Co-Located with PZ-4 & 27	77	65-75	4221.02	4223.52	5.76	
PZ-29		NE Corner of OWP	17	5.5-15.5	4211.15	4213.99	12.49	
PZ-30		NE Corner of OWP	17	5.5-15.5	4210.61	4213.39	11.96	
SC-PZ-1		SE Corner of OWP	--	5-10	4212.67			
SC-PZ-2		SE Corner of OWP	--	2-7	4210.9			
PMW-1D		West of Facility	--	30-40	4234.88	17.43	17.43	
PMW-1S		West of Facility	--	15-25	4234.87	18.18	18.18	
MW-21[1]		East Dike of CWP (near PZ-8)	60.5	40-60	4215.5	4218.8	6.57	
MW-22A[1]		East Dike of CWP (near PZ-10)	35	24-34	4215.69	4218.32	6.97	
MW-22B[1]		East Dike of CWP (near PZ-10)	65.2	54-64	4215.68	4218.15	6.79	
MW-23[1]		East Dike of CWP (near PZ-13)	67.3	56-66	4216.98	4219.58	10.58	
34911	SE	West of Facility (BLM Well)	284	174-284	--	N/A	N/A	Dirt/mud bottom
34950		West of Facility (BLM Well)	70	50-70	--	59.54	59.54	
438726		West of Facility (BLM Well)	109	--	--	N/A	N/A	
35129		West of Facility (BLM Well)	323	170-200	4305	89.14	89.14	
35092	NW	West of Facility (BLM Well)	274	173-274	4365	152.73	152.73	

bgs - below ground surface
amsl - above mean sea level
TBD - to be determined
CWP - Current waste ponds
OWP - Old waste pond
BLM - Bureau of Land Management
1 - Proposed well (not drilled)

US MAGNESIUM WATER-LEVEL MONITORING FIELD SHEET
Dec-17

Field Staff: Jake Trauscht

Well ID	Date and Time	Location Description	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Depth to Water Measurement (ft below TOC)	Comments	GW Elev
LF-01	~~9/12/2017~~ 12-1-17	North of Landfill	15.8	5.4-15.4	4219.63	4224.10	8.25		
LF-02	~~9/12/2017~~	North of Landfill	13.5	3-13	4221.99	4224.89	8.88		
LF-03	~~9/12/2017~~	North of Landfill	12.1	2-12	4216.92	4220.06			
MW-1	~~9/12/2017~~	South of Main Gate	77	58-68	4223.33	4223.33			
MW-2	~~9/12/2017~~	West of Facility	72.5	57.5-67.5	4224.26	4226.88	9.75		
MW-3	~~9/12/2017~~	Main Ditch	17	5-15	4221.44	4223.97	7.81		
MW-4A	~~9/12/2017~~	Main Ditch	15	4-14	4221.47	4224.03	8.09		
MW-4B	~~9/12/2017~~	Main Ditch	35	22.5-32.5	4221.53	4224.10	7.83		
MW-5A	~~9/12/2017~~	Main Ditch	20	8-18	4223.86	4226.48	10.70		
MW-5B	~~9/12/2017~~	Main Ditch	38	27-37	4224.19	4226.80	10.50		
MW-6	~~9/12/2017~~	South of Gypsum Pile	20	7-17	4222.98	4225.77	9.68		
MW-7	~~9/12/2017~~	South of Gypsum Pile	20	7.5-17.5	4224.46	4227.05	10.90		
MW-8A	~~9/12/2017~~	Main Ditch	23	6-21	4222.62	4225.62	10.01		
MW-8B	~~9/12/2017~~	Main Ditch	38	27-37	4222.44	4225.22	9.61		
MW-9	~~9/12/2017~~	Northern Bank of OWP	95	59-69	4211.29	4213.87	5.43		
MW-10	~~9/12/2017~~	NE Corner of OWP	80	68-78	4210.61	4213.20	11.14		
MW-11	~~9/12/2017~~	NE of OWP	15	3-13	4204.02	4206.75	6.92		
MW-12	~~9/12/2017~~	NE of OWP	15	3-13	4203.57	4206.28	7.33		
MW-13A	~~9/12/2017~~	NE of CWP	11.04	2.5-7.5	4221.96	4221.96	9.83		
MW-13B	~~9/12/2017~~	NE of CWP	21.34	9-19	4221.88	4221.88	9.15		
MW-14	~~9/12/2017~~	NE of CWP	18.86	5-15	4219.6	4219.6	6.44		
MW-15A	~~9/12/2017~~	East of CWP on Dike	10.98	2-7	4220.98	4220.98	7.67		
MW-15B	~~9/12/2017~~	East of CWP on Dike	21.08	9-19	4220.71	4220.71	7.31		
MW-16	~~9/12/2017~~	Gypsum Pile	0	0.5-1.5	--	NA			
MW-17	~~9/12/2017~~	West of CWP	21.1	7-17	4219.78	4219.78	4.87		
MW-18	~~9/12/2017~~	West of Facility	24.38	12-22	4229.29	4229.29			
MW-19A	~~9/12/2017~~	West of CWP	19.48	7-17	4218.51	4218.51	3.79		
MW-19B	~~9/12/2017~~	West of CWP	35.9	23-33	4218.35	4218.35	3.16		
MW-20A	~~9/12/2017~~	SE of Facility	20.24	12-17	4227.83	4227.83	13.49		
MW-20B	~~9/12/2017~~	SE of Facility	32.26	19-29	4228.14	4228.14	14.12		
PZ-01	~~9/12/2017~~	SE of Facility	19.5	9.17-19.17	4220.96	4224.06	13.78		
PZ-02	~~9/12/2017~~	Co-Located with MW-1	16.3	8-16	4220.64	4223.70			
PZ-03	~~9/12/2017~~	Co-Located with MW-2	20.5	10-20	4223.68	4226.47	11.64		
PZ-04	~~9/12/2017~~	West of Facility Co-Located with PZ-27 & 28	17	6.5-16.5	4220.65	4224.40	9.45		
PZ-05	~~9/12/2017~~	North Embankment of OWP	14	3.5-13.5	4211	4214.46	8.09		
PZ-06	~~9/12/2017~~	NE Corner of OWP	14	3.5-13.5	4210.54	4214.22	12.23		
PZ-07	~~9/12/2017~~	East side of OWP	14	3.5-13.5	4205.36	4212.33	7.61		

US MAGNESIUM WATER-LEVEL MONITORING FIELD SHEET
Dec-17

Field Staff: Jake Trauscht

Well ID	Date and Time	Location Description	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Depth to Water Measurement (ft below TOC)	Comments	GW Elev
PZ-08	~~9/12/2017~~ 12-1-17	Between OWP and CWP	15	3.5-13.5	4215.9	4218.71	6.86		
PZ-10	~~9/12/2017~~	Between OWP and CWP	15	4-14	4215.99	4218.72	6.50		
PZ-11	~~9/12/2017~~	Between OWP and CWP	15	4-14	4215.46	4218.27	6.12		
PZ-12	~~9/12/2017~~	Between OWP and CWP	15	4-14	4216.64	4219.23	8.91		
PZ-13	~~9/12/2017~~	Between OWP and CWP	18	7.5-17.5	4217.63	4220.50	10.59		
PZ-14	~~9/12/2017~~	SE Corner of CWP	15	4.5-14.5	4216.83	4219.94	8.34		
PZ-16	~~9/12/2017~~	SE Corner of CWP	15	4-14	4215.55	4218.44	5.36		
PZ-18	~~9/12/2017~~	Southern Side of CWP	17	3.25-13.25	4215.28	4217.96	6.47		
PZ-20	~~9/12/2017~~	West of CWP	15	3-13	4216.58	4216.58	5.22		
PZ-22	~~9/12/2017~~	West of CWP	15	3-13	4217.44	4220.26	5.68		
PZ-24	~~9/12/2017~~	West of CWP along Main Ditch	15	3-13	4216.82	4219.53	4.34		
PZ-26	~~9/12/2017~~	Between OWP and CWP	15	3.5-13.5	4218.26	4220.85	6.56		
PZ-27	~~9/12/2017~~	West of Facility Co-Located with PZ-4 & 28	17	6.5-16.5	4221.09	4223.57	8.69		
PZ-28	~~9/12/2017~~	West of Facility Co-Located with PZ-4 & 27	77	65-75	4221.02	4223.52	7.89		
PZ-29	~~9/12/2017~~	NE Corner of OWP	17	5.5-15.5	4211.15	4213.99	11.90		
PZ-30	~~9/12/2017~~	NE Corner of OWP	17	5.5-15.5	4210.61	4213.39	11.34		
SC-PZ-1	~~9/12/2017~~	SE Corner of OWP	--	5-10	4212.67				
SC-PZ-2	~~9/12/2017~~	SE Corner of OWP	--	2-7	4210.9				
PMW-1D	~~9/12/2017~~	West of Facility	--	30-40	4234.88	4234.88	16.93		
PMW-1S	~~9/12/2017~~	West of Facility	--	15-25	4234.87	4234.87	18.75		
MW-21	~~9/12/2017~~	East Dike of CWP (near PZ-8)	60.5	50-60	4215.50	4218.18	6.41		
MW-22A	~~9/12/2017~~	East Dike of CWP (near PZ-10)	35	24-34	4215.69	4218.32	6.68		
MW-22B	~~9/12/2017~~	East Dike of CWP (near PZ-10)	65.2	54-64	4215.68	4218.15	6.58		
MW-23	~~9/12/2017~~	East Dike of CWP (near PZ-13)	67.3	56.1-66.1	4216.98	4219.58	10.42		
34911	~~9/12/2017~~	West of Facility (BLM Well)	284	174-284	--				
34950	~~9/12/2017~~	West of Facility (BLM Well)	70	50-70	--				
438726	~~9/12/2017~~	West of Facility (BLM Well)	109	--	--				
35129	~~9/12/2017~~	West of Facility (BLM Well)	323	170-200	4305				
35092	~~9/12/2017~~	West of Facility (BLM Well)	274	173-274	4365				
35212	~~9/12/2017~~	West of Facility (Desert Power Well)	250	190-250	4335				

bgs - below ground surface
amsl - above mean sea level
TBD - to be determined
CWP - Current waste ponds
OWP - Old waste pond
BLM - Bureau of Land Management

Groundwater Discharge Control Plan

Groundwater Discharge
Permit Application – Part C

Stantec

Prepared for:
US Magnesium

Prepared by:
Stantec

December 15, 2017

Sign-off Sheet

This Groundwater Discharge Permit application document entitled Groundwater Discharge Control Plan was prepared by Stantec Inc. ("Stantec") for the account of US Magnesium LLC (US Magnesium). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and US Magnesium. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

Jacob Trauscht

Reviewed by Susan Eyzaguirre

Susan Eyzaguirre, PE, PG

Approved by Chad Tomlinson

Chad Tomlinson, PE

Table of Contents

1.0 INTRODUCTION 1
1.1 PURPOSE AND SCOPE 1
1.2 BACKGROUND 1
2.0 HISTORICAL FACILITY OPERATIONS 2
2.1 OLD WASTE POND HISTORICAL OPERATIONS 2
2.2 CURRENT WASTE POND HISTORICAL OPERATIONS 2
3.0 CURRENT FACILITY DISCHARGE CONTROL COMPONENTS 3
4.0 PLANNED FACILITY IMPROVEMENTS 3
4.1 RCRA CARVE-OUT CLEANUP PROJECT 3
4.1.1 Wastewater Discharge Piping Installation and Ditch Closure 4
4.1.2 Sanitary Lagoon Refurbishment or Capping 4
4.2 WASTEWATER TREATMENT PLANT 4
5.0 PROPOSED GROUNDWATER DISCHARGE CONTROL SYSTEM 5
5.1 PROPOSED POND DESIGN 5
5.1.1 Location and Description 5
5.1.2 Containment Method 6
5.1.3 Dike and Barrier Wall Design 7
5.1.4 Construction Sequencing 7
5.2 SUPPORTING DESIGN INVESTIGATIONS AND STUDIES 8
5.2.1 Spatial Extent and Suitability of the Deeper Silty Clay Unit 8
5.2.2 Geochemical Evaluation 8
5.2.3 Water Balance Modelling 9
5.2.4 Groundwater Flow Modeling 10
5.2.5 Pending Predesign Investigations 11
6.0 REFERENCES 11

LIST OF APPENDICES

Appendix A – Corrective Measures Implementation Work Plan
Appendix B – Draft Outline Construction Quality Assurance Plan
Appendix C – Geochemical Report
Appendix D – Water Balance Report
Appendix E – Groundwater Model Report
Appendix F – Barrier Wall Compatibility Testing Proposal

LIST OF TABLES

Table 5-1 Neutralization Capacity of Sediments Above and Within the Deeper Silty Clay Unit
Table 5-2 Data Used to Evaluate the Water Balance Model

LIST OF FIGURES

Figure 1-1 Location Map
Figure 1-2 Old Waste Pond and Current Waste Pond
Figure 5-1 Current Waste Pond Conceptual Groundwater Discharge Control Design
Figure 5-2 Conceptual Groundwater Discharge Control Design
Figure 5-3 Typical Retrofitted Waste Pond Section
Figure 5-4 Thickness of Deeper Silty Clay Unit
Figure 5-5 Elevation of Top of Deeper Silty Clay Unit
Figure 5-6 30-Yr Calculated Particle Path-lines: Climate-based Projection Partially Enclosed Pond

Acronyms and Abbreviations

ave	average
amsl	above mean sea level
AOC	Administrative Order on Consent
bgs	below ground surface
BLM	Bureau of Land Management
CaCO3	calcium carbonate
CWP	Current Waste Pond
DWQ	Division of Water Quality
Facility	US Magnesium facility
GLEI	Great Lakes Environmental and Infrastructure
GSL	Great Salt Lake
GWDP	Groundwater Discharge Permit
HDPE	high-density polyethylene
kg	kilograms
NPDES	National Pollutant Discharge Elimination System
OWP	Old Waste Pond
RCRA	Resource Conservation and Recovery Act
RWP	Retrofitted Waste Plan
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

The state of Utah requires a Groundwater Discharge Permit (GWDP) for facilities that may result in discharge of pollutants to groundwater. GWDP requirements include implementation of appropriate groundwater discharge control measures to reduce or prevent wastewater from entering groundwater. This Groundwater Discharge Control Plan fulfills one of the requirements of Part C (Accompanying Reports and Plans) of the GWDP application for the US Magnesium facility (Facility) located in Rowley, Utah (**Figure 1-1**).

The Facility processing plant produces a low-pH wastewater stream that is currently conveyed to unlined evaporation ponds. An expanded and retrofitted wastewater evaporation pond (Retrofitted Waste Pond [RWP]) is proposed for the US Magnesium facility (Facility) to meet requirements outlined in Utah Administrative Code (UAC) R317-6.

1.1 PURPOSE AND SCOPE

This plan describes the components of US Magnesium's Current Waste Pond (CWP) as well as upgrades to the discharge control system that will be implemented as part of the GWDP for the US Magnesium Rowley production facility (the Facility).

1.2 BACKGROUND

US Magnesium has operated the Facility located in Tooele County along the west shore of Great Salt Lake (GSL) since 1972. The Facility is located within the Lakeside Valley, an extension of Skull Valley, Utah, and is situated at an elevation of approximately 4,220 feet above mean sea level (amsl) as shown in **Figure 1-1**.

The Facility utilizes solar evaporation to produce a concentrated brine from GSL waters which is used as a raw material source for magnesium chloride, which is electro-chemically processed to produce primary magnesium-metal (approximately 60,000 metric tons per year), chlorine (approximately 30 million gallons of pure liquid per year) as well as other products derived from these primary products (ERM, 2016). The Facility currently utilizes an approximately 285-acre wastewater impoundment (the CWP), which receives discharges from a series of unlined earthen ditches that combine into the main ditch, which conveys water to the CWP (**Figure 1-2**). The only other wastewater stream, a gypsum based slurry, discharges to the northern end of the CWP which, over time, has created a rust-colored gypsum pile.

Adjacent to the US Magnesium Facility are two other industrial facilities: ATI Titanium, which is no longer operating (southwest of the Facility) and The Hill Brothers Chemical facility, located southeast of the Facility, which produces a variety of chemical products for industrial and construction purposes (ERM, 2016) (**Figure 1-2**).

2.0 HISTORICAL FACILITY OPERATIONS

2.1 OLD WASTE POND HISTORICAL OPERATIONS

Prior to using the CWP to store wastewater at the Facility, the Old Waste Pond (OWP), located northeast of the CWP, was utilized for wastewater disposal (**Figure 1-2**). The approximately 800 acre OWP was constructed in the mid-1970s and at that time was permitted by the United States Environmental Protection Agency (USEPA) under National Pollutant Discharge Elimination System (NPDES) permit UT-000779 as a 'no discharge facility'. A second dike was constructed surrounding the OWP in 1980 in response to observed seepage along its eastern dike. This dike formed a channel which was filled with brine in order to create a hydraulic barrier to wastewater discharges (ERM, 2016).

In April 1984, the OWP was inundated by GSL waters due to rising lake levels and wastewater was diverted to a holding area while dike repairs occurred. In June 1984, the repaired dike sections were breached and wastewater was diverted to solar evaporation pond 1 west, located south of the CWP/OWP, per the facility contingency plan (**Figure 1-2**)(ERM, 2016).

In June 1985, GSL waters breached the solar pond dike, flooding the Stansbury Bay solar evaporation ponds, including solar evaporation Pond 1. Wastewater flows were then directed to the CWP, which was developed in low-lying mudflats separated from the GSL lakebed (and OWP) by southeast oriented beach ridges. Shortly after this, the OWP was completely inundated by GSL waters. The OWP remained inundated in water until the early 1990s when the lake level receded and the dikes surrounding the OWP were repaired. From the time of the dike repairs to November 2017, US Magnesium did not discharge wastewater to the OWP. However, the OWP has occasionally received water from the CWP due to seepage through the eastern dike of the CWP and through breaches, notably in April 2012 and spring/summer 2015 (ERM, 2016). In November 2017, US Magnesium began discharging wastewater to the OWP through a Utah Department of Environmental Quality (UDEQ), Division of Water Quality (DWQ) permitted overflow pipe from the CWP to the OWP.

2.2 CURRENT WASTE POND HISTORICAL OPERATIONS

The CWP was constructed in June 1985 in response to flooding of the OWP by GSL waters. The CWP was developed in a natural low-lying playa separated from the GSL and the OWP by southeast trending beach ridges composed primarily of oolitc sands (ERM, 2016). In October 1986, leakage occurred along the northwestern dike of the CWP, discharging wastewater onto BLM property north of the CWP. The dikes surrounding the CWP were raised and widened to 30 feet in December 1986 in order to protect the CWP from rising GSL levels. In July 1987, the Executive Secretary of the Utah Bureau of Water Pollution Control concluded the CWP appeared to meet the

requirements of the Utah Wastewater Disposal Regulations and approved the CWP (ERM, 2016).

Wastewater leaked from the CWP into the OWP through the eastern dike in February 1989 and February 1990. The cause of the seepage in both areas appeared to originate from a borrow channel inside the eastern dike that may have damaged the natural clay liner that is located near the surface (ERM, 2016). In response to several leakage incidents from the eastern dike of the CWP into the OWP, a high-density polyethylene (HDPE) curtain was installed along the eastern dike in the fall of 1998 (ERM, 2016). The Utah Department of Environmental Quality (UDEQ) did not renew the discharge permit in 1999 (ERM, 2016). Since then, the CWP has been the primary discharge point for wastewater at the Facility.

3.0 CURRENT FACILITY DISCHARGE CONTROL COMPONENTS

Current discharge control components present at the CWP are comprised of a series of dikes that surround the CWP, preventing discharge of surface water into the surrounding playa. Portions of the dike along the eastern side of the CWP have been reinforced with an HDPE curtain to reduce leakage through the eastern dike. In response to a UDEQ Division of Water Quality 'Warning Letter of Violation' sent to US Magnesium in November 2016, US Magnesium has taken actions to prevent further discharges from the Northwestern dike of the CWP. These actions included installation of a DWQ-permitted overflow pipe designed to allow flow from the CWP to the OWP at an approximate pipe invert elevation of 4214 feet amsl in order to lower water elevations within the CWP and prevent discharges from the North embankment (UDEQ, 2016).

Underlying the CWP are two units of silty clay, a discontinuous shallow unit located 5 to 10 feet below ground surface (bgs) and a deeper, continuous unit located approximately 35 to 55 feet bgs (the Deeper Silty Clay Unit). The Deeper Silty Clay Unit acts as a hydraulic barrier separating the shallow aquifer into an upper shallow aquifer zone (Upper Aquifer Zone) and lower shallow aquifer zone (Lower Aquifer Zone), preventing migration of water from the Upper Aquifer Zone into the Lower Aquifer Zone.

4.0 PLANNED FACILITY IMPROVEMENTS

This section describes facility improvements that US Magnesium has begun or plans to implement at the Facility. Refer to Section 5.0 of this plan for proposed groundwater discharge control system.

4.1 RCRA CARVE-OUT CLEANUP PROJECT

US Magnesium has begun implementation of the Resource Conservation and Recovery Act (RCRA) Carve-out Cleanup Project pursuant to the U.S. Environmental Protection Agency (USEPA) Region 8 Administrative Order on Consent (AOC), USEPA RCRA Docket

No. RCRA-08-2016-0004, effective August 3, 2016. See **Appendix A** for a detailed description of the proposed work plan. The RCRA Carve-Out Project is composed of two primary components:

1) Installation of a wastewater discharge piping system to replace the current unlined ditches; ditches are to be closed and capped following installation of new discharge piping
2) Refurbishment or closure of the sanitary Lagoon located between the Central Ditch and the Chlorine Ditch (**Figure 1-2**).

4.1.1 Wastewater Discharge Piping Installation and Ditch Closure

The existing wastewater ditches at the Facility, which discharge to the CWP, are the Western Ditch, Central Ditch, Chlorine Ditch, and the Main Ditch, which collects streams from the other three ditches and conveys the combined wastewater discharge to the CWP (**Figure 1-2**). A portion of the wastewater in these earthen channels likely discharge to groundwater and have likely contributed to groundwater mounding beneath the Facility (ERM, 2016). In order to address these concerns, US Magnesium has agreed to close these unlined ditches and replace them with a series of conveyance pipes that will deliver wastewater to the CWP per the EPA AOC (USM, 2017). Once the piping has been installed and wastewater streams have been successfully diverted from the ditches, the ditches will be abandoned and contaminated sediments will be consolidated as backfill to fill the ditches. The ditches will then be capped with a minimum 2-feet thick cover of clean clayey-soils installed over the contaminated soils and sediments. US Magnesium has implemented a soil vapor assessment in the RCRA Carve-Out Cleanup Project area and, if necessary, will propose a vapor mitigation system (**Appendix A**).

4.1.2 Sanitary Lagoon Refurbishment or Capping

The sanitary lagoon, located between the Central Ditch and the Chlorine Ditch (**Figure 1-2**), will be refurbished to remain in operation. Further details regarding refurbishment will be determined once the corrective measures design has been completed (**Appendix A**).

4.2 WASTEWATER TREATMENT PLANT

US Magnesium has committed to construct a wastewater treatment plant (Filtration Plant) at the Facility to remove organic constituents from Facility wastewater prior to discharging to the RWP. Details of the Filtration Plant will be determined during final design; however, it is not expected to alter the pH or general water quality (i.e. TDS, total metals) of the water discharging to the RWP.

5.0 PROPOSED GROUNDWATER DISCHARGE CONTROL SYSTEM

The current discharge control components of the CWP have been deemed inadequate by the DWQ. In response, US Magnesium has undertaken an extensive study of potential solutions to prevent continued discharge of wastewater into the Upper Aquifer Zone underlying the Facility (see the Hydrogeologic Report for a detailed description of geology and hydrogeology beneath the Facility).

The following sections describe the components of the proposed discharge control system as well as completed, on-going, and future investigations and studies to support the design. The two primary design drivers for sizing the retrofitted waste pond (RWP) (footprint and height of dikes) are:

- The evaporative and storage area is great enough to offset wastewater inflows, and
- Maintain freeboard of at least 2-feet (24 inches) per UAC R649-9.

The control system described in this document is a conceptual level design and therefore details of the system are subject to change during the detailed design. The detailed design process will ensure all local, state and federal regulations are met, notably UAC R649-9 which governs waste management and disposal.

The proposed RWP described in this document is based on the current Main Ditch flows to the CWP. US Magnesium is reviewing these flow data with the purpose of determining methods to potentially reduce the volume of wastewater reporting to the waste pond. The intent of reducing flows to the waste pond would be to reduce the required footprint of the proposed RWP.

5.1 PROPOSED POND DESIGN

US Magnesium proposes to construct the RWP by expanding the size of the CWP and implementing modifications that will reduce the potential for migration of impacted groundwater in the Upper Aquifer Zone beyond the proposed footprint of the RWP. Conceptual engineering drawings are shown in **Figures 5-1**, **5-2**, and **5-3** and an outline-level Construction Quality Assurance/Quality Control Plan for construction of the proposed discharge control system is included in **Appendix B**.

5.1.1 Location and Description

US Magnesium plans to continue utilizing the CWP as part of the proposed RWP. Once the proposed modifications to the CWP are implemented and flows in the Upper Aquifer Zone are contained, evaporation will provide the only outlet for wastewater.

A water balance model for the Facility indicates the current evaporative area of the CWP is not sufficient to manage the future anticipated discharge flows. The CWP has

an approximate evaporative area of 285 acres at a normal pond water elevation of 4214 feet amsl. However, the water balance model indicates that an evaporative area of approximately 800 acres is required to achieve a water balance based on current and anticipated future inflows. Therefore, US Magnesium proposes to expand the CWP eastward into a portion of the OWP to achieve sufficient evaporative area in the RWP (**Figure 5-1**). Given that the OWP was the original receiving body for plant discharges prior to June 1986, the soils within the OWP footprint have already been impacted by Facility discharges. Additionally, the CWP is currently discharging to the OWP via the DWQ-permitted overflow pipe (refer to Section 3.0). Given that the evaporative area needed to achieve a water balance is greater than what is available within the CWP footprint, it was deemed prudent to achieve the required evaporative area in the RWP by expanding into the previously impacted OWP. The proposed RWP would utilize approximately 600 acres of the OWP. Wastewater flow would be discharged from the CWP using the existing overflow pipe or via an engineered spillway if deemed beneficial during the detailed design process (**Figure 5-3**). The current dike separating the CWP from the OWP would remain and would potentially be under water during high pond levels (**Figure 5-3**).

5.1.2 Containment Method

US Magnesium proposes to reduce the potential for migration of impacted groundwater in the Upper Aquifer Zone from outside the RWP footprint by installing a hydraulic barrier wall (barrier wall). The barrier wall will be a slurry wall installed through the eastern, southern and northern dikes as shown on **Figure 5-1**. As part of the design, the existing dikes will be raised and some new sections of embankment will be constructed from compacted earthen fill (see **Figures 5-1**, **5-2**, and **5-3**). The barrier wall will be installed at the centerline of the dike from an elevation two feet above the annual high water level (4217.5 feet amsl) and will extend (be keyed) approximately three feet into the low permeability (K = 2.8x10-8 cm/s to 3.4x10-7 cm/s) Deeper Silty Clay Unit. The actual required minimum key depth of the barrier wall into the Deeper Silty Clay Unit will be determined from seepage analyses and cone penetration tests (CPT) that will be performed as part of detailed designs.

The Deeper Silty Clay Unit underlies the existing ground surface at depths ranging from approximately 31 to 44 feet below ground surface (bgs) along the proposed RWP perimeter (See **Figures 5-4** and **5-5** and refer to Section 5.2.1 for a discussion of the spatial extent of the Deeper Silty Clay Unit). In addition to the thickness and lateral extent of the low permeability Deeper Silty Clay Unit, an upward gradient between the Lower Aquifer Zone and the Upper Aquifer Zone (i.e. below and above the Deeper Silty Clay Unit) will limit or prevent migration of water into the Deeper Aquifer Zone (vertical gradients are discussed in the Hydrogeological Report of this application [Stantec, 2017]).

As part of the proposed conceptual design, a containment system utilizing a western barrier wall was considered (see **Appendix E**). However, this option was not pursued

due to the small volume of groundwater currently flowing through the western boundary of the proposed RWP (~50 gallons per minute), and the conservative groundwater modeling results which predict impacted groundwater would not leave the containment area with or without the western wall. The lack of a western barrier wall also acts as a catchment for potentially contaminated groundwater currently located upgradient of the pond that is not possible with a pond that is completely enclosed with a barrier wall.

5.1.3 Dike and Barrier Wall Design

The new dike sections enclosing the RWP will be constructed and existing dikes raised to an elevation of approximately 4220 feet amsl to provide at least two feet of freeboard from projected maximum water levels within the proposed RWP (per UAC R649-9) and to prevent flooding from GSL during high water years (**Figures 5-2** and **5-3**). This will provide approximately eight feet of freeboard above the maximum historical water level of the Great Salt Lake (4211.6 feet amsl, USGS, 2007). The final top elevation of the dikes necessary to provide sufficient freeboard to contain wave action will be determined during detailed design. Embankments will be constructed (or modified in the case of existing embankments) with 4:1 (horizontal:vertical) slopes and a minimum top width of 20 feet to provide sufficient working area for installation of the barrier wall. Due to the low pH of the wastewater, US Magnesium will conduct a barrier wall slurry mix compatibility study (refer to Section 5.2.5) to determine the most appropriate slurry backfill mixture for the barrier wall. The results of this study will be incorporated into the detailed design.

5.1.4 Construction Sequencing

Detailed construction sequencing will be determined during detailed design. Due to the scale of this project (approximately 21,280 linear feet of Barrier Wall), more than one construction season will be necessary to construct the entire discharge control structure. A preliminary construction sequence is described below.

- Phase I: Embankment Construction

  Raise and widen existing embankments and construct new embankments beginning in the northwest corner and proceeding clockwise around the proposed RWP.

- Phase II: Barrier Wall Installation

  Trench will be excavated and supported with slurry followed by backfill with a soil mixture as determined in the compatibility test

- Phase III: Final survey of in-place groundwater discharge control system components

5.2 SUPPORTING DESIGN INVESTIGATIONS AND STUDIES

The following investigations and studies have been performed, are on-going, or are planned in order to support the design of the containment structures described in Section 5.1.

5.2.1 Spatial Extent and Suitability of the Deeper Silty Clay Unit

The Deeper Silty Clay Unit is a critical component of the groundwater discharge control system because it provides a physical barrier to wastewater entering the Lower Aquifer Zone and provides a barrier to potential underflow beneath the barrier wall and beyond the perimeter of the RWP. Forty-one historical borings, as well as eleven borings installed in June 2017, have been used to map the spatial extent and thickness of the Deeper Silty Clay Unit (**Figures 5-4** and **5-5**). Borings advanced around the perimeter of the CWP/OWP indicate the top of the Deeper Silty Clay Unit is approximately 35 to 55 feet bgs, with depth to clay increasing towards the east (**Figure 5-4**). Thickness of the Deeper Silty Clay Unit within the footprint of the CWP/OWP ranges from 11 to 18 feet, with the thickness increasing towards the east (**Figure 5-5**).

Samples collected from eleven borings advanced into the Deeper Silty Clay Unit in June 2017 were analyzed to evaluate the vertical hydraulic conductivity of the Deeper Silty Clay Unit. Results of laboratory tests reported vertical hydraulic conductivities of the Deeper Silty Clay Unit ranging from $2.8x10^{-8}$ cm/s to $3.4x10^{-7}$ cm/s, approximately two orders of magnitude lower than the maximum permeability ($1.0x10^{-5}$ cm/s) required by the UDEQ in design of compacted clay liners for landfill use (UDEQ, 2006) (See **Appendix A** of Hydrogeologic Report for geotechnical data and boring logs).

5.2.2 Geochemical Evaluation

The sediments underlying the CWP/OWP contain materials potentially reactive with the low-pH wastewater. Samples collected from the six boreholes advanced below the CWP were analyzed for calcium carbonate equivalency to evaluate the buffering capacity of the sediments above and within the Deeper Silty Clay Unit. **Appendix C** presents a detailed description of the results of this evaluation. Below is a summary of the methods and conclusions of this analysis.

The buffering capacity of the materials underlying the CWP area was conservatively estimated utilizing the measured flow rate into the pond (1100 gpm) and field-measured pH of the waste stream and surface water (0.0 to 1.15). Further, the evaporative area of the CWP at 4214 feet amsl (approximately 285 acres) was utilized to calculate the volume of material available to buffer the wastewater primarily because soil data are available for this area. The pH range utilized for this approach is conservative because the lowest value (pH = 0.0) was measured from the plant effluent directly, whereas measured pH values from the CWP water (pH = 0.76 to 1.15) are higher. Due to the logarithmic nature of the pH scale, this relatively small difference in pH results in significant variations in estimated buffering capacity as discussed below. In

addition, the ponded area of the CWP utilized for the analysis (approximately 285 acres) is significantly smaller than would be available under the proposed RWP (approximately 800 acres), resulting in a significantly larger volume of potentially reactive sediments available to buffer the same volume of low-pH water.

Due to the logarithmic nature of the pH scale, the range of pH values measured in the waste stream result in a significant range in estimated buffering capacity, with the sediments above the Deeper Silty Clay Unit having a buffering capacity estimated to last 25 to 350 years in the Northwestern CWP and 55 to 800 years in the Southeastern CWP. The buffering capacity of the Deeper Silty Clay Unit itself varies from 15 to 200 years in the Northwestern CWP and 60 to 900 years in the Southeastern CWP (**Table 5-1**). This analysis suggests the sediments below the pond provide sufficient buffering capacity for the projected lifetime of the plant.

Table 5-1

Neutralization Capacity of Sediments Above and Within the Deeper Silty Clay Unit

pH		Assumed Acid Loading Rate (kg $CaCO_3$/year)	Neutralization capacity of Sediments Above the Deeper Silty Clay Unit (years)	Neutralization capacity of the Deeper Silty Clay Unit (years)
Northwestern CWP				
Low pH	0.00	1.10E+08	25	15
Ave pH	0.59	2.80E+07	100	55
High pH	1.15	7.75E+06	350	200
Southeastern CWP				
Low pH	0.00	1.10E+08	55	60
Ave pH	0.59	2.80E+07	220	240
High pH	1.15	7.75E+06	800	900

Ave average
CaCO3 calcium carbonate
Kg kilograms

5.2.3 Water Balance Modelling

A complete description of the water balance model is included as **Appendix D**. The following text summarizes the methods and results of this analysis.

A water balance study was performed to evaluate and verify that the proposed RWP layout described above is sufficiently sized for both average precipitation and high precipitation years. The water balance utilized dynamic evaporation rates, with peak evaporation rates in summer and minimum evaporation rates in winter. The data used to evaluate the modeled storage requirements of the CWP and OWP are summarized in **Table 5-2**.

Table 5-2
Data Used to Evaluate the Water Balance Model

Input	Description
Wastewater Discharge Rate	950 gpm, as measured by the recently installed Cutthroat flume in the Main Ditch.
Gypsum Slurry Discharge Rate	150 gpm, as calculated based on inflows from the calcium chloride system underflow (50 gpm), desulfation system underflow (50 gpm), and 50 percent additional volume assumed for conservatism.
Precipitation	Daily rainfall for 62 years of record. 11.8 inches per year on average. High water years inserted to simulate high water projection.
Evaporation	Hourly rates for an average year which equals 45.4 inches.
Stage-area-storage relationships	Developed from 2015 LIDAR survey. Some assumptions were required for the CWP.

Results from the water balance model indicate that the maximum expected water storage capacity will reach an elevation of 4218 feet amsl, with a surface area of 1025 acres. The maximum annual pond elevation assuming average rainfall is 4215.5 feet amsl, with a surface area of 856 acres. Results from the water balance model were used as input conditions for the groundwater flow model discussed below and in **Appendix E**.

5.2.4 Groundwater Flow Modeling

A complete description of the computer groundwater flow model, simulations, and sensitivity analyses is included as **Appendix E**. Below is a summary of the overall groundwater modeling approach and results.

A numerical groundwater flow model was constructed to predict the impact of the proposed discharge control structures on groundwater flow (i.e. barrier wall around the north, east and south sides of the RWP). The modeling software MODFLOW (Harbaugh, 2005) was utilized to simulate groundwater flow in three-dimensions incorporating aquifer heterogeneity and variable water elevations in the RWP. The aquifer beneath the Facility was modeled as a five layer system to represent the different stratigraphic layers. Stage storage information from the water-balance was utilized as input to model the groundwater response to the pond utilizing the maximum expected storage capacity (Maximum pond elevation of 4218 feet amsl). Water elevation of the RWP was simulated under two scenarios: a quarterly-fluctuating stage, based on the past 23 years of historical evaporation and precipitation rates, and a maximum pond stage scenario, where a pond elevation of 4220 feet amsl was conservatively held constant for 30 years. Particle transport over a 30-year period for both scenarios was simulated as part of the model to determine if water would discharge from the RWP into the surrounding aquifer (**Figure 5-6**). The model indicates that, over the 30-year simulation period, groundwater beneath the RWP does not migrate to the surrounding aquifer by

lateral transport toward the west of the Facility, nor does it migrate to the Lower Aquifer Zone through the underlying Deeper Silty Clay Unit.

5.2.5 Pending Predesign Investigations

In addition to the investigations and studies presented above, several ongoing studies will inform the final design of the groundwater discharge control system. These include the following studies.

Slurry Wall Compatibility Study. Due to the very acidic nature of the wastewater, a compatibility test will be performed to determine the appropriate slurry mix for the barrier wall. Great Lakes Environmental and Infrastructure (GLEI) contractors have provided US Magnesium with a proposal to perform a bench scale compatibility study utilizing water that is representative of water that will be in contact with the barrier wall. GLEI's work plan for the proposed compatibility study is included as **Appendix F**.

Cone Penetration Tests. To confirm the depth and lateral continuity of the Deeper Silty Clay Unit, cone penetration tests (CPT) will be performed along the length of the proposed slurry wall.

Borrow Source Evaluation. Potential borrow sources for embankment material will be identified and evaluated to ensure materials meet specifications and the required volume of material is present.

Wastewater Flow Reduction. US Magnesium is reviewing the flows reporting to the waste pond with the purpose of determining methods to potentially reduce the volume of wastewater reporting to the waste pond. The intent of reducing flows to the waste pond would be to reduce the required footprint of the proposed RWP.

6.0 REFERENCES

ERM, 2016. Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model, US Magnesium LLC. June 2016.

Harbaugh, A.W. (2005), MODFLOW-2005, The U.S. Geological Survey modular groundwater model – the Ground-Water Flow Process, U.S. Geological Survey Techniques and Methods, 6-A16.

Stantec, 2017. Groundwater Discharge Permit Hydrogeologic Report. December, 2017.

US Magnesium, 2017.

Utah Department of Environmental Quality (UDEQ), 2006. Preparation of Solid Waste Facility Closure and Post-Closure Cost Estimates: Guidance. May 2012.

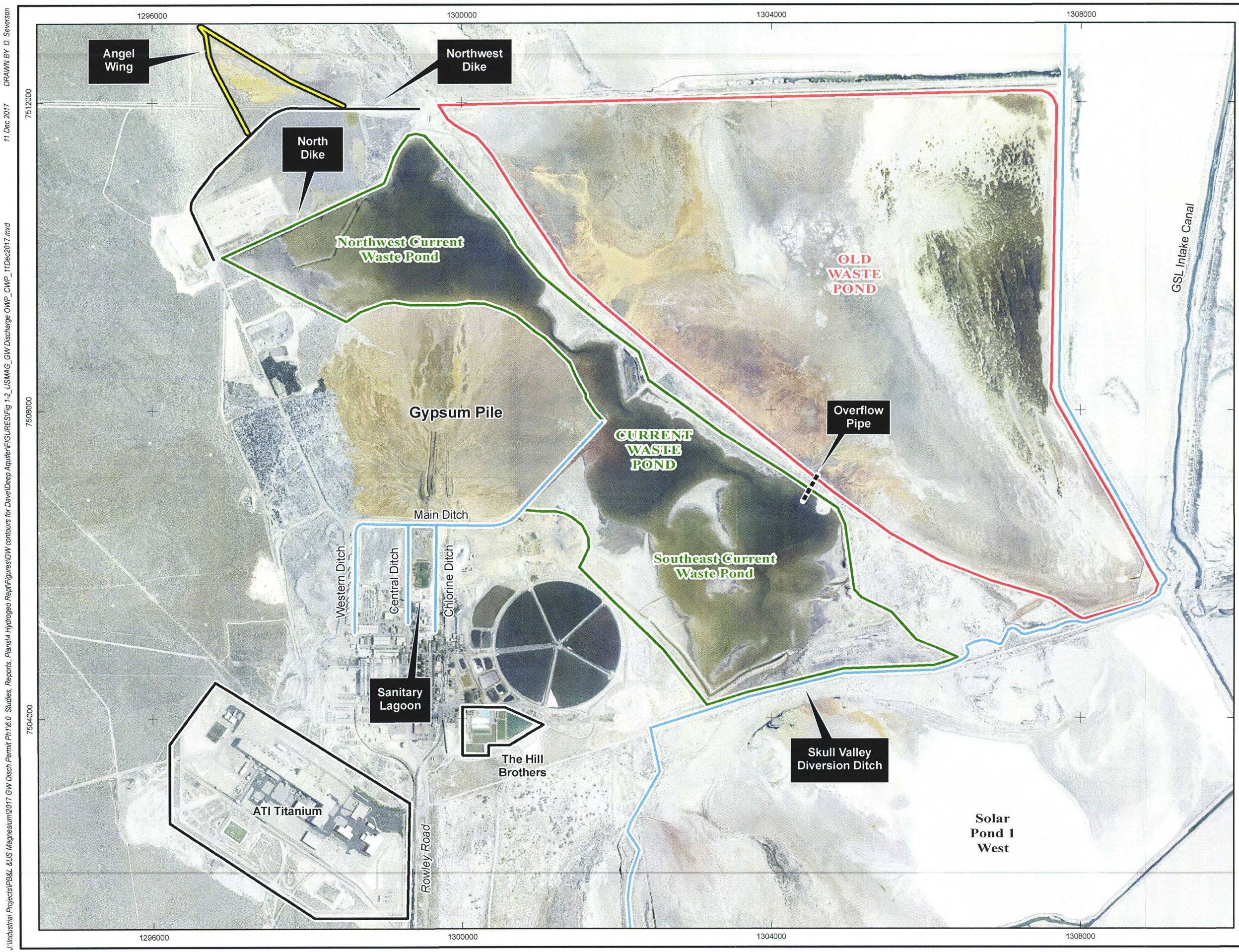
UDEQ, 2016. Warning: Letter of Violation – Unpermitted Discharges to Waters of the State, Uncontrolled Releases of Contaminants and Failure to Report: Violations of the Utah Water Quality Act, 19-5-107. 17 November 2016.

FIGURES

DRAWN BY D. Severson

19 Sep 2017

C:\Data\MWH\PB&L &US Magnesium\USMAG_Hydrogeologic Report_Sep2017\FIGURES\Figure 1-1_USMAG_Location Map_19Sep2017.mxd



EXPLANATION

N
W E
S

0 600 1200
Feet

USmag®

US MAGNESIUM

Old Waste Pond and Current Waste Pond

Figure 1-2

11 Dec 2017 DRAWN BY D. Severson

J:\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph16.0 Studies, Reports, Plans\4 Hydrogeo Rept\Figures\GW contours for Dave\Deep Aquifer\FIGURES\Fig 1-2_USMAG_GW Discharge OWP_CWP_11Dec2017.mxd

Drawn by D. Severson

8 Nov 2017

C:\Data\WWHVPB&L &US Magnesium\FIGURES\Fig 5-1_Current Waste Pond Concept GW Discharge Control_11Dec2017.mxd

CONCEPTUAL GROUNDWATER DISCHARGE CONTROL DESIGN SUMMARY

Barrier wall
LENGTH: 21,280 ft

Existing berm to be retrofitted
LENGTH: 9,040 ft

New berm to be constructed
LENGTH: 11,846 ft

Extent of northern barrier wall to be confirmed during detail design

Refer to Figure 5-2 for typical groundwater discharge control design detail

Refer to Figure 5-3 for conceptual cross-section of retrofitted pond

Extent of southern barrier wall to be confirmed during detail design

Northwest Current Waste Pond

Southeast Current Waste Pond

CURRENT WASTE POND

OLD WASTE POND

B'

B

A

A'

C'

C

N

W

E

S

0 750 1500

Feet

Aerial Photography 2 March 2016

NOTES:

1. Existing berm will be scarified to a depth of 8-inches and re-compacted to 98% Standard Proctor at +/- 2% of Optimum Moisture Content prior to placement of additional berm fill.
2. 20 feet is the minimum embankment width being proposed. Width of embankment may increase to accommodate construction of slurry wall.
3. General Berm Fill is to have a minimum the following properties:
   Percent passing a #200 sieve - 25%
   Plasticity Index - >10%and shall plot above the A-line
   General fill shall be placed in loose lifts not exceeding 8-inches and compacted to 98% (+/-2%) at +/-2% of Optimum Moisture Content.
4. Conceptual depth of slurry wall to "key" into clay is 45 feet bgs (measured from historical ground surface elevation). Ultimate depth of slurry wall will be confirmed based on cone penetration test data to be collected as part of the groundwater discharge permit investigation. Slurry wall will be installed to an elevation of 4216 (2 feet above of top operating water level). Slurry wall mix design will be based on result of compatibility testing to be performed in support of permit application. Refer to Contingency Plan for contingent HDPE cut-off installation.
5. Existing ground underlying new embankments will be scarified to a depth of 12-inches and re-compacted to 98% Standard Proctor. Following compaction, the subgrade receiving berm fill will be proof rolled using a fully loaded haul truck or fully laden water truck. Any weak spots will be excavated to a depth of 12-inches and replaced with competent backfill and compacted to 98% of Standard Proctor at +/-2% of optimum moisture content.
6. Overflow pipe between Current and Former Waste Ponds was installed as part of a contingency action. Under the conceptual design, the overflow pipe will remain to permanently convey water from the Current Waste Pond to the Former Waste Pond to achieve required containment area.

Stantec

USMag®

CURRENT WASTE POND CONCEPTUAL GROUNDWATER DISCHARGE CONTROL DESIGN

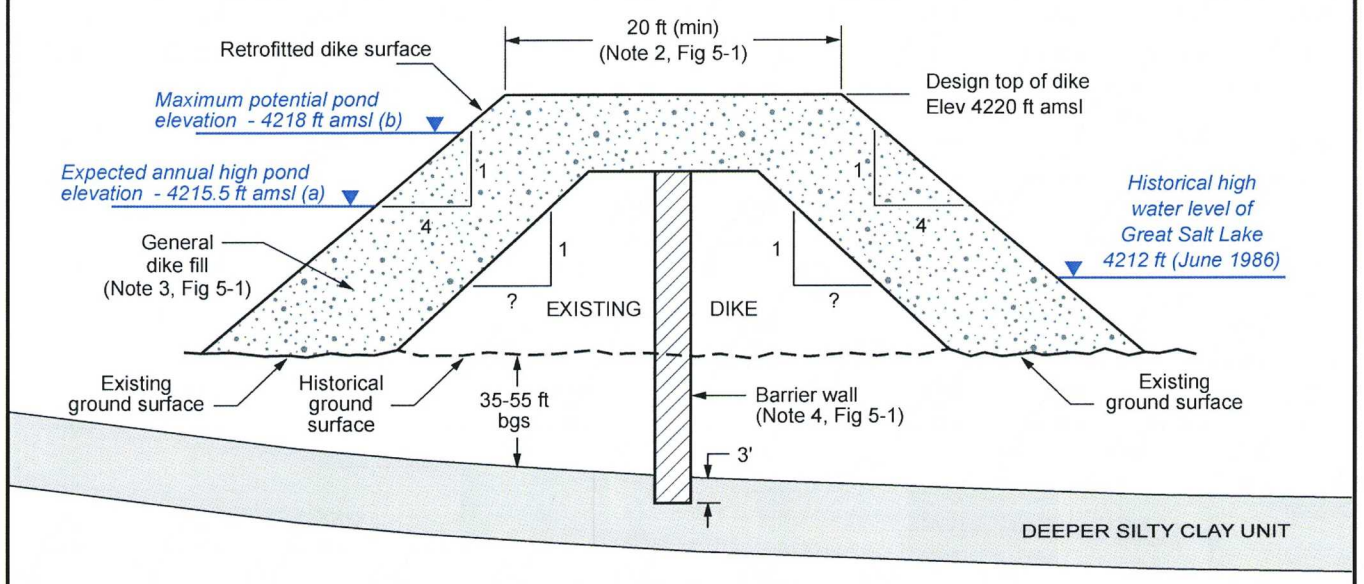
Figure 5-1

DRAWN BY D. Severson

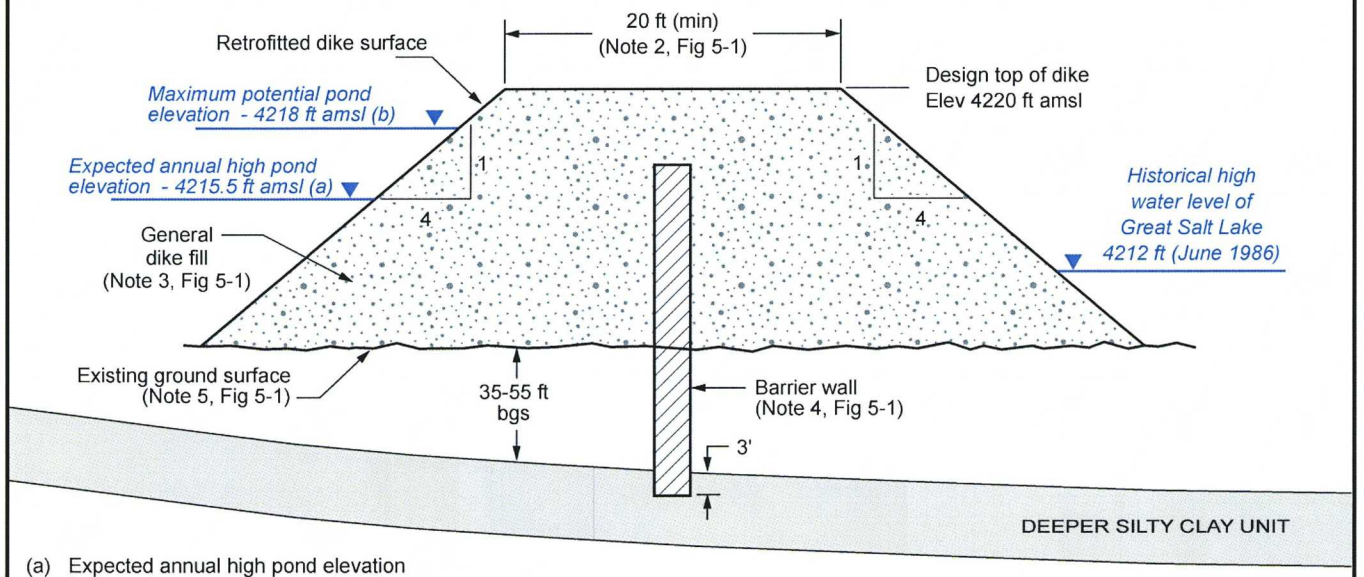
5 Dec 2017

C:\Data\MWH\PB&L &US Magnesium\FIGURES\Fig 5-3_USMag_Concept GW Discharge Control Design_5Dec2017.ai

NOT TO SCALE



CROSS SECTION A-A'
TYPICAL EXISTING DIKE RETROFIT



CROSS SECTION B-B'
TYPICAL NEW DIKE SECTION

(a) Expected annual high pond elevation is based on average precipitation (12.5 inches per year)

(b) Maximum potential pond elevation is based on actual historical precipitation data (1956 - 1998) followed by two years of the maximum historical 1-year precipitation (23.3 inches per year)

ft amsl	Feet above mean sea level
ft bgs	Feet below ground surface

See Figure 5-1 for cross section alignments

Stantec

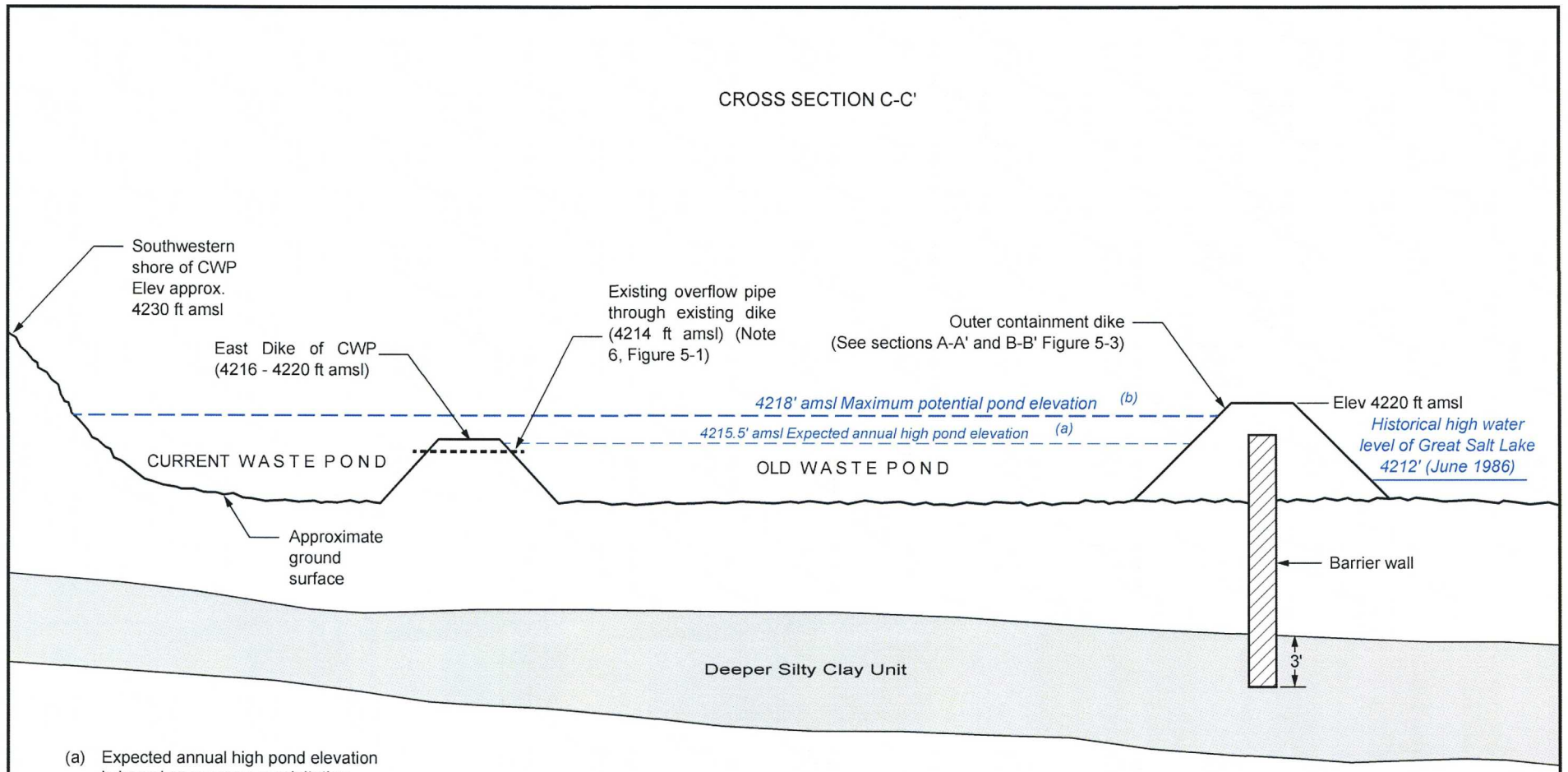
USMag®

CONCEPTUAL GROUND WATER DISCHARGE CONTROL DESIGN

Figure 5-2

C:\Data\WWH\PB&L &US Magnesium\FIGURES\Fig 5-2_USMag_Typical Current and Former Waste Pond Section_5Dec2017.ai 5 Dec 2017 DRAWN BY D. Severson

CROSS SECTION C-C'



(a) Expected annual high pond elevation is based on average precipitation (12.5 inches per year)

(b) Maximum potential pond elevation is based on actual historical precipitation data (1956 - 1998) followed by two years of the maximum historical 1-year precipitation (23.3 inches per year)

NOT TO SCALE

ft amsl	Feet above mean sea level
ft bgs	Feet below ground surface

See Figure 5-1 for cross section alignments

Stantec

USmag®

TYPICAL RETROFITTED WASTE POND SECTION

Figure 5-3

Drawn by: C Gallegos

Date: 9/27/2017

E:\PB&L &US Magnesium\FIGURES\Fig 3_2b Thickness of Deeper Silty Clay Unit_20170927.mxd

EXPLANATION

- Monitoring well
- Piezometer
- Soil boring
- Western Extent of Clay (Estimated)

Thickness of Clay Layer (ft)

- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18

MW-1, MW-2, MW-4B, MW-5B, MW-8B, MW-9, MW-10, MW-21, MW-22B, MW-23, PMW-1D, SB-04, SB 1, SB 2, SB 5, SB 6, SB 7, SB 9, PZ-28

N W E S

0 750 1500

Feet

Stantec

USmag®

THICKNESS OF DEEPER SILTY CLAY UNIT

Figure 5-4

Drawn by: C Gallegos

Date: 9/27/2017

E:\PB&L &US Magnesium\FIGURES\Fig 3_2a_ELEVATION OF TOP OF DEEPER SILTY CLAY UNIT_20170927.mxd

EXPLANATION

- Monitoring well
- Piezometer
- Soil boring
- Western Extent of Clay (Estimated)

Top of Clay Layer (ft)

- 4166
- 4168
- 4170
- 4172
- 4174
- 4176
- 4178
- 4180
- 4182
- 4184
- 4186
- 4188
- 4190
- 4192
- 4194
- 4196
- 4198
- 4200
- 4202
- 4204
- 4206
- 4208

MW-10, MW-9, SB 9, MW-21, MW-22B, MW-23, SB 2, SB 1, 10R, SB'6, 4, 9R, 7R, 8R, 6R, 1, 2, 3, 5, 12, 13, 18P, 9P, 10P, 7P, 11P, 6P, 8P, 16P, 5P, 15P, 4P, 14P, 2P, 13P, 3P, 15P, 1P, 12P, MW-4B, MW-5B, MW-8B, SB 5, PZ-28, SB-04, PMW-1D, MW-2, SB 7, MW-1

N W E S

0 750 1500

Feet

Stantec

USmag®

ELEVATION OF TOP OF DEEPER SILTY CLAY UNIT Figure 5-5

Proposed Barrier Wall: Partially Enclosed

Calculated Flow Direction of Native Groundwater

Theoretical Particle Starting Locations

Calculated Pathlines of Simulated Theoretical Particles

Modeled Fluctuating Expansion Pond Stages (4218 ft amsl MAX)

Modeled Fluctuating Existing Pond Stages (4218 ft amsl MAX)

Calculated Saltwater Equivalent Elevations
(ft amsl - 1 ft interval)

4199
4201
4203
4205
4207
4209
4211
4213
4214
4216
4210
4212
4208

N
W
E
S
0
1500
Feet

Stantec

USmag®

US MAGNESIUM
30-YR CALCULATED PARTICLE PATH-LINES: CLIMATE-BASED PROJECTION PARTIALLY ENCLOSED POND
Figure 5-6

17 Nov 2017

Z:\Projects\Clients\US Magnesium - PB&LF\Figures\ReportFigures\Figure 5-6_30 Yr Calc Part Path_Lines_Climate Based.mxd

APPENDIX A – CORRECTIVE MEASURES IMPLEMENTATION WORK PLAN

Corrective Measures Implementation Work Plan
US Magnesium LLC
Rowley, Utah

RCRA Carve-Out Cleanup Project
U.S. Environmental Protection Agency Region 8
Administrative Order on Consent (AOC),
RCRA Docket No. RCRA-08- 2016-0004

May 26, 2017
Revised August 9, 2017

Table of Contents

Page

1.0 INTRODUCTION 1-1

1.1 PURPOSE AND OBJECTIVE 1-1

1.2 PROJECT DELIVERY STRATEGY 1-1

1.2.1 Project Delivery Method 1-1

1.2.2 Technical Manager Meetings/Design Review Meetings 1-2

1.2.3 Design Sequencing 1-2

1.2.4 Value Engineering 1-2

1.2.5 Permits 1-3

1.3 PROJECT ROLES AND RESPONSIBILITIES 1-3

1.3.1 Environmental Protection Agency 1-3

1.3.2 US Magnesium 1-3

1.3.3 Engineering and Construction Contractors 1-4

1.4 DATA MANAGEMENT AND RECORDS RETENTION 1-4

1.5 ORGANIZATION OF WORK PLAN 1-4

2.0 BACKGROUND SUMMARY 2-1

2.1 LOCATION 2-1

2.2 RCRA CARVE-OUT PROJECT AREA 2-1

3.0 PROJECT ELEMENTS 3-1

3.1 PROJECT ELEMENTS 3-1

3.2 COMPLETION CRITERIA 3-2

4.0 DESIGN CONSIDERATIONS AND DELIVERABLES 4-1

4.1 WASTEWATER DISCHARGE PIPING SYSTEM PLAN 4-1

4.1.1 Design Considerations 4-1

4.1.2 Design Deliverables 4-2

4.2 DITCH ABANDONMENT, CONSOLIDATION AND CAPPING PLAN 4-3

4.2.1 Design Considerations 4-3

4.2.2 Design Deliverables 4-6

4.3 SANITARY LAGOON REFURBISHMENT OR CAPPING PLAN 4-7

4.3.1 Design Considerations 4-7

4.3.2 Design Deliverables 4-7

4.4 INSTITUTIONAL CONTROL IMPLEMENTATION AND ASSURANCE PLAN 4-8

4.5 SEMI-ANNUAL REPORTS 4-8

4.6 CORRECTIVE MEASURES IMPLEMENTATION AND FINAL REPORTS 4-9

Table of Contents

Page

5.0 PROJECT SCHEDULE 5-1

APPENDIX

A ALS Environmental Laboratory Method EPA TO-15 VOC List and Detection Limits

FIGURES

1 Site Location Map 2-2
2 RCRA Carve-Out Cleanup Project Area Map 2-3
3 Preliminary Design for New Wastewater Piping System and Ditch Abandonment and Capping 4-10
4 Soil Gas Probe Locations for Soil Vapor Assessment 4-11
5 Preliminary RCRA Carve-Out Cleanup Project Schedule ..... follows Section 5.0

1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVE

This Corrective Measures Implementation (CMI) Work Plan has been prepared by US Magnesium LLC (USM) and presents the organization, objectives, and activities associated with designing the work elements to implement the RCRA Carve-Out Cleanup Project ("Project") pursuant to the U.S. Environmental Protection Agency (EPA) Region 8 Administrative Order on Consent (AOC), U.S. EPA Docket No. RCRA Docket No. RCRA-08-2016-0004, effective August 3, 2016.

The objective of the Project design phase is to prepare engineering plans and technical specifications that meet EPA's requirements for approval and are suitable for procuring construction materials and contractors to implement the Project. In accordance with the AOC, this CMI Work Plan outlines the design, construction, operation, maintenance and monitoring of the activities to implement the Project and includes a schedule for expeditious implementation of the Project.

Although this CMI Work Plan describes the process and strategy for preparing the design for the Project, it does not contain design details such as design calculations, assumptions, technical specifications, etc. As contemplated in the AOC, these details will be developed during the actual design process by the design team and will be included in the design submittals. Moreover, this CMI Work Plan presents the design approach and process as it is anticipated at this stage. Components of the design approach and process may change or evolve as the design progresses and additional data and detailed design information are developed. Any unanticipated changes to the design approach or processes described in this CMI Work Plan identified during its implementation will be communicated and resolved with EPA. Additional details regarding the project delivery strategy for the Project are presented below.

1.2 PROJECT DELIVERY STRATEGY

The overall strategy is to deliver the Project efficiently, cost-effectively, and in a manner that satisfies the concepts and requirements described in the AOC. The project delivery strategy includes the following components:

1.2.1 Project Delivery Method

The Project will be a traditional design-bid-build project delivery. The design team (described below in Section 1.3) will prepare the design and bid documents in accordance with this CMI Work Plan. These design/bid documents then will be used to obtain bids from qualified suppliers and contractors, and the selected contractor(s) will perform the construction activities. During Project construction, the design team or other qualified engineering or construction-

manager entity may act as USM's agent to review the progress of the work and confirm that each Project element is constructed in accordance with its approved design.

1.2.2 Technical Manager Meetings/Design Review Meetings

Throughout the Project design process, periodic meetings or teleconferences will be held with EPA, other agency personnel as requested by EPA, and the design-team project manager and technical staff, as appropriate, to review progress and important or significant technical issues, discuss design parameters and assumptions, and discuss potential design changes. The goals of these meetings are to keep the lines of communication open and to get EPA, and other agency personnel designated by EPA, input and consensus early in the Project design process (as opposed to relying solely on the traditional review/response-to-comments approach to communicate and address potential issues).

In addition to the technical manager meetings discussed above, design review meetings or teleconferences will be scheduled within one week (if possible) of receiving EPA comments on the Project design submittals. The purpose of the design review meetings is to allow the design team the opportunity to seek clarification on EPA comments and to resolve any significant comments prior to initiating modification of the designs.

1.2.3 Design Sequencing

The Project design will be sequenced to mirror the anticipated chronological order (or phases) of the Project construction as set forth in the AOC Statement of Work (SOW). For example, the new wastewater discharge piping system will be first in the construction sequence for the Project and the plans for that work accordingly will be the first developed during the design. In addition, design elements that are sufficiently defined will proceed earlier in the design process, whereas those elements potentially impacted by data gaps or where performance testing may be necessary to define / refine the design basis will progress after the needed design data or performance testing results are obtained. This staggered design effort is expected to streamline the overall schedule for completion of the Project. The anticipated Project schedule is presented in Section 5.0.

1.2.4 Value Engineering

Construction contractors and outside technical experts will be consulted during the design process to help identify procedures, processes, and construction techniques that could improve quality, or streamline implementation or future operation and maintenance of the Project. For example, construction contractors may be solicited at key points during the design process where it is determined that outside expertise would enhance the design and construction of the Project. The objective is to identify value-engineering ideas early such that they can be incorporated into the Project design.

1.2.5 Permits

Based on USM's review of the scope of the Project and development of the design considerations and criteria presented in Section 4.0, USM has not identified any federal, state, or local permits or approvals that will be required to complete the Project. If any permits are determined to be necessary during the detailed design and/or contractor procurement tasks, USM will submit timely and complete applications and take such actions as are necessary to obtain any such permits or approvals.

1.3 PROJECT ROLES AND RESPONSIBILITIES

The key personnel and their roles and responsibilities for design and implementation of the Project are presented below.

1.3.1 Environmental Protection Agency

EPA is the lead agency governing the design and construction of the Project. EPA is responsible for reviewing and approving all plans and deliverables related to implementing the Project. The EPA Project Manager is Mr. David Duster.

1.3.2 US Magnesium

USM is responsible for implementing the Project in accordance with the AOC. USM has overall responsibility for procuring consultants and contractors to perform the work, budgeting and securing the necessary funds, and assuring that the requirements of the AOC are met. The specific individuals involved and their respective roles are as follows:

Project Director. The USM Project Director is Mr. Tom Tripp. He will be responsible for the contractual commitments and for ensuring that necessary resources are dedicated to the project. He also will assure the technical, budget, and schedule requirements are met.

Project Manager. Mr. Rob Hartman will serve as the USM Project Manager. Mr. Hartman will be responsible for day-to-day communication with the Project Director as well as with the staff assigned to perform the various project tasks. As the USM Project Manager, he will define and clarify the scope of work and objectives for each major activity. Mr. Hartman has over 25 years of experience including 16 years in the mining and mineral processing industry as a project manager and remediation project director. His experience has focused on CERCLA Remedial Design and Remedial Action and emergency removal actions, RCRA waste unit closure and corrective action, and facility decommissioning and asset recovery.

Engineering Lead. The USM Engineering Lead will be Mr. Shane Ellis. He will be responsible for coordinating the necessary resources to accomplish the design of the various elements and to complete the Project design phase. He will ensure that the various plans and design submittals meet USM's requirements and good engineering practices, and will be the engineer of record for

assuring that construction of the Project elements meet the design. Mr. Ellis is a registered professional (civil) engineer (registered P.E. in Utah) with over 10 years of experience designing and overseeing construction of underground piping and backfill projects.

1.3.3 Engineering and Construction Contractors

In addition to its internal environmental, engineering and construction resources, USM may utilize qualified technical consulting, engineering, and construction firm(s) to prepare and/or review the designs and implement the Project.

1.4 DATA MANAGEMENT AND RECORDS RETENTION

During the design and implementation (construction) of the Project, USM will utilize existing data sources and acquire data and information to document successful completion of the Project and the requirements of Section VII (Work to be Performed) of the AOC. USM anticipates that the majority of the data and documentation will be generated and stored as electronic files. Consistent with USM's standard practice, uniquely identified file folders have been created for its engineering and environmental staff to store all data and documentation related to the Project on USM's secured server. That sever is backed up at least daily. Documents such as field notes that originate on hard copy will be scanned into electronic files for storage on the server and the originals will be maintained in hard copy file folders.

Until five years after the termination of the AOC, USM will retain, and will instruct its contractors and agents to preserve, all non-identical copies of all documents, records, or other information (including documents, records, or other information in electronic form) in its or its contractors' or agents' possession or control, or that come into its or its contractors' or agents' possession or control, and that relate in any manner to USM's performance of its obligations under the AOC. This information-retention requirement will apply regardless of any contrary corporate or institutional policies or procedures. At any time during this information-retention period, upon request by the EPA, USM will provide copies of any documents, records, or other information required to be maintained under the AOC.

1.5 ORGANIZATION OF WORK PLAN

The remainder of this Work Plan is comprised of the following sections:

- Section 2.0 presents a summary description of the site and the RCRA Carve-Out Project area.
- Section 3.0 presents a description of the Project elements.
- Section 4.0 describes the Project design considerations and contents of the design deliverables and reports.

- Section 5.0 presents a preliminary schedule for the design, design deliverables and Project implementation.

2.0 BACKGROUND SUMMARY

USM is a commercial producer of magnesium and magnesium alloys that operates a facility in Rowley, Tooele County, Utah. This section includes a summary of the site including the location and physical setting, and a description of the RCRA Carve-Out Project area. More detailed information is contained in the Corrective Measures Study, US Magnesium Facility, Proposed Filtration Plant Project Area, ERM, December 2015.

2.1 LOCATION

The USM plant is located in Rowley, Tooele County, Utah (see Figure 1). The USM plant is located in the Lakeside Valley adjacent to Stansbury Bay of the Great Salt Lake (GSL). The Site includes an active primary magnesium production facility, which has been in operation since 1972. The site encompasses portions of Lakeside Valley, the Lakeside Mountains to the west, the Great Salt Lake (GSL) to the north and northeast, and solar evaporation ponds in Stansbury Bay to the southeast. Elevations in the area surrounding the plant range from about 4,200 feet above mean sea level in the GSL lakebed and playa to over 6,500 feet above mean sea level in the Lakeside Mountains.

2.2 RCRA CARVE-OUT PROJECT AREA

The Project area encompasses the ditches and sanitary lagoon at the facility, as denoted in Appendix 1 (RCRA Carve-Out Cleanup Project Area Map) of the AOC, which is included as Figure 2 in this CMI Work Plan.

The Project area encompasses a portion of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Preliminary Remedial Investigation (PRI) Area 1 wastewater ditches including the Western Ditch, Central Ditch, Chlorine Ditch, and Main Ditch up to and including its intersection with the Current Wastewater Pond (CWP). The Project area also includes dredge spoil areas between the ditches where material from within the ditches may have been placed and the Former Boron Ditch area. The Project Area also includes the entire approximately 1.6 acre Sanitary Lagoon (PRI Area 3) located between the Central Ditch and the Chlorine Ditch.

Figure 1. Site Location Map

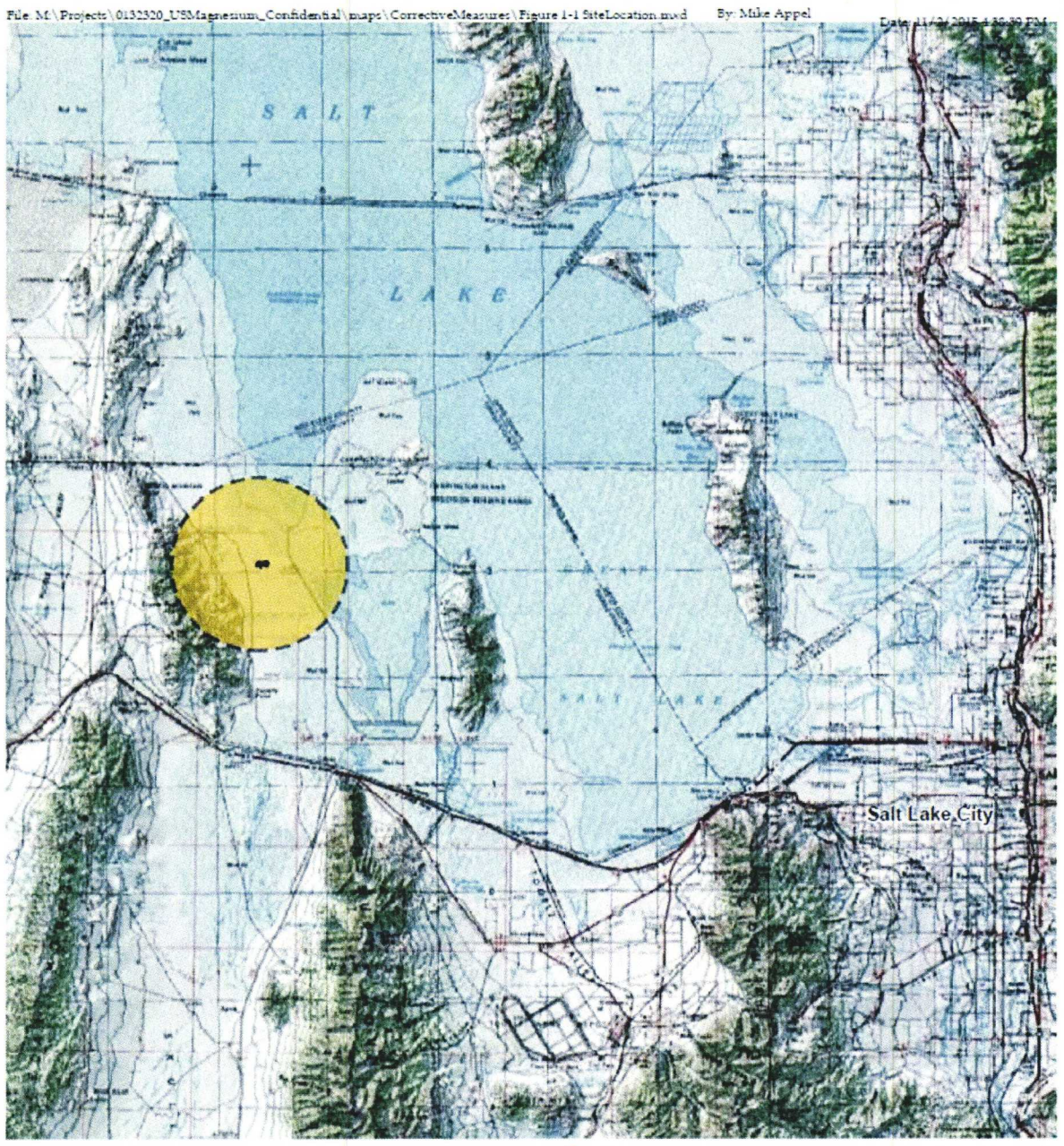
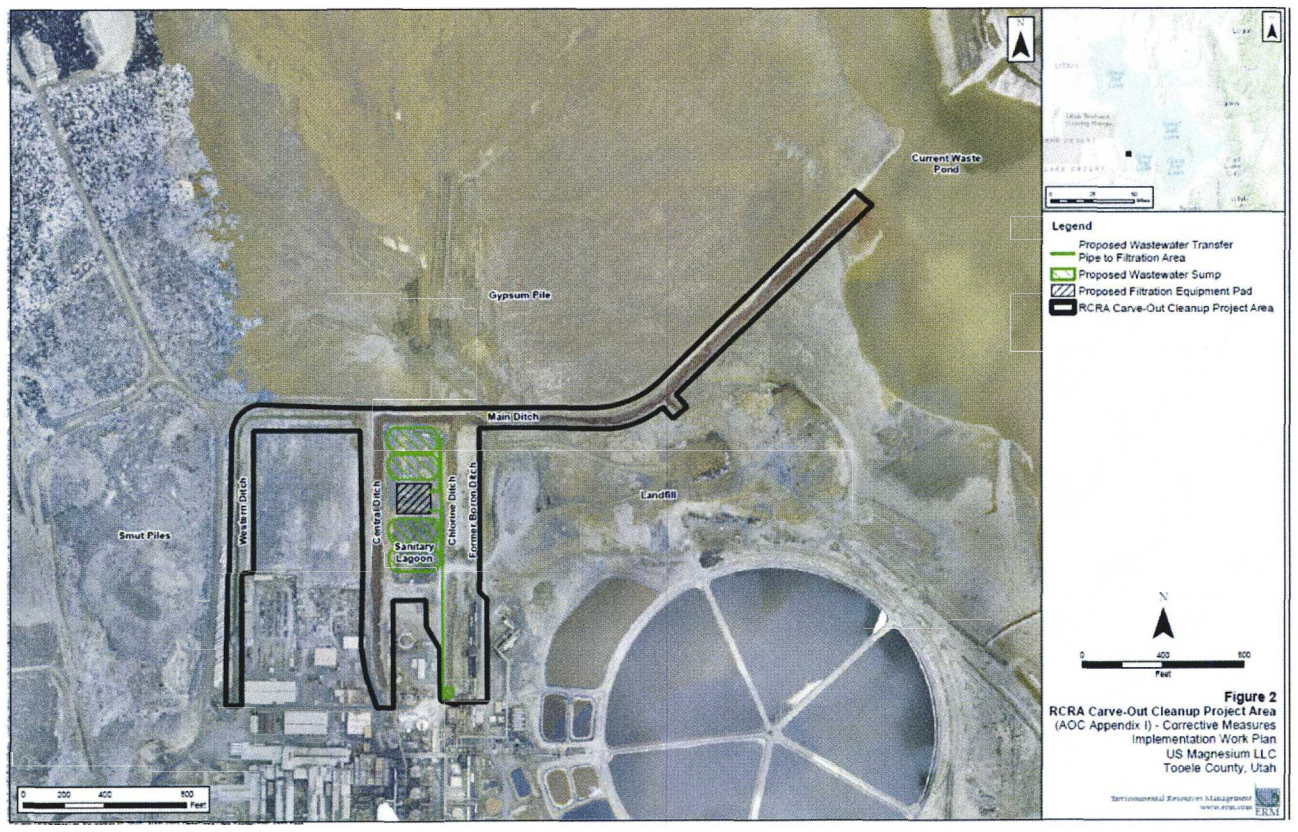


Figure 2. RCRA Carve-Out Cleanup Project Area Map (Area boundary from AOC Appendix 1)



3.0 PROJECT ELEMENTS AND COMPLETION CRITERIA

3.1 PROJECT ELEMENTS

As described in Section 26 of the AOC, the Project will consist of the following elements:

Wastewater Discharge Piping System

Wastewater currently discharged to the ditches will be conveyed to the CWP through pipes in accordance with a wastewater discharge piping system plan. This plan may include locating pipes within the boundaries of existing ditches.

Abandonment, Consolidation and Capping Wastewater Ditches

1. Abandon the wastewater ditches through backfilling and capping contaminated soils and sediments within or adjacent to the ditches. Dredge spoils adjacent to the ditches will be placed into the ditch network. Contaminated soils, if any, in other areas within the RCRA Carve-Out Cleanup Project Area, including the future filtration plant area, may be placed into the ditch network or, as described in task 3 below, capped, to be determined during the corrective measures design. The ditches will be backfilled to grade and capped using clean clayey soils extracted from on-site borrow pits or other suitable on-site sources, or other suitable barrier.

2. Excavate contaminated sediments in the outer main ditch for consolidation with the contaminated ditch sediments within the central ditch network sediments. Depth and lateral area will be determined during the corrective measures design using information gathered from CERCLA investigative studies. EPA will work with USM to develop a suitable protocol that will appropriately define the amount of confirmatory sampling. The activities called for in this subparagraph will not be required if the Utah Division of Water Quality and EPA have approved a retrofit option for the CWP before these activities are scheduled to occur under this CMI Work Plan.

3. Install a minimum 2-foot thick cap using clayey soils extracted from on-site borrow pits or other suitable on-site sources or other suitable barrier on the closed ditches, and, if applicable, on other contaminated areas within the RCRA Carve-Out Cleanup Project Area, to eliminate burrowing animals and minimize water infiltration. Cap design to reduce infiltration must include topographical design to promote runoff, and run-on controls. Capping necessary to minimize water infiltration will not be required if the Utah Division of Water Quality and EPA have approved a retrofit option for the CWP before these activities are scheduled to occur under this CMI Work Plan.

4. Develop and implement soil vapor assessment and, if necessary, mitigation.

Sanitary Lagoon Refurbishment or Capping

The sanitary lagoon will be either refurbished to remain in operation or abandoned, to be determined during the corrective measures design. Dredge spoils adjacent to the sanitary lagoon will be placed into the ditch network. If the sanitary lagoon is refurbished, the corrective measures design will specify requirements for closure of the sanitary lagoon at the end of its operation. If the sanitary lagoon is abandoned, it will be closed in place through backfilling and capping, or contaminated soils in the sanitary lagoon will be excavated and placed in the ditch network, to be determined during the corrective measures design.

Institutional Controls

Establish institutional controls and post suitable warning signs to manage risk within the RCRA Carve-Out Cleanup Project area.

3.2 COMPLETION CRITERIA

The AOC specifies the work requirements, but does not include any narrative or numeric cleanup objectives. For most of the Project elements, the cleanup objectives will be achieved when each element has been implemented (construction completed) in accordance with the EPA-approved plans and specifications. The completion criteria for the Project elements are summarized below.

Wastewater Discharge Piping System

- Completion of construction in accordance with design, specifications and quality control requirements in the EPA-approved wastewater discharge piping system plan.

Abandonment, Consolidation and Capping Wastewater Ditches

- Demonstration of achievement of the soil cleanup objectives for the excavation of dredge spoils and contaminated soil within the Project area by confirmatory soil sampling and analysis in accordance with the Sampling and Analysis Plan (SAP). The SAP will specify numeric soil cleanup objectives that will be met during implementation of this element of the Project.

- If required, demonstration of achievement of the cleanup objectives for the excavation of contaminated sediments in the outer main ditch for consolidation within the central ditch network within the Project area by confirmatory sampling and analysis in accordance with the SAP. The SAP will specify numeric outer main ditch sediment cleanup objectives that will be met during implementation of this element of the Project.

- Completion of construction in accordance with design, specifications and quality control requirements in the EPA-approved ditch abandonment, consolidation and capping plan.

- Adherence to the post-implementation monitoring and maintenance plan for monitoring the integrity of the soil cap will be documented in the Final Report described in Section 4.6.

Sanitary Lagoon Refurbishment or Capping

- Demonstration of achievement of the soil cleanup objectives for the excavation of contaminated soil within the sanitary lagoon by confirmatory soil sampling and analysis in accordance with the SAP. The SAP will specify numeric soil cleanup objectives that will be met during implementation of this element of the Project.

- Completion of construction in accordance with design, specifications and quality control requirements in the EPA-approved sanitary lagoon refurbishment/closure plan.

Institutional Controls

- Completion of surveying and documentation of the limits and posting of warning signs around the perimeter of the Project area soil cap consistent with the EPA-approved Institutional Control Implementation and Assurance Plan (ICIAP).

- Adherence to the post-implementation assurance provisions of the ICIAP will be documented in the Final Report described in Section 4.6.

4.0 DESIGN CONSIDERATIONS AND DELIVERABLES

This section provides a summary of the design considerations, including information necessary to finalize the Project design, and a list of the deliverables (e.g., plans, specifications) for the four Project elements described in Section 3.0.

4.1 WASTEWATER DISCHARGE PIPING SYSTEM PLAN

4.1.1 Design Considerations

The primary design considerations and criteria are:

- Pipe sizing based on current and projected maximum combined wastewater discharge (flow) to the CWP;
- Configuration for connecting the multiple current outfall pipes to the new wastewater piping to the CWP that will minimize potential for operational upsets, leakage and maintenance;
- Alignment of new piping that will allow gravity flow to the CWP;
- Piping and valving that will allow for possible separation of non-acidic wastewater from acidic wastewater and filtration of acidic wastewater streams;
- Arrangement for connections and alignment of new piping to allow pipe access for inspections and maintenance;
- Allow for integration/connection of the new piping with the design (e.g., location, footprint, piping and access) of the proposed wastewater filtration treatment plant; and
- System design that is cost-effective.

Based on USM's extensive experience in handling acidic wastewaters, high density polyethylene (HDPE) pipe is compatible with the acidic wastewater streams and will be specified for the new piping. USM has completed a preliminary design for pipe alignment and sizing. *See* Figure 3. However, before completing the final piping system design, USM needs to verify flow estimates.

USM has ordered and will be installing flow measurement equipment to measure the current combined wastewater flow in the main ditch to confirm or adjust the design basis for the pipe sizing. The wastewater flow will be measured using a Cutthroat flume. The flume will be placed in an excavated channel next to the existing channel, instrumentation installed and checked, and then the downstream end of the new channel will be excavated out to the main ditch. Finally, the upstream end will be breached to allow flow from the main channel into the new channel and the

main channel diked off. The sonic water-level detector/datalogger will be set to log at 15- or 30-minute intervals to evaluate peak short-term flow. USM plans to install the flume and flow measurement instrumentation in August 2017 and log flow data over about a 30-day period.

In November 2015, USM performed a LIDAR topographic survey of the site. The topographic map elevations are accurate to about 0.2 feet. The topographic map will aid in designing the alignment of the new piping to provide for gravity flow to the CWP.

4.1.2 Design Deliverables

The anticipated wastewater piping plan design deliverables include but are not limited to:

- Plan and profiles for the new piping;
- Details for the connections of the current piping to the new piping and valve arrangements;
- Calculations or published documentation supporting pipe sizing and manufacturer cut-sheets for valves;
- Specifications and quality control testing requirements for construction of the piping and connections;
- A construction plan describing the construction scope, planned sequence, and preliminary schedule;
- If the new piping alignment includes a section(s) of piping within the boundaries of the existing ditches, the construction plan will include integrating and coordinating the schedule for installation of the new wastewater piping with abandonment and capping of that section(s) of the existing ditches.

The draft wastewater discharge piping system plan (design deliverable) will be developed and submitted to EPA at a pre-final (90%) level. USM is not planning to prepare an Operation and Maintenance Plan (OMP) for the new wastewater piping because operation and maintenance will become part of the facility operations when the new piping begins to convey wastewater from the plant to the CWP. The preliminary schedule for submittal of the draft wastewater discharge piping system plan to EPA is presented in Section 5.0.

USM anticipates that a minimal volume of waste will be generated during the Project. Wastes that may be generated during implementation of the Wastewater Discharge Piping System Plan are expected to be limited to packaging materials (e.g., wood pallets, cardboard, plastic, strapping) and HDPE pipe scraps (e.g., pipe off cuts, trimming and bead shavings). These wastes are expected to be non-hazardous wastes and will be disposed in the on-site landfill as trash.

4.2 DITCH ABANDONMENT, CONSOLIDATION AND CAPPING PLAN

As specified in the AOC, if the Utah Department of Environmental Quality (DEQ), Division of Water Quality (DWQ) and EPA have approved a retrofit option for the wastewater pond, then (1) the outer main ditch sediments will not need to be excavated and consolidated in the central ditch network prior to capping and (2) the 2-foot soil cap over the closed ditches does not need to minimize water infiltration. Thus, the status of the Groundwater Discharge Permit (GWDP) and design for retrofitting the wastewater pond are overarching considerations for the Ditch Abandonment, Consolidation and Capping Plan. The Plan will also take into consideration the design (e.g., location, footprint, piping and access) of the proposed wastewater filtration treatment plant.

4.2.1 Design Considerations

The primary design considerations and criteria are:

- Volume of fill material required to backfill the Western Ditch, Central Ditch and Chlorine Ditch up to the Main Ditch;
- Length of the section of the Main Ditch that will be abandoned and volume of fill required;
- Volume of dredge spoils adjacent to the ditches that will be used as backfill in the ditches;
- Potential volume of contaminated soil in other portions of the Project area, including contaminated soil within the sanitary lagoon, that may be used as backfill in the ditches;
- Potential volume of contaminated sediments in the outer Main Ditch that may be consolidated into the Central Ditch network as backfill;
- Source and volume of additional fill material that may be required to backfill the ditches to the design subgrade elevation (i.e., general fill grade prior to constructing the soil cap);
- Source and volume of the soil that will be used to construct the 2-foot soil cap over the backfilled ditches and, if applicable, on other contaminated areas within the Project area. Representative samples of the identified borrow soil will be collected and analyzed for site-related COPCs to assure the soil is suitable for capping. The samples will be collected, managed and analyzed consistent with the CERCLA Remedial Investigation (RI) protocols;
- The soil cap will be designed to minimize the potential for any burrowing animals;

- The trench backfill and soil cap will be designed to drain precipitation laterally off the capped areas and minimize potential run-on of precipitation;
- The soil cap will be designed to minimize long-term maintenance; and
- Based on the results of the soil vapor assessment, if needed, a soil vapor mitigation plan will be integrated into the capping plan.

As described above, the 2015 LIDAR-generated topographic map will be used to calculate the volumes of materials using a computer aided design (CAD) software program such as AutoCAD® Civil 3D®. In addition, USM engineering staff have performed ground-based topographical surveys of the bottom of the wastewater ditches to obtain those elevations. A CAD program will also be used to design the grade for the backfill and capping to drain precipitation laterally off the capped areas.

The preliminary estimate of the fill volume required to backfill the wastewater ditches level to within 2 feet of the surrounding grade is approximately 80,000 cubic yards (CY) as shown on Figure 3. As part of finalizing the design, USM will estimate the volume of fill available from consolidation of the dredge spoils, contaminated soil and sediments from within the Project area. Other fill sources, such as the adjacent gypsum pile, will be identified and evaluated to account for a shortfall in the volume of backfill in the ditches. The grading and capping plan will also account for any fill volume surplus or shortfall related to the sanitary lagoon refurbishment as described in Section 4.3 below.

USM has a current borrow pit of clayey silt soil that is a potential source for the soil cap. The preliminary estimate of the soil volume required to construct the 2-foot soil cap over the wastewater ditches is approximately 45,000 cubic yards (CY). The estimated volume of cap soil is expected to be available from the current borrow pit. Samples from the potential sources of cap material will be collected and submitted for physical testing to determine the maximum dry density, grain size distribution and Atterberg limits. Additional physical testing may be performed to obtain site-specific input parameters to model predicted infiltration through the cap using computer-modeling software such as UNSAT-H or HYDRUS® if the cap is required to minimize water infiltration.

Monitoring and Maintenance Plan

A monitoring and maintenance plan will be developed that will assure the integrity of the soil cap in the Project area. Visual inspections of the cap surface will include checking for any evidence of burrowing animals and erosion from precipitation run-on or run-off erosion. Consistent with the Institutional Control Implementation and Assurance Plan described in Section 4.4 below, the visual inspections will also include checking for any unauthorized ground disturbance or excavation within the capped area and that the warning signs are present and

legible. The monitoring and maintenance plan will including a description of the conditions that will require maintenance and, if triggered, the required maintenance actions.

Soil Vapor Assessment

As required by the AOC, USM will complete a soil vapor assessment within the Project area within ninety days after EPA approval of this CMI Work Plan. The assessment will focus on the area proposed for the wastewater filtration plant because volatile organic compound (VOC) vapors, if present in soil pore space, could accumulate beneath the structures and result in potential VOC exposure to workers at the wastewater filtration plant.

USM will perform soil gas sampling by installing two temporary shallow soil gas probes in the proposed location of the wastewater filtration plant as shown on Figure 4. Gas vapor probes (GVPs), such as the AMS GVP (http://www.ams-samplers.com/hand-tooling/soil-gas-samplers/original-gvp-kit.html) will be installed to a depth of about 1.5 feet. Soil gas samples will be collected and analyzed in accordance with EPA Method TO-15 per EPA's *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Compendium Method TO-15, Determination Of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography / Mass Spectrometry* (GC/MS) (EPA/625/R-96/010b, January 1999) and *Supplement to EPA Compendium Method T0-15. Reduction of Method Detection Limits to Meet Vapor Intrusion Monitoring Needs* (ManTech Environmental Technology, Inc. and National Exposure Research Laboratory, U.S. Environmental Protection Agency, Undated).

The Method TO-15 Summa canisters will be connected to the GVPs and set to sample for a 24-hour period. The samples will then be submitted to the ALS Environmental (ALS) laboratory in Salt Lake City, Utah for analysis. ALS is a NELAC accredited laboratory that provides environmental analytical services and, specifically, routinely analyzes gas samples following EPA Method TO-15.

Based on prior sampling of the wastewater ditch sediments for VOCs, the results for sediment sample DMA-Sed-PRI1-2 were reviewed to identify soil vapor constituents of potential concern (SVCOPCs). The location of sample DMA-Sed-PRI1-2 is shown on Figure 4. Sediment VOC concentrations greater than 100 micrograms per kilogram (ug/kg) were reported in sample DMA-Sed-PRI1-2 for the following:

- Bromodichloromethane
- Bromoform
- Carbon tetrachloride
- Dibromochloromethane
- Tetrachloroethene

The soil gas samples will be analyzed for the full list of the EPA Method TO-15 VOCs, which includes the SVCOPCs listed above. The full list of the EPA Method TO-15 VOCs and ALS's Method Detection Limits (MDLs) and Reporting Limits(s) are contained in Appendix A.

Following receipt of the laboratory results for the SVCOPCs, USM will evaluate the results and provide the results to EPA. Depending on the results, USM, in consultation with EPA, may propose additional sampling rounds and/or sample locations. Ultimately, USM will consult with EPA regarding the results of the soil vapor assessment and determine if a soil vapor mitigation plan is warranted.

4.2.2 Design Deliverables

- Plan(s) and profiles for the consolidation of dredge spoils (and, if required, contaminated sediments from the outer Main Ditch) into the central ditch network, backfilling and capping the ditches;
- Specifications, quality control testing requirements and a construction quality assurance plan for consolidation, backfilling and capping;
- A SAP for confirmation sampling after excavation of dredge spoils adjacent to the ditches and contaminated soil in other portions of the Project area have been consolidated as fill in the ditches. The SAP will include proposed numeric cleanup criteria for the constituents of potential concern (COPC) identified in the dredge spoils and Project area soil based on prior sampling and analytical results;
- A construction plan describing the construction scope, planned sequence, and preliminary schedule;
- A monitoring and maintenance plan for monitoring the integrity of the soil cap, including a description of the conditions that will require maintenance actions;
- If the plan includes consolidation of contaminated sediments in the outer Main Ditch into the central ditch network as backfill, a SAP for confirmation sampling in the outer Main Ditch, including proposed numeric cleanup criteria for the constituents of potential concern (COPC) identified in the outer Main Ditch sediments based on prior sampling and analytical results, will be included in the design submittal; and
- If determined to be warranted, a soil vapor mitigation plan.

The draft ditch abandonment, consolidation and capping plan (design deliverable) will be developed and submitted to EPA at a pre-final (90%) level. The preliminary schedule for

submittal of the draft ditch abandonment, consolidation and capping plan to EPA is presented in Section 5.0.

USM anticipates that a minimal volume of waste will be generated during the Project. Wastes that may be generated during implementation of the Ditch Abandonment, Consolidation and Capping Plan are expected to be limited to disposable personal protective equipment and /or sampling equipment (e.g., latex/nitrile gloves, soil gas probe sample tubing). These wastes are expected to be non-hazardous wastes and will be disposed in the on-site landfill as trash.

4.3 SANITARY LAGOON REFURBISHMENT OR CAPPING PLAN

4.3.1 Design Considerations

Currently USM is planning to refurbish and continue to use the sanitary lagoon; therefore, the design considerations are focused on that option. The capacity of the current lagoon is greater than necessary to contain the current and anticipated future flows to the lagoon. The refurbishment plan will take into consideration the minimum capacity (footprint and depth) of the lagoon, removal of contaminated sediments within the portion of the lagoon that will be retained and a closure plan for when it ceases operation. The plan will also take into consideration the design (e.g., location, footprint, piping and access) of the proposed wastewater filtration treatment plant. As described above, the 2015 LIDAR-generated topographic map will be used to design the grading for the lagoon retrofit using a computer aided design (CAD) software program such as AutoCAD® Civil 3D®.

4.3.2 Design Deliverables

- A plan for the refurbishment of the sewage lagoon, including drawings and profiles as appropriate;
- Specifications and quality control testing requirements;
- A SAP for confirmation sampling after excavation of contaminated soil within the sanitary lagoon. The SAP will include proposed numeric cleanup criteria for the constituents of potential concern (COPC) identified in the sanitary lagoon soil based on prior sampling and analytical results;
- A construction plan describing the construction scope, planned sequence, and preliminary schedule; and
- A closure plan for when the sanitary lagoon ceases operation.

The draft sanitary lagoon refurbishment/closure plan (design deliverable) will be developed and submitted to EPA at a pre-final (90%) level. The preliminary schedule for submittal of the draft sanitary lagoon refurbishment/closure plan to EPA is presented in Section 5.0.

USM anticipates that a minimal volume of waste will be generated during the Project. Wastes that may be generated during implementation of the Sanitary Lagoon Refurbishment or Capping Plan are expected to be limited to vegetative clearing (e.g., trees, brush). These wastes are expected to be non-hazardous wastes and will be disposed in the on-site landfill as trash.

4.4 INSTITUTIONAL CONTROL IMPLEMENTATION AND ASSURANCE PLAN

The overall objective of the institutional controls for the Project area is to prevent unintended disturbance of the soil cap and potential exposure to the underlying contaminated soil and fill materials. USM will prepare an ICIAP for the Project area that will include provisions for:

- Documenting the as-built construction and limits of the Project area soil cap;
- Prohibiting disturbance or excavation into the capped area except if necessary to maintain the cap or install underground utilities within the capped area;
- Procedures for any excavation within the capped area and requirements for managing fill removed from beneath the cap and re-construction of the soil cap; and
- Posting warning signs around the perimeter of the soil-capped Project area.

USM will submit the draft ICIAP to EPA concurrently with the draft ditch abandonment, consolidation and capping plan (design deliverable) consistent with the schedule presented in Section 5.0.

4.5 SEMI-ANNUAL REPORTS

On or before January 31st and July 31st of each year, and continuing until termination of the AOC pursuant to Section XVII (Termination and Satisfaction), USM will submit a report for the Project for the preceding six months that will include:

a. the status of any construction or compliance measures;
b. completion of milestones;
c. problems encountered or anticipated, together with implemented or proposed solutions;
d. status of permit applications;
e. reports to state agencies;
f. operation and maintenance difficulties or concerns;
g. a description of any non-compliance with the requirements of the AOC and an explanation of the violation's likely cause and of the remedial steps taken, or to be taken, to prevent or minimize such violation. If the cause of a violation cannot be fully explained at the time the report is due, USM will investigate the cause of the violation

and submit an amendment to the report, including a full explanation of the cause of the violation, within thirty (30) days of the date USM becomes aware of the cause of the violation.

As required by AOC Paragraph 39, the semi-annual reports will be signed by a USM official and will include the following certification:

> "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

4.6 CORRECTIVE MEASURES IMPLEMENTATION AND FINAL REPORTS

USM will prepare a Corrective Measure Implementation Report (CMIR) after the construction elements of the Project have been completed. The CMIR will include a summary of the construction of the corrective measures, including any modification(s) to the design and/or specifications, quality control and quality assurance documentation, confirmation sample analytical results, if required, and as-built drawings and photographs. The construction elements of the Project will be certified by the USM Engineering Lead (professional engineer [PE] registered in Utah) and/or a consulting PE registered in Utah if contracted for specific tasks or elements of the Project.

USM will submit the CMIR to EPA for review and approval. Upon EPA approval of the CMIR, it will be incorporated by reference into the Final Report that USM submits under paragraph 82 of the AOC. After USM has maintained satisfactory compliance with the AOC for a period of five (5) years, USM may request that the EPA issue a determination that USM has met the requirements of the AOC. Within thirty (30) days after USM requests such a determination, USM will submit to EPA the Final Report. At the time USM submits the Final Report, USM will document its compliance with the other conditions of paragraph 82 (continued compliance for five years and payment of any accrued stipulated penalties) for EPA to issue a determination that USM has met the requirements of the AOC.

Figure 3. Preliminary Design for New Wastewater Piping System and Ditch Abandonment and Capping

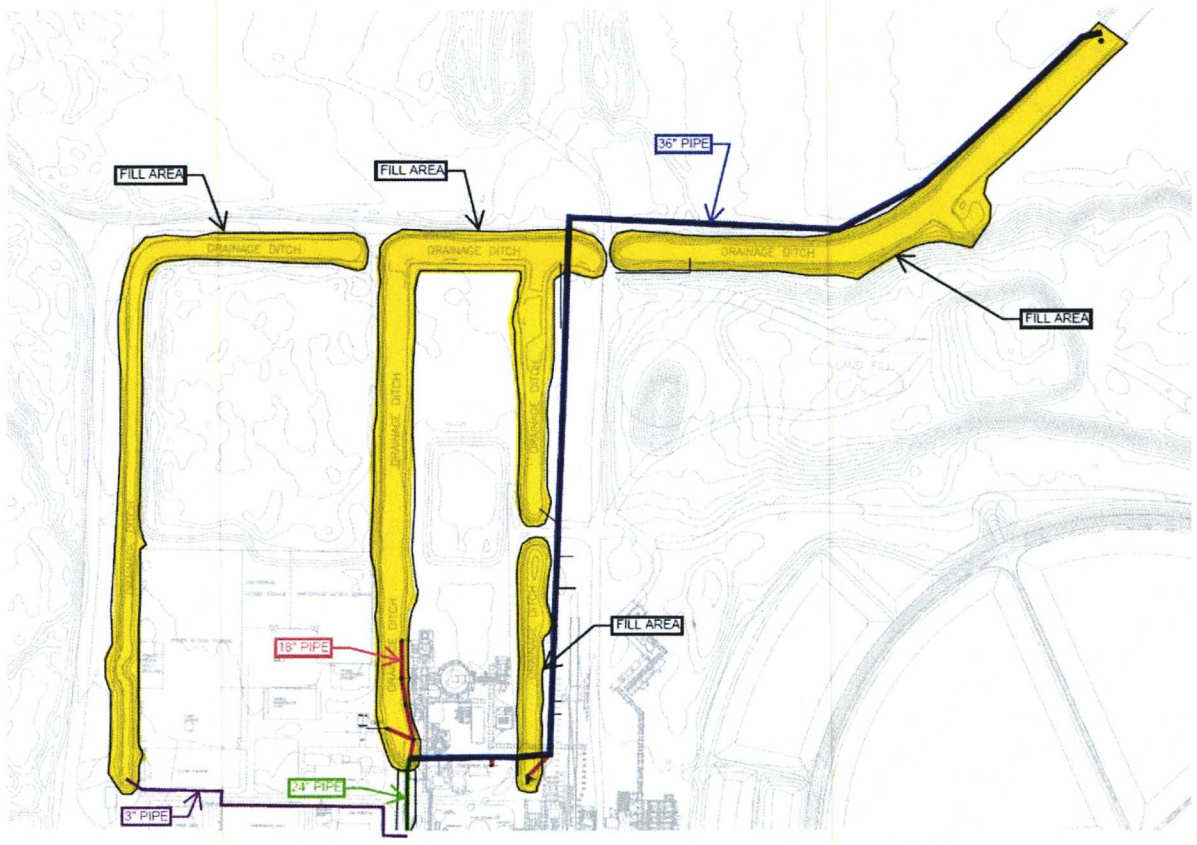
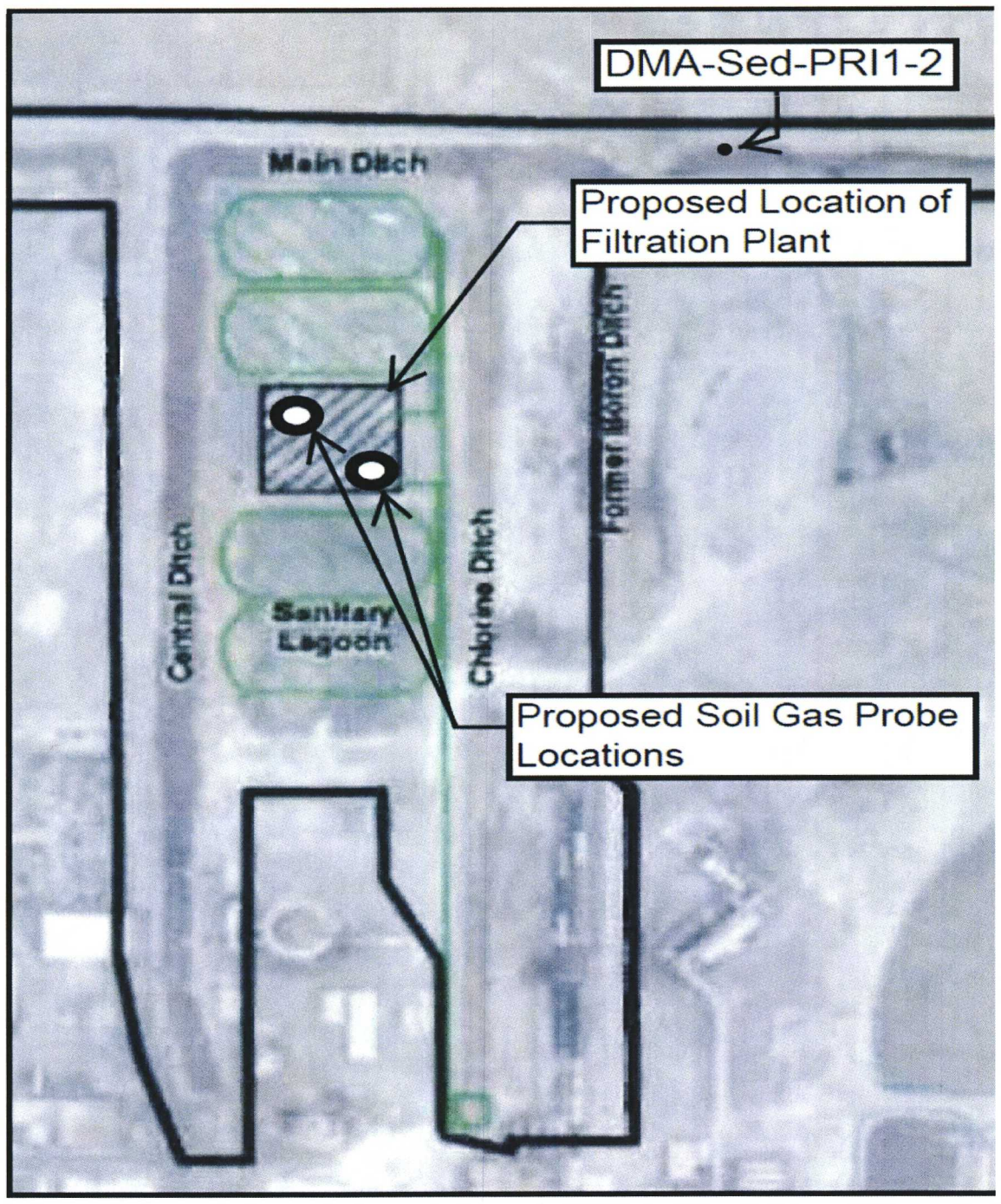


Figure 4. Soil Gas Probe Locations for Soil Vapor Assessment

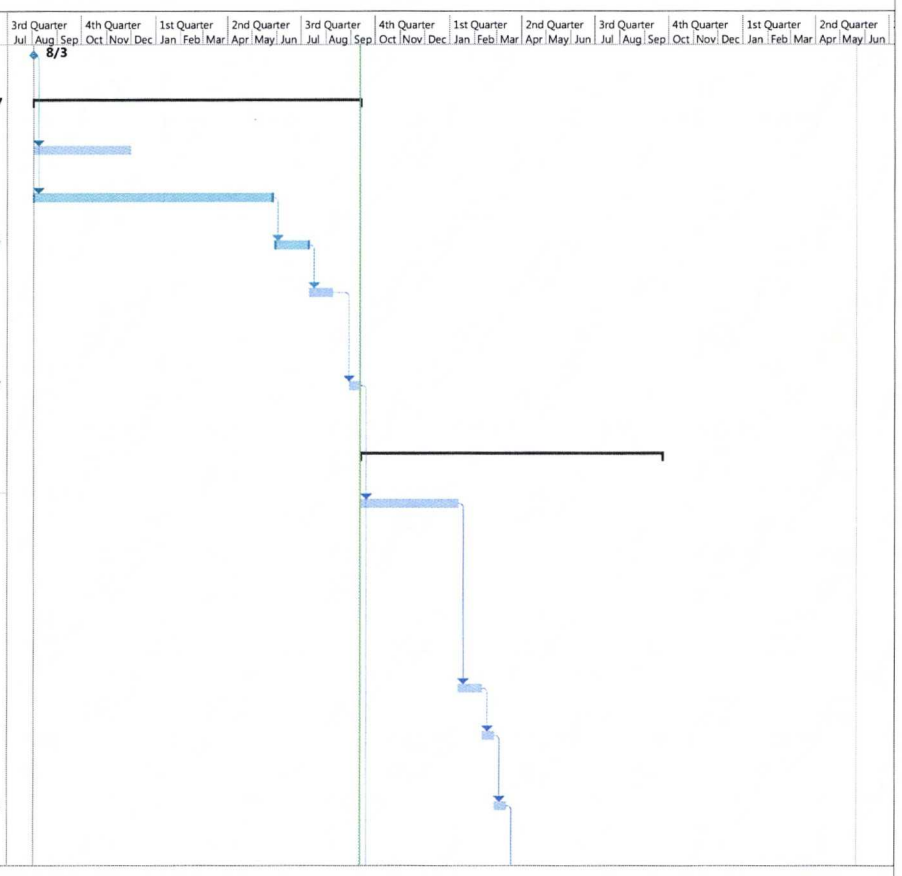


5.0 PROJECT SCHEDULE

The preliminary schedule for completing the design and implementing the Project is presented on Figure 5. The preliminary schedule is consistent with the AOC Appendix 2 SOW. The preliminary schedule for the Project will be updated with actual dates for completed tasks and projected dates for completion of in-progress tasks. The updated schedules will be submitted to EPA with the semi-annual reports described in Section 4.5.

Figure 5. Preliminary Project Schedule for the RCRA Carve-Out Cleanup Project

ID	Task Mode	Task Name	Duration	Start	Finish
1		Effective Date of AOC	0 days	Wed 8/3/16	Wed 8/3/16
2		**CMI Work Plan**	**407 days**	**Wed 8/3/16**	**Wed 9/13/17**
3		Select CMI Work Plan Contractor	120 days	Wed 8/3/16	Wed 11/30/16
4		Submit Draft CMI Work Plan	297 days	Wed 8/3/16	Fri 5/26/17
5		EPA Review of Draft CMI Work Plan	42 days	Tue 5/30/17	Mon 7/10/17
6		USM Reponses to EPA Comments and Submit Final Work Plan	30 days	Tue 7/11/17	Wed 8/9/17
7		EPA Review and Approval of CMI Work Plan	15 days	Wed 8/30/17	Wed 9/13/17
8		**Wastewater Discharge Piping System Plan**	**375 days**	**Thu 9/14/17**	**Sun 9/23/18**
9		USM Submit to EPA Draft Wastewater Discharge Piping System Plan to Convey Wastewater to the Pond, in Preparation of Ditch Closure	120 days	Thu 9/14/17	Thu 1/11/18
10		EPA Comments on Piping System Plan	30 days	Fri 1/12/18	Sat 2/10/18
11		USM Respond to EPA Comments and Submit Final Plan	15 days	Sun 2/11/18	Sun 2/25/18
12		EPA Approval of Final Piping System Plan	15 days	Mon 2/26/18	Mon 3/12/18

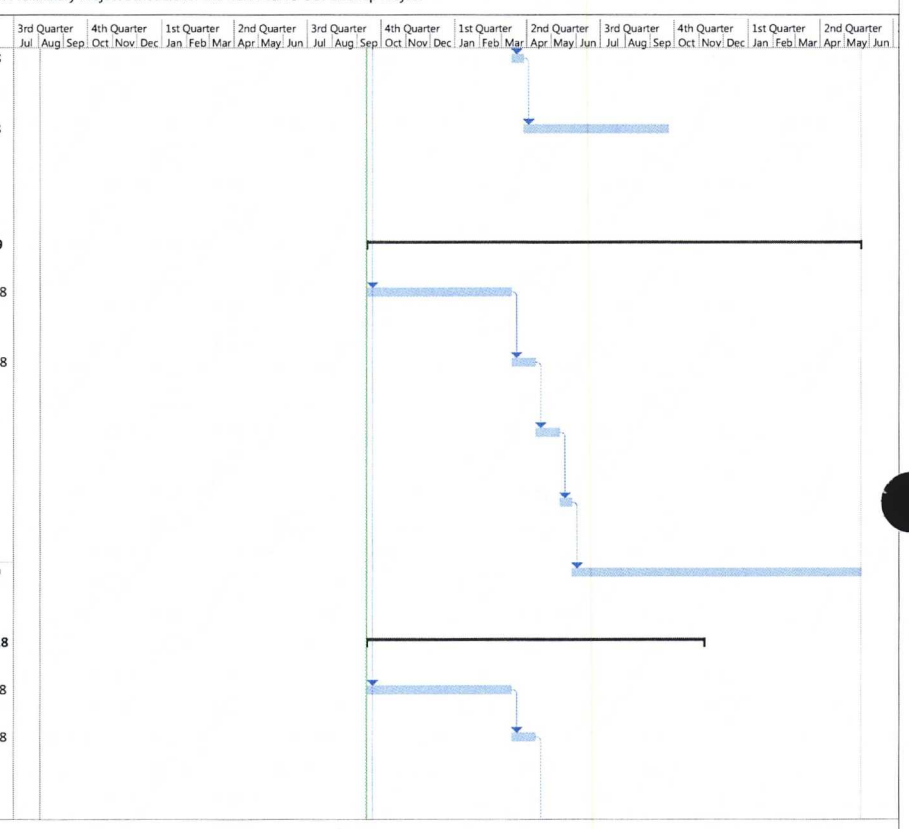


Project: US Mag AOC Schedule

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Figure 5. Preliminary Project Schedule for the RCRA Carve-Out Cleanup Project

ID	Task Mode	Task Name	Duration	Start	Finish
13		USM Order Pipe for Wastewater Discharge System	15 days	Tue 3/13/18	Tue 3/27/18
14		USM Complete Installation of Wastewater Discharge Piping System	180 days	Wed 3/28/18	Sun 9/23/18
15		**Ditch Closure Plan**	**615 days**	**Thu 9/14/17**	**Tue 5/21/19**
16		USM Submit Draft Ditch Closure Plan to EPA	180 days	Thu 9/14/17	Mon 3/12/18
17		EPA Comments on Draft Ditch Closure Plan	30 days	Tue 3/13/18	Wed 4/11/18
18		USM Respond to EPA Comments and Submit Final Plan	30 days	Thu 4/12/18	Fri 5/11/18
19		EPA Approval of Final Ditch Closure Plan	15 days	Sat 5/12/18	Sat 5/26/18
20		USM Complete Implementation of Ditch Closure Plan	360 days	Sun 5/27/18	Tue 5/21/19
21		**Capping Plan**	**420 days**	**Thu 9/14/17**	**Wed 11/7/18**
22		USM Submit Draft Capping Plan to EPA	180 days	Thu 9/14/17	Mon 3/12/18
23		EPA Provide Written Response to Draft Capping Plan	30 days	Tue 3/13/18	Wed 4/11/18

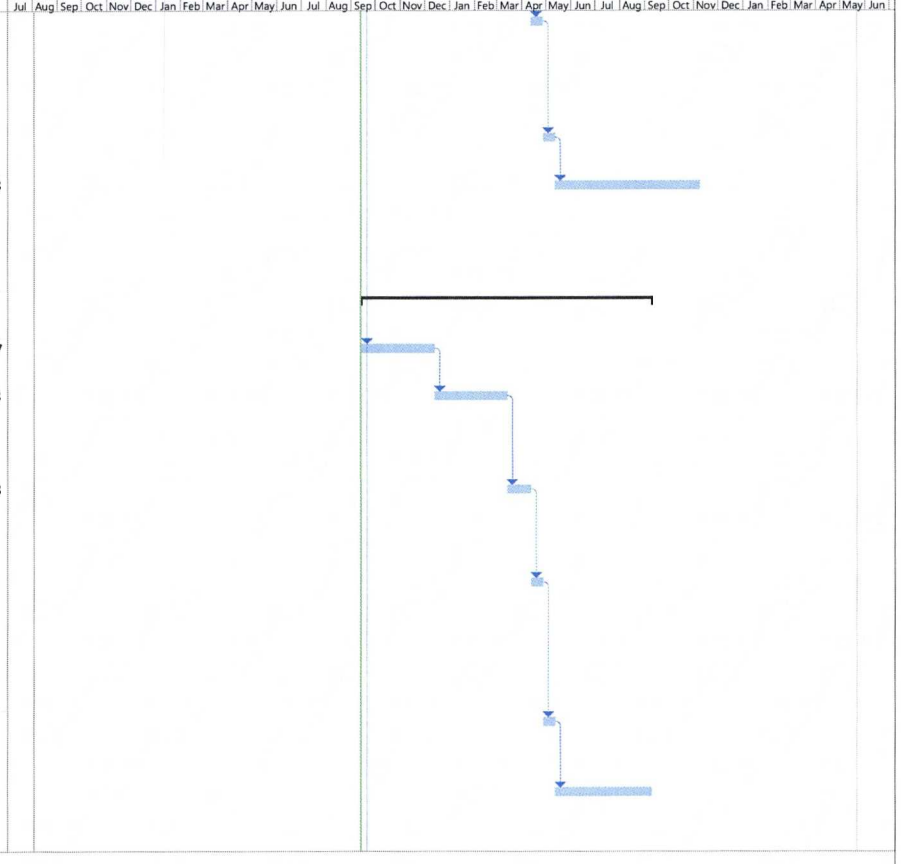


Project: US Mag AOC Schedule

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Figure 5. Preliminary Project Schedule for the RCRA Carve-Out Cleanup Project

ID	Task Mode	Task Name	Duration	Start	Finish
24		USM Provide Written Response to EPA Comments and Submit Final Capping Plan to EPA	15 days	Thu 4/12/18	Thu 4/26/18
25		EPA Approval of Final Capping Plan	15 days	Fri 4/27/18	Fri 5/11/18
26		USM Complete Capping of Closed Ditches and of Contaminated Soils in "Other Areas."	180 days	Sat 5/12/18	Wed 11/7/18
27		**Soil Vapor Assessment**	**360 days**	**Thu 9/14/17**	**Sat 9/8/18**
28		USM Complete Soil Vapor Assessment	90 days	Thu 9/14/17	Tue 12/12/17
29		If Needed, USM Submit Soil Vapor Mitigation Plan to EPA	90 days	Wed 12/13/17	Mon 3/12/18
30		EPA Provide Written Comments on Draft Soil Vapor Mitigation Plan	30 days	Tue 3/13/18	Wed 4/11/18
31		USM Provide Written Responses to EPA Comments and Submit Final Vapor Mitigation Plan	15 days	Thu 4/12/18	Thu 4/26/18
32		EPA Approve Final Soil Vapor Mitigation Plan	15 days	Fri 4/27/18	Fri 5/11/18
33		USM Implement Final Soil Vapor Mitigation Plan	120 days	Sat 5/12/18	Sat 9/8/18

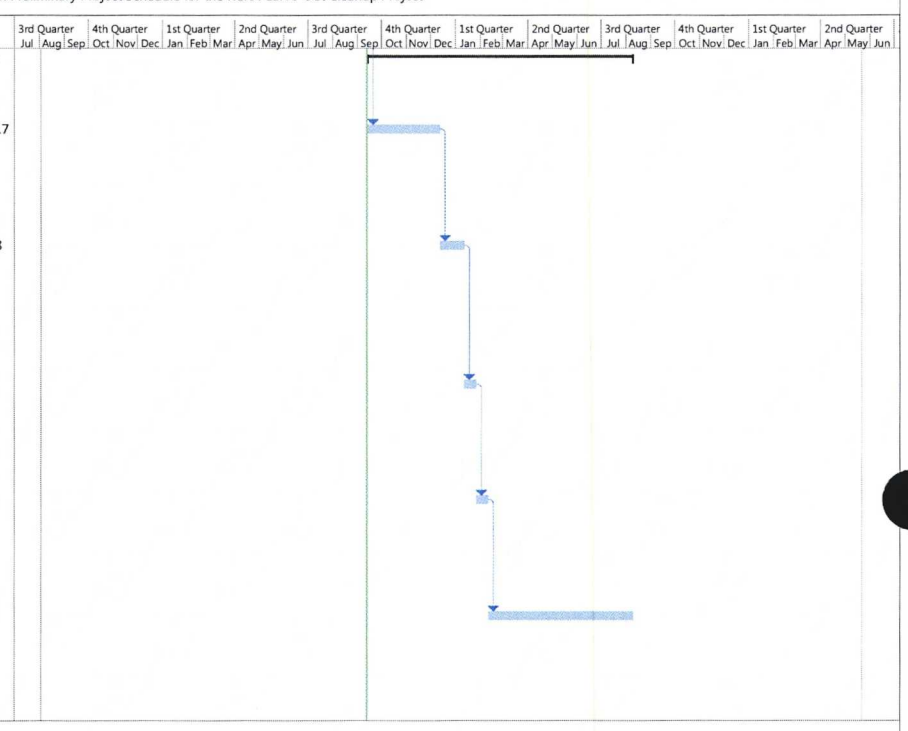


Project: US Mag AOC Schedule

Task | Project Summary | Manual Task | Start-only | Deadline
Split | Inactive Task | Duration-only | Finish-only | Progress
Milestone | Inactive Milestone | Manual Summary Rollup | External Tasks | Manual Progress
Summary | Inactive Summary | Manual Summary | External Milestone

Figure 5. Preliminary Project Schedule for the RCRA Carve-Out Cleanup Project

ID	Task Mode	Task Name	Duration	Start	Finish
34		**Sanitary Lagoon Refurbishment/ Closure Plan**	**330 days**	**Thu 9/14/17**	**Thu 8/9/18**
35		USM Submit Draft Plan for Refurbishment of Closure of Sanitary Lagoon to EPA	90 days	Thu 9/14/17	Tue 12/12/17
36		EPA Provide Written Comments on Draft Plan for Refurbishment/ Closure of Sanitary Lagoon	30 days	Wed 12/13/17	Thu 1/11/18
37		USM Provide Written Response to EPA on Draft Plan and Submit Final Plan to EPA	15 days	Fri 1/12/18	Fri 1/26/18
38		EPA Approve Final Plan for Refurbishment/ Closure of Sanitary Lagoon	15 days	Sat 1/27/18	Sat 2/10/18
39		USM Implement Final Plan for Refurbishment/ Closure of Sanitary Lagoon	180 days	Sun 2/11/18	Thu 8/9/18



Project: US Mag AOC Schedule

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

APPENDIX A

ALS Environmental Laboratory Method EPA TO-15 VOC List and Detection Limits

ALS Environmental - Salt Lake City
Detection Limits / Control Limits

Method: EPA TO-15
Matrix: Air

		Detection Limits			Control Limits Historical/Performance			
Compound	CAS Number	MDL	RL	Units	LCL	UCL	RPD	
Dichlorodifluoromethane	75-71-8	0.15	0.5	ppb				
Methyl chloride	74-87-3	0.15	0.5	ppb				
Freon 114	76-14-2	0.15	0.5	ppb				
Vinyl chloride	75-01-4	0.15	0.5	ppb				
1,3-Butadiene	106-99-0	0.15	0.5	ppb				
Bromomethane	74-83-9	0.15	0.5	ppb				
Ethyl chloride	75-00-3	0.15	0.5	ppb				
Freon 11	75-69-4	0.15	0.5	ppb				
Freon 113	76-13-1	0.15	0.5	ppb				
1,1-Dichloroethene	75-35-4	0.15	0.5	ppb				
Acetone	67-64-1	0.3	1	ppb				
Carbon disulfide	75-15-0	0.15	0.5	ppb				
Methylene chloride	75-09-2	0.15	0.5	ppb				
trans-1,2-Dichloroethene	156-60-5	0.15	0.5	ppb				
Methyl t-butyl ether	1634-04-4	0.15	0.5	ppb				
Vinyl acetate	108-05-4	0.2	0.5	ppb				
Methyl ethyl ketone	78-93-3	0.15	0.5	ppb				
cis-1,2-Dichloroethene	156-59-2	0.15	0.5	ppb				
1,1-Dichloroethane	75-34-3	0.15	0.5	ppb				
Ethyl acetate	141-78-6	0.3	1	ppb				
n-Hexane	110-54-3	0.15	0.5	ppb				
Chloroform	67-66-3	0.15	0.5	ppb				
Tetrahydrofuran	109-99-9	0.15	0.5	ppb				
1,2-Dichloroethane	107-06-2	0.15	0.5	ppb				
1,1,1-Trichloroethane	71-55-6	0.15	0.5	ppb				
Carbon tetrachloride	56-23-5	0.15	0.5	ppb				
Benzene	71-43-2	0.15	0.5	ppb				
Cyclohexane	110-82-7	0.15	0.5	ppb				
Trichloroethene	79-01-6	0.15	0.5	ppb				
1,2-Dichloropropane	78-87-5	0.15	0.5	ppb				
Bromodichloromethane	75-27-4	0.15	0.5	ppb				
Heptane	142-82-5	0.15	0.5	ppb				
cis-1,3-Dichloropropene	10061-01-5	0.15	0.5	ppb				
Methyl isobutyl ketone	108-10-1	0.15	0.5	ppb				
trans-1,3-Dichloropropene	10061-02-6	0.15	0.5	ppb				
1,1,2-Trichloroethane	79-00-5	0.15	0.5	ppb				
Toluene	108-88-3	0.15	0.5	ppb				
2-Hexanone	591-78-6	0.32	1	ppb				

ADDRESS 960 West LeVoy Drive, Salt Lake City, Utah, 84123 USA | PHONE +1 801 266 7700 | FAX +1 801 268 9992
ALS GROUP USA, CORP. Part of the ALS Group An ALS Limited Company

Environmental www.alsglobal.com
RIGHT SOLUTIONS RIGHT PARTNER

ALS Environmental - Salt Lake City
Detection Limits / Control Limits

Method: EPA TO-15
Matrix: Air

		Detection Limits			Control Limits			
					Historical/Performance			
Compound	CAS Number	MDL	RL	Units	LCL	UCL	RPD	
Tetrachloroethene	127-18-4	0.15	0.5	ppb				
Dibromochloromethane	124-48-1	0.15	0.5	ppb				
1,2-Dibromoethane	106-93-4	0.15	0.5	ppb				
Chlorobenzene	108-90-7	0.15	0.5	ppb				
Ethyl benzene	100-41-4	0.15	0.5	ppb				
m,p-Xylene	179601-23-1	0.15	0.5	ppb				
o-Xylene	95-47-6	0.15	0.5	ppb				
Styrene	100-42-5	0.3	1	ppb				
Bromoform	75-25-2	0.3	1	ppb				
1,1,2,2-Tetrachloroethane	79-34-5	0.15	0.5	ppb				
4-Ethyl toluene	622-96-8	0.3	1	ppb				
1,3,5-Trimethylbenzene	108-67-8	0.3	1	ppb				
1,2,4-Trimethylbenzene	95-63-6	0.3	1	ppb				
1,3-Dichlorobenzene	541-73-1	0.3	1	ppb				
1,4-Dichlorobenzene	106-46-7	0.3	1	ppb				
Benzyl chloride	100-44-7	0.37	1	ppb				
1,2-Dichlorobenzene	95-50-1	0.3	1	ppb				
1,2,4-Trichlorobenzene	120-82-1	0.42	1	ppb				
Hexachloro-1,3-butadiene	87-68-3	0.3	1	ppb				

APPENDIX B – DRAFT OUTLINE CONSTRUCTION QUALITY ASSURANCE PLAN

DRAFT OUTLINE
CONSTRUCTION QUALITY ASSURANCE PLAN
GROUNDWATER DISCHARGE PERMIT
US MAGNESIUM, ROWLEY, UTAH

Note: 'Bentonite' as it appears in this document is only a placeholder. Slurry wall materials will be determined as part of the compatibility study (See Appendix F).

1.0 GENERAL

1.1 INTRODUCTION

1.2 PURPOSE

1.3 SCOPE

1.4 DOCUMENT ORGANIZATION

2.0 PROJECT ORGANIZATION

2.1 RESPONSIBILITY AND AUTHORITY

2.1.1 Contractor

2.1.2 QC Contractor

2.1.3 QC Site Monitor(s)

2.1.4 Construction Manager

2.1.5 Design Engineer

2.1.6 QA Engineer

2.1.7 Health and Safety Officer

2.1.8 QC Testing Laboratory

2.2 PROJECT MEETINGS

2.2.1 Pre-Construction Meeting

2.2.2 Daily Meetings

2.2.3 Weekly Progress Meetings

2.2.4 Problem or Work Deficiency Meetings

3.0 PERSONNEL QUALIFICATIONS AND TRAINING

3.1 CONTRACTOR'S PROJECT MANAGER

3.2 CONSTRUCTION MANAGER

3.3 QA ENGINEER

3.4 QC MONITOR(S)

3.5 HEALTH AND SAFETY OFFICER

1.5 QC TESTING LABORATORY

3.6 SURVEYOR

4.0 DEFINITIONS RELATING TO CONSTRUCTION QUALITY ASSURANCE

4.1 CONSTRUCTION QUALITY ASSURANCE AND CONSTRUCTION QUALITY CONTROL

4.2 USE OF THE TERMS IN THIS CQA PLAN

5.0 APPLICABLE ORGANIZATIONS AND STANDARDS

5.1 APPLICABLE ORGANIZATIONS
5.2 APPLICABLE STANDARDS
6.0 CONSTRUCTION ACTIVITIES AND SUBMITTAL REQUIREMENTS
6.1 CONSTRUCTION ACTIVITIES
6.2 SUBMITTAL AND ACCEPTANCE REQUIREMENTS
7.0 EARTHWORK
7.1 CONSTRUCTION TESTING
7.2 PREPARED SUBGRADE
7.3 DIKE GENERAL FILL
8.0 SOIL-BENTONITE SLURRY WALL
8.1 BENTONITE
8.2 MIX WATER
8.3 SLURRY (INITIAL AND IN-TRENCH)
8.4 SOIL-BENTONITE BACKFILL
8.5 CONSTRUCITON QUALITY ASSURANCE EVALUATION
9.0 SURVEYING
10.0 CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION
10.1 DOCUMENTATION
11.0 REFERENCES

LIST OF TABLES

Table 7-1 Minimum Frequency of Testing for CQC Evaluation of Prepared Sub-grade
Table 7-2 Minimum Frequency of Testing for CQC Evaluation of General Fill
Table 8-1 Material Testing Requirements for Slurry Wall

LIST OF FIGURES

Figure 2-1 CQA Organizational Chart

APPENDIX C – GEOCHEMICAL REPORT

Stantec

To:	Rob Hartman (US Magnesium)	From:	Jim Finley, PhD (Stantec)
CC:	Susan Eyzaguirre (Stantec)	Date:	12/15/2017

Reference: US Magnesium Groundwater Discharge Permit Application – Geochemical Evaluation of Sediments Beneath the CWP

1.0 INTRODUCTION

US Magnesium LLC's (USM) current waste pond (CWP) receives low pH wastewater via three unlined ditches (Western, Central and Chlorine Ditches) that converge into the Main Ditch, which deposits wastewater midway through the CWP. For the purposes of this study the CWP has been divided into the Northwestern Waste Pond (NWP) and the Southeastern Waste Pond (SEP), where the Main Ditch serves as the dividing line. The sediments underlying the waste pond are composed of silty clays, clays and oolites which contain varying amounts of carbonate. The carbonate portion of these materials react with the low-pH waste water, neutralizing the acidity of the wastewater. By-products of the chemical reaction are proportional between carbonate alkalinity and CO2(g), depending on the final pH. This reaction between waste solution and sediments was previously predicted during geochemical analysis of sediments collected as part of an assessment of a proposed waste pond northwest of the plant (MWH, 2015). Additionally, there are dissolution features (i.e. sink holes, piping, off-gassing) associated with the existing waste ponds that are consistent with geochemical reaction between the waste solution and carbonate-rich underlying sediments (ERM, 2016).

A drilling campaign in June, 2017 installed four groundwater monitoring wells and seven boreholes (See Appendix A of the Hydrogeological Report for details) (Stantec, 2017a). Five of the boreholes were drilled at a 45 degree angle in order to sample sediments beneath the waste ponds. Boreholes were advanced to a depth to intercept the spatially contiguous clay-rich layer that has been proposed as the effective bottom liner of the waste ponds. Sediment samples were collected every 5 feet during borehole drilling. A portion of the samples were submitted to the Utah State University Soils Laboratory for quantification of weight percent calcium carbonate in the sediments (See Appendix A of the Hydrogeological Report)(Stantec, 2017a). Sediment samples collected within the clay-rich layer were submitted to The Mineral Lab laboratory for analysis by x-ray diffraction of clay mineralogy to understand the potential reactivity of clay minerals in contact with waste solution (See Appendix A of the Hydrogeological Report) (Stantec, 2017a).

A silty clay unit (the Deeper Silty Clay Unit, see Hydrogeological report for detailed description) is located beneath the current waste ponds, along with sand and silty sediment, as seen in Figures 1 and 2. Clay layers can act as barriers to passage of overlying substances; however, in the current setting, consideration (and measurement) of the amount of carbonate present within the clay layer is necessary. A high concentration of calcium carbonate in the Deeper Silty Clay

Unit could result in a large amount of void spaces should the waste solution come in contact and react with the layer. These void spaces could enable seepage of the wastewater from the containing ponds, limiting the effectiveness of the Deeper Silty Clay Unit. The objective of this report is to present results from the laboratory analyses of calcium carbonate content in and above the confining Deeper Silty Clay Unit, and the mineralogy of the Deeper Silty Clay Unit with the purpose of predicting the remaining buffering capacity of the sediments underlying the CWP.

This analysis focuses on the remaining buffering capacity of the CWP and does not address the buffering capacity beneath the proposed retrofitted wastewater pond (RWP) as carbonate analysis of the sediments in the RWP are not available. Expansion of the CWP will likely result in a significant increase in buffering capacity since wastewater inflows (i.e. acidity loading rates) will remain the same while the area of the RWP is more than double the CWP.

2.0 METHODS

In order to quantify the amount of calcium carbonate in the sediment under the CWP, samples from cores were collected every 5 feet and analyzed to determine the percent carbonate (as CaCO3) present. These cores were taken from six angled boreholes, four new vertical monitoring wells, and one vertical borehole.

For purposes of the analysis, the North waste pond group includes SB-3, SB-4, SB-5 and MW-21, while the South waste pond group consists of MW-21, MW-22B, MW-23, SB-2, SB-1, and SB-6. The core from SB-7 was excluded in these groupings because it is intended to represent baseline conditions and is purposefully located away from both waste ponds in an area unaffected by waste solutions. Using the equivalent vertical depth, converted from the reported angled depth, and the corresponding calcium carbonate percent, two plots were constructed to display the relationship between depth and carbonate content. The first plot is a compilation of all samples, while the other two plots are of the North and the South groups (Figure 3).

In order to further analyze the amount of calcium carbonate in the soil, Table 1 was created to relate the depths and peaks of carbonate concentrations for each well/borehole. The peak concentrations shown in Figure 3 correspond to zones of elevated carbonate content; therefore showing areas in the soil that could be more reactive with the low pH waste solution. Table 1 displays the average depth at which the peak carbonate content occurs and the associated average calcium carbonate percentage (in weight percent).

Tables 2 (North waste pond) and Table 3 (South waste pond) show the estimated total mass of calcium carbonate present in the underlying sediment, as well as the mass of carbonate in the Deeper Silty Clay Unit. For estimating the total mass of calcium carbonate beneath the North and South waste ponds, the evaporation area of the CWP at an elevation of 4214 feet above mean sea level was utilized: (1) North waste pond surface area is 111 acres and (2) South waste pond area is 174 acres. Finally, an estimate of the total mass of carbonate was calculated assuming a porosity of 30 percent and a soil bulk density of 1200 kg/m3. Table 4 shows the

estimated neutralizing capacity of both the clay layer and the overlying sediments for the North and South ponds.

Acidity loading rate due to waste water flows from the main ditch entering the current waste pond (CWP) was calculated utilizing 2013 flow data from the client (US MAG 2013) and field pH measurements collected during a July 2015 groundwater sampling event performed by ERM (ERM 2016) and a July 2017 sampling event conducted by Stantec. Samples of materials from the clay layer were submitted to The Mineral Lab in Golden, Colorado for mineral analysis by x-ray diffraction (XRD). The focus of the mineralogical evaluation is the clay materials in the Deeper Silty Clay Unit that would act as the lower hydraulic barrier if a vertical hydraulic barrier wall is installed. The shallowest sample analyzed was from a depth of 32 feet (SB-5) and the deepest material tested was from a depth of 46 feet (SB-2). While clay mineralogy is the focus, the analysis also provided information about the bulk mineralogy, which is useful in identifying potentially reactive mineral phases in the Deeper Silty Clay Unit. The laboratory report for the XRD analysis is included for reference as Appendix A of the Hydrogeological Report (Stantec, 2017a).

3.0 RESULTS

The plots of the North and South waste ponds show that the cores within each group follow similar trends (Figures 1& 2). While the cores were not all taken from the same location, they show similar relationships between depth and calcium carbonate concentration, indicating that the sediment under the ponds is somewhat uniform spatially. However, both MW-21 and MW-23 display less carbonate content than the other locations; likely a result of being located farther from the active waste ponds (compared to the soil boring locations on the pond embankments). In order to be conservative, the calcium carbonate results from these borings were not used on this evaluation.

Results from the Northwest waste pond group indicate a peak in calcium carbonate percent at an average depth of 7.1 feet with an average carbonate content of 69.1 wt%. There is a smaller peak at around 32 feet with an average carbonate content of 40.7%. The South group results show two distinct peaks at an average depth of 4.3 feet and 15.5 feet with average carbonate content of 72.3 and 74.2 wt%, respectively. These peaks show the depths where layers of highly reactive sediment occur. This is important in order to understand the amount of material that could dissolve if low pH waste solution contacts the material. In the Northwest waste pond group, the layer representing the large peak appears to be approximately 10 feet thick while the deeper layer is around 8 feet thick. The shallow layer in the Southeast waste pond sediment is around 1.5 to 2 feet thick while the deeper layer is approximately 5 feet thick.
Using the results from the carbonate content analysis, the assumptions about sediment porosity, bulk density, and surface area of the North and South ponds, estimates of the total mass of carbonate in the sediment underlying the ponds were calculated. The sediment column under the Northwest waste pond, but above the clay layer, contains approximately 1.4 billion kg of carbonate. The mass of carbonate in the clay layer beneath the Northwest waste pond is

approximately 750 million kg. In the Southeast waste pond sediment, the total mass of carbonate in the sediment column above the clay layer is approximately 3 billion kg and the estimated mass of carbonate in the clay layer is 3.4 billion kg.
For estimation of the annual acid loading rate, the following relationship was utilized to convert pH measurements into hydrogen ion (H+) activity in the waste solution (assuming for purposes of this calculation that activity equals concentration):

$$pH = -\log([H^+])$$

Where [H+] is the activity of the hydrogen ion in mol/L. For purposes of this calculation, the assumption is made that activity equals concentration. In order to properly account for the difference between activity and concentration in the high total dissolved solids waste solution, the concentrations of major cations and anions are needed for input to a geochemical model. This equation can be rearranged to solve for the concentration of hydrogen ions:

$$[H^+] = 10^{-pH}$$

The concentration of hydrogen ions are converted to equivalent $CaCO_3$ using the reaction of calcium carbonate to carbonic acid:

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + H_2CO_3$$

This reaction indicates that for every two moles of H+ reacted, one mole of $CaCO_3$ is also consumed, and therefore the molar concentration of $CaCO_3$ is calculated as follows:

$$[CaCO_3] = 0.5 * [H^+]$$

Molar and mass concentrations of H+ and $CaCO_3$ were calculated for five samples as shown in Table 4.

The most recent combined flow rates for waste water entering the CWP is 1,100 gallons per minute based on flows from the cut-throat flume (see Appendix D of the Discharge Control Plan for flow data)(Stantec, 2017b). The mass concentrations of H+ and $CaCO_3$ were utilized, along with the waste water flow rates, to calculate a mass loading rate (M_i) utilizing the following formulas:

$$M_i = [H^+] * Q_{waste}$$
$$M_i = [CaCO_3] * Q_{waste}$$

Where:

M_i is the mass loading rate in mg/s
[H+] or [$CaCO_3$] is the mass concentration in mg/L
Q_{waste} is the flow rate of the waste into the CWP in L/s

Results for the calculated mass loading rates are shown in Table 5.
Table 6 shows the low, average and high pH values of waste solution, the estimated annual loading rate of acid (as equivalent $CaCO_3$), and neutralizing capacity (in years) of the

underlying sediment and clay layer. In both cases, the pH ranges from 0-1.15, and the assumption was made that the mass loading of acid to the Northwest and Southeast areas of the CWP is an even split of the total acid loading. For the Northwest pond and at the current annual loading rates, the neutralization capacity of sediment above the Deeper Silty Clay Unit ranges from 25 to 350 years and the neutralization capacity of the clay ranges from 15 to 200 years. For the Southeast CWP area, the neutralization capacity to the sediment above the Deeper Silty Clay Unit ranges from 55 to 800 years and the neutralization capacity of the Deeper Silty Clay Unit ranges from 60 to 900 years.

Results of the XRD analysis are separated into bulk and clay mineral categories. Within the bulk mineral category, there are minerals that are highly reactive (halite), reactive in contact with waste solution (calcite and aragonite), slightly reactive (e.g., dolomite), and minerals that are essentially inert (e.g., quartz, plagioclase feldspar, and K-feldspar) (Table 7). In the Northwest CWP area, the reactive carbonate content ranges from 12 to 43 wt%, which corresponds well with the other laboratory analysis. In the South pond area, reactive carbonates range from 11 to 43 wt%, again with good correspondence with the other laboratory analysis. While dolomite is a carbonate mineral, the solubility of dolomite is much lower than the solubility of the reactive carbonates. Dolomite would likely act as a slower dissolving mineral when in contact with waste solution. The aluminosilicate minerals (quartz, plagioclase feldspar and K-spar) are probably inert, even in contact with low-pH waste solution and would therefore, serve as the interconnected framework of the lower boundary layer.

Clay minerals identified include mixed illite-mica, smectite, chlorite and kaolinite (Table 7). The mixed layer illite-mica is the most abundant of the clay minerals followed by smectite. Chlorite, kaolinite, and the fine-grained aluminosilicate clinoamphibole could be identified, by the XRD pattern, but were present in amounts too low to quantify. Thus, the main influences on clay properties and potential response to contact with waste solution are from illite-mica and smectite.

4.0 DISCUSSION

The results from the geochemical analysis completed on samples of sediment collected from below the Northwest and Southeast areas of the CWP indicate that roughly one-third of the sediment underlying the waste ponds is composed of calcium carbonate. This concentration of carbonate, along with the low pH waste that overlies it, results in a reactive geochemical system that has the potential to modify groundwater flow paths due to dissolution of the carbonate minerals. Based on the available information, there is more carbonate in the Southeast CWP area than in the Northwest CWP area, both in the sediments overlying the Deeper Silty Clay Unit and in the Deeper Silty Clay Unit itself. The higher carbonate content is probably due to the larger size of the Southeast CWP compared to the Northeast CWP, which have surface areas of 174 acres and 111 acres, respectively. At the Northwest CWP, the sediment overlying the Deeper

Silty Clay Unit contains twice as much carbonate as the clay layer. At the Southeast CWP, there is more carbonate in the Deeper Silty Clay Unit than in the sediment overlying it.

The neutralization capacity of the soils beneath the two waste pond areas differs greatly. While the wastewater pH varies from 0 to 1.15, the soil buffering capacity varies by hundreds of years. This indicates that a slight change in the pH of the system could change the duration of the neutralization capacity of the underlying sediment. This is particularly relevant in reference to the source of the measured pH values. The lowest measured pH value (pH = 0.00) was measured directly from the waste stream while measurements of pond waters, which are more representative of water interacting with sediments, were higher (pH = 0.76 to 1.15). This indicates that the low and even average pH values utilized for this assessment result in conservative estimates of remaining buffering capacity.

Stratigraphic and spatial variability beneath the site are evident in the analysis results. For the Northwest CWP, the neutralization capacity of the sediments above the Deeper Silty Clay Unit is approximately twice as long as that of the Deeper Silty Clay Unit itself. For the Southeast CWP, the neutralizing capacity of the sediment above the Deeper Silty Clay Unit and the Deeper Silty Clay Unit itself are very similar; however, the buffering capacity of the Deeper Silty Clay Unit is slightly greater than that of the overlying sediments.

The high amount of calcium carbonate in the sediment indicates that while the waste solution is currently contained, prolonged interaction between the two will result in dissolution, potentially leading to seepage of the wastewater. Thirty percent (by weight) of the underlying material is made of calcium carbonate that, when it reacts with low pH waste solution, could result in voids that will alter groundwater flow. While dissolution of the sediment above the clay has no effect on the waste containment for a vertical hydraulic barrier wall groundwater discharge control system that is keyed into the clay layer, the presence of carbonate in the Deeper Silty Clay Unit could alter the barrier properties if waste solution were to contact the Deeper Silty Clay Unit. However, based on the analysis presented in this report, migration of unreacted waste solution to the depth of the clay layer is unlikely to occur for decades to hundreds of years.

5.0 REFERENCES

ERM. June 2016. Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model.

MWH, 2015. Draft Preliminary Design Basis and Feasibility Evaluation Report Proposed New Evaporation Pond. August 2015.

Stantec, 2017a. Groundwater Discharge Permit Hydrogeologic Report. December, 2017. US Magnesium, 2017.

Stantec, 2017b. Groundwater Discharge Permit Groundwater Discharge Control Plan. December, 2017. US Magnesium, 2017.

TABLES

Table 1: Depths of Peak Carbonate Concentrations for North and South Waste Ponds

North Waste Pond Boreholes				
Sample	Peak depth (ft)	Calcium Carbonate %	Secondary peak depth (ft)	Calcium Carbonate %
SB-3	10.6	65.6	31.8	45.2
SB-4	3.5	71.8	28.3	42.7
SB-5	7.1	70.0	35.4	34.1
Average	7.1	69.1	31.8	40.7

South Waste Pond Boreholes				
Sample	Peak Depth (ft)	Calcium Carbonate %	Secondary peak depth (ft)	Calcium Carbonate %
SB-1	5	81.7	15.0	74.3
SB-2	3.5	79.3	17.7	70.0
SB-6	3.5	53.9	14.1	68.1
MW-22B	5	74.3	15.0	84.2
Average	4.3	72.3	15.5	74.2

Table 2 Calculated Mass of Carbonate in North Waste Pond Area

True Depth (ft bgs)	SB-3 Calcium Carbonate %	SB-4 Calcium Carbonate %	SB-5 Calcium Carbonate %	Average Calcium Carbonate %	Mass of $CaCO_3$ (kg)	Total Mass of $CaCO_3$ in Clay (kg)	Total Mass of $CaCO_3$ above clay (kg)
3.5	18.6	71.8	23.5	38.0	220,903,098	750,350,196	1,375,842,119
7.1	18.6	46.4	70.0	45.0	261,722,148		
10.6	65.6	15.5	29.1	36.7	213,699,736		
14.1	45.2	18.0	39.6	34.3	199,293,012		
17.7	14.9	10.5	16.1	13.8	80,437,541		
21.2	21.7	15.5	9.9	15.7	91,242,584		
24.7	21.7	32.2	9.3	21.1	122,457,152		
28.3	23.5	42.7	29.7	32.0	186,086,848		
31.8	45.2	41.5	31.0	39.2	228,106,459		
35.4	11.8		34.1	22.9	133,262,195		
38.9	31.0			31.0	180,084,047		
42.4	35.9			35.9	208,897,494		

Table 3 Calculated Mass of Carbonate in South Waste Pond Area

Depth (ft bgs)	SB-2 $CaCO_3$ %	SB-6 $CaCO_3$ %	Average $CaCO_3$ %	Mass of $CaCO_3$ (kg)	Total Mass of $CaCO_3$ in Clay (kg)	Total Mass of $CaCO_3$ above clay (kg)
3.5	79.3	53.9	66.6	605,590,327	3,369,217,966	3,055,606,772
7.1	27.2	19.8	23.5	214,069,139		
10.6	18.0	67.5	42.7	388,704,489		
14.1	69.3	68.1	68.7	625,307,221		
17.7	70.0	16.1	43.0	391,521,188		
21.2	29.7	18.6	24.1	219,702,537		
24.7	19.8	20.4	20.1	183,085,448		
28.3	20.4	8.7	14.6	132,384,862		
31.8	20.4	32.2	26.3	239,419,432		
35.4	30.3	34.1	32.2	292,936,716		
38.9	34.1	36.5	35.3	321,103,708		
42.4	21.7		21.7	197,168,944		
46.0	34.7		34.7	315,470,310		

Depth (ft)	M22-B $CaCO_3$ %	SB-1 $CaCO_3$ %	Average $CaCO_3$ %	Mass of CaCO3 (kg)
5	74.3	81.7	78.0	1,003,798,470
10	21.7	21.1	21.4	275,036,825
15	84.2	74.3	79.3	1,019,686,318
20	16.7	29.7	23.2	298,638,555
25	15.5	26.0	20.8	267,018,213
30	18	20.4	19.2	247,250,520
35	11.8	13.0	12.4	159,563,623
40	31	32.8	31.9	410,550,585
45	27.9	34.1	31.0	398,574,450
50	39	40.9	39.9	513,800,681
55	42.1		42.1	541,676,614
60	42.1		42.1	541,676,614
65	56.3		56.3	724,379,889

Table 4 Field pH Measurements and Calculated Concentrations of H^+ and $CaCO_3$

Location	Sample Date	pH	$[H^+]$ (mol/L)	$[H^+]$ (mg/L)	$[CaCO_3]$ (mol/L)	$[CaCO_3]$ (mg/L)
Main Ditch	July 2017	0.00	1	10007.9	0.5	50,043
PRI1-008	July2015	0.78	0.166	167.3	0.0830	8,305
PRI1-003	July2015	0.27	0.537	541.3	0.269	26,874
PRI1-006	July2015	1.15	0.0708	71.4	0.0354	3,543
PRI1-007	July2015	0.76	0.174	175.2	0.0869	8,696
	Average	0.59	0.256	257.9	0.128	12,803

Table 5 H^+ and $CaCO_3$ Mass Loading Rates

Location	pH	H^+ Mass Loading Rate (mg/s)	H^+ Mass Loading Rate (kg/yr)	$CaCO_3$ Loading Rate (mg/s)	$CaCO_3$ Loading Rate (kg/yr)
Main Ditch	0.00	6.99E+04	2.21E+06	3.47E+06	1.10E+08
PRI1-008	0.78	1.16E+04	3.66E+05	5.76E+05	1.82E+07
PRI1-003	0.27	3.76E+04	1.18E+06	1.87E+06	5.88E+07
PRI1-006	1.15	4.95E+03	1.56E+05	2.46E+05	7.75E+06
PRI1-007	0.76	1.22E+04	3.83E+05	6.04E+05	1.90E+07
Average	0.59	1.79E+04	5.64E+05	8.89E+05	2.80E+07

Table 6 Loading rate and neutralization capacity

	pH	H^+ Loading Rate (kg/yr)	$CaCO_3$ Loading Rate (kg $CaCO_3$/yr)
Low pH	0.00	2.21E+06	1.10E+08
Average pH	0.59	5.64E+05	2.80E+07
High pH	1.15	1.56E+05	7.75E+06

North Waste Pond				
	pH	**Acid Loading Rate (kg $CaCO_3$/yr)**	**Neutralization capacity to clay layer (yr)**	**Neutralization capacity of clay layer (yr)**
Low pH	0.00	1.10E+08	25	15
Avg. pH	0.59	2.80E+07	100	55
High pH	1.15	7.75E+06	350	200
South Waste Pond				
Low pH	0.00	1.10E+08	55	60
Avg. pH	0.59	2.80E+07	220	240
High pH	1.15	7.75E+06	800	900

Stantec

Table 7: X-Ray Diffraction Results

		Quartz	**Calcite**	**Aragonite**		**Clinoamphibole**	**Unidentified**
Location	Depth (ft bgs)	SiO_2	$CaCO_3$	$CaCO_3$	$($ $_4$	$(Na,K)(Ca,Na)_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH,F)_2$	
MW-21	40	19	13	12		<1	<5
MW-21	45	10	14	29		-	<5
MW-22B	40	16	11	13		-	<5
MW-22B	50	14	14	23		<2	<5
MW-23	40	22	12	5		<3	<5
MW-23	50	13	13	26		<2	<5
SB-1	40	15	15	16		<2	<5
SB-1	45	16	13	11		<2	<5
SB-2	42	30	11	-		<2	<5
SB-2	46	9	13	18		-	<5
SB-3	39	22	11	8		<3	<5
SB-3	42	10	16	18		<2	<5
SB-4	40	14	15	20		<2	<5
SB-4	45	14	15	25		<2	<5
SB-5	32	24	12	<5		-	<5
SB-5	35	19	14	13		<2	<5
SB-6	35	19	11	6		<2	<5
SB-6	39	15	17	15		<2	<5
SB-7	30	24	22	-		<2	<5
SB-7	35	23	18	6		<2	<5

FIGURES

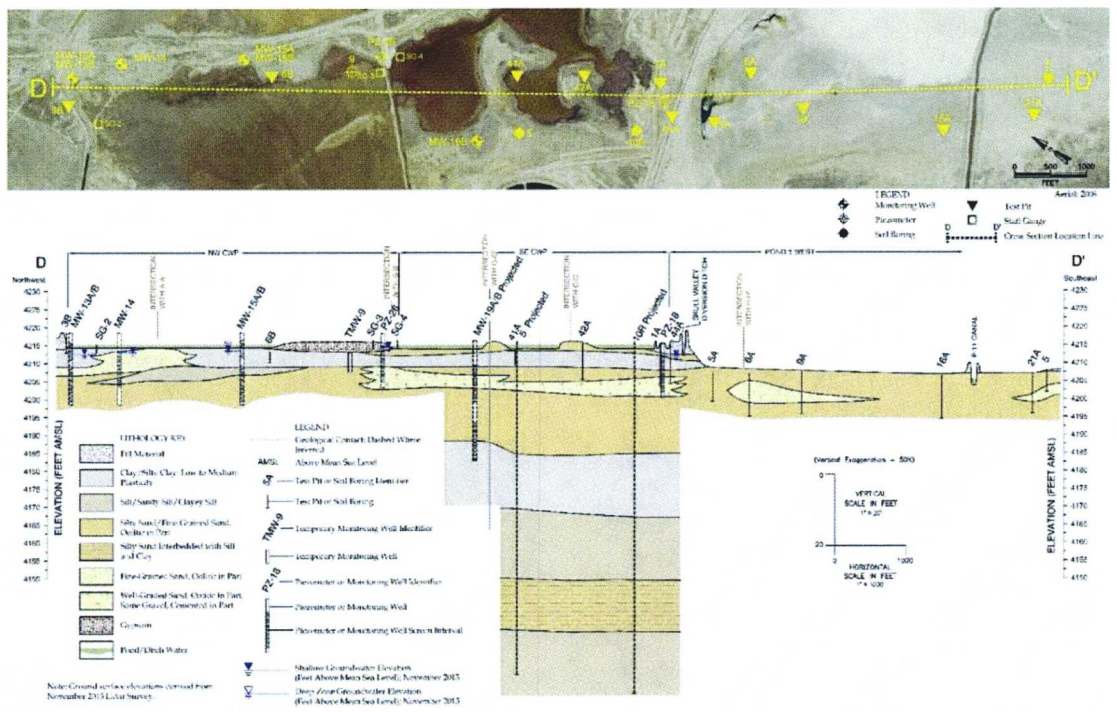


Figure 1 Northwest to southeast cross-section (ERM, 2016)

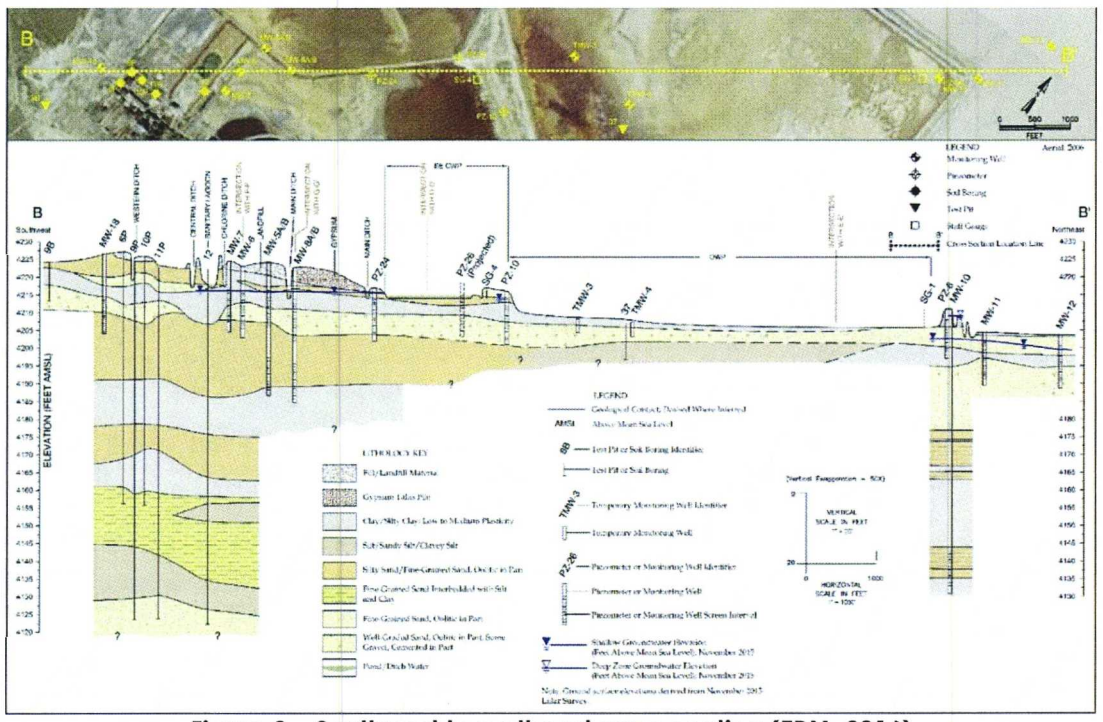


Figure 2 Southwest to northeast cross-section (ERM, 2016)

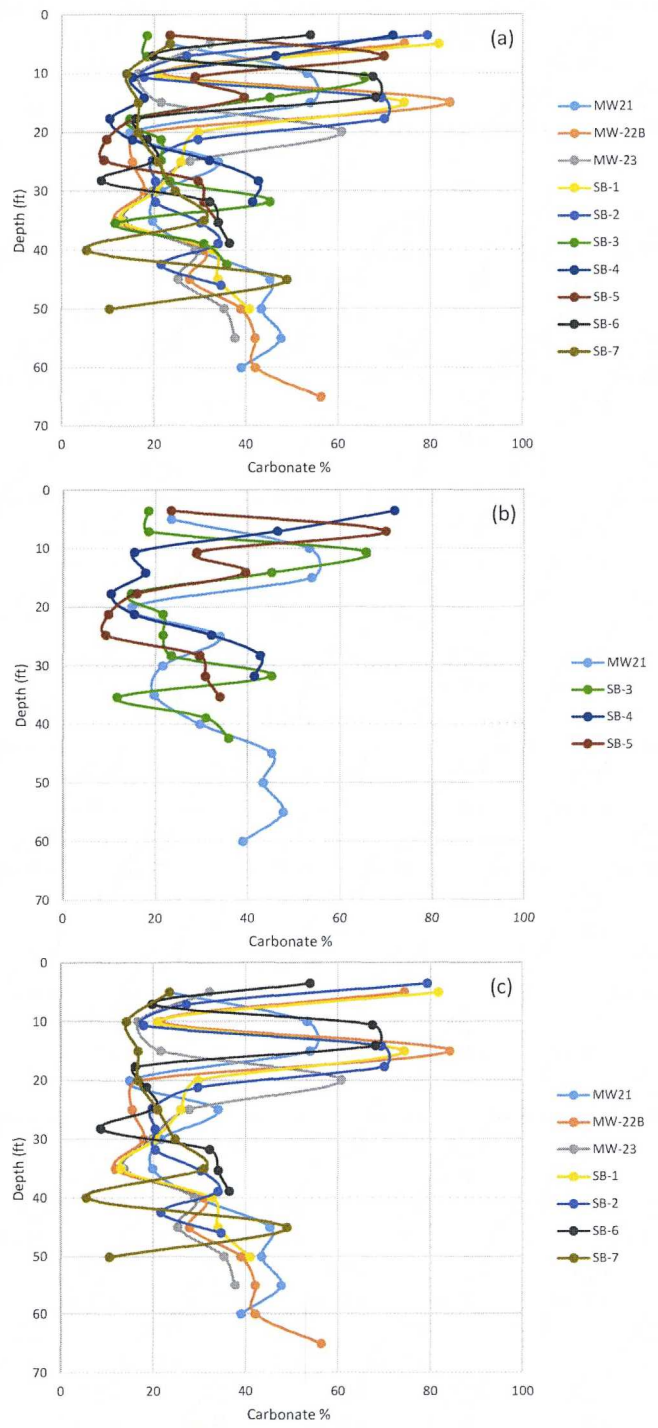


Figure 3: Depth profiles of carbonate content for all boreholes (a), North waste pond boreholes (b), and South waste pond boreholes (c)

APPENDIX D – WATER BALANCE REPORT

Stantec

To:	Rob Hartman (US Magnesium)	From:	Alexander Edstrom PE, MSc (Stantec);Paul Haby, PhD (Stantec)
CC:	Susan Eyzaguirre PE, PG, PMP Project Manager (Stantec)	Date:	12/12/2017

Reference: US Magnesium Groundwater Discharge Permit Application - Water Balance Model and Results

1.0 INTRODUCTION

This technical memorandum presents the water balance modeling and analysis used to support US Magnesium's Groundwater Discharge Control Plan which is a component of US Magnesium's Utah Groundwater Discharge Permit application. The water balance model was used to simulate potential water levels within a proposed new expanded and retrofitted waste pond (RWP) to be constructed within the footprints of the Current Waste Pond (CWP) and Old Waste Pond (OWP) as described in the US Magnesium Groundwater Discharge Control Plan (Stantec, 2017). Some of the assumptions within the model were conservative to evaluate maximum potential water levels. The results show that maximum water levels within the pond are not likely to exceed the proposed pond crest elevation of 4220 feet above mean sea level (ft amsl).

The Groundwater Discharge Control Plan (Stantec, 2017) outlines proposed plans to retrofit the CWP and OWP. These areas have been impacted by past US Magnesium facility (Facility) operations. Under the Groundwater Discharge Control Plan for the GWDP, Facility wastewater will be isolated and contained within the CWP and OWP footprints by installing a proposed vertical hydraulic barrier wall (barrier wall). The barrier wall will restrict the lateral flow of groundwater in the Upper Aquifer Zone of the regional shallow aquifer directly under the proposed RWP area. Vertical flow to the Lower Aquifer Zone of the regional shallow aquifer will be restricted by the in-place low permeability clay unit (Deeper Silty Clay Unit) located between the Upper and Lower Aquifer Zones. The Deeper Silty Clay Unit is encountered approximately 35-45 feet below ground surface in the areas of the CWP and OWP. Through this proposed design, only minimal vertical seepage will pass through the Deeper Silty Clay Unit as outlined in the Groundwater Discharge Control Plan.

Two possible configurations for the proposed barrier wall have been considered. One configuration would include a west barrier wall, while the second option would not have a west barrier wall. The configuration without a west barrier wall would leave the west (upgradient) side of the RWP open to groundwater inflow and surface water run-on from the west upland area. This water balance analysis assumes no west barrier wall. The absence of a west barrier wall increases the total potential run-on area to the west of the CWP. Therefore, evaluating the water balance without the west barrier wall is more conservative.

Primary inflows to the proposed wastewater storage area include wastewater flows produced by US Magnesium operations, a separate gypsum slurry discharge which outflows on the gypsum stack (here-on called gypsum slurry water), and incidental stormwater that reports to the CWP and OWP. The results of this analysis show that the no west barrier wall option will provide sufficient evaporative capacity to contain discharges from the US Magnesium process facility and incidental stormwater based on the data and assumptions described within this memorandum. Although not explicitly modeled, the less conservative west barrier wall option which would receive less water from precipitation run-on would also support the proposed design.

This memorandum discusses the technical details and results of the water balance model and is divided into the following sections:

1. Introduction
2. Conceptual water balance model
3. Computational water balance model and input data
4. Results
5. Conclusions
6. References

2.0 CONCEPTUAL WATER BALANCE MODEL

The water balance model simulates water levels in the RWP, in the areas of the CWP and OWP, as a function of direct rainfall and rainfall runoff, wastewater inflow, gypsum slurry water inflow, and water lost to evaporation from pond surfaces. The proposed barrier wall will be tied into the Deeper Silty Clay Unit located approximately 35-45 feet below ground surface in the area of the CWP and OWP. The barrier wall will restrict lateral groundwater migration and the Deeper Silty Clay Unit will limit vertical flux to the Lower Aquifer Zone. Therefore, evaporation is the only assumed loss for the model. **Figure 1** shows a conceptual model of the water balance used in the evaluation of the Groundwater Discharge Control Plan.

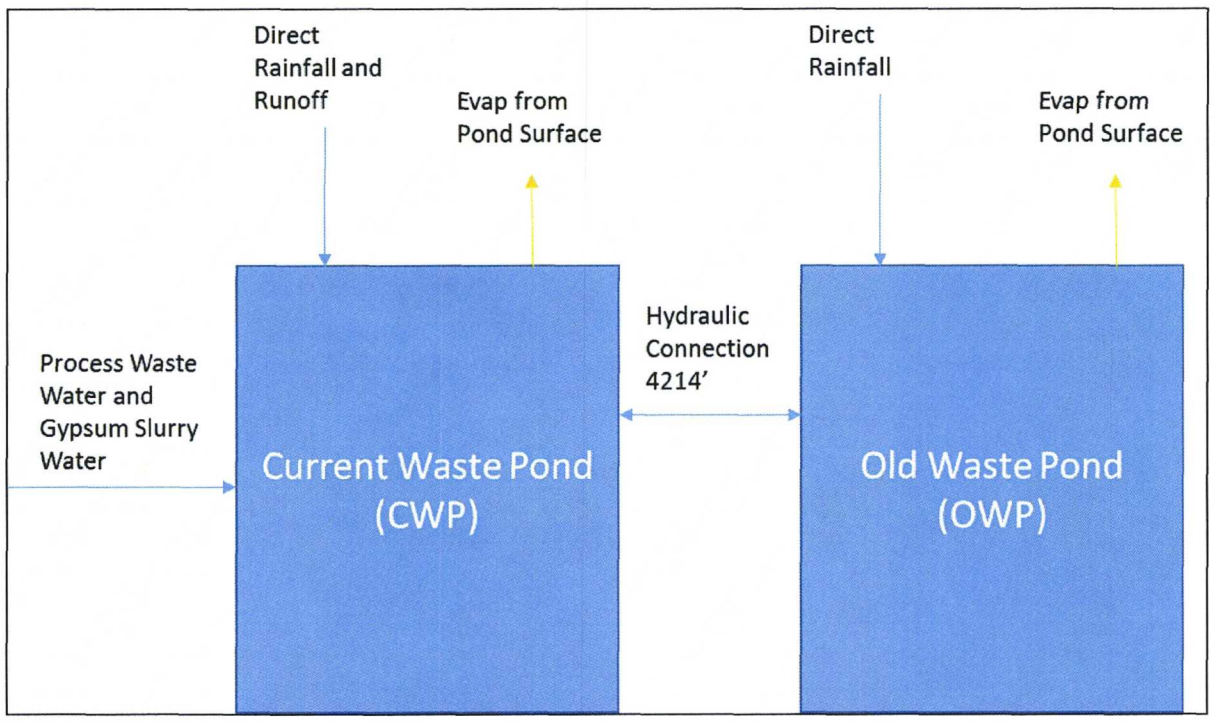


Figure 1 – Water Balance Conceptual Model

The primary inflows to the water balance model were:

- Process wastewater (minus gypsum slurry water) from US Magnesium facilities
- Gypsum slurry water produced by the US Magnesium operation
- Direct rainfall and stormwater runoff into the CWP
- Direct rainfall within the OWP embankments.

The only outflow from the water balance model was evaporation. As the volume of water stored in the CWP or OWP increases, so does the surface area of that pond. As the surface area

increases, the calculated evaporation from the surface of the pond also increases. Therefore, the evaporation from the pond surfaces balances the various inflows.

As shown in the conceptual model, a hydraulic connection between the CWP and OWP was assumed at an invert elevation of 4214 feet above mean sea level (ft amsl). This connection represents the recently installed overflow connector piping discussed in the Groundwater Discharge Control Plan (Stantec, 2017). There are four potential scenarios depending on the water levels in the ponds:

1. The water levels of the CWP or OWP are below 4214 ft amsl. In this condition, water levels raise or lower independently of each other. That is, the ponds are not hydraulically connected. In this scenario, the water volume in each pond is a function of local inflow and evaporation.

2. The water level in the CWP is at 4214 ft amsl, but the water in the OWP is below 4214 ft amsl. In this condition, any additional water to the CWP is freely passed into the OWP.

3. The water level in the OWP is at 4214 ft amsl, but the water in the CWP is below 4214 ft amsl any additional water gained by the OWP is freely passed into the CWP. This scenario is not expected to occur often, but may occur during significant precipitation events or if the plant were to shut down. A plant shutdown condition was not modeled at this time.

4. The water levels in the CWP and OWP are both above 4214 ft amsl. In this condition, the ponds are hydraulically linked and are assumed to raise and lower together. This simplification assumes that wastewater and gypsum slurry flow initially reporting to the CWP are also available at the OWP without any delay.

The conceptual water balance model provided the model framework to build the mathematical water balance. The dynamic conditions described in this section were built into the mathematical water balance described in the following section.

3.0 COMPUTATIONAL WATER BALANCE MODEL AND INPUT DATA

This section describes the computational water balance model and input data used to evaluate potential water levels under the proposed Groundwater Discharge Control Plan. Model calculations and results were produced using GoldSim version 11.1.7 (GoldSim Technology Group, LLC). GoldSim is an industry standard software used to evaluate dynamic systems with feedback responses. A screen capture of the GoldSim model is shown on **Figure 2**. The model represents the same processes described by the conceptual model in Section 2. Each element represents an input, lookup table, or equation used to mathematically simulate the water level in both ponds over time.

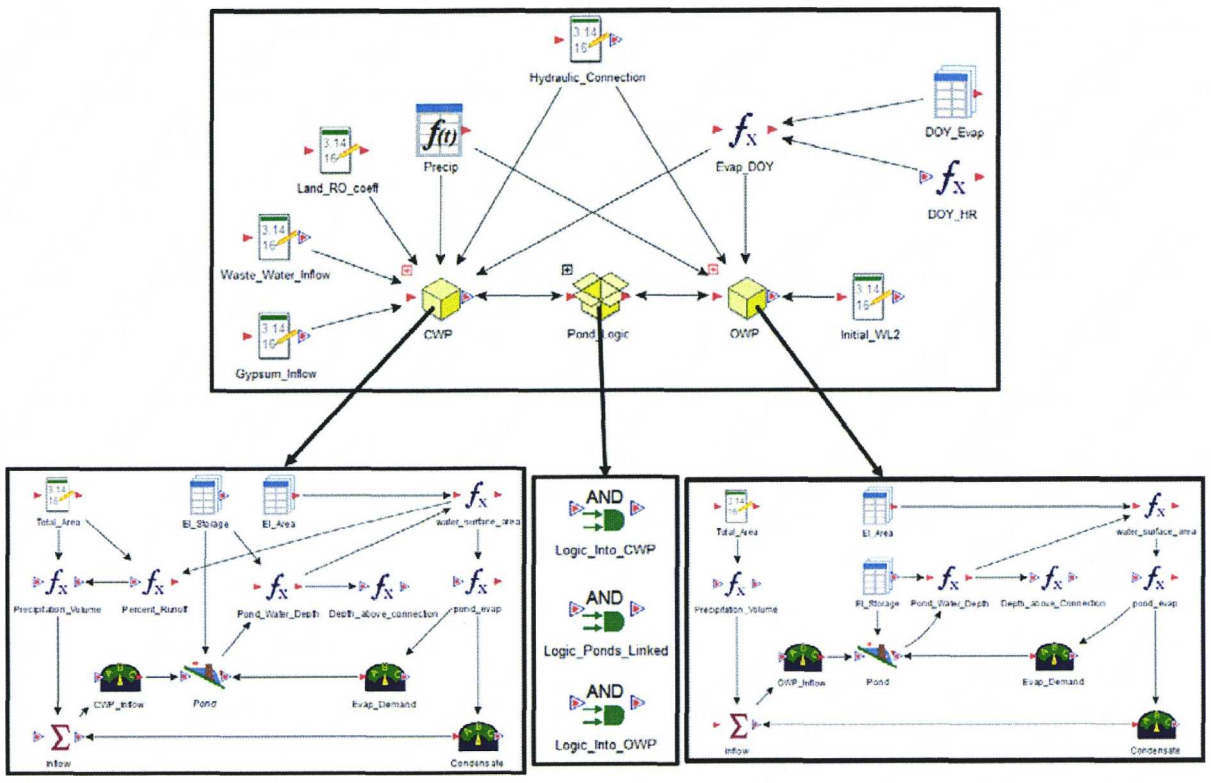


Figure 2 – GoldSim Model Used to Calculate Simulated Water Levels

As stated in Section 2, the primary inflows to the model are from wastewater, gypsum slurry water, and precipitation both as direct precipitation and runoff into the CWP and OWP. The only modeled outflow was evaporation. The pond water levels were calculated using stage-area-storage relationships to simulate pond changes. Input data used in the simulations are described in more detail in the following sections.

3.1 WASTEWATER AND GYPSUM SLURRY WATER FLOWS

Flow rates for the wastewater ditches and the gypsum slurry water were provided by US Magnesium. Wastewater flows from the plant are currently discharged to a series of collection ditches. These ditches are currently unlined; however, US Magnesium is planning to transport future wastewater in-pipe until water is discharged at the CWP (the closure of the unlined ditches is part of the RCRA Carve-Out Cleanup. An overview of this work is given in the Groundwater Discharge Control Plan). Gypsum slurry water is currently transported via pipe to the gypsum stack, where water is freely discharged from the pipes onto the existing gypsum pile.

To estimate potential wastewater discharges under future operations, US Magnesium installed a Cutthroat flume to measure flow rates for combined wastewater and stormwater runoff from the plant area reporting to the main wastewater collection ditch (Main Ditch). Flows were collected between August 15, 2017 and November 19, 2017 (**Figure 3**). The average flow for this period was 930 gallons per minute (gpm). For conservatism, this value was rounded up to 950 gpm.

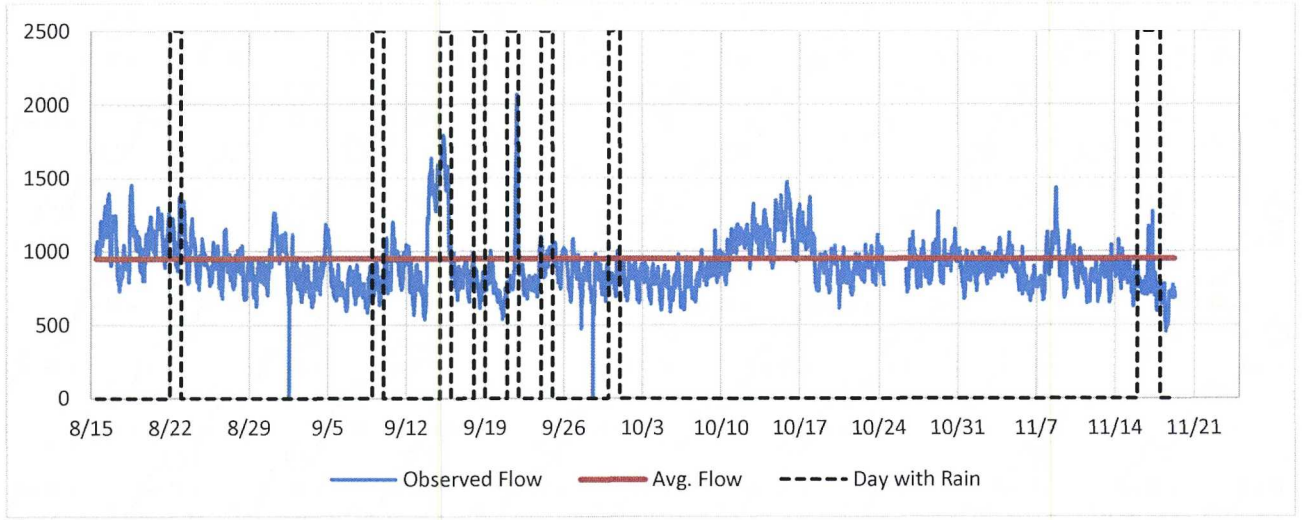


Figure 3 – Wastewater flow rates measured by the US Magnesium Cutthroat flume

The use of a flume to estimate future wastewater rates from the plant introduces some uncertainty. Some of those uncertainties are:

1. The flows measured at the pipe are not the direct outflows from the wastewater producing facilities.

2. Wastewater is transported in unlined ditches. These ditches are expected to lose some flow between where wastewater enters the unlined ditches and where flow is measured at the flume. Therefore, the flows measured at the flume may underestimate actual wastewater produced by US Magnesium operations. The true volume of wastewater produced at the plant is not measured at this time.

3. The ditches also receive stormwater runoff from the plant area. US Magnesium provided stormwater delineations indicating the runoff area is approximately 57 acres. **Figure 3** shows periods of rainfall with respect to observed peak flow measurements. Days with observed precipitation are shown by the black dashed boxes labeled "day with rain." Peaks occurring on a day with rainfall are assumed to coincide with stormwater runoff from the plant area.

4. The period of recorded data represents a relatively short period of time. Continued measurements at the flume may indicate increased or decreased average wastewater flow rates.

5. Changes in US Magnesium operations would influence wastewater flow rates. Changes could increase or decrease average wastewater discharge rates.

The other waste stream sent to the CWP is the free water from the gypsum slurry flow that is passed to the gypsum stack. The gypsum slurry water was modeled as a constant flow of 150 gpm. This flow rate was estimated by US Magnesium based on the two underflows sent to the gypsum slurry line. These inflows are the calcium chloride system underflow and the desulfation system underflow. Both underflows are approximately 50 gpm. An additional 50 gpm is assumed for conservatism. Although the gypsum slurry contains dissolved solids and is not purely liquid flow, it was assumed that the 150 gpm flow rate from the discharge point is all free water. Similar to the wastewater flow rate, there is uncertainty around the future discharge rate of the gypsum slurry flow.

3.2 PRECIPITATION DATA AND ANALYSIS

The precipitation record used in the water balance was developed with the following goals:

1. The weather record should be as long as possible. In general, climate normal conditions are considered over a thirty-year period (for example, see https://www.ncdc.noaa.gov/news/defining-climate-normals-new-ways).

2. The data should be observed on daily or sub-daily periods. Intense periods of precipitation may significantly increase the stored capacity of water within the CWP and OWP. Use of monthly precipitation records may artificially dampen these changes in simulated water levels.

3. The model should include a design storm to evaluate the proposed pond design against a period of maximum precipitation.

The criteria outlined above were used to develop a precipitation record, which is outlined in this section.

US Magnesium specific precipitation data were only available on monthly intervals between May 2011 and March 2016 as reported by ERM (2016). The average total annual precipitation for this period of time was 7.27 inches per year using the available annual data (**Table 1**). Due to the short period of available record, the data was not used in the water balance.

Table 1 – Monthly and Annual Total Precipitation at US Magnesium (source - ERM, 2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (Inches)
2011					5.06	0.63	0.87	0.14	0.05	0.85	0.56	0.14	
2012	0.95	0.26	0.06	0.45	0.69	0	0.52	0	1.2	1.05	0.67	0.97	6.82
2013	0.41	0.27	0	0.41	0.92	0	0.58	0.12	1.32	0.53	0.11	1.05	5.72
2014	0.41	0.29	0.69	0.68	0.37	0.33	0.87	1.355	2.0	0	0.5	0.14	7.66
2015	0.62	0.03	0.07	1.19	3.92	0.23	0.17	0.69	0.79	0.71	0.15	0.34	8.91
2016	0.8	0.1	1.43										
Avg	0.64	0.19	0.45	0.68	2.19	0.24	0.60	0.46	1.07	0.63	0.40	0.53	7.27

The average total annual precipitation (January – December) from nearby weather stations with daily precipitation records is summarized in **Table 2**. The data for these weather stations were obtained from the National Oceanic and Atmospheric Administration (NOAA). **Figure 4** shows the location, average precipitation, and elevation of these stations. The Utah Climate Center weather station database contained a number of additional weather stations; however, the stations available on the NOAA website typically had greater periods of record (10+ years) with continuous monitoring.

Table 2 – Summary of annual precipitation (Jan-Dec) records and statistics

Station ID	Station Name	Total Station Period of Record	Years of Precip	mean (in)	std (in)	min (in)	max (in)	Elevation (ft)
-	US Magnesium	2011-05 to 2016-03	4	7.27	-	5.72	8.91	~4215
USC00420194	Antelope Island	1952-09-16 to 1972-08-31	21	14.34	4.98	2.52	21.73	4232.2
USC00427578	Saltair Salt Plant	1956-05-07 to 1991-08-31	36	11.60	4.32	4.87	22.19	4210.2
USC00423348	Grantsville 2 W	1906-01-01 to 2017-11-05	61	11.12	3.46	0.43	20.62	4550.1
US1UTSL0062	Magna 1.2 W	2010-07-21 to 2017-01-02	8	14.88	7.10	0.20	24.11	4375.2
USC00428771	Tooele	1896-03-01 to 2017-11-07	67	17.95	4.24	8.91	28.34	4944.1
USC00427052	Promontory	1981-10-01 to 1994-12-31	14	9.84	3.96	5.19	19.47	4215.1
USS0012J07S	Mining Fork	1988-09-21 to 2017-11-08	30	35.96	7.98	11.18	50.11	8221.5
US1UTSL0061	West Valley City	2009-09-05 to 2017-11-06	9	16.49	5.28	4.65	22.85	4317.1
USC00421149	Callister Ranch	1967-05-01 to 1984-10-23	18	12.13	3.10	6.67	16.54	4262.3
USC00420506	Bear River Refuge	1937-08-04 to 1984-02-29	35	12.10	4.73	1.24	27.45	4213.1

Station ID	Station Name	Total Station Period of Record	Years of Precip	mean (in)	std (in)	min (in)	max (in)	Elevation (ft)
US1UTWB0001	West Haven 2.0	2008-07-01 to 2017-11-08	10	14.71	4.62	5.22	21.70	4239.1
USW00024127	SLC Int. Airport	1941-11-01 to 2017-11-08	70	15.59	3.43	8.72	24.30	4225.3
USC00428978	Utah Test Range	1989-09-01 to 2017-11-07	29	8.89	2.85	1.80	15.61	4440.2

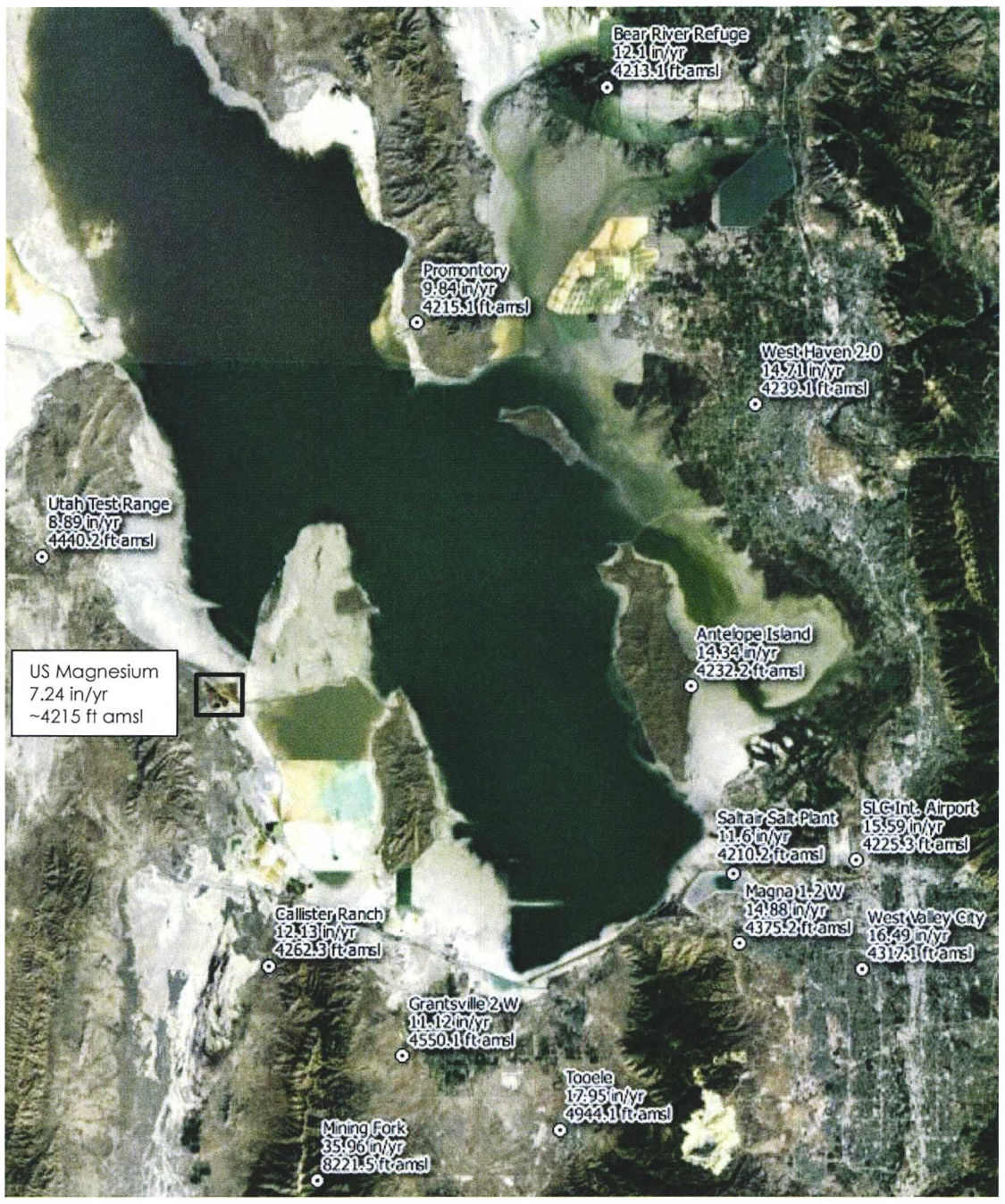


Figure 4 – Annual Average precipitation values around Great Salt Lake

From a review of the information shown in **Table 2**, stations at greater elevations (Mining Fork and Tooele) produced greater annual average precipitation. Stations located east of Great Salt Lake, near the Wasatch Mountains also received greater annual average precipitation compared to stations located west of Great Salt Lake. These trends reflect the dominate weather systems of the region, which generally move west to east and south to north. The Wasatch Mountains obstruct weather systems, causing orographic-induced precipitation as systems moving west to east pass over the mountains.

The Grantsville weather station was selected for use in the water balance. The average annual precipitation from the US Magnesium weather station was compared against the Grantsville station (**Figure 5**). For the limited data available at the US Magnesium specific weather station, the Grantsville station received more precipitation.

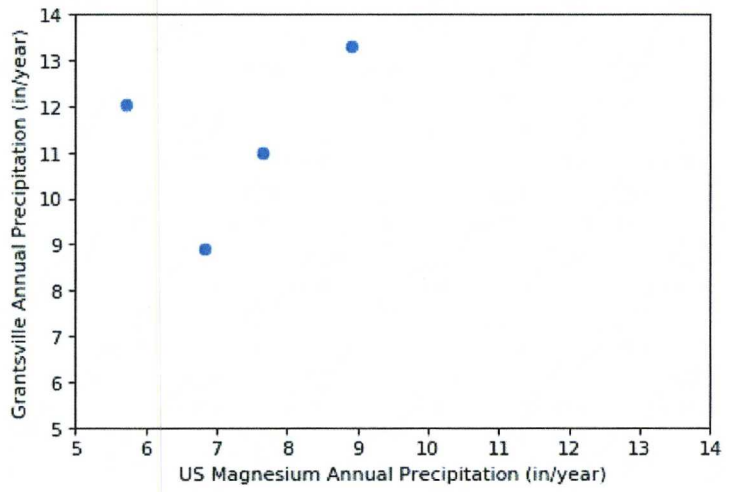


Figure 5 – Comparison of annual precipitation recorded at the US Magnesium and Grantsville weather stations between January 1, 2012 and December 31, 2015

The Grantsville weather station has 61 years of precipitation data with 95 percent data coverage (1,090 missing records out of 22436 total days). The raw annual total rainfall (January to December) is shown below on **Figure 6.** Missing precipitation record counts are shown on **Figure 7** with the majority of those records occurring during a two-year period of record between Aug 1, 1997 and October 31, 1999 where no station information was available. These dates make up 823 of the total 1,090 missing precipitation records, 76 percent.

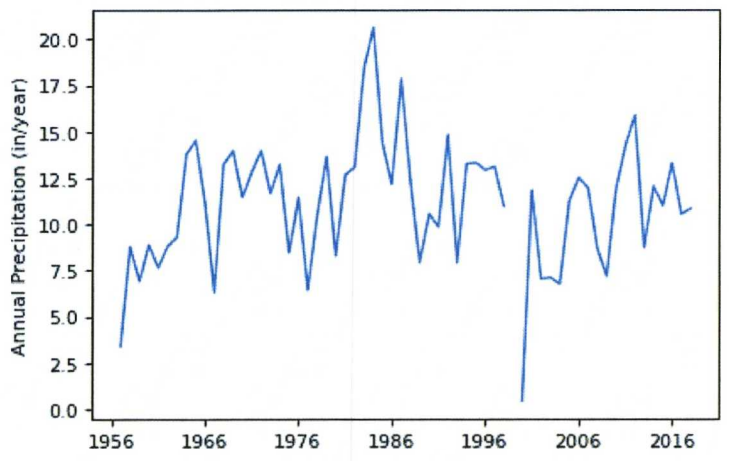


Figure 6 – Raw precipitation record, annual precipitation (in/year, Jan 1 – Dec 31)

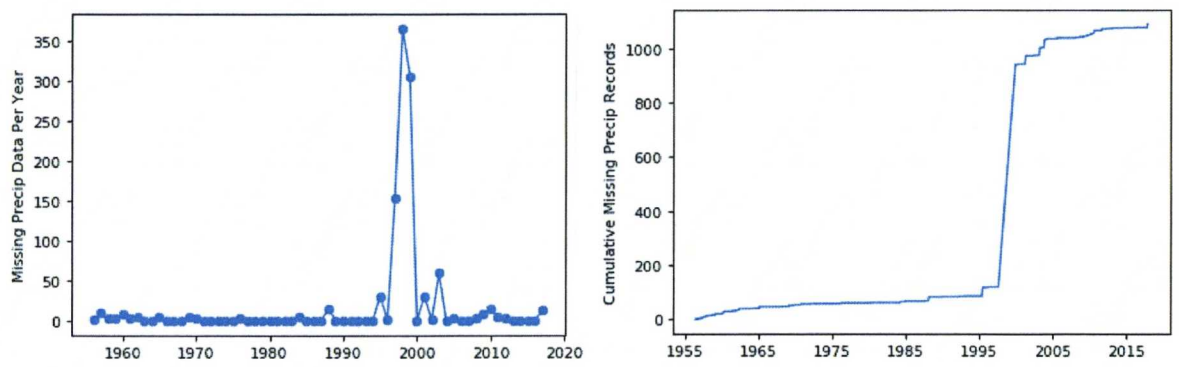


Figure 7 – Missing data from the raw precipitation record, by year and cumulative

To develop a complete precipitation record, missing values from Aug 1, 1997 to October 31, 1999 were replaced with daily records from the maximum precipitation year. This was done to evaluate a potential design-storm type condition as specified at the beginning of the section. The maximum precipitation year was selected by calculating the rolling sum precipitation over a 365-day period. The rolling sum calculation evaluates the sum of the current day's precipitation, plus the total precipitation over the previous 364 days. This calculation is made for every day, minus the first 364 days in the record. The 365-day rolling precipitation record is shown on **Figure 8**.

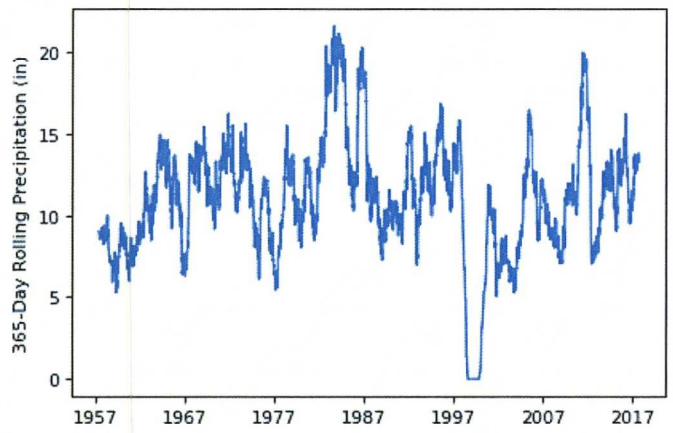


Figure 8 – 365 day rolling total precipitation at the Grantsville weather station

The maximum precipitation year began on August 21, 1982 and ended on August 21, 1983. The daily rainfall recorded over that period of time is shown on **Figure 9**. Day-of-the-year precipitation from the maximum precipitation year was inserted into the equivalent day-of-the-year between August 1, 1997 and October 31, 1999. For example, the missing precipitation for August 1 in years 1997, 1998, and 1999 was replaced with the precipitation record of August 1, 1983. The adjusted annual precipitation record, for dates between January 1 and December 31. All other missing precipitation data not between August 1, 1997 and October 31, 1999 were assigned by linearly interpolating between observed values. The annual precipitation, after filling missing data, is shown on **Figure 10**. The adjusted daily values (**Figure 11**) were used in the water balance model to evaluate potential water levels. A comparison of the summary statistics for the raw and adjusted rainfall data are given in **Table 3**.

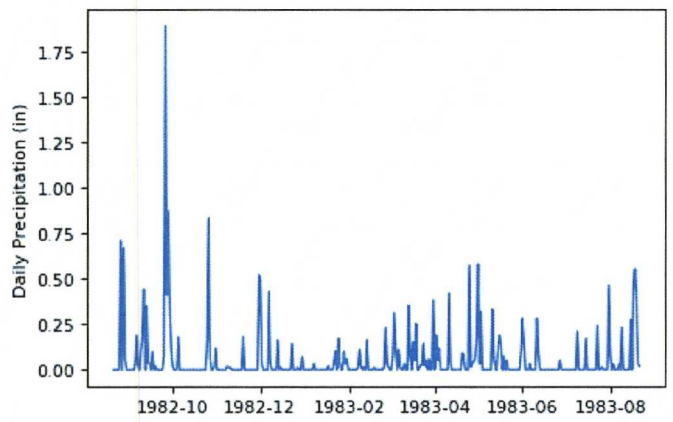


Figure 9 - Daily precipitation values recorded during the maximum precipitation at the Grantsville weather station

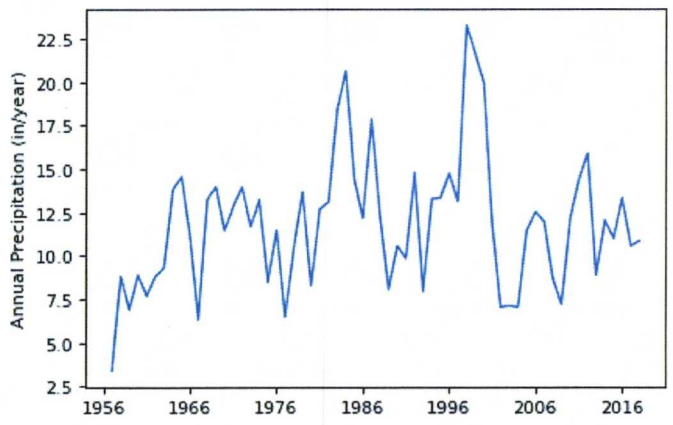


Figure 10 – Adjusted annual precipitation based on Grantsville 2 weather station (Jan 1 – Dec 31)

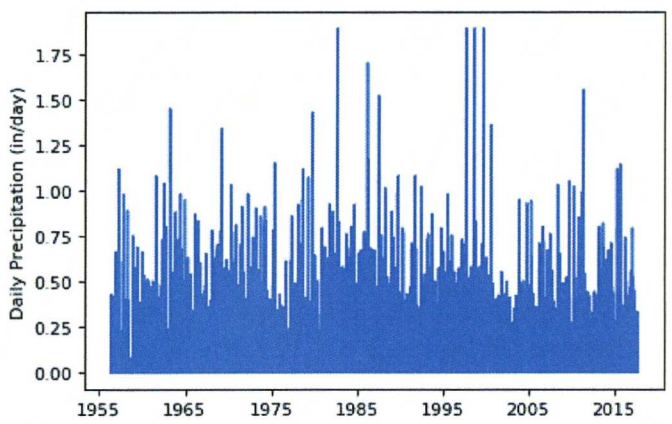


Figure 11 – Adjusted precipitation record, daily precipitation depths

Table 3 – Comparison of the raw and adjusted rainfall records for the Grantsville weather station

Station Name	Station Condition	Years of Precip	mean (in)	std (in)	min (in)	max (in)
Grantsville 2 W	Raw weather data	61	11.12	3.46	0.43	20.62
Grantsville 2 W	Adjusted data	62	11.85	3.87	3.41	23.26

Using daily rainfall records from the maximum precipitation year adds conservatism to the analysis. The previous maximum annual precipitation increased from 20.62 to 23.26 inches. Comparing **Figure 6** with **Figure 10** shows that previously missing precipitation data becomes the highest precipitation years on record. This was done purposefully, to evaluate the model results under multiple high precipitation years. To determine the statistical likelihood that a given year would receive 23.26 inches of precipitation, the initial annual Grantsville precipitation depths were fit to a Pearson Type 3 statistical distribution (**Figure 12**). Similar statistical fits were obtained

for the log-normal and general extreme value distributions, which are not shown below. The data fit is shown below and the fitting parameters are given in **Table 4**. The fitted distribution was then used to project to determine the expected return period of the new maximum annual precipitation shown on **Figure 10** (23.26 inches).

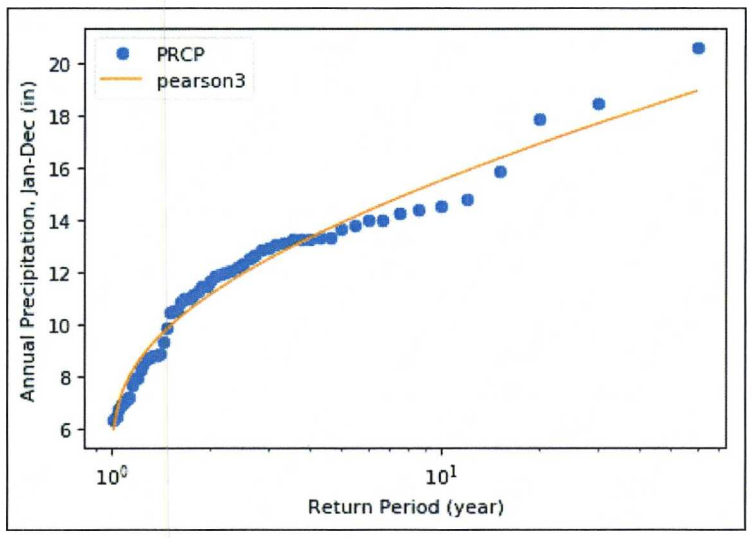


Figure 12 – Fitted Pearson Type 3 distribution to observed annual precipitation at the Grantsville weather station

Table 4 – Fitting parameters for the Pearson Type 3 statistical distribution using the raw data from the Grantsville 2 weather station.

Distribution	Mean	Standard Deviation	Skew
Pearson Type 3	11.427	3.057	0.572

Using the fitted distribution, an annual precipitation of 23.26 inches is equivalent to a 911 year event. That is, for any individual year, the likelihood of the precipitation exceeding 23.26 inches is approximately 0.1 percent. Over multiple years, the chances of the annual precipitation exceeding 23.26 inches increases. Rephrased, it is more likely for a 0.1 percent storm to occur if a storm that size has not been observed. As shown on **Figure 13**, there is a 10 percent chance of a 23.26 inch precipitation event during a 100-year period. That is, if the proposed waste storage pond operated for 100-years, there is a 10 percent chance at least one year would receive 23.26 inches of precipitation. If the Facility operates less than 100 years, the Facility is less likely to receive 23.26 inches of precipitation in an individual year.

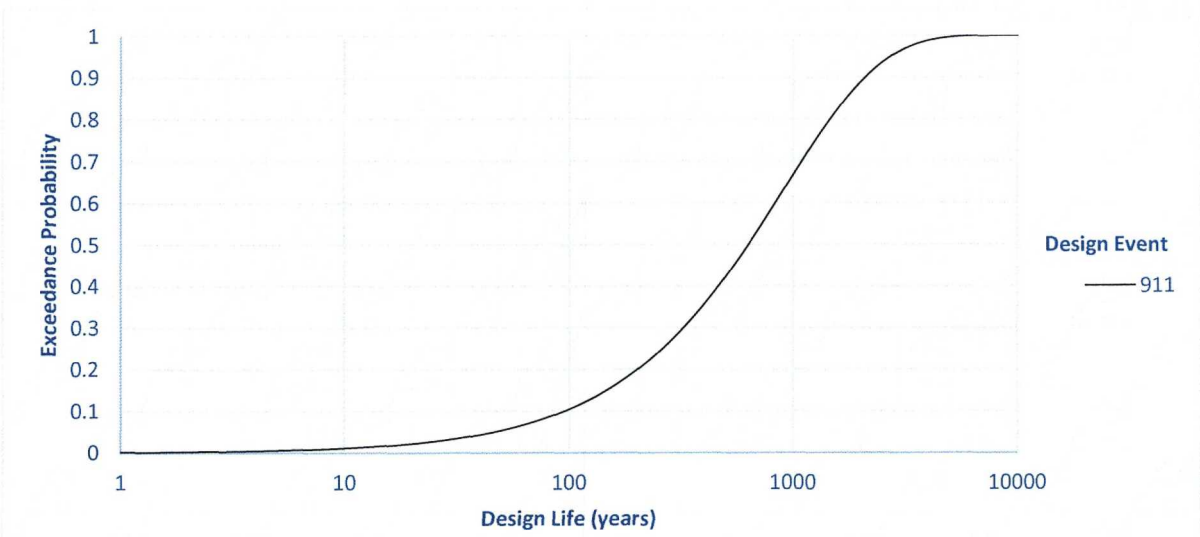


Figure 13 – The likelihood a 911-year precipitation event occurs as the design life of a Facility increases.

As outlined at the beginning of the section, the adjusted precipitation record has a long period of record with daily rainfall totals and was modified to include a design storm. The likelihood of observing the design storm event is approximately 0.1 percent in any given year and approximately 10 percent if the Facility remains in operation for 100-years.

The adjusted precipitation record, as presented on **Figure 10** and **Figure 11** was used to evaluate future potential water levels at the US Magnesium Facility. For consistency, the dates of 1965 to 2017 were used in the results; however, these results are assumed to also reflect potential future water levels.

3.3 DIRECT RAINFALL AND RUNOFF

The runoff area for the OWP will be equal to the area within the proposed barrier wall; therefore, it was assumed that all rainfall over the OWP would report to the pond instantly. The CWP has a total runoff area of approximately 768 acres including up to 495 acres directly over the maximum pond footprint and a minimum area of 273 acres over land. It was assumed 100 percent of precipitation over land and over the pond report to the CWP. No precipitation losses were assumed. The total rainfall contributing area is shown in **Table 5**. Note that although a west barrier wall has been considered for the site, no west-wall barrier was assumed for modeling. If the west barrier wall were required, the total run-on area would decrease. Direct rainfall and runoff areas for the CWP and OWP are shown on **Figure 14**.

Table 5 – Summary of runoff areas and runoff percent used in the water balance model

Runoff Area	Area (ac)	Percent Runoff
Minimum CWP Land Area	273	100
Maximum CWP Direct Precipitation Area	495	100

Runoff Area	Area (ac)	Percent Runoff
CWP Total	768	100
OWP Total	607	100

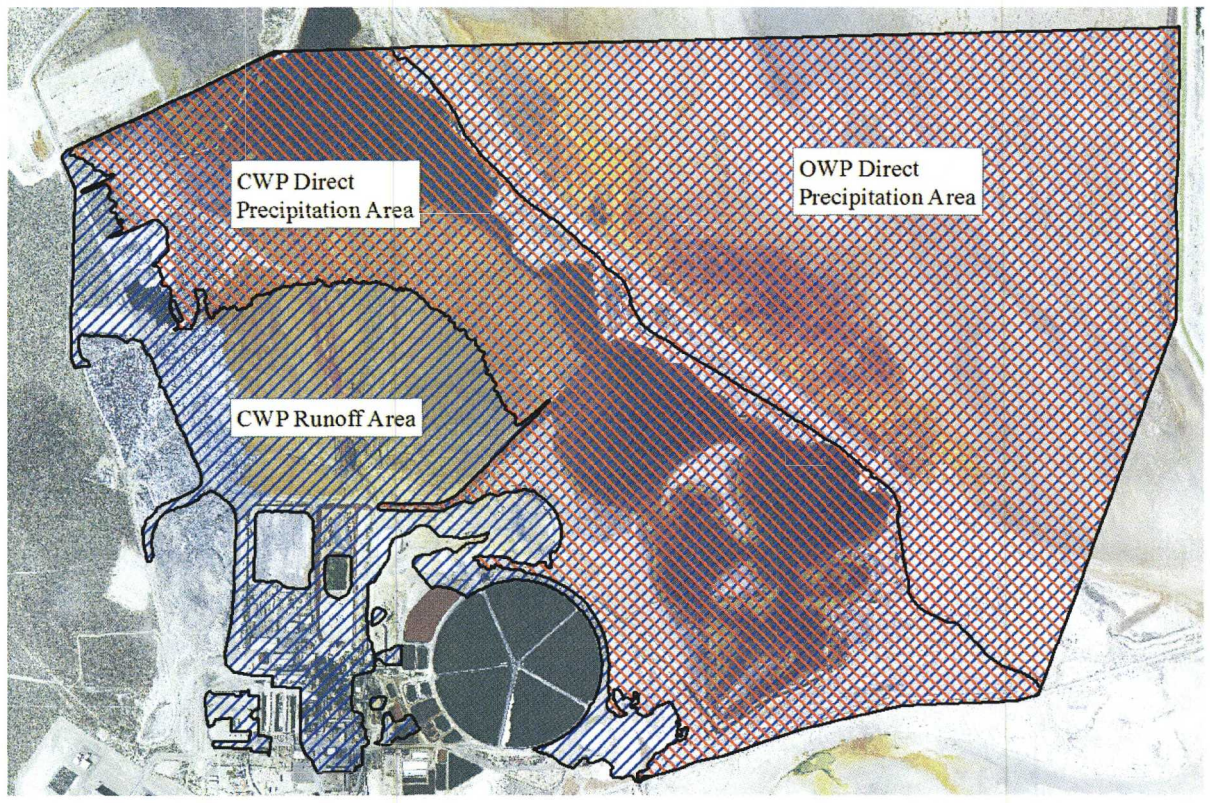


Figure 14 – CWP and OWP runoff areas

3.4 EVAPORATION DATA AND ANALYSIS

3.4.1 Calculated Freshwater Evaporation Rates from Three Weather Stations

US Magnesium does not collect site specific pan evaporation rates. Therefore, it was necessary to calculate an assumed evaporation rate to use in the water balance. Calculated evaporation rates for the Eagle Range, Salt Lake City International Airport, and Brigham City weather stations were compared. The locations of these stations are shown on **Figure 15**. These weather station records were retrieved from the NOAA Local Climatological Database (LCD) or the NOAA United States Climate Resource Network (USCRN) database. These databases contain measurements every one hour or less for solar irradiance, wind speed, temperature, relative humidity and other factors useful in calculating robust evaporation estimates. A summary of the available data for each weather station is shown in **Table 6**. Despite being spread over multiple

locations in the vicinity of Great Salt Lake, estimated annual evaporation rates were similar at each weather station.

Figure 15 – Location of weather stations with sub-daily measurements used to calculate evaporation rates compared to the location of US Magnesium

Table 6 – Summary of weather stations used to estimate freshwater evaporation rates

Weather Station	Data Source	Station ID #	Sample Frequency	Dates Analyzed	Calculated Annual Fresh Water Evaporation (Jan-Dec, in/year)
Eagle Range	NOAA LCD	00480	1-hour	2014-07-31 12:58:00 - 2017-07-06 03:58:00	47.2
Salt Lake City Intl. Airport	NOAA LCD	24127	1-hour	1996-06-30 17:00:00 - 2017-08-13 21:54:00	47.5
Brigham City	NOAA USCRN	04138	5-minutes	2012-06-11 12:05:00 - 2017-07-07 21:00:00	46.1

Initial freshwater evaporation rates were calculated using the Penman (1948) equation shown below.

$$\lambda E = \frac{\Delta H + p\, c_p \frac{(e_s(T) - e)}{ra}}{\Delta + \gamma}$$

Where:

p	density of air (kg m^{-3})
c_p	specific heat of air at constant pressure (J kg^{-1} °C)
T	air temperature (°C)
e	vapor pressure of air (kPa)
$e_s(T)$	saturation vapor pressure of water at temperature T
Δ	slope of the saturation vapor pressure curve (kPa $°C^{-1}$)
γ	"constant" of the psychrometer equation (kPa $°C^{-1}$)
λ	latent heat of evaporation (J kg^{-1})
E	water vapour flux (kg m^{-2} s^{-1})
H	total available energy = Rn – G, i.e. the difference between the net radiation flux density and the heat flux density into a water body

A number of incremental calculations are required prior to using the Penman equation. Those incremental calculations are not described here, but can be found in Jensen and Allen (2016), which was used to develop the calculations used in this technical memorandum. The approach outlined by Jensen and Allen (2016) is based on standard evaporation calculations that are also available from the Food and Agricultural Organization's Technical Report No. 56 (FAO 56), which is an industry standard reference for the calculations of evaporation and evapotranspiration and is freely available online. FAO 56 is an excellent reference for daily calculations; however, Jensen and Allen (2016) also provide a number of sub-daily computations not found in FAO 56.

For the Brigham City weather station, wet bulb temperature was calculated using the equation outlined by Stull (2011). This equation was not required for evaporation estimates at Eagle Range or Salt Lake City, because the NOAA LCD datasets include wet bulb temperature directly. The NOAA USCRN datasets do not include a wet bulb temperature measurement, thus the Stull (2011) approximation was used.

3.4.2 Adjusting Freshwater Evaporation Rates for Salinity Concentrations

Evaporation rates from fresh water represent a potential maximum evaporation rate for a given water body; however, there are a number of factors that can reduce actual evaporation rates from a water surface. One of those factors is the salinity of a water body. As salinity increases, water molecules are less able to freely interact with the environment. Therefore, more energy is required for an equivalent amount of water to evaporate from a water body surface. Without additional energy, evaporation still occurs, but at a reduced rate.

To determine reduced evaporation rates as a function of salinity, evaporation calculations were performed using a modified version of the Penman Equation as described by Calder and Neal

(1984). The equation is nearly identical to the Penman Equation with the addition of an activity term as shown below.

$$\lambda E = \frac{\Delta H + p\, c_p \dfrac{\left(e_s(T) - {}^{e}/_{a_w(T_O)}\right)}{ra}}{\Delta + {}^{\gamma}/_{a_w(T_O)}}$$

Where:

$a_w(T_O)$	activity of water in solution at temperature T_O (°C).
T_O	surface temperature (°C; assumed to equal air temperature T)

The activity term represents the ionic composition of a solution on a scale from zero to one. A value of one represents activity in a solution that is equal to pure water, where the water molecules are free to interact with the environment. An activity of zero indicates that there is no free water to interact with the environment and all the water molecules are reacting with the environment. Increasing ionic concentrations, which is equivalent to increased salinity, causes more ionic bonding of free water molecule, reducing the activity of the water. Less active water results in less evaporation than more active water. For more technical discussions on the role of activity in geochemistry see, for example, White (2013).

To evaluate the potential range of activity coefficients, surface water samples collected by ERM (2016) were entered into a PHREEQC geochemical solution model (USGS, 2017). The locations of the surface samples that were analyzed are shown on **Figure 16** below. The input data used for the geochemical modeling and the resulting activity coefficients are presented in **Table 7**. The Pitzer database was used to determine the thermodynamic relational states of each sample shown in **Table 7**. The results indicate that the activity of the surface water sampled near the wastewater ditches (PRI1), the southern portion of the CWP (PRI5), and the northern portion of the CWP (PRI6) have activity values of 0.95 or greater, indicating the surface water will behave similarly to freshwater. Using the modified Penman equation and a constant activity coefficient of 0.95 resulted in a minor reduction of annual average evaporation values. Each weather station, on average, had a less than 2 percent change in evaporation rates (**Table 8**).

Figure 16 – Location of ERM surface water samples (Figure 5-1 in ERM 2016)

Table 7 – Surface water data from ERM (2016) used to evaluate potential water activity

Sample Location	Input Data (Table 5-1; ERM 2016)								Result
	pH	Dissolved Calcium	Chloride	Dissolved Potassium	Dissolved Magnesium	Dissolved Manganese	Dissolved Sodium	Sulfate	Activity Coefficient
	-	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	-
PRI1-003	0.27	280,000	37,000	54,000	1,600,000	530	1,000,000	1,300	0.969
PRI1-006	1.15	1,500,000	22,000	92,000	4,300,000	550	1,400,000	2,200	0.983
PRI1-007	0.76	210,000	10,000	44,000	170,000	110	1,000,000	490	0.991
PRI1-008	0.78	3,700,000	21,000	64,000	590,000	280	1,500,000	670	0.983
PRI1-009	1.09	2,700,000	14,000	87,000	1,200,000	260	1,700,000	550	0.989
PRI1-010	0.82	4,900,000	24,000	93,000	2,500,000	460	1,600,000	770	0.98
PRI1-011	1.25	4,300,000	20,000	100,000	2,300,000	510	1,600,000	470	0.985
PRI1-013	0.66	7,300,000	26,000	49,000	830,000	110	1,100,000	470	0.978

Sample Location	Input Data (Table 5-1; ERM 2016)								Result
	pH	Dissolved Calcium	Chloride	Dissolved Potassium	Dissolved Magnesium	Dissolved Manganese	Dissolved Sodium	Sulfate	Activity Coefficient
	-	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	-
PRI1-014	2.99	810,000	9,700	72,000	1,400,000	830	1,500,000	1,100	0.993
PRI5-002	0.49	5,100,000	37,000	130,000	3,900,000	3,000	2,000,000	2,400	0.968
PRI5-008	0.51	6,200,000	39,000	170,000	4,100,000	3,300	2,600,000	2,500	0.966
PRI5-010	0.49	6,200,000	39,000	190,000	4,300,000	3,500	2,800,000	3,200	0.965
PRI5-017	0.41	7,200,000	45,000	230,000	4,700,000	4,300	3,400,000	3,500	0.959
PRI5-018	6	5,600,000	52,000	1,800,000	8,200,000	15,000	10,000,000	2,500	0.953
PRI5-019	7.76	210,000	6,100	150,000	140,000	15	3,700,000	680	0.994
PRI6-002	0.47	7,500,000	41,000	180,000	4,800,000	5,000	2,700,000	3,700	0.963
PRI6-004	0.42	8,000,000	43,000	170,000	4,900,000	5,100	2,600,000	3,400	0.961
PRI6-006	0.53	7,900,000	8.4	190,000	4,900,000	5,000	2,800,000	3,800	0.990
PRI6-008	0.43	7,900,000	42,000	180,000	5,000,000	4,700	2,800,000	3,400	0.961
PRI6-017	0.46	6,500,000	40,000	140,000	4,200,000	4,400	2,200,000	2,900	0.965

Table 8 – Changes to estimated annual evaporation rates with an activity coefficient of 0.95

Weather Station	Calculated Annual Fresh Water Evaporation (activity = 1) (Jan-Dec, in/year)	Calculated Water Evaporation from US Mag Surface Water (activity = 0.95) (Jan-Dec, in/year)	Percent Difference
Eagle Range	47.2	46.6	1.3%
Salt Lake City Intl. Airport	47.5	46.8	1.5%
Brigham City	46.1	45.4	1.5%

Due to the similar evaporation rates calculated for each weather station, the lowest predicted annual value of 45.4 inches per year (Brigham City) was chosen for use in the model for simulation of evaporation from the pond surfaces. The Brigham City 5-minute increment evaporation data were aggregated to average hourly and daily values. Average hourly data were used in the water balance model (**Figure 17**). Average daily evaporation rates, calculated from the 5-minute weather data, are shown on **Figure 18** for reference.

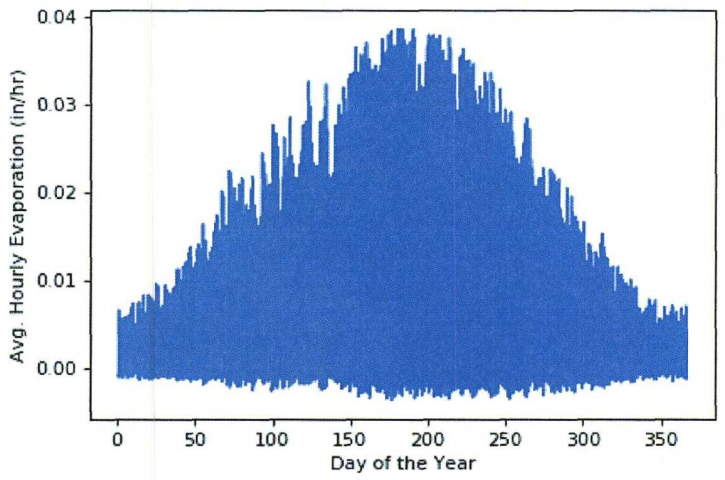


Figure 17 – Calculated average hourly evaporation rates with 0.95 activity coefficient

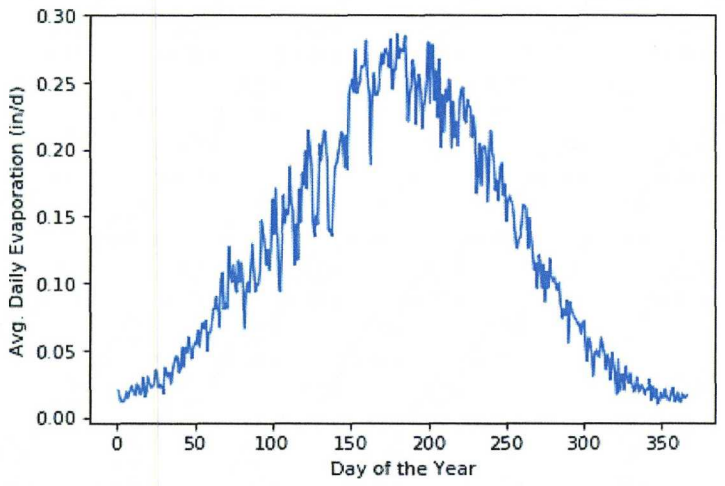


Figure 18 – Calculated average daily evaporation rates with 0.95 activity coefficient

The annual average evaporation rate 45 inches per year represents an approximation using weather station data from the Brigham City weather station and water samples collected by ERM (2016). As with other variables in the water balance, future evaporation rates could increase or decrease. These changes to evaporation rates would be linked to changes in US Magnesium process operations, which would be related to changes in water quality. However, these are questions that cannot be answered with confidence at this time; therefore, hourly evaporation rates equivalent to 45 inches per year were selected to represent future evaporation rates.

3.4.3 Literature Review of Evaporation Rates near Great Salt Lake

Published research regarding the effect of salinity on evaporation near Great Salt Lake dates back to at least 1934 when Adams published the document, "Evaporation from Great Salt

Lake." Some of the data presented by Adams is available in "The effect of Salinity on Evaporation" by Harbeck (1955). Harbeck summarizes many of the physical properties required to evaluate evaporation rates from saline solutions.

Harbeck (1955) indicates that the total dissolved solids concentration of sea water is approximately 35,000 parts per million. The data collected by ERM (2016) show TDS concentrations between 10,000 and 95,000 parts per million in the wastewater ditches and CWP (**Figure 19**). By comparison, concentrations for the South Arm of Great Salt Lake were estimated to be 94,000 parts per million in 1998 and the theoretical concentration for an undivided lake was estimated to be approximately 190,000 parts per million (Loving and Waddell, 2000).

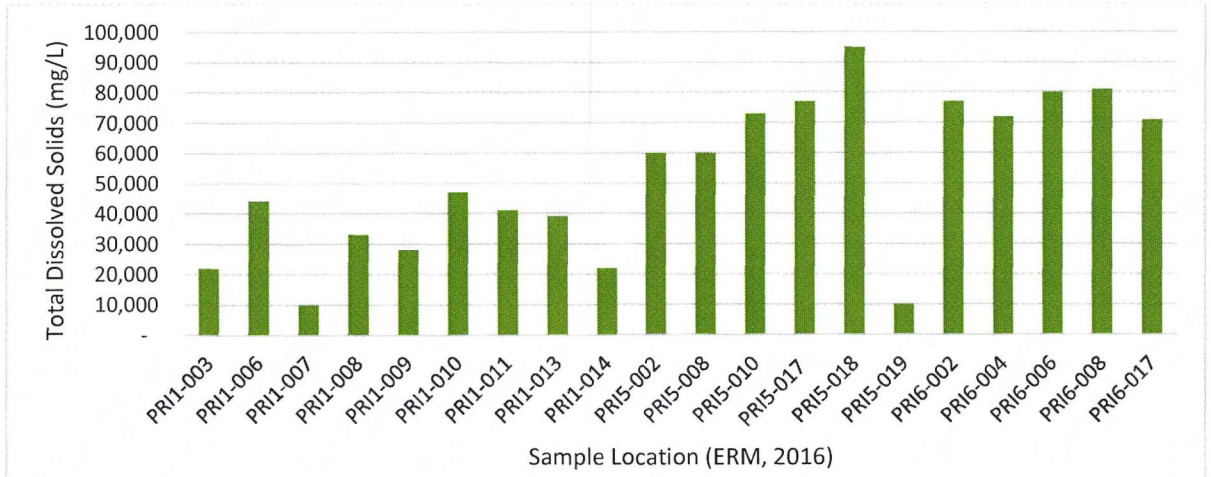


Figure 19 – Total dissolved solids concentrations at selected sample locations (ERM, 2016)

Waddell and Fields (1974) calculated monthly water and salt levels within Great Salt Lake for periods of 1931 to 1973. The results of their analysis showed estimated annual fresh water evaporation rates ranging from 51 to 62 inches per year, with adjusted saline evaporation rates of 45 inches per year for the entire Great Salt Lake, on average. This is the same annual average evaporation rate calculated in this memorandum.

As part of their study, Waddell and Fields (1974) also evaluated evaporation rates from brine solutions during summer months. The brine data was provided by Morton Salt. The brines analyzed had specific gravity measurements of approximately 1.225, indicating the brines were near saturation for sodium chloride (Waddell and Fields, 1974). Although not stated in their report, the sampled brines reported by Waddell and Fields were likely taken from concentration ponds upstream of the Morton extraction process. The evaporation rates associated with these brines were, on average, 75 percent lower than evaporation rates of fresh water.

Loving et al. (2000) updated the work of Waddell and Fields, analyzing the water balance and salt balance of Great Salt Lake between 1987 and 1998. Their evaporation estimates were based on the same approach used by Waddell and Fields (1974), which is a function of total dissolved solids and water density. Annual evaporation for the entire Great Salt Lake was given in terms of total volume and not evaporation rates. However, a range of pan evaporation rates

were reported at Saltair which varied between 37 and 57 inches per year. The range of evaporation rates was surprising because the variability of calculated evaporation rates described in Section 3.4.1 where fairly uniform.

The following were reviewed with respect to calculating evaporation rates from climatological variables: Calder and Neal (1984), Salhortra et al. (1985), Sartori (2000), Mohammed (2006), Akridge (2008), Mohammed and Tarboton (2012), and relevant chapters from Jensen and Allen (2016). In general the calculations used in these publications rely on changes to vapor pressure, which were most readily described using procedures outlined by Calder and Neal (1984), Mohammed (2006), and Mohammed and Tarboton (2012). In addition to these articles, a number of additional USGS publications for research on Great Salt Lake can be found at https://ut.water.usgs.gov/greatsaltlake/publications/.

The reviewed literature suggests the evaporation calculations applied within this memorandum would provide credible estimates for evaporation rates for the US Magnesium CWP and OWP.

3.5 POND STAGE-AREA-STORAGE RELATIONSHIPS

Stage-Area-Storage relationship curves are used to describe the various distance, area, volume relationships that occur as water fills a ponding space. Stage-Area-Storage relationships were developed assuming the constructed groundwater discharge control system would include a vertical barrier wall along the northern, eastern, and southern perimeters of the CWP and OWP. The inclusion of a barrier wall along the western area of the CWP is still being evaluated. Inclusion of the west barrier wall would decrease stormwater to the CWP, which would likely reduce the total water volume captured by the CWP and OWP. The continual growth of the gypsum pile will decrease available water storage to some degree, these losses have not been included in this analysis.

The stage (elevation) and area for the ponds were based on a 2015 LIDAR survey of the US Magnesium property. Contours were restricted at the preliminary barrier wall locations. Pond storage (volume) estimates were made using the average-end-area formula shown below. **Table 9** and **Table 10** show the data for the CWP and OWP, respectively. **Figure 20** and **Figure 21** show the stage-area-storage relationships graphically for the CWP and OWP, respectively.

$$S_i = (E_i - E_{i-1}) * \frac{\left(\frac{A_i + A_{i-1}}{2}\right)}{43560} + S_{i-1}$$

Where:

E_i = Elevation of the contour (ft)
E_{i-1} = Elevation of the previous contour (ft)
A_i = Area of the current contour (ft^2)
A_{i-1} = Area of the previous contour (ft^2)
S_i = Storage volume of the pond at the contour level (acre-ft)
S_{i-1} = Storage volume of the pond at the previous contour level (acre-ft)
43560 = conversion from ft^3 to acre-ft

Table 9 – Stage-area-storage relationship data for the CWP

Elevation	Area (ft²)	Area (ac)	Storage (ac-ft)	Notes
4210.5	2030079	46.6042	0	Area Assumed to be 80% of area at elevation 4211
4211	2537599	58.25526	26.21486492	Area Assumed to be 80% of area at elevation 4211.5
4211.5	3171999	72.81907	58.98344607	Area Assumed to be 80% of area at elevation 4212
4212	3964998	91.02384	99.94417251	Area Assumed to be 80% of area at elevation 4212.5
4212.5	4956248	113.7798	151.1450806	Area Assumed to be 80% of area at elevation 4213
4213	6195310	142.2247	215.1462156	Area Assumed to be 80% of area at elevation 4213.5
4213.5	7744137	177.7809	295.1476344	Area Assumed to be 80% of area at elevation 4214
4214	9680172	222.2262	395.149408	Area taken from LIDAR
4214.5	10947924	251.3298	513.5383875	Area taken from LIDAR
4215	11259756	258.4884	640.9929361	Area taken from LIDAR
4215.5	11894571	273.0618	773.8804927	Area taken from LIDAR
4216	14573614	334.5641	925.7869751	Area taken from LIDAR
4216.5	15960220	366.3962	1101.027067	Area taken from LIDAR
4217	16952210	389.1692	1289.918423	Area taken from LIDAR
4217.5	17952582	412.1346	1490.244367	Area taken from LIDAR
4218	18627209	427.6219	1700.183481	Area taken from LIDAR
4218.5	19203436	440.8502	1917.301507	Area taken from LIDAR
4219	19661135	451.3575465	2140.35345	Area taken from LIDAR
4219.5	20587316	472.6197429	2371.347772	Area taken from LIDAR
4220	21582800	495.4729033	2613.370933	Area taken from LIDAR

Table 10 – Stage-area-storage relationship data for the OWP

Elevation	Area (ft²)	Area (ac)	Storage (ac-ft)	Notes
4206	6418143	147.340	0	Area taken from LIDAR
4206.5	9345948	214.553	90.47343516	Area taken from LIDAR
4207	13166583	302.263	219.6775848	Area taken from LIDAR
4207.5	14569110	334.461	378.8585597	Area taken from LIDAR
4208	15710225	360.657	552.6380352	Area taken from LIDAR
4208.5	16961708	389.387	740.1491328	Area taken from LIDAR
4209	20492940	470.453	955.1092358	Area taken from LIDAR
4209.5	22126693	507.959	1199.712273	Area taken from LIDAR
4210	22635979	519.651	1456.614662	Area taken from LIDAR
4210.5	23037238	528.862	1718.742858	Area taken from LIDAR
4211	23443230	538.183	1985.504039	Area taken from LIDAR

Elevation	Area (ft^2)	Area (ac)	Storage (ac-ft)	Notes
4211.5	23650183	542.934	2255.783043	Area taken from LIDAR
4212	23791230	546.171	2528.059292	Area taken from LIDAR
4212.5	23902412	548.724	2801.783136	Area taken from LIDAR
4213	24053150	552.184	3077.010193	Area taken from LIDAR
4213.5	24164418	554.739	3353.740956	Area taken from LIDAR
4214	24424572	560.711	3632.603386	Area taken from LIDAR
4214.5	24582265	564.331	3913.863929	Area taken from LIDAR
4215	24982207	573.513	4198.324857	Area taken from LIDAR
4215.5	25402623	583.164	4487.493992	Area taken from LIDAR
4216	25679411	589.518	4780.66453	Area taken from LIDAR
4216.5	25836012	593.113	5076.322374	Area taken from LIDAR
4217	25977428	596.360	5373.690601	Area taken from LIDAR
4217.5	26076420	598.632	5672.438582	Area taken from LIDAR
4218	26154656	600.428	5972.203712	Area taken from LIDAR
4218.5	26215146	601.817	6272.765022	Area taken from LIDAR
4219	26270871	603.096	6573.993313	Area taken from LIDAR
4219.5	26306548	603.915	6875.746176	Area taken from LIDAR
4220	26342233	604.734	7177.908602	Area taken from LIDAR

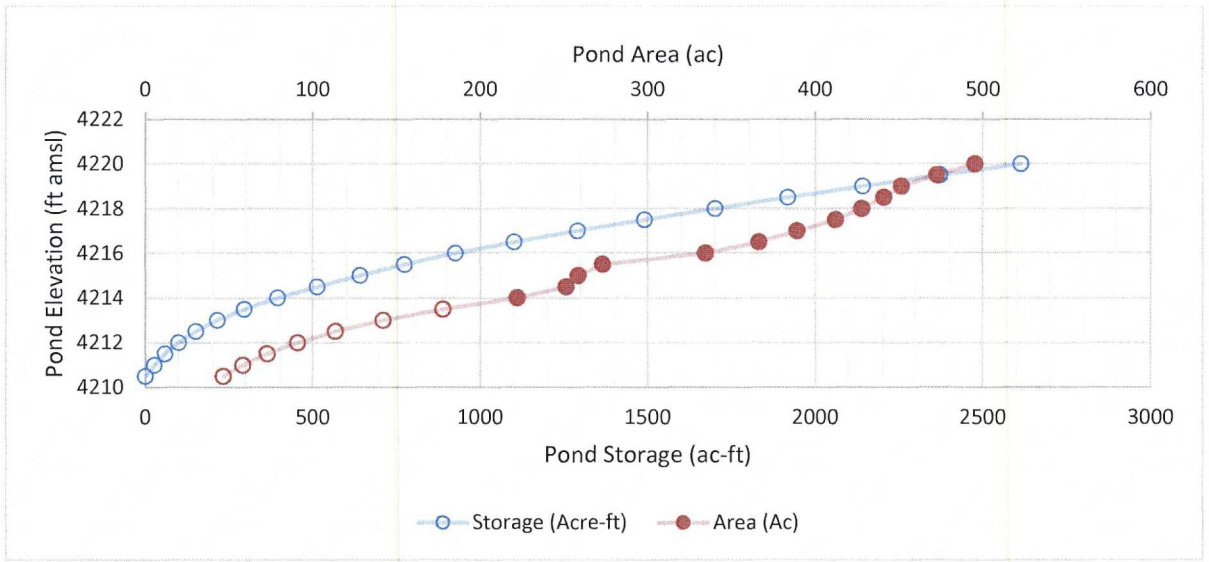


Figure 20 – Graphical stage-area-storage data for the CWP

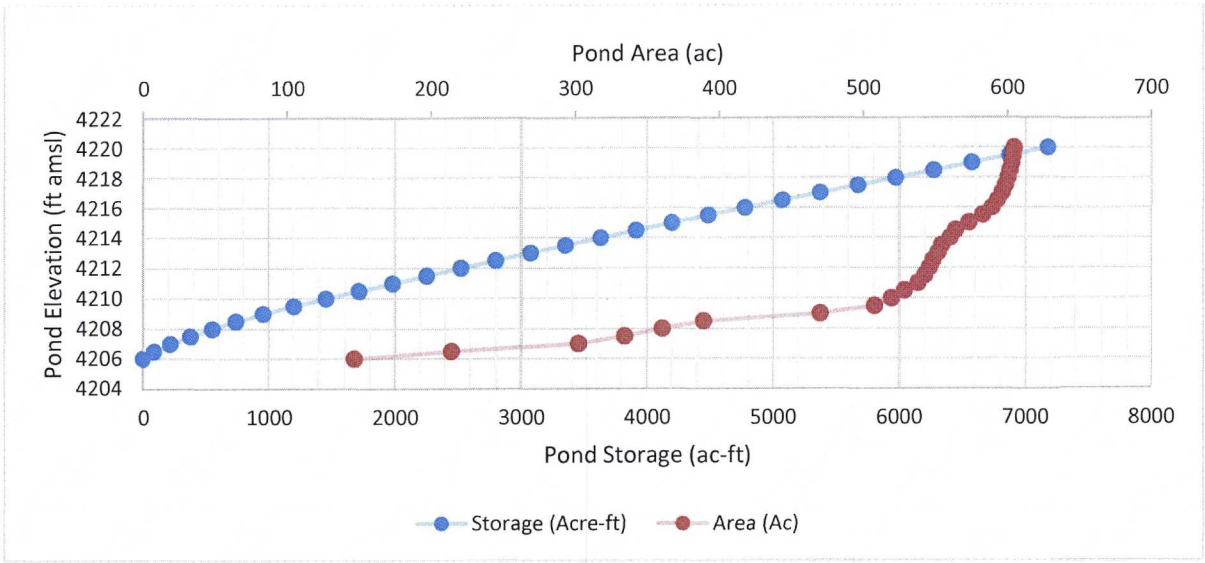


Figure 21 – Graphical stage-area-storage data for the OWP

As noted in **Table 9**; contour areas below 4214 ft amsl were assumed to be 80 percent of the next greater elevation. These assumptions were necessary because pond elevation data below the 2015 LIDAR water surface were not available. The water level at the time of the 2015 LIDAR survey was approximately 4214 ft amsl. Assumed area and data points for the CWP are shown with hollow circles on **Figure 20**. Note the assumed areas at below 4214 ft amsl are part of the total storage estimates above 4214 ft amsl; therefore, the entire stage-storage curve for the CWP shows hollow circles. The total storage volume of the CWP, below 4214 ft amsl, is 295 ac-ft. This is equivalent to 11 percent of the total estimated pond capacity at 4220 ft amls (2613 ac-ft).

3.6 INITIAL WATER LEVELS IN THE CWP AND OWP

Initial water levels (and related pond volume) were assumed for the CWP and OWP in order to provide a starting point for the model and to reduce the time delay necessary for the ponds to fill and become hydraulically connected. These assumed values have some influence on the calculated model results during early years in the water balance; however, after a number of years, the simulated results are not affected by the initial conditions.

The CWP was assumed to be filled to the level of the hydraulic connection at 4214 ft amsl. The OWP will start empty at the time of construction, but will eventually reach some typical operating level. It was assumed this operating level might be near 4214 ft amsl, so an initial water level of 4213 ft amsl was selected for the OWP.

4.0 RESULTS

The water balance model was used to calculate expected water levels in the CWP and OWP (areas included in the proposed footprint of the RWP) using the input data described in Section 3 and summarized in **Table 11**. The simulated water levels in the CWP and OWP (and annual precipitation depths) are shown on **Figure 22**. Note on resulting figures that water levels in the CWP and OWP are equivalent when the water level is above 4214 ft amsl. The maximum water level of 4217.8 ft amsl occurs in March 2000 after the multiple years of maximum precipitation were added to the weather record as described in Section 3.2.

Table 11 – Input data used to model the proposed barrier wall configuration

Input	Description
Wastewater Discharge Rate	950 gpm as measured by the recently installed Cutthroat Flume in the Main Ditch.
Gypsum Slurry Discharge Rate	150 gpm. Calculated based on inflows from the calcium chloride system underflow (50 gpm), desulfation system underflow (50 gpm), and 50 percent additional volume assumed for conservatism.
Precipitation	Raw precipitation record from the Grantsville 2 weather station, with missing data replaced as described in Section 3.2.
Run-on Area	100% contribution from upstream areas.
Evaporation	Hourly values for an average calendar year as measured by the Brigham City weather station. Evaporation rates were adjusted based on measured ionic concentrations of surface waters in the CWP and waste ditches (data from ERM, 2016).
Stage-area-storage relationships	Developed from 2015 LIDAR survey. Some assumptions were required for the CWP.
Initial Water Levels	Assumed the CWP was filled to 4214 ft and the OWP was filled to 4213 ft.
Simulation Period	Results show 1956 to 2017, but reflect future water levels based on input precipitation that were recorded during the designated year.

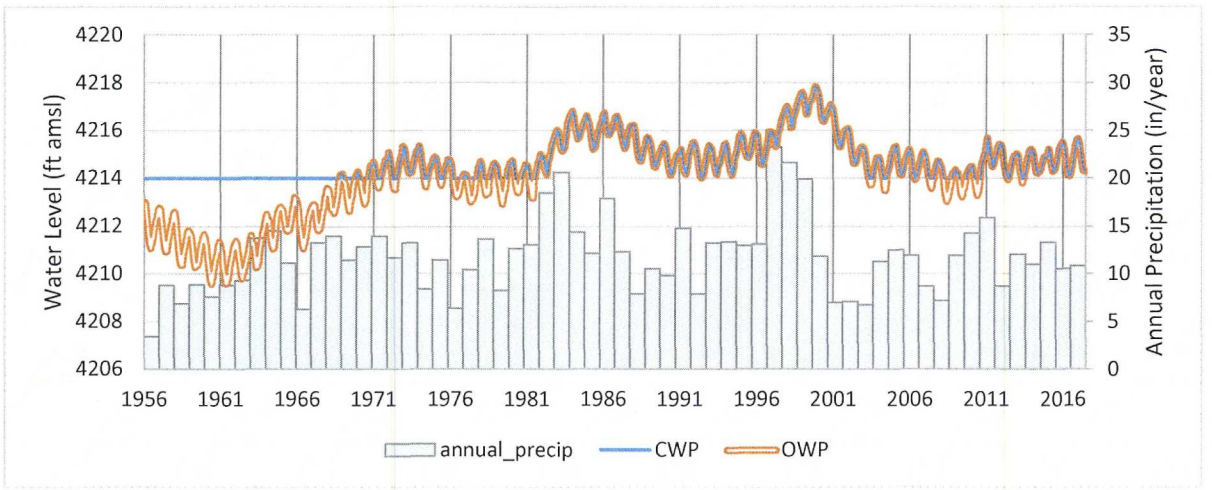


Figure 22 – Projected water levels in the CWP and OWP

The water surface areas for water surface elevations of 4218 ft amsl (maximum simulated water level) and 4220 ft amsl (maximum potential water level) are shown on **Figure 23**. The figure reflects the "no west barrier wall" option. The inundation area would be slightly restricted with the inclusion of a west barrier wall. In the figure, although the Main Ditch shows ponded water, this area will be filled as part of the RCRA Carve-Out Cleanup project work described in the Groundwater Discharge Control Plan.

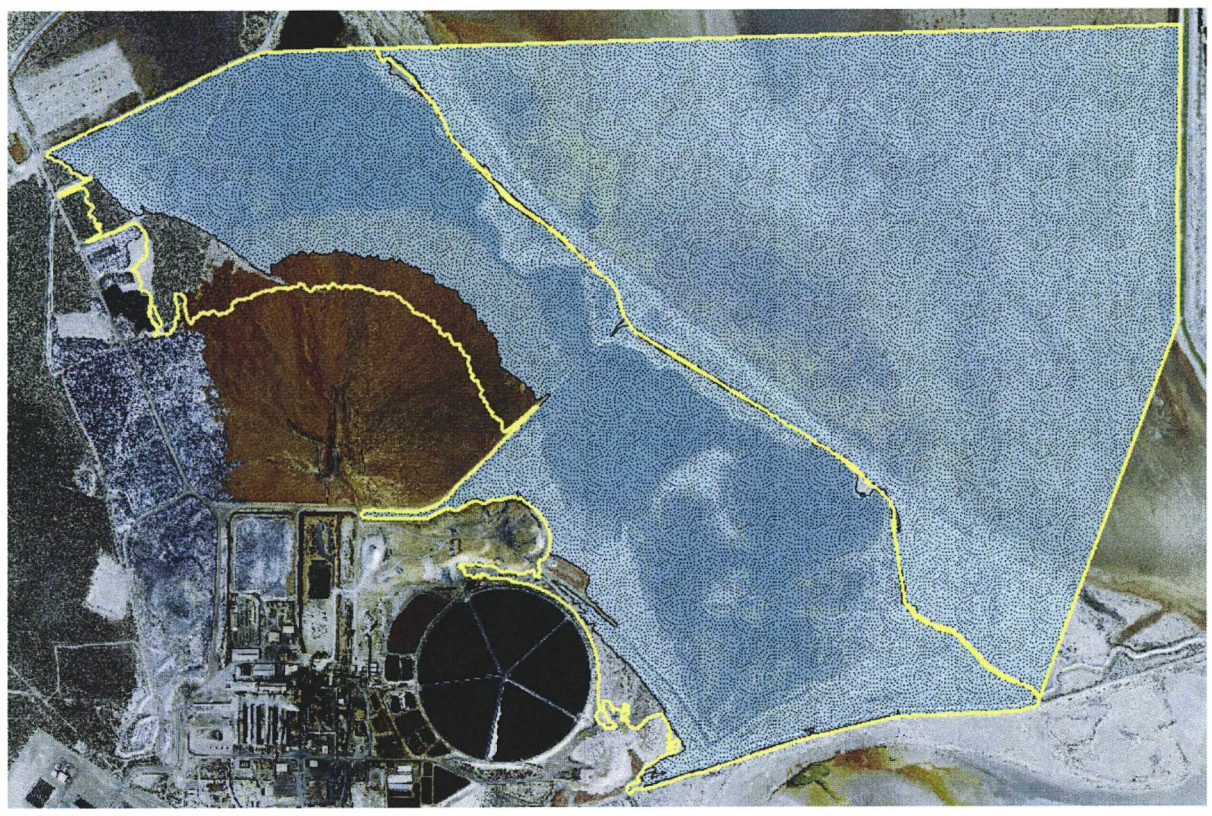


Figure 23 – Water surface area at 4218 (blue fill) and 4220 (yellow outline) ft amsl

4.1 ADDITIONAL CLIMATE CONSIDERATIONS

To evaluate potential climate variability, two additional weather records were analyzed: the first analyzing multiple wet years and the second analyzing multiple average precipitation years.

The multiple wet-year analysis used the maximum precipitation year that was shown in Section 3.2 (**Figure 8**) reduced by 7.5 percent to produce a daily rainfall record with an annual precipitation amount of 20.0 inches per year (**Figure 24**). The weather record was reduced to determine the weather record that would produce annual water levels approaching, but not exceeding, the maximum proposed crest of the CWP and OWP, 4220 ft amsl (**Figure 25**).

The multiple average year record was developed for a period of 365 days that produced approximately 12.5 inches of rainfall over that period (**Figure 26**). The resulting water levels are

shown on **Figure 27**. An additional simulation was conducted to evaluate the impact of the initial water surface elevation. In this scenario, the initial elevation of both ponds was set to 4219.9 ft amsl. The average year precipitation record was used to predict the length of time required for the pond to reach typical operating levels under these conditions. The results of this analysis are shown on **Figure 28**.

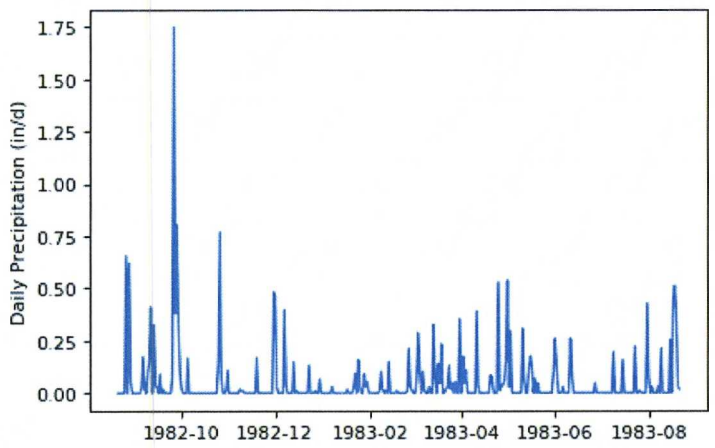


Figure 24 – Wet year record for additional analysis (20 inches in 365 days)

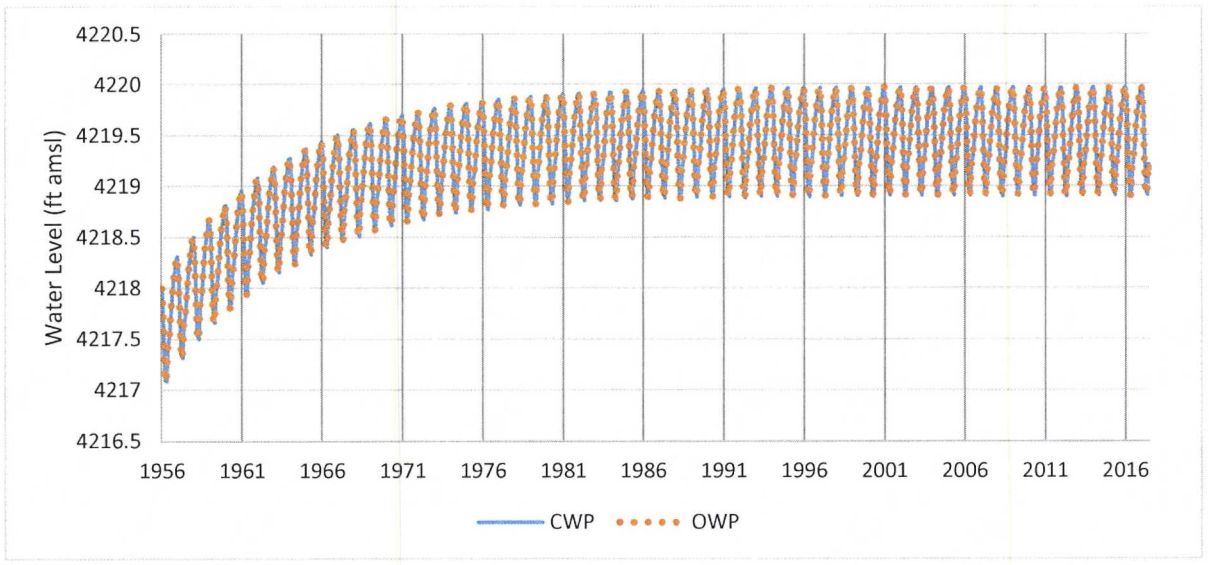


Figure 25 – Water level results for repeated wet years

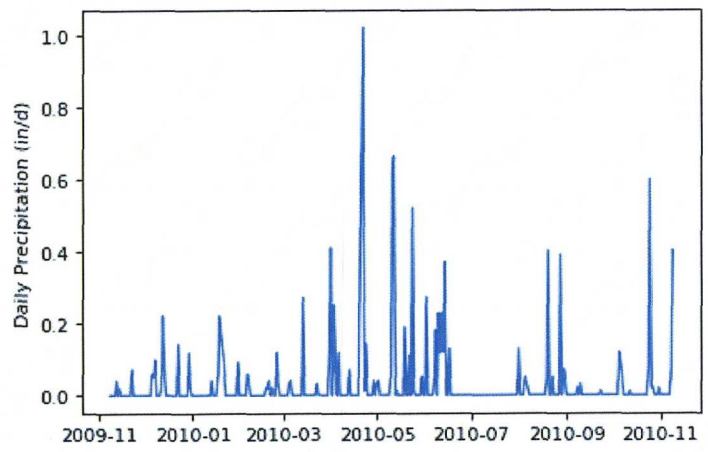


Figure 26 – Average year precipitation record for additional analysis (12.5 inches in 365 days)

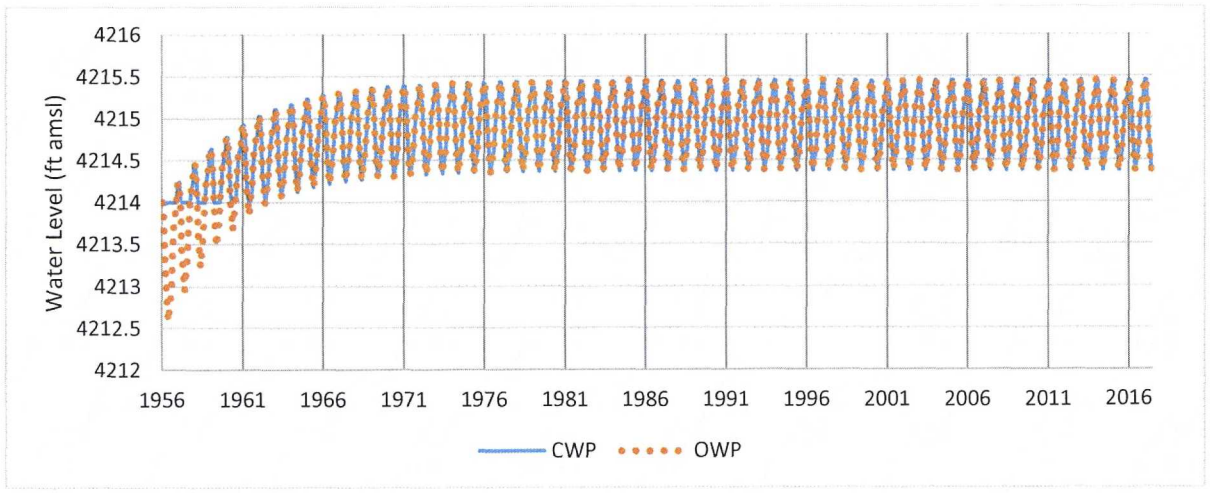


Figure 27 – Water level results for repeated average years

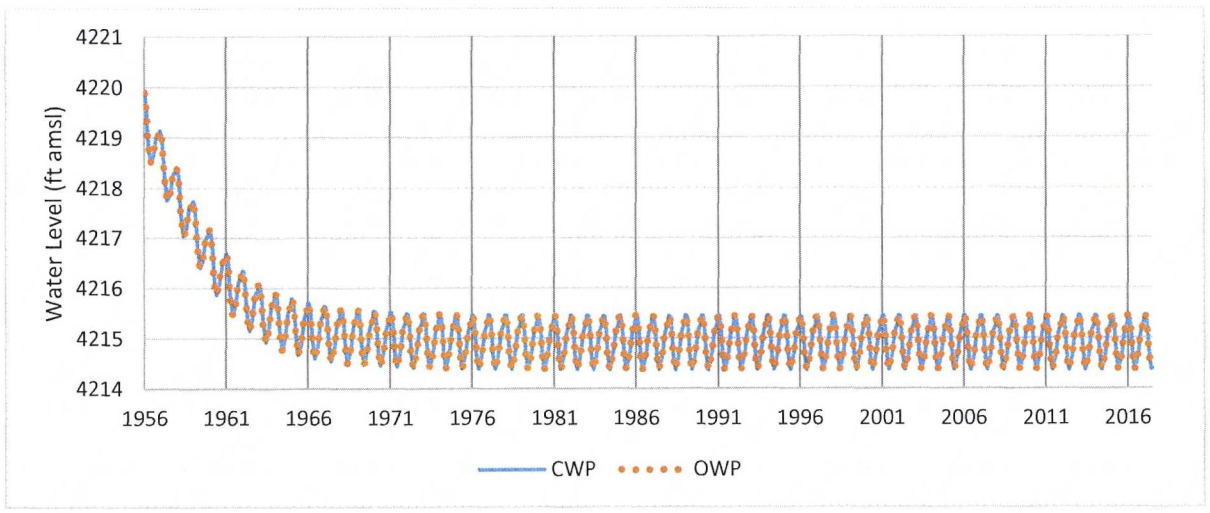


Figure 28 – Water level results for repeated average years with high initial water levels

These results show the expected operating levels of the CWP and OWP under repeated wet years and under repeated average precipitation years. The operating level after repeat wet years is nearly 4220 ft amsl. The operating level after repeat average years is approximately 4215.5 ft amsl. As estimated from **Figure 28**, it takes approximately 15 years to reach steady state conditions under these assumptions. The peak water level drops approximately 3 feet after the first 5 years and only 1 foot after.

4.2 SENSITIVITY TO RUNOFF LOSSES

Sensitivity analyses were conducted to evaluate potential reduced water levels associated with various modeled runoff losses. As described in Section 3.3, the overall surface area draining toward the CWP is approximately 768 acres. Of this area, the maximum area of direct precipitation onto the CWP is 495 acres. The value of 495 acres is the equivalent water surface area of the CWP at an elevation of 4220 ft amsl (see **Table 8**). However, as the pond surface area decreases, the amount precipitation falling over land area within the CWP increases. That is, the runoff area over land changes with water surface area. This was calculated as:

$$Runoff\ area\ over\ land = 768\ acres - Current\ Water\ Surface\ Area$$

In the model simulations up to this point, all rainfall was assumed to be instantly routed to the pond, with no losses for rainfall over land. For the simulations presented below, constant runoff losses were assumed for all precipitation over land. Evaluations were made for 100, 75, 50, and 25 percent runoff. The results for 100 percent runoff match the results shown on **Figure 25**. The results with different runoff coefficients are shown on **Figure 29**. Note that all results are shown for the OWP. The CWP maintains water levels near 4214 ft amsl, unless the water level is great than 4214 ft amsl for both ponds.

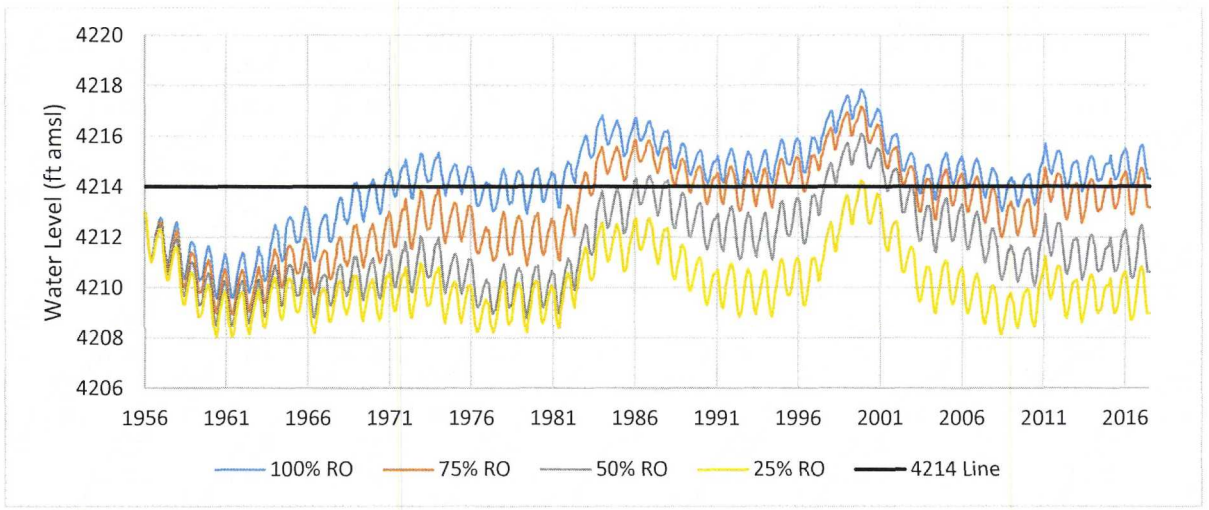


Figure 29 – Changes in OWP water level associated with given runoff coefficients

Figure 30 shows the relative difference in water levels between 100 percent runoff and 75, 50, and 25 percent runoff. The negative value indicates how much lower the water level is compared to the 100 percent runoff line.

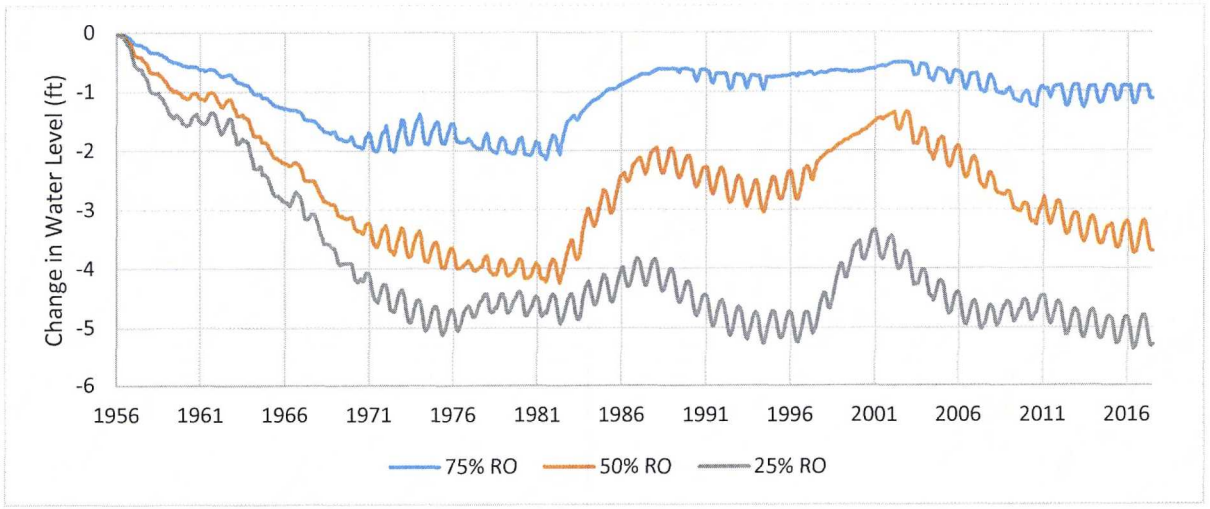


Figure 30 – Difference between 100% runoff and reduced runoff water levels in the OWP

The average change in water levels are -1.0, -2.6, and -4.0 feet for 75, 50, and 25 percent runoff respectively. The results from this sensitivity analysis show how much the results of this water balance could be overestimated. These results do not consider impacts or runoff related to variable runoff storm intensity or antecedent soil moisture. Future analysis using the water balance model developed for this project could provide more detailed estimates of likely pond levels with reduced runoff and bare soil evaporation impacts.

5.0 CONCLUSIONS

The results of this analysis demonstrate that the proposed barrier wall is sufficiently sized for the simulated conditions expected at the US Magnesium site. The simulated inflows to the CWP were 950 gpm from wastewater, 150 gpm from the gypsum slurry water, direct precipitation onto the CWP water surface, and precipitation runoff. Direct precipitation and precipitation runoff were simulated by the modified Grantsville weather record. The hydraulic connection at 4214 ft amsl links the CWP to the OWP. Inflows from the CWP typically flow into the OWP as water levels reach 4214 ft amsl. The only other flow to the OWP is direct precipitation. Evaporation was the only assumed water loss from the CWP and OWP. The annual average evaporation (January to December) was calculated to be 45.4 inches per year. This evaporation rate reflected the expected reduction in evaporation due to measured salinity levels. The calculated water activity rates were 0.95 or greater, suggesting the measured stored water had an activity similar to pure water. Review of the literature suggests an average annual evaporation rate of 45 inches per year is an acceptable rate for use in the design of the groundwater discharge control system. Stage-area-storage curves for the OWP are likely close to what may be expected for final conditions; however, a bathymetric survey or other techniques would improve confidence in the stage-area-storage data for the CWP below an elevation of 4214 ft amsl. Additional sensitivity analyses may be performed to evaluate the change in water levels associated with different stage-area-storage relationships for the non-surveyed elevations of the CWP.

The maximum calculated water level from the modified Grantsville weather record was nearly 4217.8 ft amsl. This water level occurred after two years of high precipitation. This water level is unlikely to occur, but validates that the expected water level should not exceed the proposed crest elevation of 4220 ft amsl. Results shown by **Figure 22** were used as input data for the numerical groundwater flow model used to determine potential changes in phreatic levels resulting from stored water levels within the CWP and OWP.

Additional simulations were performed to assess the precipitation required to produce water levels of 4220 and approximate average water levels. Repeat wet years with 20 inches per year of precipitation produced annual maximum water levels just below the crest elevation of 4220 ft amsl (**Figure 25**). Repeat average rainfall years of 12.5 inches per year resulted in maximum annual water levels reaching 4215.5 ft amsl (**Figure 27**).

Lastly, a sensitivity analysis was conducted to demonstrate potential changes to projected water levels with reduced stormwater runoff. Runoff losses were modeled using a simple percent of total rainfall, which does not consider antecedent moisture conditions or rainfall intensity. Using this approach, water levels decreased between one and six feet depending on the constant loss rate applied.

6.0 REFERENCES

Akridge, D.G., 2008. Methods for calculating brine evaporation rates during salt production. Journal of Archaeological Science, 35(6), pp.1453-1462.

Allen, Richard G., et al. "FAO Irrigation and drainage paper No. 56." Rome: Food and Agriculture Organization of the United Nations 56.97 (1998): e156. Online at: https://www.kimberly.uidaho.edu/water/fao56/fao56.pdf

Calder, I.R. and Neal, C., 1984. Evaporation from saline lakes: a combination equation approach. Hydrological Sciences Journal, 29(1), pp.89-97. Online at: http://www.tandfonline.com/doi/pdf/10.1080/02626668409490924

ERM. June 2016. Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model.

Harbeck Jr., G. E. 1955. Studies of Evaporation - The Effect of Salinity on Evaporation. Geological Survey Professional Paper 272-A. Online at: https://pubs.usgs.gov/pp/0272a/report.pdf

Jensen, M.E., and Richard G. Allen. 2016. Evaporation, evapotranspiration, and irrigation water requirements/prepared by the Task Committee on Revision of Manual 70; sponsored by the Committee on Evapotranspiration in Irrigation and Hydrology of the Irrigation and Drainage Council of the Environmental and Water Resources Institute of the American Society of Civil Engineers. Online at: https://ascelibrary.org/doi/book/10.1061/9780784414057

Loving, B.L., Miller, C.W. and Waddell, K.M., 2000. Water and salt balance of Great Salt Lake, Utah, and simulation of water and salt movement through the causeway, 1987-98 (No. 2000-4221). US Geological Survey. Online at: https://pubs.usgs.gov/wri/2000/4221/report.pdf

Mohammed, I.N. 2006. Modeling Great Salt Lake. Master of Science Thesis. Online at: http://hydrology.usu.edu/dtarb/ibrahim_thesis.pdf

Mohammed, I.N. and Tarboton, D.G. 2012. An examination of the sensitivity of Great Salt Lake to changes in inputs. Water Resources Research, 48(11). Online at: http://onlinelibrary.wiley.com/doi/10.1029/2012WR011908/full

NOAA Local Climatological Data (LCD). https://www.ncdc.noaa.gov/cdo-web/datatools/lcd

NOAA US Climate Reference Network (USCRN) data https://www.ncdc.noaa.gov/crn/qcdatasets.html

Salhotra, A.M., Adams, E.E. and Harleman, D.R., 1985. Effect of salinity and ionic composition on evaporation: Analysis of Dead Sea evaporation pans. Water Resources Research, 21(9), pp.1336-1344.

Sartori, E., 2000. A critical review on equations employed for the calculation of the evaporation rate from free water surfaces. Solar energy, 68(1), pp.77-89. Online at: http://www.datakala.com/files/Translation/DataKala_Tarjome_41.pdf

Stantec, 2017. US Magnesium Groundwater Discharge Permit Application Groundwater Discharge Control Plan. December 2017.

Stull, R., 2011. Wet-Bulb Temperature from Relative Humidity and Air Temperature. J. Appl. Meteor. Climatol., 50, 2267–2269. Online at: https://doi.org/10.1175/JAMC-D-11-0143.1

Waddell, K. M. and Fields, F. K., 1977, Model for evaluating the effects of dikes on the water and salt balance of Great Salt Lake, Utah: Utah Geological and Mineralogical Survey Water-Resources Bulletin 21, 54 p. Online at: http://ugspub.nr.utah.gov/publications/water_resources_bulletins/WRB-21.pdf

White, W.M., 2013. Geochemistry. John Wiley & Sons, Inc.. ISBN 1118485270.

APPENDIX E – GROUNDWATER MODEL REPORT

Groundwater Discharge
Permit

Groundwater Flow Model:

Simulating Groundwater System Response
to a Proposed Hydraulic Barrier Wall
Controls for a Future Retrofitted
Wastewater Discharge Pond

Prepared for:
US Magnesium LLC

Prepared by:
Stantec Consulting Services

1.0 TABLES

Table 1. Predicted Groundwater Fluxes Leaving Model Domain

Table 2. Predicted Groundwater Fluxes Resulting from Sensitivity Analysis

2.0 FIGURES

Figure 1. Groundwater Flow Model Domain

Figure 2. Layer 1: Simulated Horizontal Hydraulic Conductivity Values

Figure 3. Layer 1: Simulated Vertical Hydraulic Conductivity Values

Figure 4. Layer 2: Simulated Horizontal Hydraulic Conductivity Values

Figure 5. Layer 2: Simulated Vertical Hydraulic Conductivity Values

Figure 6. Layer 3: Simulated Horizontal Hydraulic Conductivity Values

Figure 7. Layer 3: Simulated Vertical Hydraulic Conductivity Values

Figure 8. Layer 4: Simulated Horizontal Hydraulic Conductivity Values

Figure 9. Layer 4: Simulated Vertical Hydraulic Conductivity

Figure 10. Layer 5: Simulated Horizontal Hydraulic Conductivity Values

Figure 11. Layer 5: Simulated Vertical Hydraulic Conductivity Values

Figure 12. Layer 1: Simulated Specific Yield Values

Figure 13. Layer 1: Simulated Specific Storage Values

Figure 14. Layer 2: Simulated Specific Yield Values

Figure 15. Layer 2: Simulated Specific Storage Values

Figure 16. Layer 3: Simulated Specific Yield Values

Figure 17. Layer 3: Simulated Specific Storage Values

Figure 18. Layer 4: Simulated Specific Yield Values

Figure 19. Layer 4: Simulated Specific Storage Values

Figure 20. Layer 5: Simulated Specific Yield Values

Figure 21. Layer 5: Simulated Specific Storage Values

Figure 22. Steady State Layer 1 Calculated Saltwater Equivalent Hydraulic Head Piezometric Surface

Figure 23. Model-Predicted vs Observed Saltwater Equivalent Hydraulic Head

Figure 24. Calculated Layer 1 Saltwater Equivalent Piezometric Surface: Climate-Based Fully Enclosed After 23-Year Simulation

Figure 25. Calculated Layer 1 Saltwater Equivalent Piezometric Surface: Climate-Based Partially Enclosed Pond after 23-Year Simulation

Figure 26. Calculated Layer 1 Saltwater Equivalent Piezometric Surface: Maximum Pond Stage Fully Enclosed Pond after 30-Year Simulation

Figure 27. Calculated Layer 1 Saltwater Equivalent Piezometric Surface: Maximum Pond Stage Partially Enclosed Pond after 30-Year Simulation

Figure 28. Calculated Particle Path-Lines: Climate-Based Projection Fully Enclosed Pond after 23-Year Simulation

Figure 29. Calculated Particle Path-Lines: Climate-Based Projection Partially Enclosed Pond after 23-Year Simulation

Figure 30. Calculated Particle Path-Lines: Maximum Pond Stage Projection Fully Enclosed Pond after 30-Year Simulation

Figure 31. Calculated Particle Path-Lines: Maximum Pond Stage Projection Partially Enclosed Pond after 30-Year Simulation

Figure 32. Model-Predicted Westward Outflux Partially Enclosed Barrier Wall

1.0 MODELING BACKGROUND

A numerical groundwater flow model was created to evaluate the potential groundwater flow changes from expanding and reconfiguring the discharge wastewater pond at the US Magnesium facility (Facility). The expanded and reconfigured discharge pond is hereafter referred to as the Retrofitted Waste Pond (RWP). Additionally, the model was used to evaluate hydraulic containment of the RWP with two different engineering controls. The model incorporated site geological information from previous investigations and utilized groundwater elevation data from the wells placed throughout the vicinity of the Facility for calibration.

The conceptual model of the groundwater system includes mountain system recharge from the eastern slopes of the Lakeside Mountains. Mountain recharge provides groundwater that flows primarily to the northeast towards Great Salt Lake (GLS). Hydraulic gradients are very shallow as a product of the lacustrine topography and geology of the area and also are controlled to a large extent by the elevation and density of water in GLS. Additional recharge to groundwater is from the discharge ditches and ponds on the north and east side of the Facility. Recharge from the evaporation ponds also occurs but this is assumed to be mostly negligible due to the presence of low permeability evaporite deposits along the bottom of the pond beds. Natural recharge from precipitation is also mostly negligible away from the mountain front due to high evaporation rates and low annual precipitation.

2.0 MODEL DESIGN

The groundwater flow model uses MODFLOW-2005 (Harbaugh, 2005) and was constructed using Groundwater Modeling System (GMS) software (Aquaveo, 2017) as a graphical user interface for construction and post-processing. The finite-difference format of MODFLOW provides calculation of groundwater flow in three-dimensions, incorporating aquifer heterogeneity, and transient conditions. The model grid is rotated 33 degrees north of east; parallel to the primary groundwater flow direction.

The bajada along the foot of the Lakeside Mountains is the southwestern border of the model. This boundary provides groundwater flow into the groundwater model domain from the mountain front and is the uppermost point of the groundwater model. The shoreline of GSL and the inflow canal carrying water from the lake to the evaporation ponds mark the northeastern and eastern boundaries of the model. This boundary is the lowest discharge point for the groundwater model. The model extends 1.5 miles to the southeast of the point where the inflow canal empties into the northernmost evaporation pond. This border is a no-flow boundary that runs nearly perpendicular to the hydraulic gradient (**Figure 1**).

The model is comprised of 5 layers, each containing 99,244 cells, which have uniform size of 100 by 100 feet. Model layers represent the primary sedimentary aquifer units, all part of the regional shallow aquifer, identified at the site.

- Layers 1 and 2 predominantly represent silty clay to oolitic sand matrices with hydraulic conductivity values ranging from 0.001 to 150 feet/day (ft/day). The highest hydraulic conductivity region of these layers is in the immediate vicinity of the existing discharge ponds, where low-pH seepage has presumably dissolved the calcium carbonate matrix of the oolitic sands, increasing hydraulic conductivity. These two layers represent the shallowest portion of the Upper Aquifer Zone as defined in the Hydrogeologic Report (Stantec, 2017).

- Layer 3 represents a silty matrix and possesses hydraulic conductivity values ranging from 0.001 to 4 feet/day. Layer 3 extends to a depth of roughly 30 feet below land surface beneath the facility and is the deeper portion of the Upper Aquifer Zone as defined in the Hydrogeologic Report (Stantec, 2017). The bottom of layer 3 is the interface of the sand-silt matrix and the lacustrine clay layer (Deeper Silty Clay Unit) below.
- Layer 4 represents a roughly 10-foot thick, low permeability clay unit that pinches out towards the mountain front, west of the facility.
- Layer 5 represents a sandy confined aquifer that extends to a depth of roughly 150 feet beneath the facility. This layer represents the Lower Aquifer Zone described in the Hydrogeologic Report (Stantec, 2017). The bottom of Layer 5 is a no flow boundary.

2.1 BOUNDARY CONDITIONS

Mountain system recharge is represented in the model by general head boundary (GHB) conditions within each model layer along the southwest edge of the model. These head constrained, variable flux boundary (Cauchy) conditions act as the main source of groundwater inflow to the model. Model outflow to the east-southeast is simulated with the use of GHBs with head values roughly 20 feet less than the inflow GHBs. Where the model boundaries intercept the lake and inflow canal, a constant head condition was used with a head value equivalent to the average lake elevation over the last week of June 2017 (4194.312 feet above mean sea level [feet amsl]).

2.2 MODFLOW PACKAGES

The model was constructed using seven primary MODFLOW packages:

(1) BASIC package (BA6)
(2) DISCRETIZATION package (DIS)
(3) LAYER PROPERTY FLOW package (LPF)
(4) RECHARGE package (RCH)
(5) GENERAL HEAD BOUNDARY package (GHB)
(6) CONSTANT HEAD DESIGNATION package (CHD)
(7) HORIZONTAL FLOW BARRIER package (HFB),
(8) PRECONJUGATE GRADIENT (PCG) solver package.

The BA6 package handles the boundaries of the model as well as the initial water levels included in the simulation. The DIS package manages information regarding model grid (number of rows and columns, their length and width, the number of layers and their respective elevations) and stress periods (number of simulation days). The LPF package computes the terms to calculate the rate of flow into and out of storage, and the conductance components to determine flow between cells. The LPF package maintains information regarding the hydrologic parameters (e.g. hydraulic conductivity, storage coefficient, and potential rewetting criteria)

The RCH package was used to simulate recharge to the aquifer stemming from seepage from the facility outflow drains and discharge pond. Recharge is defined by specifying a recharge value for each stress period for each spatially specified cell in layer 1. The simulated recharge value represents the water that goes into the groundwater system.

The GHB and CHD packages work very similarly in that the packages permit the simulation of a Cauchy boundary condition within a cell, where hydraulic head is specified to be held at a constant value. The model adds or withdraws groundwater from the system at the location of the boundary condition to maintain this constant head value. The difference between these packages is that the GHB package possesses a "conductance" value to act as a coefficient that restricts the amount of water the model inserts or withdraws from the domain through the condition. This coefficient enables the impact of each GHB to be limited and permits the model-calculated hydraulic heads near the model boundary to be more coincident with field observations.

The HFB package was implemented to simulate proposed engineered controls of groundwater containment, such as containment walls. Horizontal flow barriers provide the ability to simulate an exceptionally low (including to the extent of impermeable) barrier for horizontal groundwater flow between specified cells. HFBs provide spatial precision and an ability to obstruct flow in a specific direction.

The PCG package was used to solve the system of simultaneous groundwater flow equations produced by the model. The solver approaches the solution iteratively through an approximation scheme.

2.3 HYDRAULIC CONDUCTIVITY AND AQUIFER STORAGE PARAMETERS

Initial estimates of vertical and horizontal hydraulic conductivity (K), specific yield (SY) and specific storage (SS) were adopted from calculations made from slug and aquifer tests performed onsite. Elsewhere, hydrologic parameters were obtained from literature values based on geologic and lithologic characteristics of the site (Freeze and Cherry, 1979). As a result, simulated hydraulic conductivity generally decreases from the mountain front to the northeast, towards the lake. The distribution of hydraulic conductivity values for each layer are displayed in **Figures 2 - 11**.

During the aquifer testing at the site (MW-22B), no notable head responses were observed at the surrounding monitor wells. Consequently, no field-derived value of aquifer storage could be estimated. No long-term head measurements have been made at the monitor wells at the facility to permit a transient calibration of simulated quantities of aquifer storage. Values of specific yield and specific storage were obtained from literature values based on the lithology of the represented media (Freeze and Cherry, 1979). The distribution of the simulated specific yield and specific storage values of the model are displayed in **Figures 12 – 21.**

3.0 METHODOLOGY

3.1 MODEL CALIBRATION

In addition to gravitational head, the hydraulic gradient of the regional aquifer is also influenced by changes in water density, as a result of salinity greatly increasing towards GSL. To accommodate the effects of density differential within the model, the average fluid density and stage of the GSL were used as a datum to which observed water levels were adjusted. The revised head based on the salinity and stage of GSL is described as a salt water equivalent head and is calculated via the following function:

$$Corrected\ Head = \left[\left(Obs\ Head_{@Well} - Stage_{GSL}\right) \times \left(\frac{\rho_{@Well}}{\rho_{GSL}}\right)\right] + Stage_{GSL}$$

$\rho_{GSL} \approx 1.23 \frac{g}{mL}$

$Stage_{GSL} = 4194.312\ ft\ amsl$

The model parameters of hydraulic conductivity and seepage flux rate from the trenches and discharge pond were calibrated to the salt water equivalent head of each monitoring well, measured during the last week of June 2017. The steady-state calculated potentiometric surface in layer 1 is displayed in **Figure 22.** Observed versus model-calculated salt water equivalent head is shown in **Figure 23**, as well as the mean absolute error and root-mean-square error values of 0.389 and 0.484 feet.

3.2 MODEL PROJECTIONS

The transient model was implemented to predict the impact of two engineering controls of groundwater flow: 1) a fully enclosing groundwater hydraulic barrier wall, and 2) a partially enclosing hydraulic barrier wall that is open to the west (the upgradient direction). The hydraulic barrier wall is designed to extend from the land surface to the top of the lacustrine clay aquitard, represented in layer 4 (layer 4 represents the Deeper Silty Clay Unit as defined in the Hydrogeologic Report [Stantec, 2017]).

Additionally, the stage of the pond was simulated under two scenarios: a quarterly-fluctuating stage, based on the past 23 years of historical evaporation and precipitation rates, and a conservative maximum pond stage scenario, where a constant stage (pond water level) of 4220 feet amsl (salt water equivalent: 4216.77 feet amsl) was held constant for 30 years. As a result, four separate scenarios were simulated within the transient model:

1. Climate-Based Pond Stage, Fully Enclosed Barrier
2. Climate-Based Pond Stage, Partially Enclosed Barrier
3. Maximum Pond Stage, Fully Enclosed Barrier
4. Maximum Pond Stage, Partially Enclosed Barrier

Under the Climate-Based Pond Stage scenarios, the spatial extent of the pond was varied based on stage-storage relationships. This was performed using GHB conditions with on/off conductance values, which allowed different regions of the pond to be activated based on changes in pond elevation over time. The spatial extents of the pond during each stress period were separated into 3 intervals, separated by 2-foot elevation contours. Within the Maximum Pond Stage scenarios, constant head conditions were used to simulate pond elevation.

MODPATH 5 (Pollock, 2010) was used to simulate particles that move at the linear pore velocity of the simulated flowing groundwater to track groundwater movement. These particles were placed within layer 1 within the footprint of the maximum pond extent for each scenario. The path-lines of these particles provide a measure of the potential distance that water emanating from the pond could travel over the specified model time.

4.0 RESULTS

The calculated potentiometric surface of layer 1 and the calculated flux between the silt and clay layers of the model (layers 3 and 4) were recorded at the end of the last stress period for each of the Maximum Pond Stage scenarios. Additionally, the calculated westward flux, moving away from the pond was recorded in the partially enclosed scenario.

Under the Climate-Based Pond Stage Scenarios, the model-predicted water-table surface at the end of the simulations of fully enclosed and partially enclosed scenarios are displayed in **Figures**

24 and **25**. For the Maximum Pond Stage Scenarios, the model-predicted water table surfaces at the end of the simulations of the fully enclosed and partially enclosed scenarios are displayed in **Figures 26** and **27**.

For all model scenarios, the model calculated that the majority of the theoretical particles move downwards, but none of the particles reach layer 3 over the 30-year period (**Figures 28 - 31**). According to the simulated partially enclosed designs, under both stage scenarios, the model predicted that none of the particles would escape the enclosed vicinity to reach the regional aquifer (the groundwater within all layers outside of the engineered barrier-enclosed area) to flow downgradient towards GSL within 30 years.

According to the maximum RWP stage condition, the flux rate leaving the ponded area was predicted by the model to be 57.2 gallons per minute (gpm) under the fully enclosed scenario and 62.2 gpm within the partially closed scenario. Of the 62.2 gpm flux within the partially closed scenario, 52.3 gpm (84%) flows downward into the clay layer from layer 3 and 9.9 gpm (16%) flows laterally westward within the upper aquifer (the top three layers). MODPATH particles were placed at the bottom of layer 3. The model calculated that no particle trajectories passed through the lacustrine clay of layer 4.

The calculated flux leaving the RWP area decreases with time as the hydraulic gradient becomes shallower. The predicted westward flux was recorded at eight time-steps within the model, and a decay function was fitted to the model's output (**Figure 32**). By summing the flows for the fitted function from one to 30 years over a time frame of zero to 30 years, a total estimated volume of 681 acre-feet is predicted to flow through the open western wall over the 30-year time domain. This groundwater is comprised of native groundwater that sourced from the enclosed area and was forced outwards by the increased stage of the pond above it.

The projected theoretical particle trajectories indicate that none of the water within the pond leaves the enclosed area within the 30-year period. Consequently, increased predicted fluxes are not the result of water physically traveling from the RWP to the model boundary. Instead, the increased stage of the RWP pushes downward on the regional aquifer and forces native groundwater outwards, away from the pond, and towards the model boundary along the perimeter of GSL. The total calculated fluxes through the perimeter of cells along the most downgradient border of the model are as follows:

Table 1
Predicted Groundwater Fluxes Leaving Model Domain
RWP at Maximum Stage of 4220 feet amsl

Model Flux (gpm)		
	Upper Aquifer	Lower Aquifer
Steady State	29	21
Maximum Pond Stage, Fully Enclosed	37	40
Maximum Pond Stage, Partially Enclosed	53	44

5.0 SENSITIVITY ANALYSIS

A sensitivity analysis was performed by varying the hydraulic conductivity (vertical and horizontal, simultaneously in every layer) and aquifer storage (specific yield and specific storage simultaneously) by +/- 25%. Additionally, the specified heads of the outflow general head and constant head conditions were varied to the historic minimum and maximum recorded stages of GSL. The calculated flux leaving the enclosed area at the end of the last stress period of the maximum stage, partially enclosed scenario was used for quantitative assessment.

Table 2
Predicted Groundwater Fluxes Resulting from Sensitivity Analyses

Sensitivity Analyses of GW Leaving Enclosed Area (gpm)		
Varied Parameter or Condition	Clay (from Layer 3 to 4)	W. Wall (Horizontally in Layer 1-3)
Standard	52.3	9.9
K -25%	39.8	7.7
K +25%	65.0	12.2
S -25%	57.2	9.1
S +25%	58.5	9.9
GSL low level (4191.35')	72.1	10.9
GSL high level (4211.85')	8.9	2.3

Varying hydraulic conductivity produced results that proportionally impacted the calculated outflow from the enclosed region, with a change of roughly +/- 25%. Predicted outflow was discovered to be less sensitive to storage, with a change of roughly +/- 10%. However, the model predicted a high degree of sensitivity to varying stage of GSL.

6.0 SUMMARY AND CONCLUSIONS

A numerical groundwater model was constructed to evaluate the overall potential changes to the groundwater system as a result of expanding and reconfiguring the current wastewater discharge pond at the US Magnesium Facility. Two engineered controls for containing groundwater were evaluated and include a fully enclosed hydraulic barrier wall surrounding the pond, and a partially enclosed hydraulic barrier wall (e.g., open on the western upgradient side). A successful calibration was performed to the available groundwater elevation data from monitoring wells that fall within the model domain. The model consists of five layers, with the upper three layers representing a stratified upper aquifer (corresponding to the Upper Aquifer Zone [Stantec, 2017]), a clay aquitard layer (corresponding to the Deeper Silty Clay Unit [Stantec, 2017]), and at greatest depth, a lower aquifer system (corresponding to the Lower Aquifer Zone, Stantec, 2017]). To accommodate the effects of groundwater density variability within the model, the average fluid density and stage of GLS were used as a datum to which observed water levels were adjusted.

Four scenarios were simulated in the model; a climate-based pond stage based on historic Facility operating data and a maximum pond stage to estimate a highly conservative condition:

1. Climate-Based Pond Stage, Fully Enclosed Barrier
2. Climate-Based Pond Stage, Partially Enclosed Barrier
3. Maximum Pond Stage, Fully Enclosed Barrier
4. Maximum Pond Stage, Partially Enclosed Barrier

Due to the combined field observations of a shallow hydraulic gradient and a relatively low hydraulic conductivity outside the current wastewater pond, the model calculates a total steady-state flow of 50 gpm across the model domain. The conclusions of the modeled scenarios are as follows:

- The model calculates that no water emanating from the discharge ponds extends vertically beyond layer 2 under any of the 4 simulated scenarios.
- Native groundwater, directly beneath the pond along the interface of the upper aquifer and lacustrine clay is predicted to travel downward into the clay but due to its slow velocity does not pass through the clay over the 30-year simulated time frame
- Under the most conservative conditions (the maximum pond stage scenario) the model predicts that no ponded water leaves the enclosed area within 30 years.

7.0 References

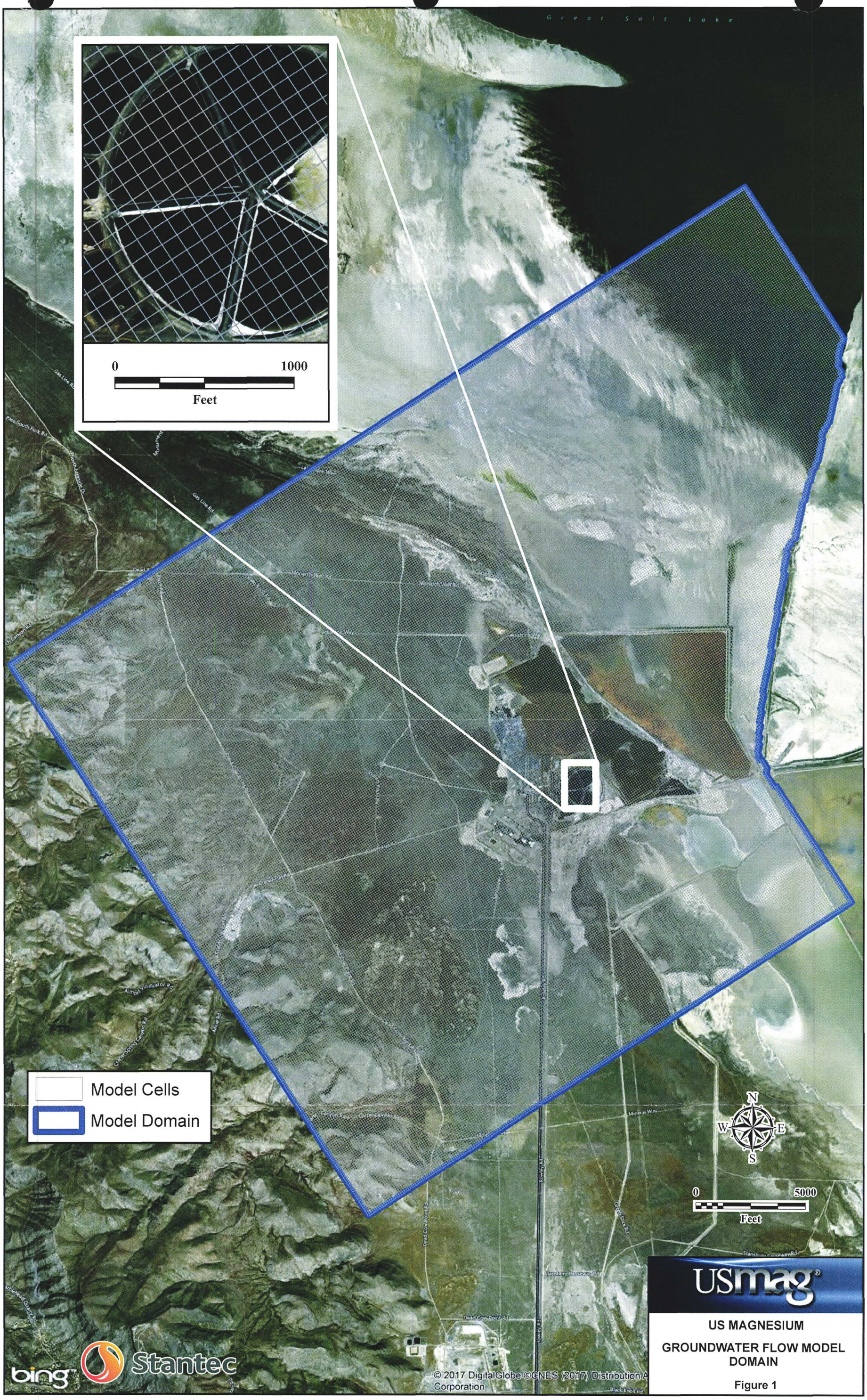
Aquaveo, 2016. Groundwater Modeling System (GMS). Aquaveo, LLC. 2016.
Freeze, R. A. and Cherry, J. A. (1979), Groundwater, Englewood Cliffs, NJ: Prentice Hall.

Harbaugh, A.W. (2005), MODFLOW-2005, The U.S. Geological Survey modular groundwater model—the Ground-Water Flow Process, U.S. Geological Survey Techniques and Methods, 6-A16.

Pollock, D. W. (2010). User guide for MODPATH version 5: a particle tracking model for MODFLOW. US Department of the Interior, US Geological Survey

Stantec, 2017. US Magnesium Groundwater Discharge Permit application Hydrogeologic Report. December, 2017.

FIGURES



USmag®

US MAGNESIUM

GROUNDWATER FLOW MODEL DOMAIN

Figure 1

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\FigureX-ModelDomain.mxd

Simulated Horizontal Hydraulic Conductivity
(ft/day)

- 0.001
- 0.01
- 0.3
- 4
- 35
- 70

Model Domain

Great Salt Lake

N
W E
S

0 5000
Feet

© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

bing

Stantec

USmag®

US MAGNESIUM
LAYER 1: SIMULATED HORIZONTAL HYDRAULIC CONDUCTIVITY VALUES

Figure 2

12 Dec 2017

I:\usphx2s02\Phx2-Files\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\K1.yr1-HK.mxd

Simulated Vertical Hydraulic Conductivity
(ft/day)

- 0.001
- 0.01
- 1.5
- 11
- 35
- 70

Model Domain

Great Salt Lake

Gas Line Rd
Lakeshore Way
Monument Rd
Pass-South Fork Rd
North Lakeside Dr
Dead Horse Pass Rd
Gas Line Rd
Almost Vindicator Rd
Cedar Spring Canyon Rd
Mine Rd
Mineral Way
Dead Cow Point Rd
Lowery Rd
Stansbury Causeway Rd
Black Knoll Rd

N
W
E
S

0 5000
Feet

bing
Stantec
© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

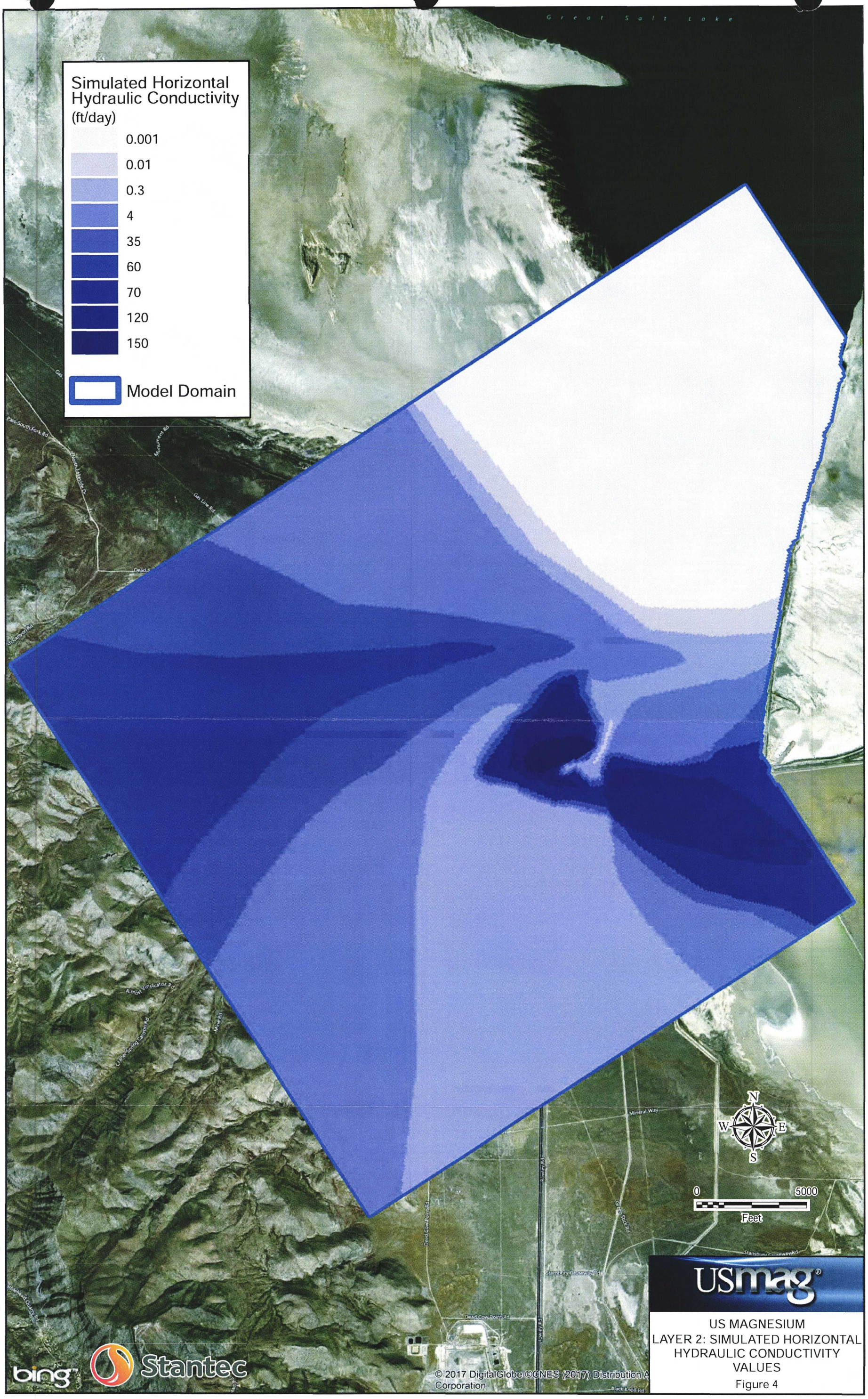
USmag®

US MAGNESIUM
LAYER 1: SIMULATED VERTICAL HYDRAULIC CONDUCTIVITY VALUES

Figure 3

12 Dec 2017

\\uspha2s021\Phx2-Files\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\KL\yr1-VK.mxd

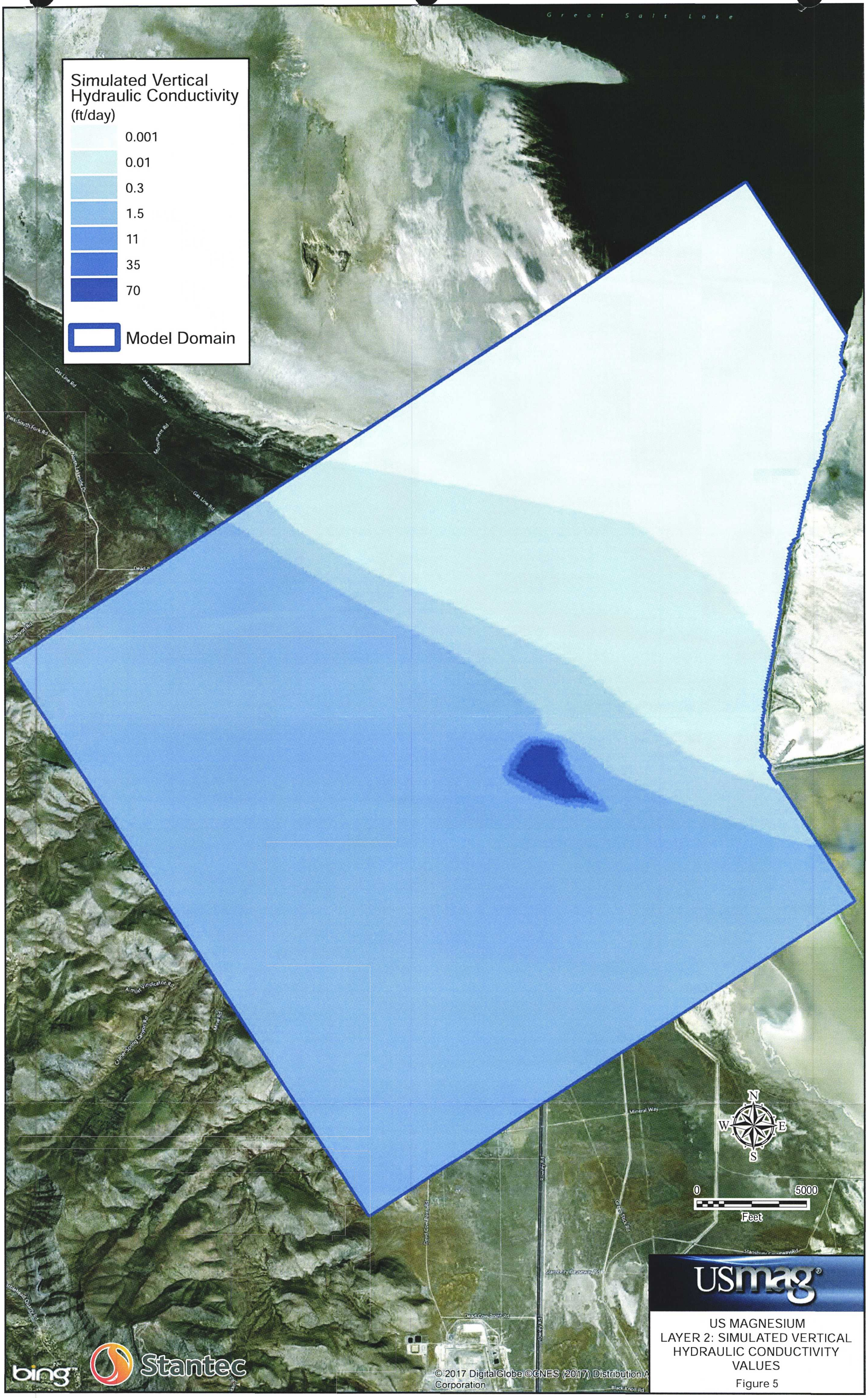


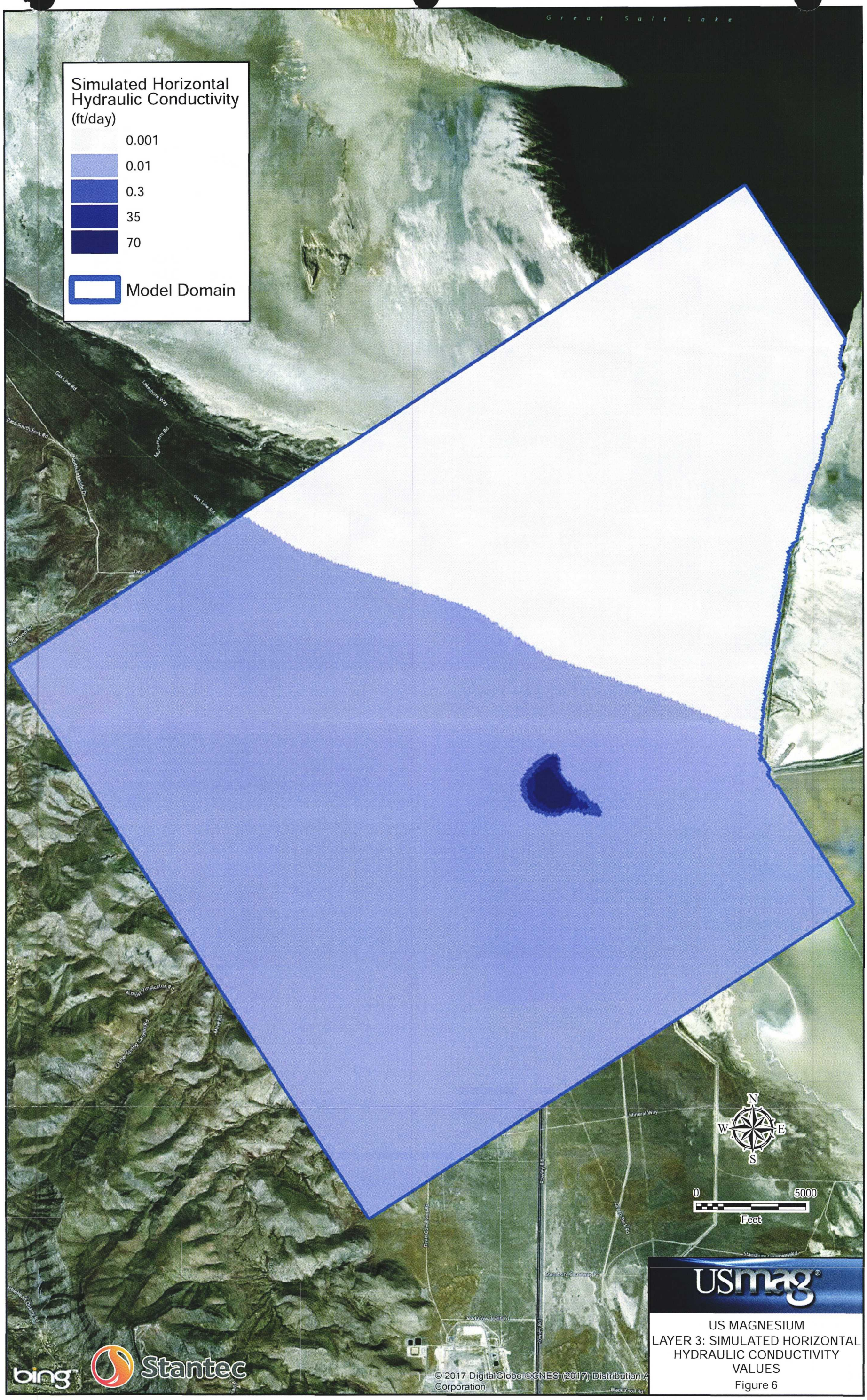
USmag®

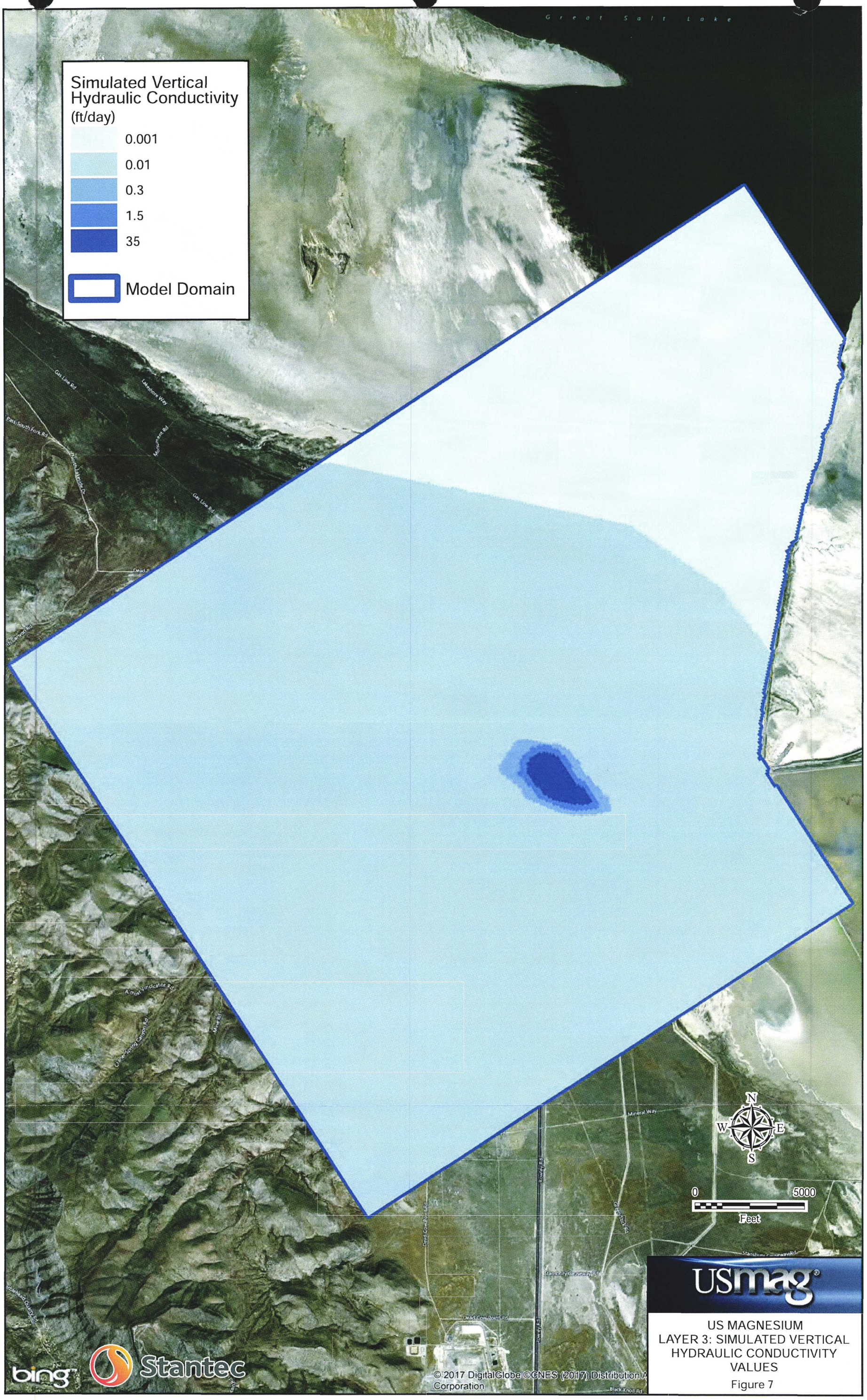
US MAGNESIUM
LAYER 2: SIMULATED HORIZONTAL HYDRAULIC CONDUCTIVITY VALUES
Figure 4

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\K1Lyr2-HK.mxd


Great Salt Lake
Simulated Vertical Hydraulic Conductivity (ft/day)
0.001
0.01
0.3
1.5
11
35
70
Model Domain
N
W
E
S
0
5000
Feet
bing
Stantec
© 2017 DigitalGlobe ©CNES (2017) Distribution Airbus DS © 2017 Microsoft Corporation
USmag
US MAGNESIUM
LAYER 2: SIMULATED VERTICAL HYDRAULIC CONDUCTIVITY VALUES
Figure 5
12 Dec 2017
Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\K\Lyr2-VK.mxd


Great Salt Lake
Simulated Horizontal Hydraulic Conductivity
(ft/day)
0.001
0.01
0.3
35
70
Model Domain
Gas Line Rd
Lakeshore Way
Monument Rd
Past South Fork Rd
North Lakeside Dr
Dead-E
Gas Line Rd
Almost Vindicator Rd
Cedar Spring Canyon Rd
Mine Rd
Dead Cow Point Rd
Lowery Rd
Mineral Way
Stansbury Causeway Rd
Black Knoll Rd
N
W
E
S
0
5000
Feet
bing
Stantec
© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation
USmag®
US MAGNESIUM
LAYER 3: SIMULATED HORIZONTAL HYDRAULIC CONDUCTIVITY VALUES
Figure 6
12 Dec 2017
Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\KLyr3-HK.mxd



12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\K\Lyr3-VK.mxd

Simulated Horizontal Hydraulic Conductivity
(ft/day)

0.001
0.01
0.3
4

Model Domain

Great Salt Lake

Gas Line Rd
Lakeshore Way
Pass South Fork Rd
North Lakeside Dr
Monument Rd
Gas Line Rd
Dead F
Dry Canyon Rd
Almost Vindicator Rd
Cedar Spring Canyon Rd
Mine Rd
Mineral Way
Dead Cow Point Rd
Lowery Rd
Stansbury Causeway Rd
Green Stock Rd
Black Knoll Rd

N
W
E
S

0
5000
Feet

© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

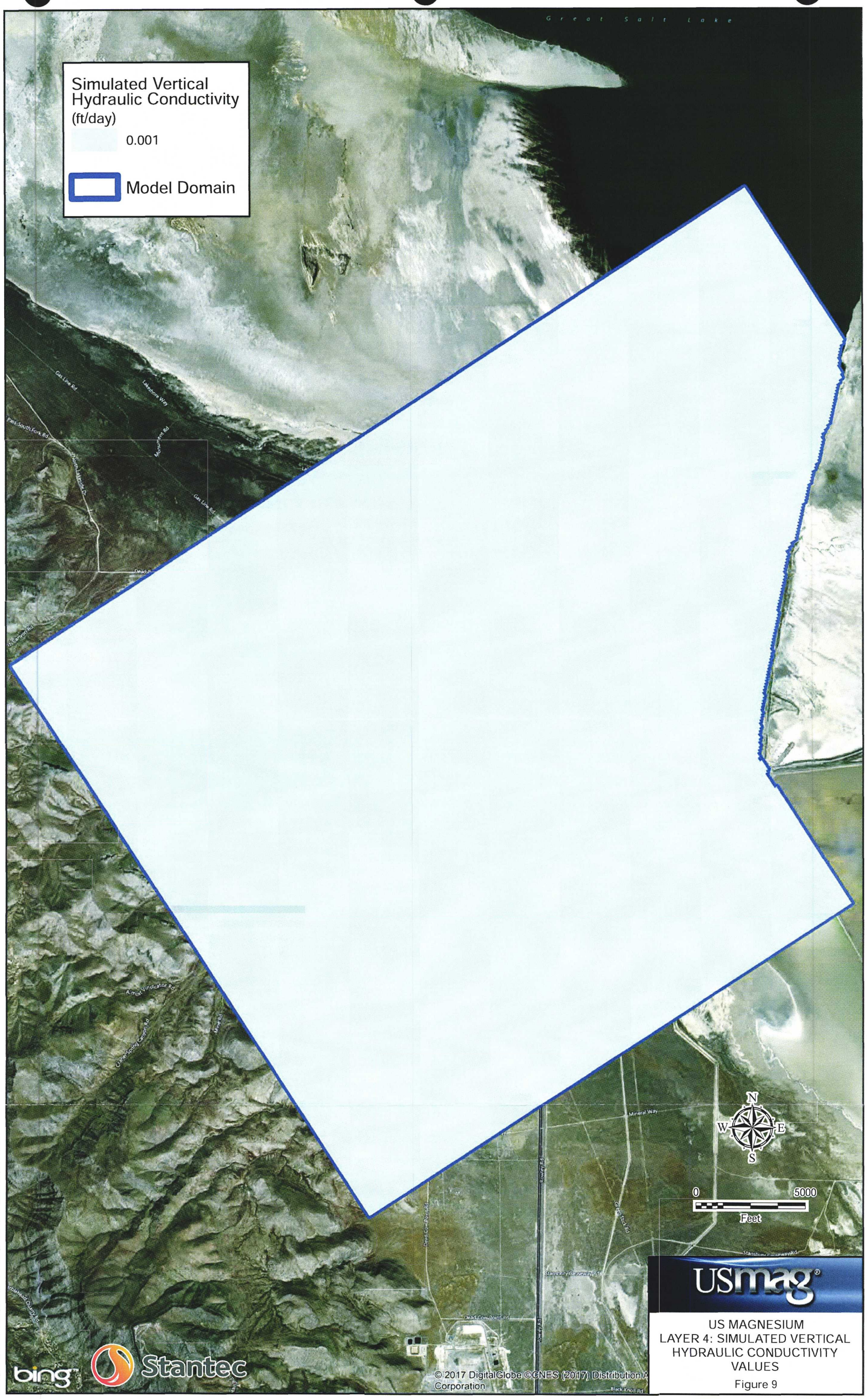
bing
Stantec

USmag®

US MAGNESIUM
LAYER 4: SIMULATED HORIZONTAL HYDRAULIC CONDUCTIVITY VALUES
Figure 8

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\KLyr4-HK.mxd



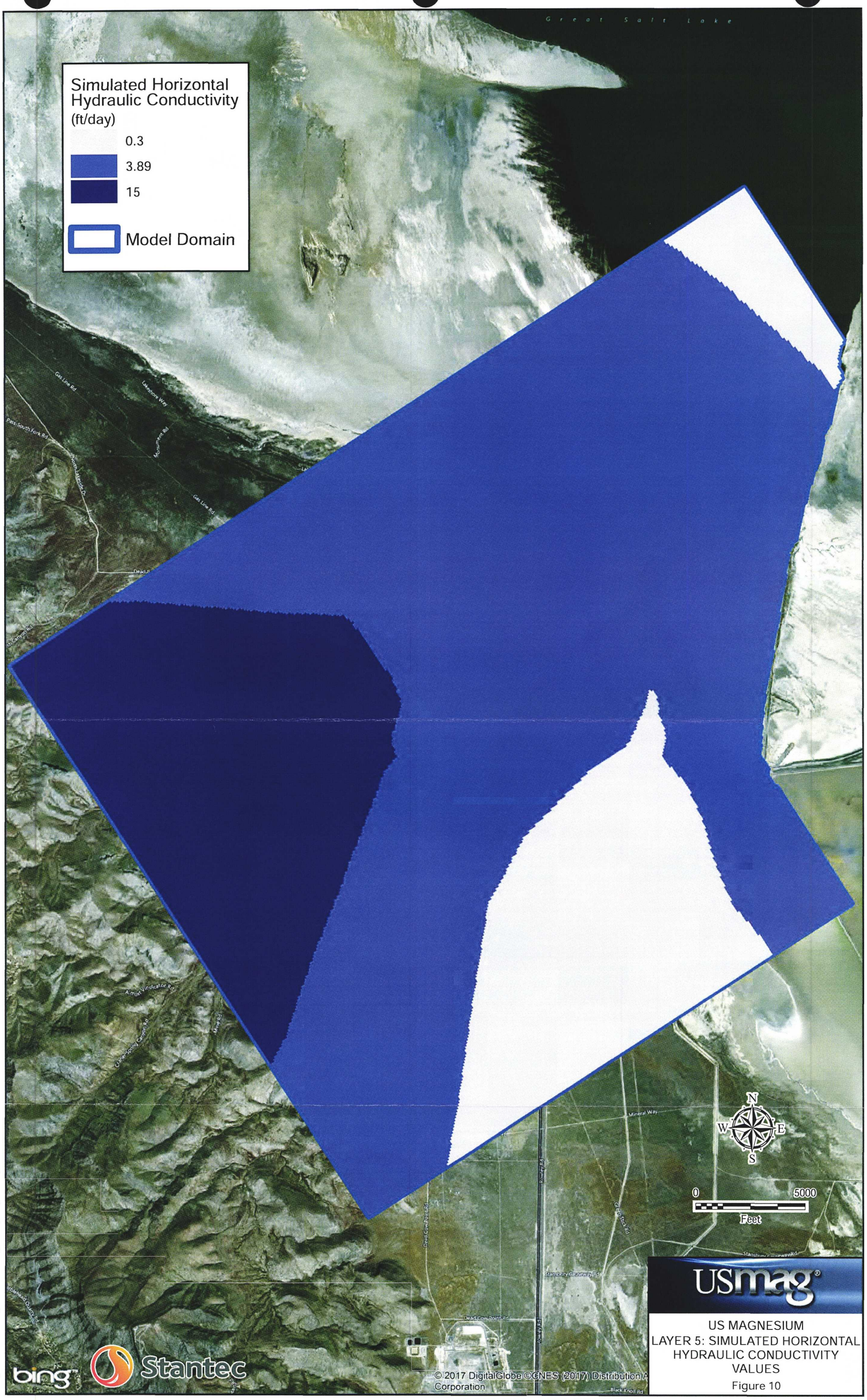
USmag®

US MAGNESIUM
LAYER 4: SIMULATED VERTICAL HYDRAULIC CONDUCTIVITY VALUES

Figure 9

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\KLyr4-VK.mxd


Great Salt Lake
Simulated Horizontal Hydraulic Conductivity
(ft/day)
0.3
3.89
15
Model Domain
Gas Line Rd
Lakeshore Way
Monument Rd
Pass-South Fork Rd
North Lakeside Dr
Dead Ln
Gas Line Rd
Gr Canyon Rd
Almost Vindicator Rd
Corner Spring Canyon Rd
Mine Rd
Mineral Way
Rowley Rd
Dead Cow Point Rd
Grantsville Rd
Stansbury Causeway Rd
Black Knoll Rd
N
W
E
S
0
5000
Feet
© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation
bing
Stantec
USmag®
US MAGNESIUM
LAYER 5: SIMULATED HORIZONTAL HYDRAULIC CONDUCTIVITY VALUES
Figure 10
12 Dec 2017
Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\KLyr5-HK.mxd

Simulated Vertical Hydraulic Conductivity
(ft/day)
0.01
Model Domain

Great Salt Lake

Gas Line Rd
Lakeshore Way
Monument Rd
Pass South Fork Rd
North Lakeside Dr
Gas Line Rd
Dead-in
Almost Vindicator Rd
Cedar Spring Canyon Rd
Mineral Rd
Dead Cow Point Rd
Rowley Rd
Stansbury Causeway Rd
Mineral Way
Black Knoll Rd

N
W
E
S

0
5000
Feet

bing
Stantec
© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

USmag®

US MAGNESIUM
LAYER 5: SIMULATED VERTICAL HYDRAULIC CONDUCTIVITY VALUES
Figure 11

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&LI\Figures\ReportFigures\KlLyr5-VK.mxd

Simulated Specific Yield

0.00001

0.01

0.1

0.15

Model Domain

Great Salt Lake

Gas Line Rd

Lakeshore Way

Monument Rd

North Lakeside Dr

Gas Line Rd

Almost Vindicator Rd

Mine Rd

Dead Cow Point Rd

Stansbury Causeway Rd

Black Knoll Rd

N

W

E

S

0

5000

Feet

bing

Stantec

© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

USmag®

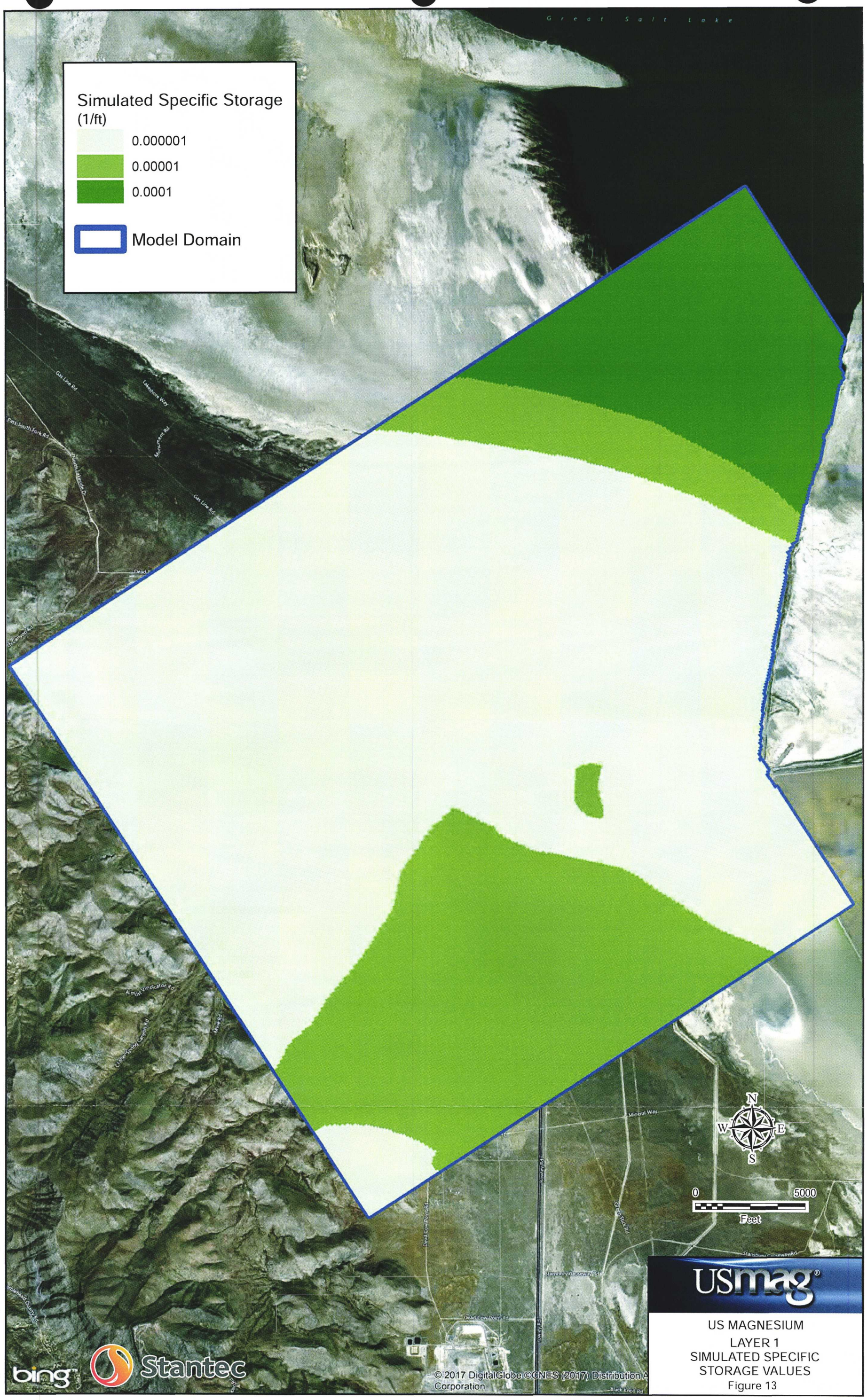
US MAGNESIUM

LAYER 1
SIMULATED SPECIFIC
YIELD VALUES

Figure 12

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\StorageLyr1-SY.mxd



12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\StorageLyr1-SS.mxd

Great Salt Lake

Simulated Specific Yield

0.00001

0.01

0.1

0.15

Model Domain

Gas Line Rd

Lakeshore Way

Pass South Fork Rd

North Lakeside Dr

Monument Rd

Gas Line Rd

Dead Ln

Almost Vindicator Rd

Cedar Spring Canyon Rd

Mine Rd

Mineral Way

Dead Cow Point Rd

Stansbury Causeway Rd

Black Knoll Rd

N

W

E

S

0

5000

Feet

© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

bing

Stantec

USmag®

US MAGNESIUM

LAYER 2
SIMULATED SPECIFIC
YIELD VALUES
Figure 14

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&I\Figures\ReportFigures\StorageLyr2-SY.mxd

Simulated Specific Storage (1/ft)

0.000001

0.00001

0.0001

Model Domain

Great Salt Lake

Gas Line Rd

Lakeshore Way

Pass-South Fork Rd

Monument Rd

North Lakeside Dr

Dead...

Gas Line Rd

...n Canyon Rd

Almost Vindicator Rd

Cutler-Spring Canyon Rd

Mine Rd

Mineral Way

Dead Cow Point Rd

Lowery Rd

Gates Stock Rd

Stansbury Causeway Rd

Black Knoll Rd

N

W E

S

0 5000

Feet

bing

Stantec

© 2017 DigitalGlobe ©CNES (2017) Distribution A... Corporation

USmag®

US MAGNESIUM

LAYER 2

SIMULATED SPECIFIC STORAGE VALUES

Figure 15

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&I\Figures\ReportFigures\StorageLyr2-SS.mxd

Great Salt Lake

Simulated Specific Yield

0.00001

0.01

0.1

Model Domain

Gas Line Rd

Lakeshore Way

Monument Rd

Gas Line Rd

Dead...

Almost Vindicator Rd

Mine Rd

Dead Cow Point Rd

Mineral Way

Stansbury Gilsonwy Rd

Black Knoll Rd

N

W

E

S

0

5000

Feet

bing

Stantec

© 2017 DigitalGlobe ©CNES (2017) Distribution A... Corporation

USmag®

US MAGNESIUM

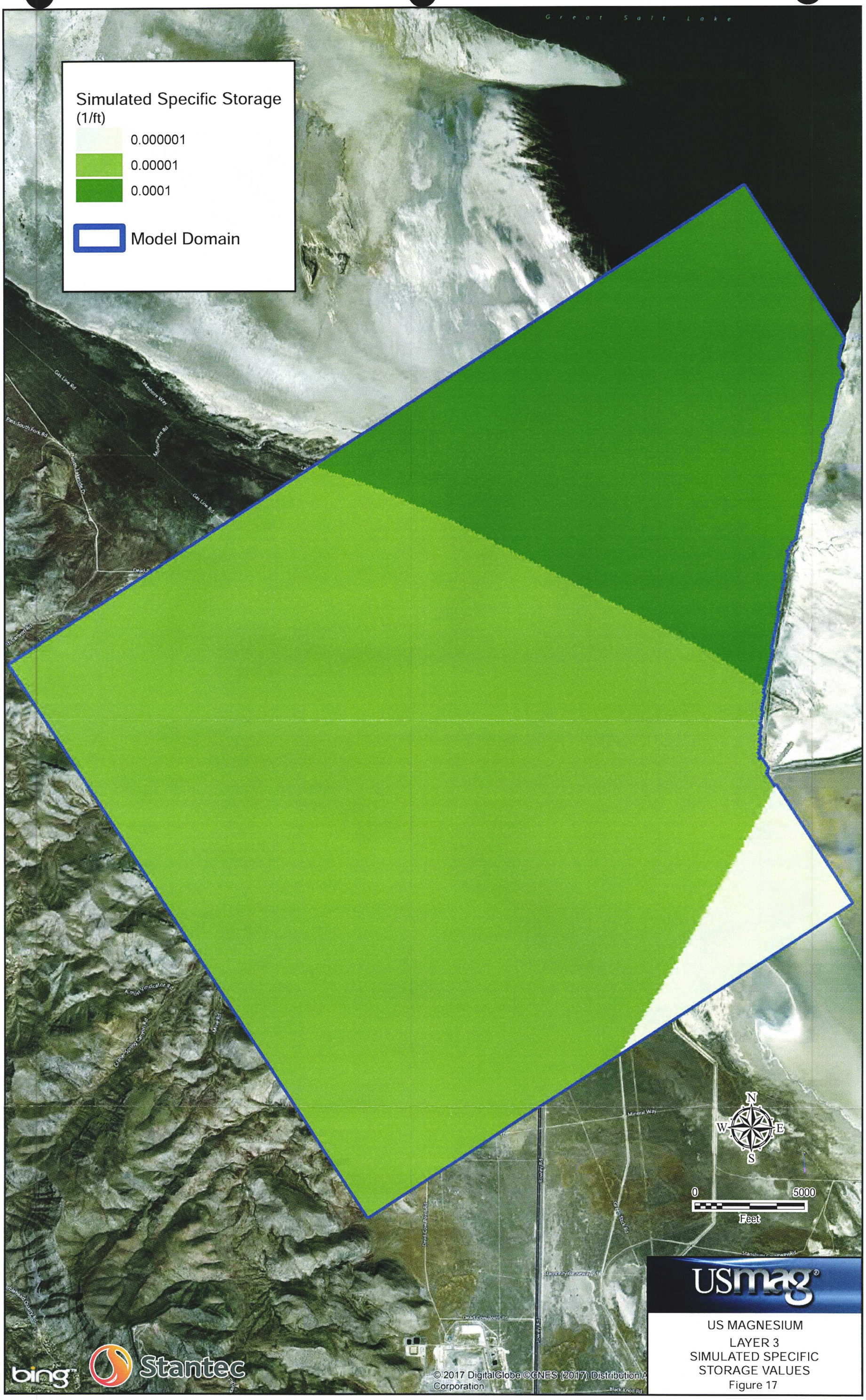
LAYER 3

SIMULATED SPECIFIC YIELD VALUES

Figure 16

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\Storage\Lyr3-SY.mxd



12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\StorageLyr3-SS.mxd

Simulated Specific Yield

0.00001

0.01

0.1

Model Domain

Great Salt Lake

Gas Line Rd

Lakeshore Way

Monument Rd

Gas Line Rd

Dead Cow Point Rd

Stansbury Causeway Rd

Mineral Way

N

W

E

S

0 5000

Feet

bing

Stantec

© 2017 DigitalGlobe ©CNES (2017) Distribution A
Corporation

USmag®

US MAGNESIUM

LAYER 4

SIMULATED SPECIFIC YIELD VALUES

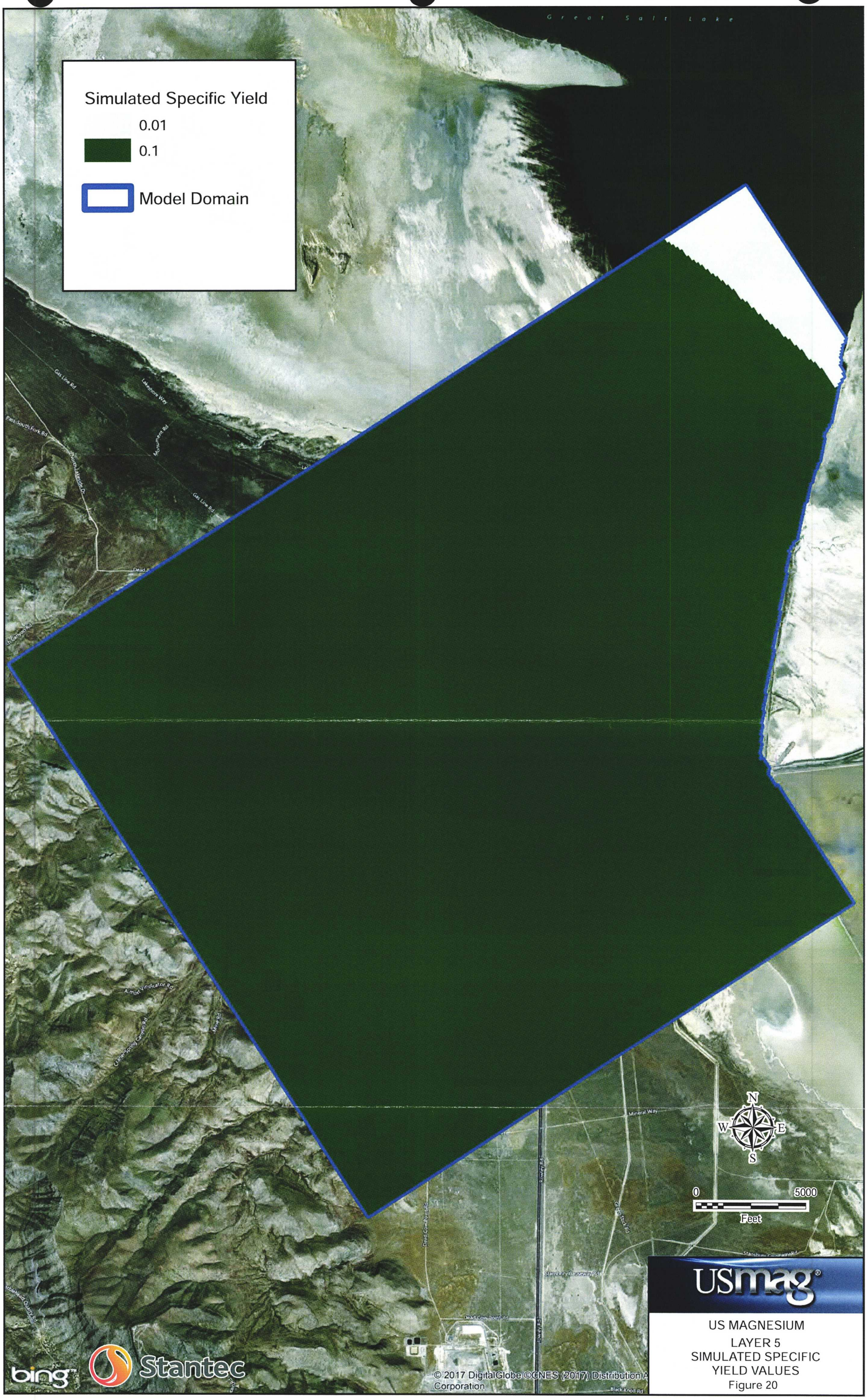
Figure 18

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\Storage\Lyr4-SY.mxd

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\StorageLyr4-SS.mxd



12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\StorageLyr5-SY.mxd

Great Salt Lake

Simulated Specific Storage (1/ft)

0.000001

0.00001

Model Domain

Gas Line Rd

Lakeshore Way

Pass South Fork Rd

Monument Rd

North Lakeside Dr

Gas Line Rd

Dead...

...d Canyon Rd

Almost Vindicator Rd

Mine Rd

Cedar Spring Canyon Rd

Marble Head Quarry Rd

Dead Cow Point Rd

Rowley Rd

Mineral Way

Stansbery Causeway Rd

Black Knoll Rd

N

W E

S

0 5000

Feet

bing

Stantec

© 2017 DigitalGlobe ©CNES (2017) Distribution A... Corporation

USmag®

US MAGNESIUM

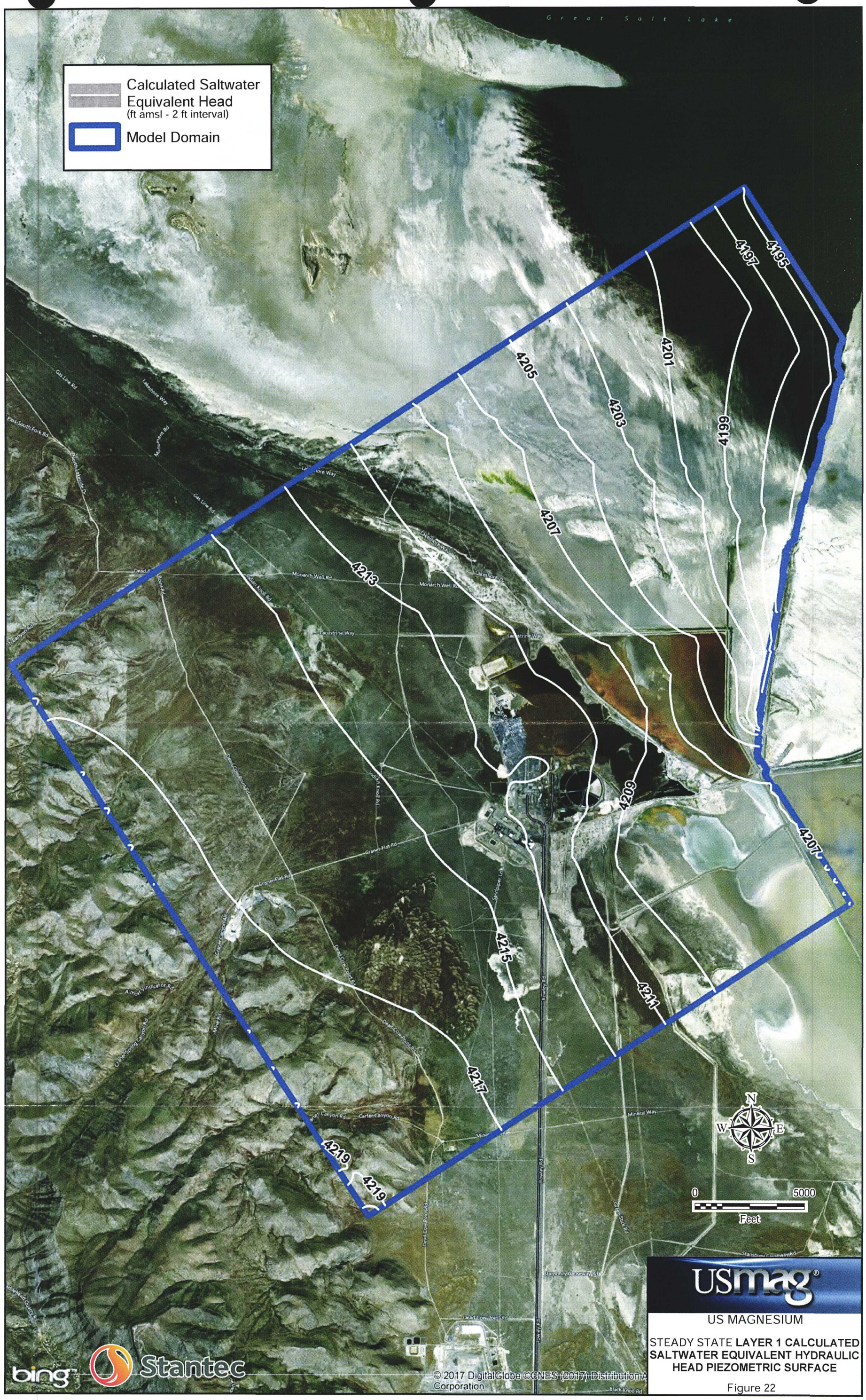
LAYER 5

SIMULATED SPECIFIC STORAGE VALUES

Figure 21

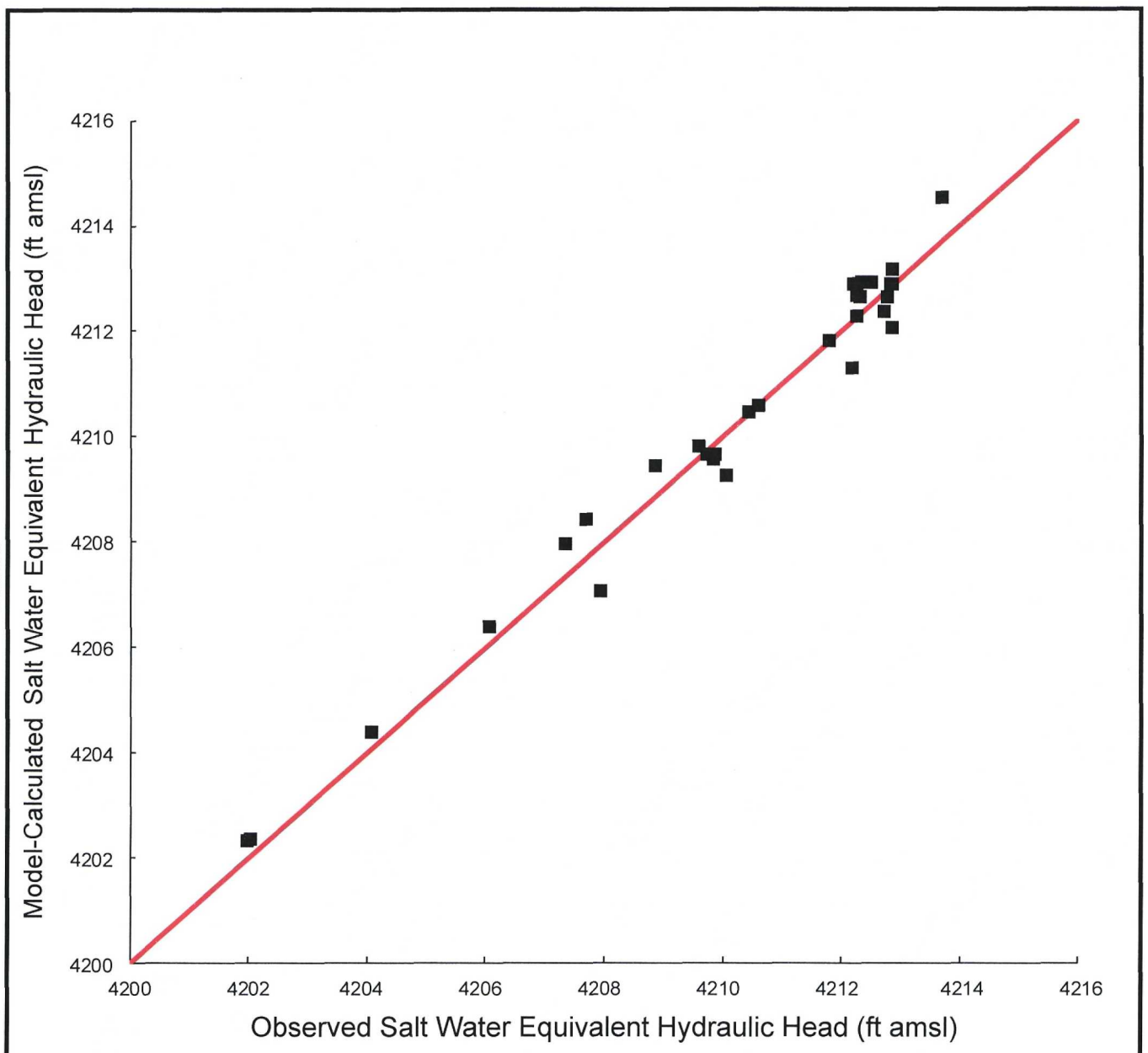
12 Dec 2017

\\usphx2s02\Phx2-Files\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\StorageLyr5-SS.mxd



12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&LI\Figures\ReportFigures\Final Head Maps\Figurex-ClimateBased_FullyEnclosed.mxd



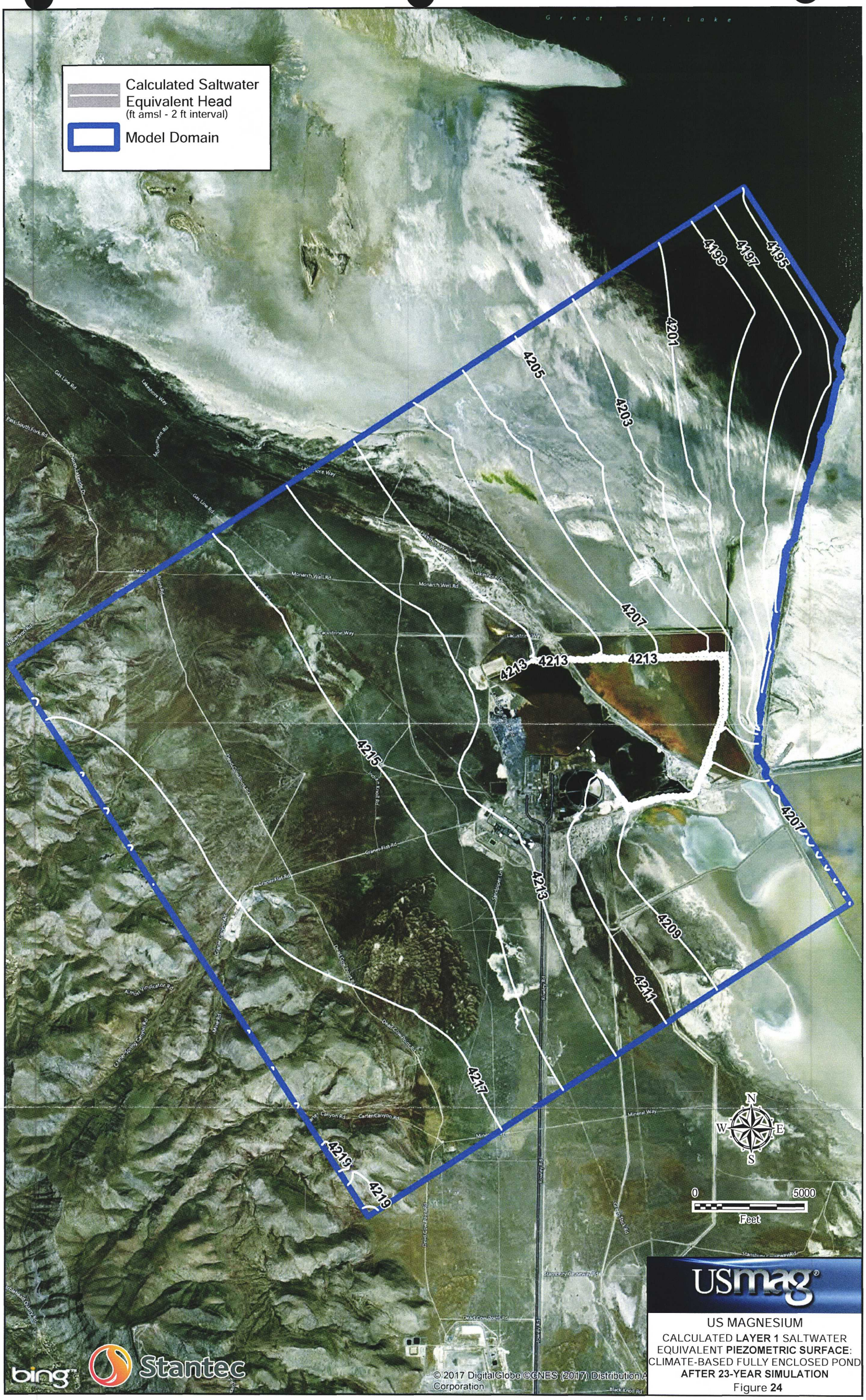
Mean Absolute Error: 0.389 ft

Root-Mean Square Error: 0.484 ft

\\wssic1s01\FO\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph2\6.0 Studies, Reports, Plans\11 Groundwater Model\Figures 12 Dec 2017

USmag®

US MAGNESIUM
MODEL-PREDICTED VS OBSERVED SALTWATER EQUIVALENT HYDRAULIC HEAD
Figure 23



USmag®

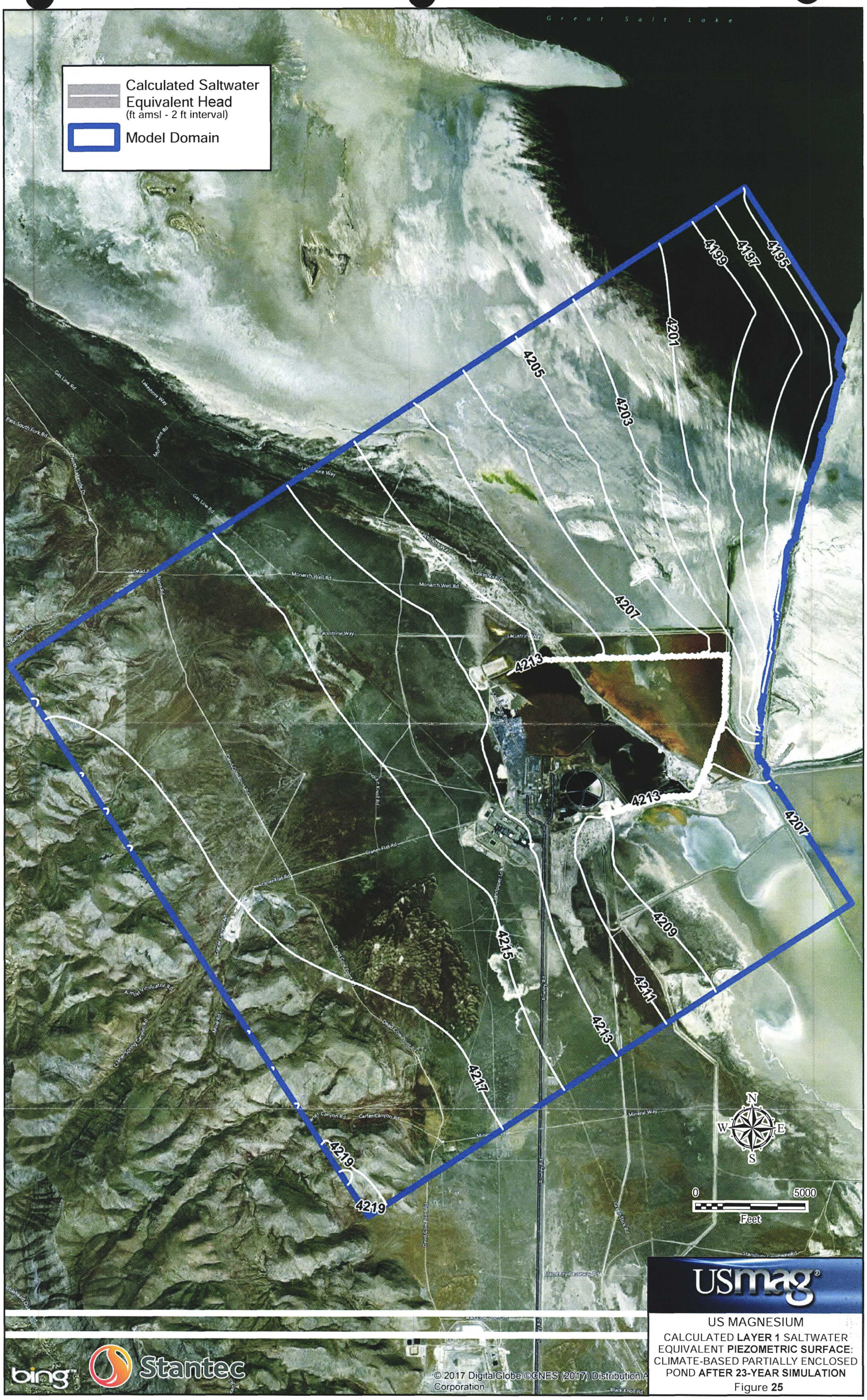
US MAGNESIUM

CALCULATED **LAYER 1** SALTWATER EQUIVALENT **PIEZOMETRIC SURFACE**: CLIMATE-BASED FULLY ENCLOSED POND **AFTER 23-YEAR SIMULATION**

Figure **24**

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\Final Head Maps\Figure x-ClimateBased_FullyEnclosed.mxd



USmag®

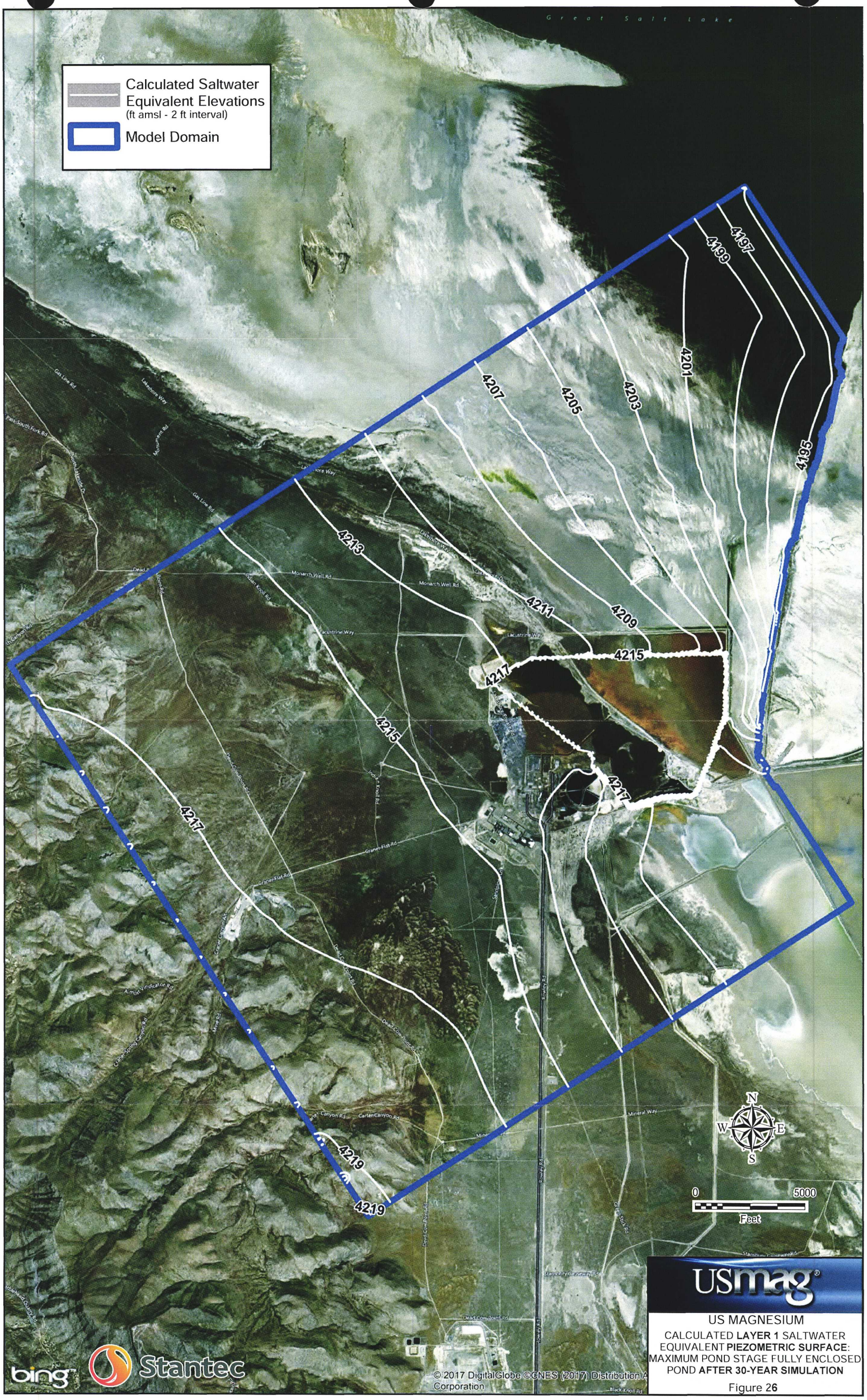
US MAGNESIUM

CALCULATED **LAYER 1** SALTWATER EQUIVALENT **PIEZOMETRIC SURFACE**: CLIMATE-BASED PARTIALLY ENCLOSED POND **AFTER 23-YEAR SIMULATION**

Figure **25**

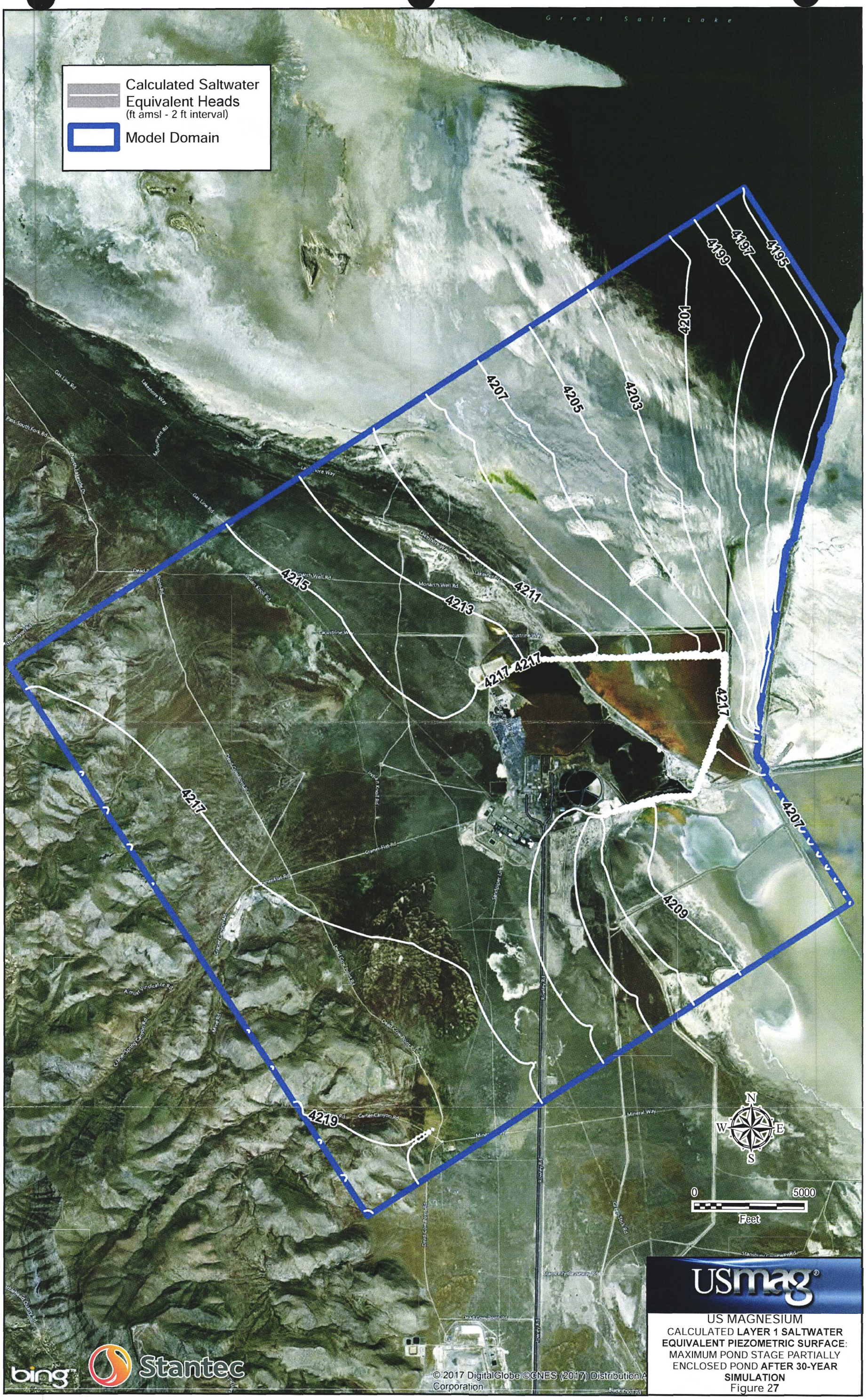
12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\Final Head Maps\FigureX-ClimateBased_PartiallyEnclosed.mxd



12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\Final Head Maps\FigureX-WorstCaseScenario_FullyEnclosed.mxd



US MAGNESIUM

CALCULATED **LAYER 1 SALTWATER EQUIVALENT PIEZOMETRIC SURFACE**: MAXIMUM POND STAGE PARTIALLY ENCLOSED POND **AFTER 30-YEAR SIMULATION**

Figure 27

12 Dec 2017

Z:\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\Final Head Maps\FigureX-WorstCaseScenario_PartiallyEnclosed.mxd

Proposed Barrier Wall: Fully Enclosed

Calculated Flow Direction of Native Groundwater

Theoretical Particle Starting Locations

Calculated Path-Lines of Simulated Theoretical Particles

Modeled Fluctuating Expansion Pond Stages (4218 ft amsl max)

Modeled Fluctuating Existing Pond Stages (4218 ft amsl max)

Calculated Saltwater Equivalent Head Contours
(ft amsl - 1 ft interval)

4199
4201
4203
4205
4207
4209
4211
4213
4212
4214
4216
4210
4208

N
W
E
S

0 1500
Feet

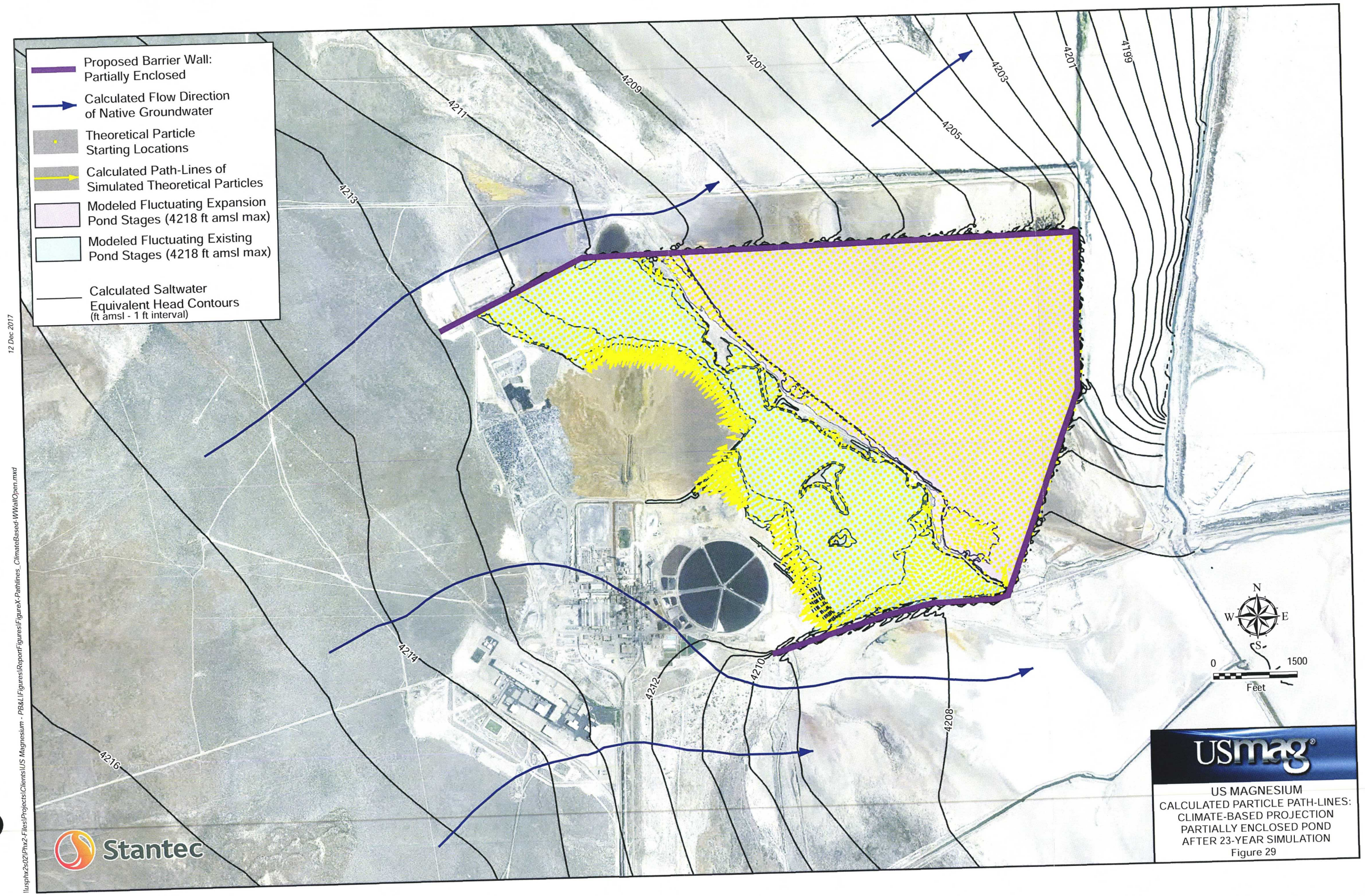
Stantec

USmag®

US MAGNESIUM
CALCULATED PARTICLE PATH-LINES:
CLIMATE-BASED PROJECTION
FULLY ENCLOSED POND
AFTER 23-YEAR SIMULATION
Figure 28

12 Dec 2017

\\usphx2s02\Phx2-Files\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\FigureX-Pathlines_ClimateBased-FullyEnclosed.mxd



12 Dec 2017

\\usphx2s02\Phx2-Files\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\FigureX-Pathlines_ClimateBased-WWallOpen.mxd

Proposed Barrier Wall: Fully Enclosed

Calculated Flow Direction of Native Groundwater

Theoretical Particle Starting Locations

Calculated Path-Lines of Simulated Theoretical Particles

Extent of Pond at Maximum Stage (4220 ft amsl)

Calculated Saltwater Equivalent Head Contours (ft amsl - 1 ft interval)

4213
4211
4209
4207
4205
4203
4201
4199
4214
4212
4210
4208
4216

N
W
E
S

0 1500
Feet

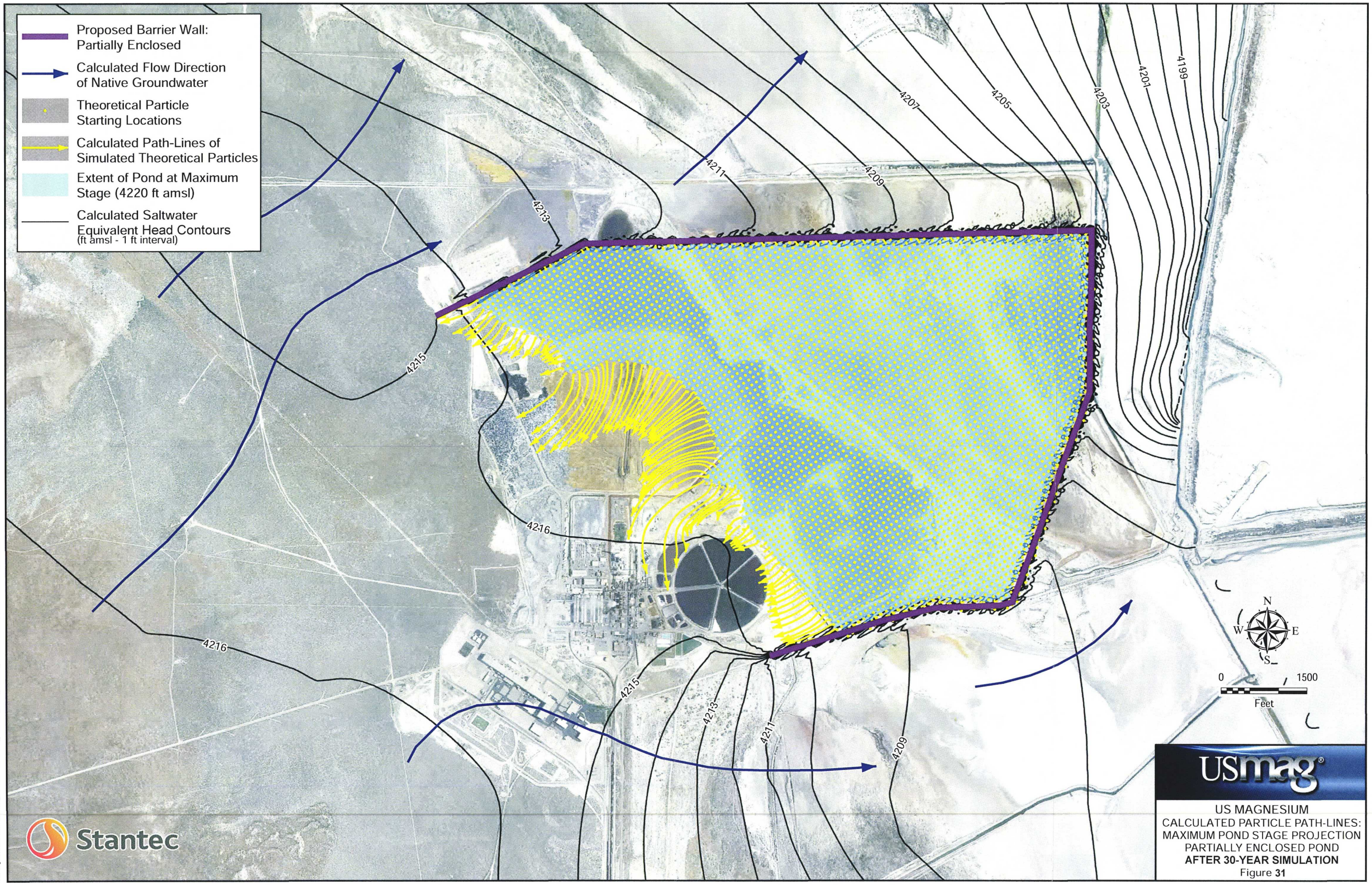
Stantec

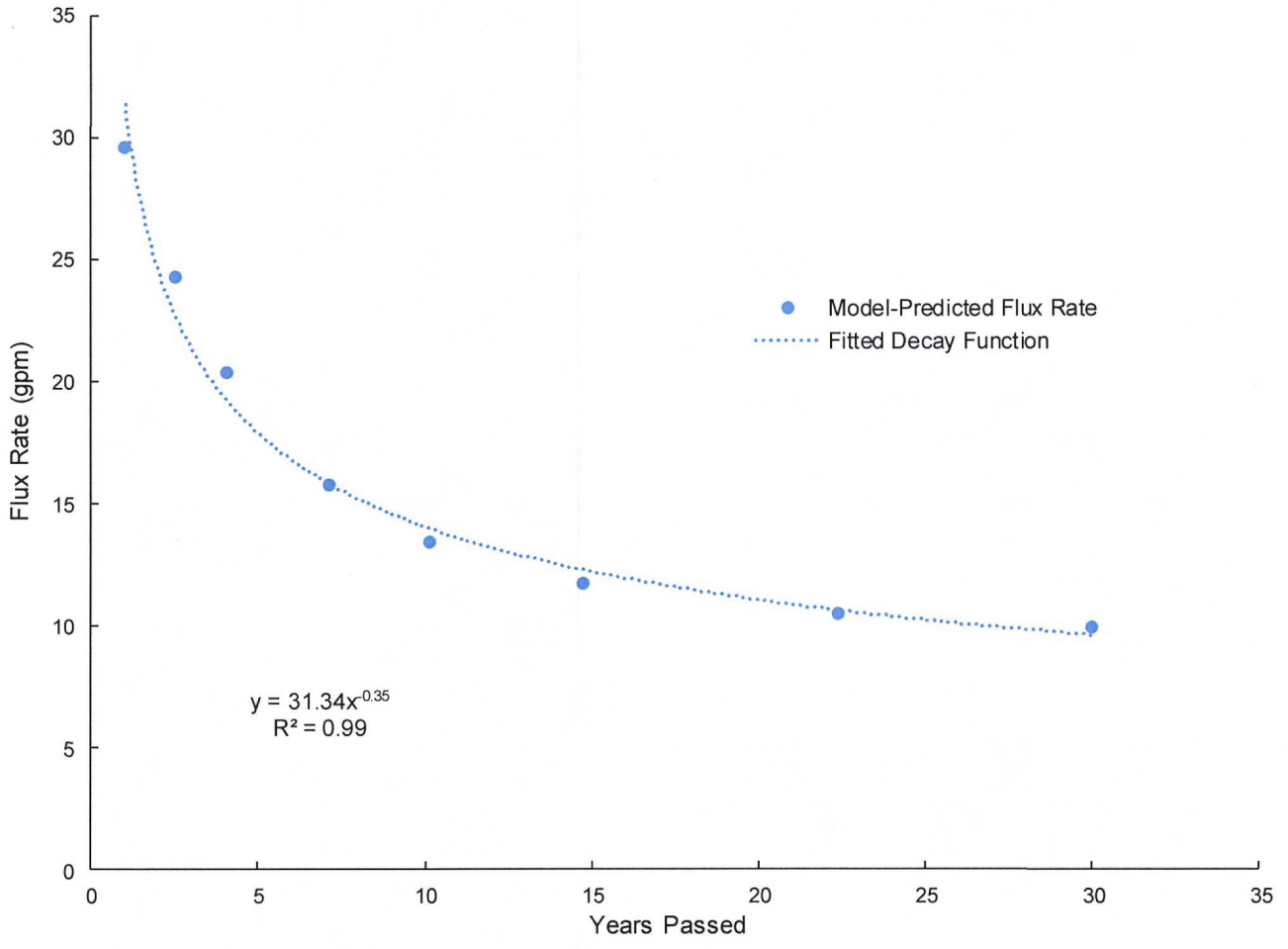
USmag

US MAGNESIUM
CALCULATED PARTICLE PATH-LINES:
MAXIMUM POND STAGE PROJECTION
FULLY ENCLOSED POND
AFTER 30-YEAR SIMULATION
Figure 30

12 Dec 2017

\\usphx2s02\Phx2-Files\Projects\Clients\US Magnesium - PB&L\Figures\ReportFigures\FigureX-Pathlines_WCS-FullyEnclosed.mxd


Proposed Barrier Wall: Partially Enclosed
Calculated Flow Direction of Native Groundwater
Theoretical Particle Starting Locations
Calculated Path-Lines of Simulated Theoretical Particles
Extent of Pond at Maximum Stage (4220 ft amsl)
Calculated Saltwater Equivalent Head Contours
(ft amsl - 1 ft interval)
4199
4201
4203
4205
4207
4209
4211
4213
4215
4216
N
W
E
S
0
1500
Feet
Stantec
USmag
US MAGNESIUM
CALCULATED PARTICLE PATH-LINES:
MAXIMUM POND STAGE PROJECTION
PARTIALLY ENCLOSED POND
AFTER 30-YEAR SIMULATION
Figure 31
12 Dec 2017
Z:\Projects\Clients\US Magnesium - PB&LI\Figures\ReportFigures\FigureX-Pathlines_WCS-WWallOpen.mxd



12 Dec 2017

\\wssic1s011\FO\Industrial Projects\PB&L &US Magnesium\2017 GW Disch Permit Ph2\6.0 Studies, Reports, Plans\11 Groundwater Model\Figures

US MAGNESIUM

MODEL-PREDICTED WESTWARD OUTFLUX PARTIALLY ENCLOSED BARRIER WALL

Figure 32

APPENDIX F – BARRIER WALL COMPATIBILITY TESTING PROPOSAL

GREAT LAKES
ENVIRONMENTAL &
INFRASTRUCTURE

GLEI.COM

6558 LONETREE BOULEVARD
ROCKLIN, CA 95765
P 916.462.6400 | F 916.783.0215

December 12, 2017

Transmitted via Email

Mr. Rob Hartman
Environmental Manager
US Magnesium, LLC
12819 N. Rowley Road
N. Skull Valley, UT 84209

Office: (801) 532-1522 ext. 1355
Mobile: (208) 241-8216

Subject: **REVISED Proposal for Slurry Cutoff Wall Compatibility Testing**
US Magnesium, LLC
Tooele County, Utah

Dear Mr. Hartman:

Per your request, the following REVISED cost proposal is to perform a compatibility testing for the proposed slurry cutoff wall in accordance with our site visit conducted on 20 July 2017, additional information provided in your email dated 21 July 2017, responses to our 21 August 2017 correspondence and follow up meeting with US Magnesium and Stantec on 1 December 2017.

PROJECT UNDERSTANDING

Based on the information provided, it is our understanding that US Magnesium is contemplating the installation of a slurry cutoff wall to mitigate impacted groundwater seepage at the project site. Based on the data presented, a summary of the existing site conditions and proposed slurry cutoff wall dimensions includes:

DESCRIPTION	VALUE
pH of wastewater	<1 (approx. 10% HCl)
TDS of wastewater	60,000 ppm
SPT blow counts	2 to +100
Depth of cut-off wall (keyed into clay layer)	45 feet
Total length	4,144 feet
Minimum width top of embankment	18 feet

In particular, it should be noted that an unusually hard layer of calcium carbonate, known as Oolite, is generally present in zones between 9 to 14 feet below ground surface with an average thickness of 1 to 5 feet. We currently assume that this layer can be readily excavated using traditional slurry trench excavation equipment (i.e. long reach excavator).

SCOPE OF WORK

Great Lakes Environmental & Infrastructure (GLE&I) proposes to support US Magnesium in the development of a Mix Design/Compatibility Study for this cutoff wall. The objective of the mix design and compatibility study is to evaluate the effectiveness of a cutoff wall at the proposed alignment over time when exposed to site groundwater and pond constituents. GLE&I understands that there are unlined ponds containing effluent from chemical processing with a pH between 1.0 and 2.0. It is presumed that this water contains a significant quantity of salts and dissolved minerals.

To effectively evaluate the materials proposed for the cutoff wall, GLE&I will require geotechnical information and soil samples acquired from borings within a localized area along the alignment of the proposed cutoff wall. The intent of the geotechnical investigation is to obtain data sufficient to define the soil strata, including key material (confining layer) and their physical properties including soil type, gradation, moisture content, and bulk (in situ) soil density. A minimum of four (4) discrete soil borings should be performed in adjacent locations (e.g. less than 5 feet apart). A minimum of (3) three bulk samples should be collected at approximately 10 ft. depth intervals at each boring location, including a sample of the key material. The total sample size should fill approximately one (1) five gallon bucket at each boring location. Geotechnical analysis including particle size gradation and Atterberg limits will be performed for each bulk sample at an Owner specified laboratory. Remaining samples of soils shall be shipped to Geo-Logic Associates laboratory in Grass Valley, California for further evaluation of potential mix designs.

Upon receipt of the bulk samples and review of boring logs and initial geotechnical lab test results, a composite soil sample will be created that will contain the blend of soils typically specified for soil-clay cutoff walls. A minimum of three mix designs will be developed that will include the slurry type intended for trenching and required percentages of dry addition of clay and other potential reagents.

The slurry intended for cutoff wall construction will be pilot tested by mixing with site soils and an additional 15% by volume of "worst case" effluent. The worst case effluent is the pond water sample representing the highest mineral content and the lowest pH. Effects on the slurry properties will be evaluated for constructability and durability purposes. A total of two (2) each, five (5) gallon buckets/carboys of each effluent will be required for compatibility testing. The effluent samples shall be collected by the Owner and shipped to Geo-Logic Associates laboratory in Grass Valley, California.

Having selected the three mix designs and the appropriate support slurry (trench slurry), samples will be taken from the composite soil sample and tested for hydraulic conductivity. One (1) hydraulic conductivity tests will be performed on each composite soil sample, including one with deionized (DI) Water as the permeant and three (3) with Worst Case Pond Water as the permeant, for a total of four (4) hydraulic conductivity tests. Testing DI water as the permeant will provide a control with which to compare to the results of the Worst Case Pond Water conductivity test.

The next phase of the study will investigate the longer term effects of Worst Case Water on the selected backfill mix commonly referred to as compatibility testing. Compatibility testing evaluates changes in hydraulic conductivity over time using Site groundwater as a permeant to determine if backfill materials degrade or are affected by Site groundwater or pond effluent. In the interest of economy, GLE&I will select one mix from the initial investigation on which to perform the compatibility study. The compatibility study will be performed in accordance with ASTM D7100 – Standard Test Method for

Hydraulic Conductivity Testing of Soils with Aqueous Solutions. The duration of the compatibility test is measured by achieving chemical equilibrium of which time is directly related to the hydraulic conductivity and length of sample, i.e. the lower the hydraulic conductivity, the longer the test will take to achieve chemical equilibrium. GLEI&I will use a large diameter flexible wall permeameter with a sample formed as thin as feasible (1/2 inch). It is expected to permeate the sample for a minimum of 10 weeks. During the compatibility test, GLE&I will measure pH, electrical conductance, and temperature of the effluent on a continuous basis. Measurements of these parameters will be data logged for evaluation of chemistry changes which may occur throughout the course of the investigation.

GLE&I commonly partners with industry experts and consultants to assist with mix design evaluation and compatibility testing, specifically in challenging environments. GLE&I intends to solicit support from long time professional associates, Slurry Engineering and Geo-Logic Associates for evaluation of the trench slurry and selection of a backfill mix design.

PRICING: COMPATIBILITY TESTING

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
001	GLE&I Project Manager	20	HR	$115.00	$2,300.00
002	GLE&I Technical Lead	40	HR	$90.00	$3,600.00
003	Slurry Engineering Consulting	50	HR	$140.00	$7,000.00
004	Geo-Logic Consulting	10	HR	$140.00	$1,400.00
005	Geo-Logic Laboratory Costs	13,500	T&M	$1.00	$13,500.00
	TOTAL BID AMOUNT				**$27,800.00**

CLOSING

This proposal is being provided to determine a not-to-exceed budget to perform the subject scope of work and is intended to be administered as a time and materials agreement. Any future formal cost proposals to perform the work will be subject to executing a mutually acceptable Subcontract Agreement. Should you require any further information or discussion of this proposal in detail, please contact me at 916-462-6400.

Yours truly,
GREAT LAKES ENVIRONMENTAL & INFRSTRUCTURE (GLEI), LLC

Matthew D. Marks
Vice President – West Region

Compliance Monitoring Plan

Utah Groundwater Discharge
Permit Application – Part C

Stantec

Prepared for:
US Magnesium LLC

Prepared by:
Stantec

December 15, 2017

Sign-off Sheet

This document entitled Compliance Monitoring Plan was prepared by Stantec, Inc. ("Stantec") for the account of US Magnesium LLC (US Magnesium). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and US Magnesium. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

Jacob Trauscht

Reviewed by _____

Susan Eyzaguirre, PE, PG

Approved by _____

Hhan Olsen, PG

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 FACILITY DESCRIPTION AND BACKGROUND 1
1.2 PROPOSED GROUNDWATER DISCHARGE CONTROL SYSTEM DESCRIPTION 2
1.3 GROUNDWATER 2
1.3.1 Hydrogeology 2
1.3.2 Current Groundwater Quality 3
1.4 SURFACE WATER 4
1.5 COMPLIANCE MONITORING OBJECTIVES 4
2.0 PROPOSED GROUNDWATER COMPLIANCE MONITORING NETWORK 4
3.0 PROPOSED GROUNDWATER PROTECTION LEVELS 5
3.1 BASELINE MONITORING RESULTS 5
3.1.1 Baseline Groundwater Sampling Results 5
3.1.2 Baseline Source Water Sampling Results 5
3.2 PROPOSED GROUNDWATER PROTECTION LEVELS AND PERFORMANCE MONITORING PARAMETERS 6
4.0 WATER SAMPLING PROGRAM 7
4.1 GROUNDWATER SAMPLING 7
4.1.1 Groundwater Sampling and Sampling Procedures 7
4.1.2 Groundwater Sampling Parameters, and Analyses 7
4.1.3 Proposed Groundwater Sampling Frequency 7
4.2 SOURCE WATER 8
4.2.1 Source Water Sampling Locations 8
4.2.2 Source Water Sampling Methods and Analytes 8
4.2.3 Sampling Frequency 9
5.0 WATER LEVEL MONITORING PLAN 9
6.0 DISCHARGE CONTROL SYSTEM INSPECTIONS 10
6.1 INSPECTION FREQUENCY 10
6.2 INSPECTION PROCEDURES 10
6.2.1 Embankment Inspections 10
6.2.2 CWP/OWP Connector Piping Inspections 11
6.2.3 Discharge Piping Inspection 11
6.2.4 Monitoring Well Inspection 11
6.3 DOCUMENTATION AND REPORTING 11
7.0 GROUNDWATER DISCHARGE PERMIT COMPLIANCE EVALUATION 12
8.0 DOCUMENTATION AND REPORTING 12
8.1 MONITORING DOCUMENTATION 12
8.2 ROUTINE MONITORING REPORTS 12
8.3 NONCOMPLIANCE NOTIFICATIONS 13
9.0 COMPLIANCE MONITORING PLAN MODIFICATION PROCESS 14

10.0 REFERENCES..... 14

LIST OF APPENDICES

Appendix A – Compliance Well/Piezometer Boring and Construction Logs
Appendix B – Standard Operating Procedures for Field Activities

LIST OF TABLES

Table 1-1 Groundwater Discharge Permit Baseline Groundwater Sampling Results
Table 1-2 Compliance Monitoring Scope and Objectives
Table 2-1a Construction Details for Proposed Compliance Wells/Piezometers Completed in the Upper Aquifer Zone
Table 2-1b Construction Details for Proposed Compliance Wells/Piezometers Completed in the Lower Aquifer Zone
Table 3-1 Groundwater Discharge Permit Source Water Sampling Results
Table 3-2 Groundwater Discharge Permit Proposed Groundwater Protection Levels
Table 4-1 Proposed Groundwater Compliance Sampling Analytes and Parameters
Table 4-2 Proposed Source Water Sampling Analytes and Parameters
Table 5-1 Construction Details for Proposed Groundwater Level Monitoring Compliance Monitoring Wells/Piezometers

LIST OF FIGURES

Figure 1-1 Location Map
Figure 1-2 Proposed Retrofitted Waste Pond Configuration
Figure 2-1 Proposed Groundwater Discharge Permit Compliance Monitoring Network

Acronyms and Abbreviations

~	approximately
>	greater than
<	less than
amsl	above mean sea level
barrier wall	hydraulic barrier wall
BAT	best available technology
bgs	below ground surface
CMP	Compliance Monitoring Plan
cm/s	centimeters per second
CWP	Current Waste Pond
DO	dissolved oxygen
DWQ	Division of Water Quality
ft/day	feet per day
GSL	Great Salt Lake
GWDP	Groundwater Discharge Permit
Main Ditch	combined discharge ditch
mg/L	milligrams per liter
MS/MSD	matrix spike / matrix spike duplicate
NTU	nephelometric turbidity units
ORP	oxidation reduction potential
OWP	Old Waste Pond
PCP	pentachlorophenol
PID	photo-ionization detector
PVC	polyvinyl chloride
RWP	Retrofitted Waste Pond
SOP	standard operating procedure
TDS	total dissolved solids
UAC	Utah Administrative Code
ug/L	micrograms per liter
UDEQ	Utah Department of Environmental Quality
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

This Compliance Monitoring Plan (CMP) fulfills one of the requirements of Part C (Accompanying Reports and Plans) of the Groundwater Discharge Permit (GWDP) application for the US Magnesium facility (Facility) located in Rowley, Utah (**Figure 1-1**). This plan complies with requirements outlined in Utah Administrative Code (UAC) R-317-6-6.3 and follows guidelines presented in the Utah Department of Environmental Quality (UDEQ) Division of Water Quality (DWQ) Ground Water Quality Protection Permitting Information Document (UDEQ, 2006).

The US Magnesium facility (Facility) processing plant produces a low-pH wastewater stream that is currently conveyed to an unlined evaporation pond. An expanded and retrofitted wastewater evaporation pond is proposed to meet Utah GWDP requirements outlined in Utah Administrative Code (UAC) R317.6. The RWP is expected to be approximately 800 acres in size and the groundwater discharge control system design concept includes installation of hydraulic barrier walls along the pond dikes to prevent migration of wastewater beyond the pond footprint (**Figure 1-2)**.

This Compliance Monitoring Plan (CMP) outlines sampling and monitoring activities proposed to evaluate the performance of the RWP that has been designed to protect surrounding groundwater. Performance monitoring activities described in this plan include:

- Groundwater sampling
- Groundwater level monitoring
- Source water (pond influent and pond surface water) sampling
- Discharge control system inspections

1.1 FACILITY DESCRIPTION AND BACKGROUND

The Rowley Facility, located in Tooele County, has been operated since 1972. As shown in **Figure 1-1**, the Facility is located along the west shore of Great Salt Lake on 4,424 acres in Lakeside Valley, an extension of Skull Valley, Utah. The Facility extracts magnesium from the mineral-rich waters of Great Salt Lake and produces principal products of elemental magnesium and chlorine. Low-pH process wastewater is currently conveyed through open, unlined ditches that discharge into an unlined evaporation pond located north and east of the processing facility. A Facility map and locations of the Current Waste Pond (CWP), including the northeast and southeast sections, and the Old Waste Pond (OWP) are shown on **Figure 1-2**.

1.2 PROPOSED GROUNDWATER DISCHARGE CONTROL SYSTEM DESCRIPTION

The Utah Administrative Code (UAC) R317-6 rules require that best available technology (BAT) be used to minimize any discharge of pollutants to groundwater. The groundwater discharge control system proposed for the US Magnesium GWDP is a Retrofitted Waste Pond (RWP) that involves expansion of the CWP and installation of a hydraulic barrier wall (barrier wall) to prevent discharged wastewater from migrating into surrounding groundwater. Before discharging to the RWP, the Facility's wastewater will be treated for organic contaminants and conveyed to the RWP through new discharge piping. A full description of the discharge control system design is presented in the US Magnesium GWDP Groundwater Discharge Control Plan (Stantec, 2017a).

1.3 GROUNDWATER

Groundwater in the vicinity of the Facility is derived from precipitation that falls within the drainage basin, primarily from snowmelt and rainfall, on lands above 6,000 feet above mean sea level (amsl). Groundwater flows across the proposed RWP area from southwest to northeast, towards Great Salt Lake (GSL). Depths to groundwater vary from approximately 0.3 to 16 feet below ground surface (bgs) in wells completed in the upper shallow aquifer zone (Upper Aquifer Zone) across the area. Higher groundwater elevations in the lower portion of the shallow aquifer (Lower Aquifer Zone) demonstrate a slight upward vertical hydraulic gradient from the Lower to Upper Aquifer Zone, indicating the pond area lies in a discharge zone of the regional groundwater system (Stantec, 2017a).

Groundwater elevations and flow directions in the vicinity of the RWP are predicted to change after the barrier wall is installed. Refer to the US Magnesium Groundwater Model Report, Appendix F of the Groundwater Discharge Control Plan, for details of groundwater modeling scenarios and results (Stantec, 2017a).

1.3.1 Hydrogeology

Groundwater immediately below and in the immediate vicinity of the RWP may be divided into three primary hydrogeologic units, all part of the regional shallow aquifer:

- Upper Aquifer Zone (to approximately 35 feet bgs)
- Deeper Silty Clay Unit (approximately 35-55 feet bgs)
- Lower Aquifer Zone (approximately 55 feet bgs to an undetermined depth).

The Upper Aquifer Zone is largely unconfined and extends down to the Deeper Silty Clay Unit, which acts as a confining layer for the Lower Aquifer Zone. The Upper Aquifer Zone consists of fine sands, silts, and clays and includes a significant layer of oolitic sands particularly in the northern portion of the RWP area. The Deeper Silty Clay Unit is a

low to medium plasticity clay/silty clay, and the Lower Aquifer Zone consists of silty and fine-grained sands interbedded with lenses of low to medium plasticity clay/silty clays.

Horizontal hydraulic conductivities calculated using Upper Aquifer Zone pumping test results range from 14-30 feet per day (ft/day) (0.0049 to 0.0106 cm/s) typically characteristic of silty sands, while horizontal hydraulic conductivities in the Lower Aquifer Zone are generally lower, in the range of 0.7 to 4 ft/day (2.5×10^{-5} to 1.41×10^{-3} cm/sec) due to a higher percentage of silty sands and clays in the Lower Aquifer Zone. Vertical hydraulic conductivities in the Deeper Silty Clay Unit are in the 10^{-7} to 10^{-8} cm/s range, which is characteristic of lean clay. (More detailed discussion and hydrogeological data analyses are included in the GWDP Hydrogeologic Report [Stantec, 2017b]).

1.3.2 Current Groundwater Quality

Overall, groundwater in the Upper and Lower Aquifer Zones in the vicinity of the RWP is of poor quality and is not suitable for potable uses. Due to total dissolved solids (TDS) concentrations, it is classified under UAC R317-6-4 Section 4.7 as Class IV Saline (TDS concentrations above10,000 milligrams per liter [mg/L]). TDS concentrations generally increase from west to east, and are higher in the Deeper Aquifer Zone than in the Upper Aquifer Zone in the RWP area.

In an effort to establish baseline groundwater quality, four rounds of groundwater samples were collected from ten wells located along the eastern dike of the CWP in 2017. TDS concentrations in wells screened in the Lower Aquifer Zone are generally higher than those screened in the Upper Aquifer Zone (85,000 - 160,000 compared to 40,000 - 73,000 mg/L, respectively). Data from these ten 2017 baseline sampling wells are included in **Table 1-1**. Concentrations of some metals (i.e., iron, arsenic, aluminum to name a few) are higher in the Upper Aquifer Zone (and in plant discharge and CWP surface water) than in the Lower Aquifer Zone.

Groundwater pH generally increases with depth and distance from the CWP. Immediately downgradient (east) of the CWP, measurements of pH in the Upper Aquifer Zone ranged from 5.4 to 7.8 during 2017 sampling events. Measured pH at MW-22A, screened within the Upper Aquifer Zone just above the Deeper Silty Clay Unit, is consistently higher than wells screened across shallower depths of the Upper Aquifer Zone. In 2017, groundwater pH measurements for the Lower Aquifer Zone ranged between 6.9 and 7.8, which are generally higher than values measured in the Upper Aquifer Zone.

US Magnesium has proposed to construct a wastewater treatment plant that will remove organic constituents from the Facility wastewater. Because the wastewater is expected to be treated for organic constituents prior to being discharged into the RWP, inorganic constituents are the focus of this CMP and Groundwater Protection Levels are not proposed for organic constituents. Organic constituents detected in the ten 2017 baseline groundwater monitoring wells are presented and discussed in the US Magnesium GWDP application Hydrogeologic Report (Stantec, 2017b).

1.4 SURFACE WATER

No perennial streams flow through or near the Facility. However, seasonal and occasional surface water flow occurs west of the Facility in the Lakeside Mountains originating from seasonal springs and snowmelt that discharge into the canyons. Groundwater seeps have been observed in the vicinity of the CWP and the OWP and resulting ponded areas vary seasonally (ERM, 2016).

1.5 COMPLIANCE MONITORING OBJECTIVES

The overall objective of monitoring activities presented in this CMP is to provide data to evaluate the effectiveness of the proposed groundwater discharge control system. Proposed compliance monitoring activities and specific objectives are outlined in the table below.

Table 1-2
Compliance Monitoring Scope and Objectives

Monitoring Activity	Description	Objectives
Groundwater Sampling	Collect and analyze groundwater samples from wells located outside and downgradient of the barrier wall, and from deeper wells located on the CWP east dike that are screened beneath the pond (below the Deeper Silty Clay Unit); analyze for compliance monitoring parameters.	• Monitor groundwater quality below, downgradient, and cross-gradient of the RWP. • Assess groundwater discharge control system performance. • Evaluate compliance with Groundwater Protection Levels established in the GWDP.
Groundwater Level Monitoring	• Measure water levels in paired piezometers completed inside and outside of the RWP barrier wall. • Measure water levels in select piezometers located immediately upgradient of the RWP.	• Evaluate barrier wall effectiveness. • Evaluate groundwater flow immediately upgradient (west) of the RWP.
Source Water Sampling and Flow Monitoring	Collect and analyze RWP influent and pond surface water samples for a full suite of constituents; measure discharge flows (UAC R317-6-6 6.3 L).	• Confirm chemistry and volume of constituents entering, and contained in, the RWP. • Assess potential changes over time.
Discharge Control System Inspections	Routinely inspect visible components of the groundwater discharge control system: plant discharge outfall, pond dikes, and monitoring wells/piezometers.	Assess condition of the groundwater discharge control system and compliance monitoring facilities.

2.0 PROPOSED GROUNDWATER COMPLIANCE MONITORING NETWORK

Groundwater compliance monitoring will include groundwater sampling and groundwater level monitoring.

Locations of proposed compliance sampling locations are shown on **Figure 2-1**. The proposed wells/piezometers are completed in both the Upper and Lower Aquifer Zones

to monitor potential groundwater chemistry impacts from discharges to the RWP. Monitoring wells and piezometers proposed for compliance groundwater sampling are located on the outside of the barrier wall (north, east, and south); those circled in yellow are completed in the Upper Aquifer Zone, and those circled in green are completed in the Lower Aquifer Zone (below the Deeper Silty Clay Unit). Proposed groundwater level compliance wells/piezometers are circled in blue.

Construction details for proposed compliance sampling wells/piezometers are listed in **Tables 2-1a** and **2-1b**, for those completed in the Upper Aquifer Zone and the Lower Aquifer Zone, respectively. Individual well/piezometer construction logs for existing proposed compliance wells/piezometers are included in **Appendix A**.

3.0 PROPOSED GROUNDWATER PROTECTION LEVELS

In accordance with UAC R317-6-4.7, Groundwater Protection Levels for Class IV groundwater are not specifically prescribed but are to be established to protect human health and the environment. Proposed groundwater compliance constituents and associated protection levels presented in this CMP are based on groundwater baseline and source water (including pond influent and CWP surface water) sampling data collected between 2014 and 2017.

3.1 BASELINE MONITORING RESULTS

3.1.1 Baseline Groundwater Sampling Results

Baseline groundwater samples were collected between February 2014 and November 2017 from ten wells/piezometers completed in the Upper Aquifer and Lower Aquifer Zones in the area of the planned RWP. Samples for up to four sampling rounds were analyzed for a full suite of inorganic constituents as shown in **Table 1-1**.

A total of eight rounds of baseline data will be required for the compliance monitoring wells/piezometers selected for the GWDP compliance monitoring program. These eight-point data sets will be used to establish Groundwater Protection Levels for each compliance monitoring well/piezometer based on the mean plus two times the standard deviation of each data set. Additional baseline sampling will be conducted once the final list of compliance sampling wells/piezometers is approved.

3.1.2 Baseline Source Water Sampling Results

Plant wastewater discharge and CWP surface water are considered source waters for the GWDP. Three combined wastewater discharge ditch (Main Ditch) samples were collected and analyzed for inorganic constituents in 2017 to characterize the processing plant effluent and assist in identifying appropriate permit compliance monitoring parameters. Source water samples were collected from the Main Ditch in June, September, and November 2017, and CWP surface water samples were

collected at five different locations in July 2015. These source water sample results are listed in **Table 3-1**. Note that concentrations of a number of inorganic constituents are significantly higher in the pond surface water than in the wastewater discharge stream; for example, aluminum, iron, manganese, potassium, sodium, sulfate, and TDS. These higher pond water concentrations are likely due to effects of evapoconcentration over time.

3.2 PROPOSED GROUNDWATER PROTECTION LEVELS AND PERFORMANCE MONITORING PARAMETERS

Groundwater sampling compliance constituents were identified based on a comparison of source water and groundwater concentrations in the vicinity of the RWP. Source water indicator constituents (those detected in source water at least one order of magnitude above concentrations in groundwater in the RWP area) were selected as compliance sampling parameters, and are listed below:

- Aluminum
- Arsenic
- Chromium
- Iron
- Nickel
- Vanadium
- Zinc

In addition to the metals listed above, low pH also is characteristic of the source water, and is proposed as a groundwater sampling compliance parameter as well. Source water pH measurements are typically less than 2 (**Table 2-1**), while groundwater pH values are typically in the 5-7 range (**Table 1-1**).

Compliance parameters and their proposed Groundwater Protection Levels for the three proposed compliance monitoring wells for which more than one sampling round has been conducted are listed in **Table 3-2.** Groundwater Protection Levels are proposed for each compliance sampling point, following the state of Utah protocol of the mean plus two times the standard deviation of baseline data collected between 2014 and 2017. (Compliance sampling locations are presented and discussed in Section 2.0 of this CMP.)

Because TDS levels at groundwater monitoring wells/piezometers located within, and downgradient of, the RWP are all greater than 10,000 mg/L, groundwater that may potentially be impacted by the pond is Class IV Saline, and is not considered to be a potential source of drinking water or as a source for industrial or agricultural uses.

4.0 WATER SAMPLING PROGRAM

4.1 GROUNDWATER SAMPLING

Groundwater sampling data will be used to evaluate groundwater quality beneath and outside (primarily downgradient) of the RWP. Water quality parameters will be measured and recorded in the field and samples will be collected and sent to a laboratory for analyses of groundwater compliance constituents and pH will be measured in the field as a compliance parameter.

4.1.1 Groundwater Sampling and Sampling Procedures

Groundwater samples will be collected according to methods and procedures outlined in Standard Operating Procedure (SOP) 20, included in **Appendix B**. Low-flow sampling methods will be used, and purge water will be disposed on the site.

4.1.2 Groundwater Sampling Parameters, and Analyses

Laboratory analytes and field-measured parameters proposed for compliance groundwater sampling are listed in **Table 4-1** below.

Table 4-1
Proposed Groundwater Compliance Sampling Analytes and Parameters

Analyte / Parameter	Laboratory Method	Baseline Source Water Range[a] (ug/L)	Downgradient Groundwater Concentration[b] (ug/L)
Aluminum (Total)	EPA 6020A	1,800 – 110,000	<50
Arsenic (Total)	EPA 6020A	84 – 460	30
Chromium (Total)	EPA 6020A	<2.0 - 350	<2.0
Magnesium (Total)	EPA 6020A	943,000 – 4,000,000	7,400,000
Nickel (Total)	EPA 6020A	<1.0 - 270	5.9 J
Vanadium (Total)	EPA 6020A	<2.0 – 1,500	<6.0
Zinc (Total)	EPA 6020A	110 - 520	9.9
pH	Measured in field	0.0 – 2.4	7.4

(a) Data from main discharge ditch and CWP surface water samples 2014 – 2017; lower end of range is typical of Main Ditch sample results and upper range typical of CWP sample results.
(b) Existing piezometer PZ-6 data for samples collected in January 2014; PZ-6 is completed in Upper Aquifer Zone and located downgradient of the proposed Retrofitted Waste Pond. These data will be updated as additional baseline groundwater sampling is conducted.

Groundwater analytes/parameters will be measured to evaluate whether source water has leaked into groundwater outside the RWP.

4.1.3 Proposed Groundwater Sampling Frequency

Compliance groundwater samples will be collected and analyzed on a semiannual basis for the first five years of compliance monitoring. However, based on data

evaluation after five years the frequency of groundwater sampling, as well as analytical parameters, may be modified as approved by DWQ (refer to Section 9.0 of this CMP).

4.2 SOURCE WATER

Source water sample results will confirm the characterization of the Facility wastewater that is discharged to, and contained in, the RWP. Water samples will be collected from the influent wastewater stream and CWP surface water to confirm identified groundwater compliance analytes and parameters. The Facility wastewater discharge stream and the surface water in the RWP will be sampled for a full suite of total metals and water quality parameters and other inorganic constituents such as nitrate, nitrite, perchlorate, cyanide, phosphate, sulfate, alkalinity, and TDS. As previously mentioned, the Facility wastewater stream will be treated for organic contaminants with a new wastewater treatment system, which is intended to be operating prior to completion of the RWP; therefore, the proposed analyte list does not include organic constituents.

In addition to the source water sampling, pond influent flows will be measured and recorded semiannually to assess the volume of water entering the proposed new wastewater pond.

4.2.1 Source Water Sampling Locations

Facility wastewater discharge samples will be collected at an effluent sampling port or at the end of the combined wastewater pipe (at the point it discharges into the RWP) and at a pond surface water location shown in **Figure 2-1**. The wastewater stream will be sampled downstream of all wastewater inflows. The RWP surface water sample will be collected at a location near the current CWP/OWP connector pipe that can be accessed along the CWP eastern dike.

4.2.2 Source Water Sampling Methods and Analytes

4.2.2.1. Pond Influent Sampling. The Facility wastewater stream will be sampled with a Teflon dipper or a peristaltic pump with disposable Teflon tubing, as described in SOP 21 in **Appendix B.** A 0.45-micron filter will be used to collect samples that require filtration in the field. Samples will be collected in containers as specified in the SOP and analyzed for constituents listed in **Table 4-2**.

Table 4-2

Proposed Source Water and RWP Surface Water Sampling Analytes and Parameters

Analyte / Parameter	Laboratory Method
Alkalinity, Total as CaCO3	EPA 310.1/SM2320B
Total & Dissolved Metals (Ca, Mg, K, Na, Al, Sb, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, Se, Ag, Tl, V, Zn)	EPA 6020A
Anions (Cl, Nitrate as N, Nitrite as N, Phosphate as P, Sulfate)	EPA 300.0
Perchlorate	EPA 6850
Total Dissolved Solids	EPA 160/SM2540C
Total Cyanide	SW9012B
pH, Dissolved Oxygen, Specific Conductivity, Oxygen Reduction Potential, Temperature	Measured in field

4.2.2.1. RWP Surface Water Sampling. The RWP surface water samples will be collected with a Teflon dipper or a peristaltic pump and disposable tubing, as outlined in SOP 21 included in **Appendix B**. A 0.45-micron filter will be used to collect samples that require filtration in the field. Samples will be collected in containers as specified in the SOP and analyzed for compliance constituents listed in **Table 4-2**.

4.2.3 Sampling Frequency

Source water samples will be collected and analyzed annually. However, based on data evaluation after five years the frequency of source water sampling, as well as analytical parameters, may be modified as approved by DWQ (refer to Section 9.0 of this CMP).

5.0 WATER LEVEL MONITORING PLAN

Groundwater levels will be measured to evaluate performance of the groundwater discharge control system. The proposed groundwater level monitoring network is presented in **Table 5-1**. Barrier wall effectiveness will be assessed by comparing water levels in proposed paired piezometers (each pair includes one piezometer located inside and one outside of the hydraulic barrier wall), and additional piezometers located upgradient of the pond to evaluate groundwater flow directions west of the RWP. Proposed piezometers will be screened from five feet below grade to the full depth of the barrier wall (entire Upper Aquifer Zone).

Prior to purging of any wells, depths to water inside each well/piezometer casing will be measured to 0.01 feet from the surveyed measuring point using an electronic water-level indicator. Groundwater elevations will be calculated for each monitoring well/piezometer by subtracting the recorded depth to water from the surveyed measuring point elevation of the wellhead.

Groundwater levels will be measured quarterly. However, based on data evaluation after five years the frequency of groundwater level monitoring may be modified as approved by DWQ (refer to Section 9.0 of this CMP).

6.0 DISCHARGE CONTROL SYSTEM INSPECTIONS

Groundwater monitoring facilities and RWP system components will be inspected to evaluate the performance and condition of the Groundwater Discharge Control System. This section provides detailed descriptions of the methods and procedures for performing and documenting routine and contingent inspections. This plan does not include actions to be taken in response to damages identified during inspections; such actions are described in the *Contingency Plan* included as part of this GWDP.

6.1 INSPECTION FREQUENCY

Routine inspections of embankments, the connector pipe that currently allows hydraulic connection between the CWP and OWP, and the wastewater discharge outfall will be performed monthly during normal operating conditions, where normal operating conditions are defined as a ponded elevation of 4,215 ft amsl or lower. During high water periods in which the ponded elevation is above 4,215 ft amsl, inspections of the embankments and CWP/OWP connector pipe will be performed weekly.

Inspections also will be performed following significant storm or seismic events. A significant storm event is one in which more than one inch of rain falls within a 24-hour period. A qualifying seismic event is defined as an event that (1) exceeds a magnitude 5.0 on the Richter Scale with an epicenter within a 20-mile radius, or (2) exceeds a magnitude 6.0 on the Richter Scale with an epicenter within a 50-mile radius.

Monitoring wells will be inspected each time a sampling or groundwater level monitoring event is performed.

6.2 INSPECTION PROCEDURES

Inspections will be performed by qualified US Magnesium personnel, typically the Environmental Manager, Environmental Coordinator or their designee.

6.2.1 Embankment Inspections

The embankment inspections will occur along the embankments of the pond and will be comprised of two passes, one beginning at the southwest terminus of the barrier wall and proceeding counter-clockwise along the embankment towards the northwest terminus of the barrier wall. A second pass will proceed in a clockwise direction back to the starting point at the southwest terminus of the barrier wall (**Figure 1-2**).

The inspector will drive at a slow speed to be able to safely observe the condition of the embankments while driving. Areas identified during the driving inspection that are

potentially problematic will be inspected on foot. The inspector will be looking for the following indicators of damage to or loss of integrity of the embankments and associated cut-off walls:

- Seepage from, or piping through, the embankment
- Subsidence/sinkholes in the top/side slopes of the embankments
- Undercutting on the inside of the embankments
- Signs of animal burrows on the top/side slopes of the embankments.

6.2.2 CWP/OWP Connector Piping Inspections

In addition to a general inspection of the RWP embankment integrity, the connector pipe embedded in the berm separating the OWP from the CWP will be inspected for any material in the pipe that may be inhibiting flow, signs of water bypass around the pipe through the embankment, and any indicators of damage to the pipe or pipe structures. The current connector pipe may be removed in favor of a breach(s) of the embankment (currently separating the CWP and OWP) within the footprint of the RWP. In that event, inspection of the connector pipe will cease.

6.2.3 Discharge Piping Inspection

The length of the wastewater discharge conveyance pipe will be inspected for potential leaks or other damage. All visible pipe joints, pipe supports and valves will be inspected. Any valves should be inspected and if possible exercised to ensure proper performance and to prevent valve lockup.

6.2.4 Monitoring Well Inspection

Monitoring wells and piezometers will be inspected during each groundwater sampling or groundwater monitoring event. This inspection will include looking for potential damage to inner and outer casings, evidence of tampering, and excessive rusting that may prevent access.

6.3 DOCUMENTATION AND REPORTING

Inspections will be documented on project-specific field forms. Well inspection notes will be written in a weather resistant field book utilized for groundwater sampling and groundwater level measurements. Inspection activities will be described and results will be included in routine Compliance Monitoring Reports submitted to DWQ as described in Section 8.2 of this CMP. All documentation and reports will stored at the Facility.

7.0 GROUNDWATER DISCHARGE PERMIT COMPLIANCE EVALUATION

Groundwater sampling data will be used to evaluate groundwater quality beneath and outside the hydraulic barrier walls. If groundwater analytical results are detected above permitted Groundwater Protection Levels for three consecutive sampling rounds, responses outlined in the Contingency and Corrective Action Plan (Stantec, 2017c) will be followed.

Evaluation of groundwater level data, inside and outside of the barrier walls as well as immediately upgradient of the RWP, will be a primary indicator of hydraulic performance of the groundwater discharge control system. In general, if the potentiometric levels inside the barrier wall are equal or higher than the groundwater levels measured on the outside of the wall, hydraulic containment is indicated. If groundwater levels become lower inside the barrier wall than outside the barrier wall in the paired piezometers, or if groundwater levels upgradient of the pond indicate groundwater is flowing from inside the RWP boundary out of the west side of the RWP boundary, results will be confirmed over two additional groundwater level monitoring events within a 60-day period. If data from all three monitoring events indicate hydraulic containment has been lost, responses detailed in the Contingency and Corrective Action Plan will be followed (Stantec, 2017c).

8.0 DOCUMENTATION AND REPORTING

8.1 MONITORING DOCUMENTATION

US Magnesium will retain records of all monitoring information, including inspection and maintenance records, monitoring field notes, instrument calibration records, and copies of all reports required by the GWDP for a period of at least five years from the date the work was completed. All documentation and reports will be stored at the Facility.

8.2 ROUTINE MONITORING REPORTS

US Magnesium will submit annual Compliance Monitoring Reports to the DWQ. These routine reports will include the following information:

1. Laboratory Analytical Data. Results of all analyses for groundwater and source water sampling. Analytical methods and method detection limits will be reported as well as sample dates, results, and dates of analyses. Data tables will include a column indicating the Groundwater Protection Level for each monitoring point, and whether the current monitoring round result is above or below compliance levels.
2. Groundwater Level Data. A table with compliance water-level piezometer data will be prepared, and will include a column that indicates whether the data for

paired piezometers and upgradient piezometer water levels indicate containment of pond water within the pond boundaries.

3. Noncompliance Indicators. A summary of all data that indicate, or suggest potential, noncompliance. A tally of how many consecutive monitoring rounds have indicated/suggested noncompliance will be reported.
4. Baseline Data (if applicable). Reporting of any new baseline groundwater monitoring results, and updated statistical calculations (i.e., mean, standard deviation).
5. Contingency Response Actions. Summary of any Contingency Plan measures that have been performed or are in progress.
6. Inspection Results. Summary of inspection results and any maintenance performed.
7. Construction or Nonroutine Maintenance. Summary of any new construction or modification to facilities that was performed during the reporting period.
8. Pond influent flow data.
9. Field Documentation. Copies of field data sheets, including groundwater sampling water quality parameter stabilization data, purge volumes, sampling methods, and inspection forms.

8.3 NONCOMPLIANCE NOTIFICATIONS

The following noncompliance issues or conditions will be reported to UDEQ within 24 hours of detection:

- Groundwater Protection Level(s) exceedance at a given compliance monitoring location for three consecutive monitoring events
- Potential loss of hydraulic containment, as indicated by groundwater level data at a given location over three consecutive monitoring rounds
- Observed RWP wastewater release to the ground surface outside the RWP boundary.

Any exceedance of permit Groundwater Protection Levels in a compliance monitoring well/piezometer groundwater sample, or indication of hydraulic containment loss, will be reported in the next routine monitoring report.

US Magnesium will follow contingency response plans for noncompliance conditions as outlined in the GWDP Contingency and Corrective Action Plan (Stantec, 2017c).

9.0 COMPLIANCE MONITORING PLAN MODIFICATION PROCESS

US Magnesium may recommend modifications to the monitoring program and, upon DWQ approval, will modify this plan. At a minimum, after the first five years of monitoring following completion of construction of the groundwater control system for the RWP, US Magnesium and DWQ will meet and review the results of the monitoring program and discuss appropriate modifications to the scope and frequency of monitoring activities outlined in this CMP. Upon DWQ approval, this CMP will be modified accordingly.

10.0 REFERENCES

ERM, 2016. *Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model*, US Magnesium NPL Site, Tooele County, Utah. June 2016.

Stantec, 2017a. US Magnesium Groundwater Discharge Permit *Groundwater Discharge Control Plan*. December 2017.

Stantec, 2017b. US Magnesium Groundwater Discharge Permit *Hydrogeologic Report*. December 2017.

Stantec, 2017c. US Magnesium Groundwater Discharge Permit *Contingency and Corrective Action Plan*. December 2017.

UDEQ, 2006. *Groundwater Quality Protection Permitting Information Document*, Utah Department of Environmental Quality Division of Water Quality, Ground Water Protection Section. December 2006.

TABLES

TABLE 1-1
GROUNDWATER DISCHARGE PERMIT BASELINE GROUNDWATER SAMPLING RESULTS
US MAGNESIUM, ROWLEY, UTAH
(Page 1 of 4)

Analyte	Units	MCL[a]	MW-13B Screened 9-19 feet bgs				MW-15B Screened 9-19 feet bgs				
			2/4/2014	8/9/2017	9/14/2017	11/2/2017	2/5/2014	8/9/2017	9/14/2017	11/2/2017	11/2/2017 (DUP)
Total Aluminum	ug/L	50 to 200	**5,400**	<1000	<1000	<1000	**6,200**	**6,300**	**7,100**	**6,100**	**6,100**
Dissolved Aluminum	ug/L		**5,600**	<1000	--	--	**6,000**	**6,000**	--	--	--
Total Antimony	ug/L	6	0.9 J	<100	<100	<100	0.78 J	<100	<100	<100	<100
Dissolved Antimony	ug/L		0.75 J	<100	--	--	0.73 J	<100	--	--	--
Total Arsenic	ug/L	10	**30**	<50	<50	<50	**42**	**68**	**66**	**95**	**96**
Dissolved Arsenic	ug/L		**28**	<50	--	--	**43**	**50**	--	--	--
Total Barium	ug/L	2,000	350	<250	<250	<250	330	630	730	820	830
Dissolved Barium	ug/L		330	<250	--	--	320	620	--	--	--
Total Cadmium	ug/L	5	1.9 J	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cadmium	ug/L		1.5 J	<50	--	--	<1.0	<50	--	--	--
Total Calcium	mg/L	NA	7,500	4570 D	3970 D	3560 D	7500	13300 D	13400 D	13800 D	14500 D
Dissolved Calcium	mg/L		7,300	4780 D	--	--	7400	13400 D	--	--	--
Total Chromium	ug/L	100	<2.0	<100	<100	<100	2.9 J	<100	<100	<100	<100
Dissolved Chromium	ug/L		<2.0	<100	--	--	2.7 J	<100	--	--	--
Total Cobalt	ug/L	NA	47 J	<50	<50	<50	85	120	180	190	190
Dissolved Cobalt	ug/L		52 J	<50	--	--	84	120	--	--	--
Total Copper	ug/L	1,300	<2.0	<100	<100	<100	3.5 J	<100	130	<100	<100
Dissolved Copper	ug/L		<2.0	<100	--	--	<2.0	<100	--	--	--
Total Iron	ug/L	300	**67,000 J**	**5,500**	**8,400**	**16,000**	**93,000**	**190,000**	**210,000**	**310,000**	**310,000**
Dissolved Iron	ug/L		**69,000 J**	**4,700**	--	--	**91,000**	**180,000**	--	--	--
Total Lead	ug/L	15	<1.0	<50	<50	<50	<1.0	**130**	<50	60	63
Dissolved Lead	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	--
Total Magnesium	mg/L	NA	4,100	4150 D	3860 D	3300 D	3500	6300 D	6480 D	7750 D	8200 D
Dissolved Magnesium	mg/L		3,800	4260 D	--	--	3400	6350 D	--	--	--
Total Manganese	ug/L	50	**8,000**	**310**	**230**	**250**	**11,000**	**15,000**	**16,000**	**21,000**	**21,000**
Dissolved Manganese	ug/L		**8,200**	**320**	--	--	**11,000**	**15,000**	--	--	--
Total Mercury	ug/L	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	ug/L		<0.1	<0.1	--	--	<0.1	<0.1	--	--	--
Total Molybdenum	ug/L	NA	23	<100	<100	<100	50	<100	<100	<100	<100
Dissolved Molybdenum	ug/L		17	<100	--	--	44	<100	--	--	--
Total Nickel	ug/L	NA	160 J	<50	<50	59	260	500	700	660	670
Dissolved Nickel	ug/L		180 J	<50	--	--	250	480	--	--	--
Total Potassium	mg/L	NA	340	970 D	1130 D	836 D	150	313 D	348 D	319 D	339 D
Dissolved Potassium	mg/L		320	962 D	--	--	150	313 D	--	--	--
Total Selenium	ug/L	50	2.7 J	<250	<250	<250	2.4 J	<250	<250	<250	<250
Dissolved Selenium	ug/L		2.8 J	<250	--	--	<5.0	<250	--	--	--
Total Silver	ug/L	100	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Silver	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	--
Total Sodium	mg/L	NA	4800 J	11300 D	12800 DJ+	10500 D	1,600	2700 D	2750 DJ+	2700 D	2840 D
Dissolved Sodium	mg/L		4,500	11100 D	--	--	1,600	2650 D	--	--	--
Total Thallium	ug/L	2	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Thallium	ug/L		<1.0	<50	--	--	<1.0	<50	--	--	--
Total Vanadium	ug/L	NA	7.3 J	<100	<100	<100	8.5 J	<100	<100	<100	<100
Dissolved Vanadium	ug/L		<2.0	<100	--	--	8.2 J	<100	--	--	--
Total Zinc	ug/L	5,000	350 J	170	<100	<100	370	560	650	910	930
Dissolved Zinc	ug/L		350 J	<100	--	--	360	370	--	--	--
Bromide	mg/L	NA	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	100 D
Chloride	mg/L	250	**33,000**	**41,000 D**	**43,000 D**	**40,000 D**	**29,000**	**45,000 D**	**53,000 D**	**59,000 D**	**59,000 D**
Cyanide	ug/L	200	30	<25 D	<10	<10	47 J	44 D	19	<10	<10
Fluoride	mg/L	4	**18**	<100 D	<100 D	<100 D	**20**	<100 D	<100 D	<100 D	<100 D
Nitrate Ion	mg/L	NA	--	<100 D	120 D	<100 D	--	<100 D	110 D	<100 D	<100 D
Nitrate-N	mg/L	10	0.29 J	<23 D	**28 D**	<23 D	0.36 J	<23 D	**24 D**	<23 D	<23 D
Nitrite Ion	mg/L	NA	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Nitrite-N	mg/L	1	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<31 D
Perchlorate	ug/L	NA	490 J	280 D	1.2 FD	<5 D	0.6	<200 D	1.2 FD	<5 D	<5 D
Phosphorus, Total (as P)	mg/L	NA	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Phosphate-P	mg/L	NA	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<33 D
Sulfate	mg/L	250	**1,900**	**2,800 D**	**2,600 DJ+**	**2,800 D**	**1,300**	**1,100 D**	**950 D**	**840 D**	**890 D**
Total Alkalinity	mg/L	NA	760	210	160	180	830	680	280	470	400
Total Dissolved Solids	mg/L	2,000	**64,000**	**53,000**	**63,000**	**38,000**	**58,000**	**60,000**	**73,000**	**64,000**	**63,000**
Hexavalent Chromium	ug/L	100	0.377 J	--	--	--	0.634	<1.0 U	--	--	--
pH		NA	5.9	6.4	7.4	6.3	5.3	5.4	6.1	5.1	5.1
Conductivity	mS/cm	NA	69.5	87.6	77.5	88.7	56.0	87.3	90.7	72.6	72.6
DO	mg/L	NA	0.0	0.2	0.1	0.7	0.0	0.2	0.0	0.3	0.3
ORP	mV	NA	26.0	-235.2	-263.8	-238.0	-12.0	-50.1	-130.3	-42.1	-42.1
Turbidity	NTU	NA	206.0	5.5	20.7	0.5	130.0	45.0	326.0	0.5	0.5
Chlorine	mg/L	NA	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0
Temperature	C	NA	10.2	21.5	18.0	17.0	9.2	20.0	20.1	19.3	19.3

[a] MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.

bold Concentration above MCL, indicated for reference only as groundwater is Class IV.

NA No MCL Established

'--' Not Analyzed

DUP Field Duplicate

D Sample dilution required for analysis: reported values reflect the dilution.

F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.

J Data are estimated due to associated quality control data.

J- Data are estimated and are potentially biased low due to associated quality control data.

J+ Data are estimated and are potentially biased high due to associated quality control data.

UJ Potential low bias, possible false negative.

mg/L milligrams per liter

ug/L micrograms per liter

mS/cm micro siemens per centimeter

C degrees Celsius

mV millivolts

NTU Nephelometric Turbidity Unit

TABLE 1-1
GROUNDWATER DISCHARGE PERMIT BASELINE GROUNDWATER SAMPLING RESULTS
US MAGNESIUM, ROWLEY, UTAH

Analyte	MW-21 Screened 50-60 feet bgs				MW-22A Screened 24-34 feet bgs				MW-22B Screened 54-64 feet bgs				
	7/13/2017	8/9/2017	9/13/2017	11/1/2017	7/12/2017	8/8/2017	9/13/2017	11/1/2017	7/12/2017	8/8/2017	9/13/2017	9/13/2017 (DUP)	11/1/2017
Total Aluminum	<20	<1000	<1000	<1000	<20	<1000	<1000	<1000	<20	<1000	<1000	<1000	<1000
Dissolved Aluminum	<20	<1000	--	--	<20	<1000	--	--	<20	<1000	--	--	--
Total Antimony	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Antimony	<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Arsenic	39 J	<50	<50	<50	**34 J**	**57**	<50	<50	**45 J**	<50	<50	<50	<50
Dissolved Arsenic	<1.0	<50	--	--	**42 J**	**55**	--	--	**35 J**	<50	--	--	--
Total Barium	46	<250	<250	<250	42	<250	<250	<250	28	<250	<250	<250	<250
Dissolved Barium	27	<250	--	--	51	<250	--	--	24 J	<250	--	--	--
Total Cadmium	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cadmium	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Calcium	390	661 D	721 D	698 D	470	785 D	713 D	662 D	370	718 D	708 D	698 D	673 D
Dissolved Calcium	440	708 D	--	--	420	732 D	--	--	290	696 D	--	--	--
Total Chromium	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Chromium	<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Cobalt	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cobalt	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Copper	<2.0	<100	<100	170	<2.0	<100	<100	150	<2.0	<100	<100	<100	130
Dissolved Copper	<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Iron	<50	<2500	**2,500**	**3,800**	<50	<2500	<2500	3,100	<50	<2500	**2,500**	<2500	3,700
Dissolved Iron	<50	<2500	--	--	<50	<2500	--	--	<50	<2500	--	--	--
Total Lead	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Lead	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Magnesium	1300	2210 D	2370 D	2230 D	1700	2560 D	2360 D	2070 D	1200	2360 D	2400 D	2360 D	2210 D
Dissolved Magnesium	1400	2400 D	--	--	1500	2380 D	--	--	950	2270 D	--	--	--
Total Manganese	**93**	**53**	<50	<50	**210**	**250**	**72**	**99**	<1.0	<50	<50	<50	<50
Dissolved Manganese	49 J	**56**	--	--	**250**	**240**	--	--	<1.0	<50	--	--	--
Total Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	<0.1	<0.1	--	--	<0.1	<0.1	--	--	<0.1	<0.1	--	--	--
Total Molybdenum	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Molybdenum	<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Nickel	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Nickel	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Potassium	930	1,760 D	1,890 D	1,640 D	1,100	1,820 D	1,820 D	1,480 D	920	1,840 D	1,970 D	1,960 D	1,700 D
Dissolved Potassium	1,000	1,850 D	--	--	970	1700 D	--	--	740	1800 D	--	--	--
Total Selenium	<5.0	<250 UJ	<250 UJ	<250	<5.0	<250	<250	<250	<5.0	<250	<250	<250	<250
Dissolved Selenium	<5.0	<250 UJ	--	--	<5.0	<250 UJ	--	--	<5.0	<250	--	--	--
Total Silver	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Silver	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Sodium	26,000	32,200 D	34,400 D	33,800 D	23,000	32,200 D	32,500 D	29,700 D	26,000	35,000 D	35,200 D	33,100 D	33,800 D
Dissolved Sodium	26,000	33,300 D	--	--	22,000	29,700 D	--	--	22,000	33,500 D	--	--	--
Total Thallium	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Thallium	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	--	--	--
Total Vanadium	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Vanadium	<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Total Zinc	<2.0	160	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Zinc	<2.0	110	--	--	<2.0	<100	--	--	<2.0	<100	--	--	--
Bromide	28J	<100 D	<100 D	<100 D	<1.0	<100 D	<100 D	<100 D	34 J	<100 D	<100 D	<100 D	<100 D
Chloride	**61,000**	**54,000 D**	**48,000 D**	**54,000 D**	**54,000**	**50,000 D**	**56,000 D**	**51,000 D**	**60,000**	**56,000 D**	**57,000 D**	**60,000 D**	**56,000 D**
Cyanide	<10	140 DJ-	120 D	180 D	<10	<25 D	56 D	<25 D	57 J	**250 D**	190 DJ	100 DJ	45 D
Fluoride	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	<100 D
Nitrate Ion	--	<100 D	110 D	<100 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Nitrate-N	<0.0226	<23 D	**25 D**	<23 D	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	<23 D	<23 D	<23 D
Nitrite Ion	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Nitrite-N	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<31 D
Perchlorate	0.1J	<200 D	2 D	<5 D	<0.2	<200 D	0.91 FD	<5 D	<0.2	<200 D	<2 D	1.5 FD	<5 D
Phosphorus, Total (as P)	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D	<100 D
Phosphate-P	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<33 D
Sulfate	**7,100**	**6,500 D**	**5,200 D**	**6,300 D**	**9,000**	**7,700 DJ-**	**6900 D**	**7400 D**	**6,600**	**6,000 D**	**5,600 D**	**5,700 D**	**6,000 D**
Total Alkalinity	410	370 J+	380	380	280	210	240	150	370	380	380	360	370
Total Dissolved Solids	**110,000**	**85,000**	**110,000**	**74,000**	**100,000**	**90,000**	**100,000**	**62,000**	**110,000**	**96,000**	**110,000**	**110,000**	**56,000**
Hexavalent Chromium	<0.275 U	<1.0 U	--	--	<0.275 R	<1.0 U	--	--	<2.2 R	<1.0 U	--	--	--
pH	7.0	6.9	6.8	6.7	7.2	7.1	7.8	7.0	7.1	7.0	7.1	7.1	6.8
Conductivity	163.0	131.8	12.7	122.3	152.0	124.5	18.3	113.5	169.0	131.9	17.4	17.4	120.7
DO	0.0	0.4	0.2	0.7	2.6	0.5	0.2	0.3	0.0	0.2	0.2	0.2	0.4
ORP	-418.0	-345.9	-372.8	-384.7	-399.0	-332.2	-361.0	-395.5	-422.0	-346.1	-381.0	-381.0	-396.1
Turbidity	1.9	2.2	1.7	2.2	1.1	0.5	0.6	3.7	0.0	1.1	2.5	2.5	0.9
Chlorine	0.1	0.0	0.1	0.2	0.2	0.0	0.6	0.1	0.0	0.2	0.8	0.8	0.3
Temperature	19.7	18.7	21.5	16.9	21.9	23.8	18.3	16.0	18.0	20.6	22.0	22.0	16.2

[a] MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.
bold Concentration above MCL, indicated for reference only as groundwater is Class IV.
NA No MCL Established
'--' Not Analyzed
DUP Field Duplicate
D Sample dilution required for analysis: reported values reflect the dilution.
F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.
J Data are estimated due to associated quality control data.
J- Data are estimated and are potentially biased low due to associated quality control data.
J+ Data are estimated and are potentially biased high due to associated quality control data.
UJ Potential low bias, possible false negative.
mg/L milligrams per liter
ug/L micrograms per liter
mS/cm micro siemens per centimeter
C degrees Celsius
mV millivolts
NTU Nephelometric Turbidity Unit

TABLE 1-1
GROUNDWATER DISCHARGE PERMIT BASELINE GROUNDWATER SAMPLING RESULTS
US MAGNESIUM, ROWLEY, UTAH

Analyte	MW-23 Screened 56-66 feet bgs				PZ-10 Screened 4-14 feet bgs			
	7/13/2017	8/8/2017	9/13/2017	11/1/2017	2/4/2014	8/8/2017	9/13/2017	11/1/2017
Total Aluminum	<20	<1000	<1000	<1000	**51 J**	<1000	<1000	<1000
Dissolved Aluminum	<20	<1000	--	--	<20	<1000	--	--
Total Antimony	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Antimony	<2.0	<100	--	--	<2.0	<100	--	--
Total Arsenic	**31 J**	<50	<50	55	**53**	**54**	**64**	**79**
Dissolved Arsenic	<1.0	<50	--	--	**53**	**58**	--	--
Total Barium	37	<250	<250	<250	110	<250	<250	<250
Dissolved Barium	23 J	<250	--	--	110	<250	--	--
Total Cadmium	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Cadmium	<1.0	<50	--	--	<1.0	<50	--	--
Total Calcium	370	857 D	879 D	836 D	7,000	8,900 D	8,840 D	8,130 D
Dissolved Calcium	670	897 D	--	--	7,800	8,770 D	--	--
Total Chromium	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Chromium	<2.0	<100	--	--	<2.0	<100	--	--
Total Cobalt	<1.0	<50	<50	<50	28 J	<50	<50	<50
Dissolved Cobalt	<1.0	<50	--	--	29 J	<50	--	--
Total Copper	<2.0	<100	<100	200	<2.0	<100	<100	<100
Dissolved Copper	<2.0	<100	--	--	2.1 J	<100	--	--
Total Iron	<50	<2,500	<2,500	3,100	**240,000 J**	**300,000**	**310,000**	**320,000**
Dissolved Iron	<50	<2,500	--	--	**240,000 J**	**310,000**	--	--
Total Lead	<1.0	**59**	<50	<50	<1.0	<50	<50	<50
Dissolved Lead	<1.0	<50	--	--	<1.0	<50	--	--
Total Magnesium	1,200	3,060 D	3,040 D	2,850 D	3,800	5,400 D	5,190 D	4,760 D
Dissolved Magnesium	2,300	3,020 D	--	--	4,200	5,340 D	--	--
Total Manganese	**170**	**180**	**170**	**160**	**16,000**	**22,000**	**22,000**	**22,000**
Dissolved Manganese	**72**	**170**	--	--	**16,000**	**22,000**	--	--
Total Mercury	<0.1	<0.1 UJ	<0.1 UJ	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	<0.1	<0.1	--	--	<0.1	<0.1	--	--
Total Molybdenum	<2.0	<100	<100	<100	2.4 J	<100	<100	<100
Dissolved Molybdenum	<2.0	<100	--	--	<2.0	<100	--	--
Total Nickel	<1.0	<50	<50	<50	45 J	140	140	150
Dissolved Nickel	<1.0	130	--	--	46 J	140	--	--
Total Potassium	950	2400 D	2510 D	2140 D	320	567 D	591 D	538 D
Dissolved Potassium	1700	2410 D	--	--	360	572 D	--	--
Total Selenium	<5.0	<250	<250	<250	<5.0	<250	<250	<250
Dissolved Selenium	<5.0	<250	--	--	4.4 J	<250	--	--
Total Silver	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Silver	<1.0	<50	--	--	<1.0	<50	--	--
Total Sodium	26,000	48,700 D	48,100 D	49,600 D	2,400 J	3,680 D	3,580 DJ+	3,370 J+ D
Dissolved Sodium	43,000	49,200 D	--	--	2,700	3,600 D	--	--
Total Thallium	<1.0	<50	<50	<50	<1.0	<50	<50	<50
Dissolved Thallium	<1.0	<50	--	--	<1.0	<50	--	--
Total Vanadium	<2.0	<100	<100	<100	<2.0	<100	<100	<100
Dissolved Vanadium	<2.0	<100	--	--	<2.0	<100	--	--
Total Zinc	<2.0	190	<100	<100	11 J	<100	<100	<100
Dissolved Zinc	<2.0	<100	--	--	<2.0	<100	--	--
Bromide	53 J	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D
Chloride	**84,000**	**73,000 D**	**89,000 D**	**77,000 D**	**28,000**	**34,000 D**	**34,000 D**	**38,000 D**
Cyanide	<10	<25 D	<25 D	<25 D	23	30 D	<10	13
Fluoride	<0.1	<100 D	<100 D	<100 D	16	<100 D	<100 D	<100 D
Nitrate Ion	--	<100 D	<100 D	<100 D	--	<100 D	100 D	100 D
Nitrate-N	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	**24 D**	**24 D**
Nitrite Ion	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D
Nitrite-N	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D
Perchlorate	<0.2	<200 D	1.1 FD	<5 D	<0.2	<200 D	0.99 FD	<5 D
Phosphorus, Total (as P)	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D
Phosphate-P	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D
Sulfate	**14,000**	**14,000 D**	**14,000 DJ+**	**14,000 D**	**1,500**	**1,400 D**	**1,400 D**	**1,200 D**
Total Alkalinity	290	270	300	270	790	840	690	560
Total Dissolved Solids	**160,000**	**140,000**	**160,000**	**110,000**	**56,000**	**45,000**	**58,000**	**40,000**
Hexavalent Chromium	<0.275 R	<1.0 U	--	--	0.159 J	<1.0 U	--	--
pH	6.9	6.9	7.5	7.4	6.2	5.7	5.8	5.5
Conductivity	895.0	162.6	122.5	157.3	52.2	69.3	36.8	72.2
DO	0.0	0.8	1.7	0.5	0.0	0.3	0.0	0.4
ORP	-395.0	-303.2	-356.0	-388.6	-125.0	-45.2	-128.1	-145.1
Turbidity	0.5	2.6	0.1	1.1	0.0	3.5	1394.0	0.5
Chlorine	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature	19.0	22.1	22.5	13.0	13.6	19.2	20.5	16.8

[a] MCLs are provided for reference only, as groundwater in the waste pond area is Class IV.
bold Concentration above MCL, indicated for reference only as groundwater is Class IV.
NA No MCL Established
'--' Not Analyzed
DUP Field Duplicate
D Sample dilution required for analysis: reported values reflect the dilution.
F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.
J Data are estimated due to associated quality control data.
J- Data are estimated and are potentially biased low due to associated quality control data.
J+ Data are estimated and are potentially biased high due to associated quality control data.
UJ Potential low bias, possible false negative.
mg/L milligrams per liter
ug/L micrograms per liter
mS/cm micro siemens per centimeter
C degrees Celsius
mV millivolts
NTU Nephelometric Turbidity Unit

TABLE 1-1
GROUNDWATER DISCHARGE PERMIT BASELINE GROUNDWATER SAMPLING RESULTS
US MAGNESIUM, ROWLEY, UTAH

Analyte	PZ-12 Screened 4-14 feet bgs				PZ-13 Screened 7.5-17.5 feet bgs				PZ-8 Screened 3.5-13.5 feet bgs				
	2/4/2014	8/8/2017	9/13/2017	11/1/2017	7/13/2017	8/8/2017	9/13/2017	11/1/2017	2/5/2014	8/9/2017	8/9/2017 (DUP)	9/13/2017	11/1/2017
Total Aluminum	**3,600**	**4,000**	**2,300**	**1,600**	<20	<1000	<1000	<1000	56J	<1000	<1000	<1000	<1000
Dissolved Aluminum	**3,600**	1,400	--	--	<20	<1000	--	--	<20	<1000	<1000	--	--
Total Antimony	0.85J	<100	<100	<100	<2.0	<100	<100	<100	0.70J	<100	<100	<100	<100
Dissolved Antimony	0.76J	<100	--	--	<2.0	<100	--	--	0.67J	<100	<100	--	--
Total Arsenic	**49**	**53**	**62**	**64**	**25**	<50	<50	<50	**130**	**70**	**59**	**72**	77
Dissolved Arsenic	**46**	<50	--	--	**24**	<50	--	--	**120**	**67**	**56**	--	--
Total Barium	210	400	360	380	150	<250	<250	<250	160	260	<250	290	300
Dissolved Barium	200	300	--	--	130	<250	--	--	160	250	<250	--	--
Total Cadmium	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Cadmium	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	<50	--	--
Total Calcium	7,600	10700 D	11000 D	10300 D	8100	7530 D	7910 D	7150 D	6,800	12400 D	8660 D	13000 D	11500 D
Dissolved Calcium	7,700	10700 D	--	--	6700	7670 D	--	--	6,800	13100 D	8610 D	--	--
Total Chromium	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<2.0	<100	<100	<100	<100
Dissolved Chromium	<2.0	<100	--	--	<2.0	<100	--	--	<2.0	<100	<100	--	--
Total Cobalt	81J	94	100	100	<1.0	<50	<50	<50	65	120	<50	140	120
Dissolved Cobalt	81J	97	--	--	<1.0	<50	--	--	60	120	<50	--	--
Total Copper	<2.0	<100	<100	<100	<2.0	<100	<100	<100	2.70	<100	<100	<100	<100
Dissolved Copper	<2.0	<100	--	--	<2.0	<100	--	--	2.50	<100	<100	--	--
Total Iron	**160,000 J**	**180,000**	**200,000**	**240,000**	**99,000**	**39,000**	**89,000**	**57,000**	**83,000**	**230000**	**300000**	**270,000**	**300,000**
Dissolved Iron	**160,000 J**	180,000	--	--	**100,000**	**44,000**	--	--	**80,000**	**230,000**	**300,000**	--	--
Total Lead	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Lead	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	<50	--	--
Total Magnesium	3,400	3,980 D	4,310 D	4,640 D	4,600	4,290 D	4,280 D	3,960 D	2,900	5,310 D	5,250 D	5,660 D	5,200 D
Dissolved Magnesium	3,300	3,950 D	--	--	3,900	4,340 D	--	--	2,900	5,770 D	5,160 D	--	--
Total Manganese	**12,000**	**15,000**	**15,000**	**17,000**	**13,000**	**4,200**	**8,400**	**3,700**	**9,500**	**18000**	**22000**	**17,000**	**19,000**
Dissolved Manganese	**12,000**	**15,000**	--	--	**13,000**	**4,700**	--	--	**9,000**	**18,000**	**22,000**	--	--
Total Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved Mercury	<0.1	<0.1	--	--	<0.1	<0.1	--	--	<0.1	<0.1	<0.1	--	--
Total Molybdenum	13	<100	<100	<100	17 J	<100	<100	<100	8.40	<100	<100	<100	<100
Dissolved Molybdenum	8.4	<100	--	--	11 J	<100	--	--	5.40	<100	<100	--	--
Total Nickel	200 J	310	330	370	50	94	84	110	180	**370**	**140**	420	410
Dissolved Nickel	190 J	310	--	--	41	97	--	--	160	360	140	--	--
Total Potassium	160	208 D	229 D	229 D	380	418 D	401 D	407 D	100	**271 D**	**555 D**	291 D	255 D
Dissolved Potassium	160	220 D	--	--	300	417 D	--	--	100	283 D	577 D	--	--
Total Selenium	2.6 J	<250	<250	<250	<5.0	<250	<250	<250	6.20	<250	<250	<250	<250
Dissolved Selenium	3.2 J	<250	--	--	<5.0	<250	--	--	6.40	<250	<250	--	--
Total Silver	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Silver	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	<50	--	--
Total Sodium	1,700	1,810 D	1,940 DJ+	2,020 J+D	2,600	2,540 D	2,490 J+D	2,530 J+D	1,300	2,350 D	3,570 D	2,350 J+D	2,200 J+D
Dissolved Sodium	1,700	1,860 D	--	--	2,300	2,610 D	--	--	1,300	2,450 D	3,580 D	--	--
Total Thallium	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<1.0	<50	<50	<50	<50
Dissolved Thallium	<1.0	<50	--	--	<1.0	<50	--	--	<1.0	<50	<50	--	--
Total Vanadium	<2.0	<100	<100	<100	<2.0	<100	<100	<100	6.5J	<100	<100	<100	<100
Dissolved Vanadium	<2.0	<100	--	--	<2.0	<100	--	--	6.7J	<100	<100	--	--
Total Zinc	69 J	140	130	150	<2.0	<100	<100	<100	15	<100	<100	<100	<100
Dissolved Zinc	70 J	140	--	--	<2.0	<100	--	--	19	<100	<100	--	--
Bromide	<0.1	<100 D	<100 D	<100 D	23 J	<100 D	<100 D	<100 D	<0.1	<100 D	<100 D	<100 D	<100 D
Chloride	**26,000**	**32,000 D**	**34,000 D**	**40,000 D**	**29,000**	**25,000 D**	**28,000 D**	**29,000 D**	**25,000**	**43,000 D**	**35,000 D**	**37,000 D**	**43,000 D**
Cyanide	0.0095 J	38 D	21	10	46 J	<25 D	<10	<10	29	33 D	25 D	<10	25
Fluoride	**15**	<100 D	<100 D	<100 D	**12**	<100 D	<100 D	<100 D	**13**	<100 D	<100 D	<100 D	<100 D
Nitrate Ion	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D		<100 D	<100 D	100 D	<100 D
Nitrate-N	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	<23 D	<23 D	<0.0226	<23 D	<23 D	**23 D**	<23 D
Nitrite Ion	--	<100 D	<100 D	<100 D	--	<100 D	<100 D	<100 D		<100 D	<100 D	<100 D	<100 D
Nitrite-N	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<0.0305	<31 D	<31 D	<31 D	<31 D
Perchlorate	0.42 J	<200 D	<2 D	<5 D	<0.2	<200 D	<2 D	<5 D	0.55	<200 D	<200 D	<2 D	<5 D
Phosphorus, Total (as P)	--	<100 D	<100 D	<100 D	#N/A	<100 D	<100 D	<100 D		<100 D	<100 D	<100 D	<100 D
Phosphate-P	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<0.0327	<33 D	<33 D	<33 D	<33 D
Sulfate	**1,300**	**1,100 D**	**1,100 D**	**920 D**	**1,300**	**3,700 D**	**1,200 D**	**1,100 D**	**1,300**	**1,200 D**	**1,400 D**	**1,100 D**	**850 D**
Total Alkalinity	800	840	690	600	710	420	430	400	1,000	760	660	640	580
Total Dissolved Solids	**190,000**	**45,000**	**58,000**	**46,000**	**61,000**	**40,000**	**48,000**	**32,000**	**51,000**	**53,000**	**45,000**	**65,000**	**43,000**
Hexavalent Chromium	0.251J	<1.0 U	--	--	<0.27 U	<1.0 U	--	--	0.671	<1.0 U	<1.0 U	--	--
pH	5.9	5.5	5.7	5.4	5.9	6.2	6.2	6.3	5.7	5.6	5.6	6.0	5.3
Conductivity	48.3	73.9	30.8	76.0	57.6	60.9	41.6	37.7	44.4	77.3	77.3	13.6	75.2
DO	0.0	0.3	0.0	0.4	2.6	2.4	4.4	3.6	0.0	0.2	0.2	0.0	0.3
ORP	-58.0	-22.6	-61.2	-135.1	4.0	-49.0	-114.7	-225.4	-25.0	-158.2	-158.2	-210.6	-221.4
Turbidity	0.0	86.4	6126.0	53.0	0.0	32.1	3.0	3.7	0.0	7.1	7.1	37.6	1.5
Chlorine	0.1	0.0	2.2	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature	12.9	20.0	19.6	16.4	20.0	19.2	22.0	16.4	12.1	21.9	21.9	21.0	18.8

[a] MCLs are provided for reference only, as groundwater in the RWP area is Class IV.
bold Concentration above MCL, indicated for reference only as groundwater is Class IV.
NA No MCL Established
'--' Not Analyzed
DUP Field Duplicate
D Sample dilution required for analysis: reported values reflect the dilution.
F Analyte was positively identified but the reported concentration is estimated; reported concentration is less than the reporting limit, but greater than the method detection limit.
J Data are estimated due to associated quality control data.
J- Data are estimated and are potentially biased low due to associated quality control data.
J+ Data are estimated and are potentially biased high due to associated quality control data.
UJ Potential low bias, possible false negative.
mg/L milligrams per liter
ug/L micrograms per liter
mS/cm micro siemens per centimeter
C degrees Celsius
mV millivolts
NTU Nephelometric Turbidity Unit

TABLE 2-1a

CONSTRUCTION DETAILS FOR PROPOSED COMPLIANCE WELLS/PIEZOMETERS COMPLETED IN THE UPPER AQUIFER ZONE US MAGNESIUM FACILITY, ROWLEY, UTAH

Well Identification	Existing or Proposed	Purpose	Well Location	Well Screen Length (feet)	Screened Interval[a] (feet bgs)
CMW-1	Proposed	- Provide groundwater sampling and elevation data in area cross-gradient of northwest corner of proposed new wastewater pond - Assess hydraulic containment around northwest corner of pond and performance of hydraulic barrier wall	Northwest of new pond	20	15 - 25
PZ-5	Existing	- Provide groundwater sampling and elevation data downgradient of proposed new wastewater pond - Assess performance of hydraulic barrier wall	North of new pond	10	3.5 - 13.5
PZ-30	Existing	- Provide groundwater sampling and elevation data downgradient of the proposed new wastewater pond - Assess performance of hydraulic barrier wall	North of new pond	20	5.5 - 15.5
CMW-2	Proposed	- Provide groundwater sampling and elevation data downgradient of the proposed new wastewater pond - Assess performance of hydraulic barrier wall	Northeast of new pond	20	15 - 25
CMW-3	Proposed	- Provide groundwater sampling and elevation data downgradient of the new wastewater pond - Provide water-level data to evaluate groundwater flow in northwest corner of new pond	East of new pond	20	15 - 25
CMW-4	Proposed	- Provide groundwater sampling and elevation data in area cross-gradient of southwest corner of new wastewater pond - Assess hydraulic containment around southwest corner of pond and performance of hydraulic barrier wall	Southwest of new pond	20	15 - 25

(a) Actual screened intervals for proposed wells will be determined during drilling activities in the field based on lithologies observed.

TABLE 2-1b

CONSTRUCTION DETAILS FOR PROPOSED COMPLIANCE WELLS/PIEZOMETERS COMPLETED IN THE LOWER AQUIFER ZONE US MAGNESIUM FACILITY, ROWLEY, UTAH

Well Identification	Existing or Proposed	Purpose	Well Location	Well Screen Length (feet)	Screened Interval[a] (feet bgs)
MW-9	Existing	- Provide groundwater sampling and elevation data downgradient of proposed new wastewater pond - Assess potential pond water impacts below Deeper Silty Clay Unit	North of new pond	10	59 - 69
MW-10	Existing	- Provide groundwater sampling and elevation data downgradient of proposed new wastewater pond - Assess potential pond water impacts below Deeper Silty Clay Unit	North of new pond	10	68 – 78
MW-21	Existing	- Provide groundwater sampling and elevation data downgradient of the proposed new wastewater pond - Assess potential pond water impacts below Deeper Silty Clay Unit	Center of new pond[c]	10	50 – 60
MW-22B	Existing	- Provide groundwater sampling and elevation data downgradient of the proposed new wastewater pond - Assess potential pond water impacts below Deeper Silty Clay Unit	Center of new pond[c]	10	54 - 64
MW-23	Existing	- Provide groundwater sampling and elevation data downgradient of the new wastewater pond - Assess potential pond water impacts below Deeper Silty Clay Unit	Center of new pond[c]	10	56.1 – 66.1

(a) Actual screened intervals for proposed wells will be determined during drilling activities in the field based on lithologies observed.

TABLE 3-1
GROUNDWATER DISCHARGE PERMIT SOURCE WATER SAMPLING RESULTS
US MAGNESIUM, ROWLEY, UTAH

Analyte	Units	Regulatory Limits[a]		Combined Discharge Ditch Data[b]			Current Waste Pond Surface Water Data[c]				
							Southeast CWP PRI5-002	Southeast CWP PRI5-008	Southeast CWP PRI5-010	Northwest CWP PRI6-006	Northwest CWP PRI6-017
		MCL	Secondary Standard	6/29/2017	9/14/2017	11/20/2017	7/9/2015	7/9/2015	7/13/2015	7/10/2015	7/8/2015
Bromide	mg/L	na	na	--	<0.1	40 D	25 J	14 J	< 18 U	21 J	< 30 U
Chloride	mg/L	na	250	--	*15,000*	**14000 D**	*37,000*	*39,000*	*39,000*	*8*	*40,000*
Cyanide	ug/L	200	na	20	<10	<10	0.0140	0.0078 J	0.0160	0.0082 J	< 0.0050 U
Total Aluminum	ug/L	na	50 to 200	*1,800*	*3,400*	**1,400**	*66,000*	*78,000*	*86,000*	*110,000*	*90,000*
Dissolved Aluminum	ug/L			*1,600*	--	--	*71,000*	*81,000*	*73,000*	*110,000*	*90,000*
Total Antimony	ug/L	6	na	<2.0	<2.0	<100	**13**	**11**	**13**	**11**	**12**
Dissolved Antimony	ug/L			<2.0	--	--	**14**	**11**	**12**	**10**	**11**
Total Arsenic	ug/L	10	na	**150**	**84**	**110**	**330 J**	**340 J**	**380 J**	**460**	**400**
Dissolved Arsenic	ug/L			**120**	--	--	**340**	**340**	**340 J**	**490**	**380**
Total Barium	ug/L	2,000	na	<5.0	<5.0	<250	**720**	**790**	**750 J-**	**1,200**	**800**
Dissolved Barium	ug/L			<5.0	--	--	**810**	**790**	**730 J+**	**900**	**770**
Total Cadmium	ug/L	5	na	<1.0	<1.0	<50	1.3 J	1.7 J	1.6 J-	1.9 J	1.8 J
Dissolved Cadmium	ug/L			<1.0	--	--	1.5 J	1.5 J	1.4 J	2	1.8 J
Total Calcium	mg/L	na	na	918	257	303	5,200	6,200	6,300	8,000	7,000
Dissolved Calcium	mg/L			917	--	--	5,100	6,200	6,200	7,900	6,500
Total Chromium	ug/L	100	na	**300**	<2.0	<100	**250**	**270**	**260 J-**	**350**	**300**
Dissolved Chromium	ug/L			**290**	--	--	**270**	**270**	**250**	**310**	**300**
Total Cobalt	ug/L	na	na	<1.0	<1.0	<50	29	33	30 J-	45	40
Dissolved Cobalt	ug/L			<1.0	--	--	30	33	29	41	40
Total Copper	ug/L	1,300	na	<2.0	120	<100	140	160	140 J-	190	170
Dissolved Copper	ug/L			<2.0	--	--	150	160	140	170 J-	170
Total Iron	ug/L	na	300	*420,000*	*200,000*	**160,000**	*860,000*	*910,000*	*970,000*	*1,200,000*	*1,100,000*
Dissolved Iron	ug/L			*370,000*	--	--	*900,000*	*870,000*	*870,000*	*1,100,000*	*1,000,000*
Total Lead	ug/L	15	na	<1.0	<1.0	<50	**53**	**63**	**57 J-**	**93**	**69**
Dissolved Lead	ug/L			<1.0	--	--	**62**	**63**	**59**	**83**	**69**
Total Magnesium	mg/L	na	na	943	3,970	3180 D	4,000	4,100	4,200	5,000	4,500
Dissolved Magnesium	mg/L			865	--	--	3,900	4,100	4,300	4,900	4,200
Total Manganese	ug/L	na	50	**290**	**560**	**320**	2,900	3,400	3,500	5,100	4,400
Dissolved Manganese	ug/L			**300**	--	--	3,000	3,300	3,500	5,000	4,400
Total Mercury	ug/L	2	na	<0.1	0.2	0.4	0.66	0.82	0.84	0.91	0.85
Dissolved Mercury	ug/L			<0.1	--	--	0.72	0.80	0.84	0.87	0.80
Total Molybdenum	ug/L	na	na	<2.0	<2.0	<100	180	200	210	250	220
Dissolved Molybdenum	ug/L			<2.0	--	--	190	200	200	250	210
Total Nickel	ug/L	na	na	150	<1.0	60	210	220	210 J	270	240
Dissolved Nickel	ug/L			130	--	--	230	210	200	240	250
Total Potassium	mg/L	na	na	55	88	65	140	160	180	180	160
Dissolved Potassium	mg/L			52	--	--	130	170	190	190	140
Total Selenium	ug/L	50	na	<5.0	<5.0	<250	5.4 J-	7.1 J-	4.3 J-	8	7.6 J-
Dissolved Selenium	ug/L			<5.0	--	--	6.5 J-	5.6 J-	5	5	7.8 J-
Total Silver	ug/L	100	na	<1.0	<1.0	<50	< 0.60 U	< 0.60 U	< 0.60 UJ	< 0.60 U	< 0.60 U
Dissolved Silver	ug/L			<1.0	--	--	< 0.60 U	< 0.60 U	< 0.60 U	< 0.60 U	< 0.60 U
Total Sodium	mg/L	na	na	1,140	1,160	1190 D	2,200	2,500	2,800	2,800	2,500
Dissolved Sodium	mg/L			1,090	--	--	2,000	2,600	2,800	2,800	2,200
Total Thallium	ug/L	2	na	<1.0	<1.0	<50	1.8 J	**2.1**	1.9 J	**2.8**	**2.2**
Dissolved Thallium	ug/L			<1.0	--	--	1.5 J	< 1.0 U	1.9 J	1.5 J	**2.3**
Total Vanadium	ug/L	na	na	900	<2.0	140	1,100	1,200	1,100	1,500	1,400
Dissolved Vanadium	ug/L			740	--	--	1,200	1,200	1,100	1,400	1,400
Total Zinc	ug/L	5,000	na	320	110	260	390 J-	420 J-	440 J-	520	480 J-
Dissolved Zinc	ug/L			320	--	--	380 J-	410 J-	410	550 J-	440 J-
Fluoride	mg/L	4.0	2.0	--	<0.1	<10 D	**6.8 J-**	**6.2 J-**	< 1.2 UJ	**6.5 J-**	**6.0 J**
Nitrate Ion	mg/L	na	na	--	110	<10 D	3	4	< 0.44 UJ	3.4 J	3
Nitrate-N	mg/L	10	na	--	**25**	<2.3 D	< 0.32 U	< 0.32 U	< 0.32 U	0	< 0.40 U
Nitrite Ion	mg/L	na	na	--	<0.1	<10 D	0	0	0	0	0
Nitrite-N	mg/L	1	na	--	<0.0305	<3.1 D	< 0.32 U	< 0.32 U	< 0.32 U	0	< 0.40 U
Perchlorate	ug/L	na	na	1.8	2	--	1.9 J	1.9 J	1.9 J	2.2 J	2.0 J
Phosphate Ion	mg/L	na	na	--	<0.1	<3.3 D	--	--	--	--	--
Phosphate-P	mg/L	na	na	--	<0.0327	<10 D	4.8 J+	2.5 J+	< 1.5 U	--	< 1.9 U
Sulfate	mg/L	na	250	--	*400*	*300 D*	*2,400*	*2,500*	*3,300 J-*	*3,800 J-*	*2,900 J-*
Total Alkalinity	mg/L	na	na	<20.0	<20.0	--	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Total Dissolved Solids	mg/L	na	2,000	*9,400*	*17,000*	*14,000*	*60,000*	*60,000*	*69,000 J*	*80,000*	*71,000*
Hexavalent Chromium	ug/L	100	na	--	--	--	--	0.18 J-	7.74 J-	6.26 J-	0.26 J
pH[d]		na	6.5 to 8.5	0.0	2.4	0.5	0.49	0.51	0.49	0.53	0.46
Conductivity[d]	mS/cm	na	na	--	35.6	63.2	197,000	595,000	0	155,000	172,000
DO[d]	mg/L	na	na	3.05	4.60	5.04	5.9	5.5	0.0	5.2	6.2
ORP[d]	mV	na	na	--	1,016	--	--	--	--	--	--
Turbidity[d]	NTU	na	na	110.000	340.5	--	--	--	--	--	--
Chlorine[d]	mg/L	na	na	--	--	0.000	--	--	--	--	--
Temperature[d]	C	na	na	33.54	23.00	15.30	--	--	--	--	--

[a] Provided for reference only; these are not applicable to wastewater discharge and groundwater in the vicinity of the waste pond area is Class IV.
[b] Data collected by Stantec to support the Utah Groundwater Discharge Permit application preparation.
[c] Data collected by ERM as part of the Draft Old Waste Pond/Current Waste Pond Area Hydrologic Conceptual Site Model (ERM, 2016)
[d] Data measured and recorded in the field.
bold - Result above regulatory limit; however, regulatory limits are provided for reference only and are not applicable to wastewater discharge.
italics - Result above Secondary Standard, for reference only. MCLs not applicable to wastewater discharge.
na No regulatory limit (MCL or Secondary Standard) established
< Analyte not detected at concentrations above the laboratory detection limit. Laboratory detection limit shown.
-- Not Analyzed
J Estimated trace concentration below the reporting limit but above the method detection limit.
J+ The result is an estimated quantity, biased high. The associated numerical value is the approximate concentration of the analyte in the sample.
J- The result is an estimated quantity, biased low. The associated numerical value is the approximate concentration of the analyte in the sample.
MCL Drinking water maximum contaminant level
U Analyte not detected
UJ The nondetected analyte was estimated at the sample quantitation limit; the reported sample quantitation limit is approximate and may be inaccurate or imprecise.
UJQ The result was qualified as a non-detected at the listed concentration due to an estimated maximum possible concentration; the associated value is an estimate.
UQ The result was qualified as a non-detected at the listed concentration due to an estimated maximum possible concentration.

TABLE 3-2
GROUNDWATER DISCHARGE PERMIT PROPOSED GROUNDWATER PROTECTION LEVELS
US MAGNESIUM, ROWLEY, UTAH

Analyte	Units	MCL[a]	MW-21 Screened Interval 50-60 feet bgs							MW-22B Screened Interval 54-64 feet bgs							MW-23 Screened Interval 56-66 feet bgs							PZ-6[c] Screened Interval 3.5-13.5 feet bgs
			Baseline Sampling Data				Statistical Results		Proposed Groundwater Protection Level[b]	Baseline Sampling Data				Statistics		Proposed Groundwater Protection Level[b]	Baseline Sampling Data				Statistics		Proposed Groundwater Protection Level[b]	Baseline Sampling Data
			7/13/2017	8/9/2017	9/13/2017	11/1/2017	Average	Standard Deviation		7/12/2017	8/8/2017	9/13/2017	11/1/2017	Average	Standard Deviation		7/13/2017	8/8/2017	9/13/2017	11/1/2017	Average	Standard Deviation		1/31/2014
Total Aluminum	ug/L	50 to 200	<20	<1000	<1000	<1000	N/A	N/A	20.00	<20	<1000	<1000	<1000	N/A	N/A	20.00	<20	<1000	<1000	<1000	N/A	N/A	20.00	<50
Total Arsenic	ug/L	10	**39 J**	<50	<50	<50	28.50	6.06	40.62	**45 J**	<50	<50	<50	29.00	8.00	45.00	**31 J**	<50	<50	**55**	34.00	12.37	58.74	30.00
Total Chromium	ug/L	100	<2.0	<100	<100	<100	N/A	N/A	2.00	<2.0	<100	<100	<100	N/A	N/A	2.00	<2.0	<100	<100	<100	N/A	N/A	2.00	<2.0
Total Iron	ug/L	300	<50	<2500	**2,500**	**3,800**	1581.25	1,375.16	4331.56	<50	<2500	**2,500**	**3,700**	1492.50	1252.24	3996.98	<50	<2500	<2500	3,100	N/A	N/A	50.00	1500.00
Total Nickel	ug/L	na	<1.0	<50	<50	<50	N/A	N/A	1.00	<1.0	<50	<50	<50	N/A	N/A	1.00	<1.0	<50	<50	<50	N/A	N/A	1.00	5.9 J
Total Vanadium	ug/L	na	<2.0	<100	<100	<100	N/A	N/A	2.00	<2.0	<100	<100	<100	N/A	N/A	2.00	<2.0	<100	<100	<100	N/A	N/A	2.00	<6.0
Total Zinc	ug/L	5,000	<2.0	**160.00**	<100	<100	45.25	28.33	101.91	<2.0	<100	<100	<100	N/A	N/A	2.00	<2.0	190	<100	<100	N/A	N/A	2.00	9.90
pH		na	6.96	6.91	6.80	6.69	6.84	0.12	4.00	7.08	6.95	7.07	6.81	6.98	0.11	4.00	6.93	6.91	7.50	7.43	7.19	0.27	4.00	7.40

[a] MCLs are provided for reference only, as groundwater in the pond area is Class IV.

[b] Proposed Groundwater Protection Level notes and assumptions:

1) Based on results to date, protection levels for analytes with positive detections were set to the average of the data set plus two times the standard deviation.

2) For analytes with results detected below the RL, but include one or more positive detections, the concentration for the results below the RL was set to half of the RL.

3) For samples with no positive detection (i.e. below the RL), the proposed Groundwater Protection Level was provisionally set to the lowest RL based on results to date, and will be finalized upon completion of baseline sampling.

4) The proposed Groundwater Protection Level for pH was set to 4.00.

[c] Data for PZ-6 are included in this table to represent likely concentrations at nearby proposed compliance monitoring well/piezometer PZ-30. (PZ-30, screened at 5.5-15.5 feet bgs, is the preferred monitoring point because it is screened slightly deeper than PZ-6.)

Bold type indicates positive detection

bgs below ground surface

na not available

N/A No positive detection, therefore no average or standard deviation was calculated

< Analyte not detected at concentrations above the laboratory reporting limit. Laboratory reporting limit shown.

- Not Analyzed

J Data are estimated due to associated quality control data.

MCL drinking water maximum contaminant level. MCL for comparison only as groundwater is Class IV.

RL laboratory reporting limit

TABLE 5-1
CONSTRUCTION DETAILS FOR PROPOSED GROUNDWATER LEVEL MONITORING COMPLIANCE WELLS/PIEZOMETERS
US MAGNESIUM GROUNDWATER DISCHARGE PERMIT, ROWLEY, UTAH

Monitoring Well Identification	Existing or Proposed	X [a]	Y [a]	Ground Surface Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Well/Piezometer Depth (ft bgs)	Screened Interval[b] (ft bgs)	Screen Length (ft)	Casing Diameter (in)	Purpose/Comments
Pond Inboard/Outboard Piezometer Pairs (completed above the deeper silty clay unit)										
PP-1 A&B	Proposed[a]	TBD	TBD	TBD	TBD	42	3.5 - 13.5	10	4	Evaluate difference in water level across the hydraulic barrier wall
PP-2 A&B	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate difference in water level across the hydraulic barrier wall
PP-3 A&B	Existing	TBD	TBD	TBD	TBD	42	5.5 - 15.5	10	4	Evaluate difference in water level across the hydraulic barrier wall
PP-4 A&B	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate difference in water level across the hydraulic barrier wall
PP-5 A&B	Existing	TBD	TBD	TBD	TBD	42	3.5 13.5	10	4	Evaluate difference in water level across the hydraulic barrier wall
PP-6 A&B	Proposed[a]	TBD	TBD	TBD	TBD	42	3.5 - 13.5	10	4	Evaluate difference in water level across the hydraulic barrier wall
PP-7 A&B	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate difference in water level across the hydraulic barrier wall
PP-8 A&B	Existing	TBD	TBD	TBD	TBD	42	5.5 - 15.5	10	4	Evaluate difference in water level across the hydraulic barrier wall
PP-9 A&B	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate difference in water level across the hydraulic barrier wall
PP-10 A&B	Existing	TBD	TBD	TBD	TBD	42	3.5 13.5	10	4	Evaluate difference in water level across the hydraulic barrier wall
Additional Piezometer Locations (located near upgradient side of pond, completed in shallow aquifer zone)										
PP-11	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate groundwater elevations around end of southern hydraulic barrier wall
PP-12	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate groundwater flow direction around end of southern hydraulic barrier wall
PP-13	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate groundwater elevations between plant infrastructure and the Retrofitted Waste Pond
MW-6	Existing	1299844.219	7506043.929	4222.98	4225.77	30	5 - 30	25	4	Evaluate groundwater elevations between plant infrastructure and the Retrofitted Waste Pond
PP-14	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate groundwater elevations between plant infrastructure and the Retrofitted Waste Pond
PP-15	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate groundwater elevations around end of northern hydraulic barrier wall
PP-16	Proposed[a]	TBD	TBD	TBD	TBD	42	5 - 40	35	4	Evaluate groundwater elevations around end of northern hydraulic barrier wall

[a] X and Y coordinates are in U.S. State Plane, NAD 83, Utah North Zone (U.S. Survey Feet)

[b] Proposed piezometers are to be screened across the full shallow aquifer zone

amsl above mean sea level
bgs below ground surface
ft feet
in inches
TBD to be determined

FIGURES

Great Salt Lake
MAP AREA
Salt Lake City
Logan
Brigham City
Randolph
Ogden
Morgan
Tooele
Heber
Vernal
Duchesne
Spanish Fork
Provo
Nephi
Price
UTAH
Castle Dale
Manti
Fillmore
Richfield
Moab
Loa
Beaver
Junction
Parowan
Panguitch
Monticello
Saint George
Kanab
0 50
Miles
US MAGNESIUM SITE FACILITIES (see Figure 2-1)
80
Stantec
USmag
US MAGNESIUM
LOCATION MAP
Figure 1-1
DRAWN BY D. Severson
19 Sep 2017
C:\Data\MWH\PB&L &US Magnesium\USMAG_Hydrogeologic Report_Sep2017\FIGURES\Figure 1-1_USMAG_Location Map_19Sep2017.mxd

DRAWN BY D. Severson

22 Nov 2017

C:\Data\MW\HPB&L &US Magnesium\FIGURES\Fig 1-2_Proposed Retrofitted Waste Pond Configuration_22Nov2017.mxd

EXPLANATION

- Existing monitoring well Lower Aquifer Zone
- Existing monitoring well Upper Aquifer Zone
- Existing piezometer Lower Aquifer Zone
- Existing piezometer Upper Aquifer Zone

MW-11
PZ-6
PZ-29
PZ-30
MW-10
PZ-5
MW-9
MW-13A
MW-13B
MW-14
CW-05
CW-06
CW-04
CW-03
CW-01
CW-02
Northwest Current Waste Pond
MW-15A
MW-15B
Former Waste Pond
MW-21
MW-16
PZ-8
PZ-26
PZ-7
PZ-27
PZ-4
PZ-28
MW-22A
MW-22B
PZ-10
PZ-11
PZ-24
Southeast Current Waste Pond
PZ-12
MW-17
MW-4A
MW-4B
MW-5A
MW-5B
MW-8A
MW-8B
MW-3
PZ-13
MW-23
MW-19A
MW-19B
MW-6
MW-7
PZ-22
PZ-14
MW-2
PZ-3
PZ-20
PZ-16
MW-18
PZ-18
MW-20A
MW-20B
PZ-1

PROPOSED HYDRAULIC BARRIER WALL

N
W
E
S

0 1000
Feet

Stantec

USmag®

US MAGNESIUM

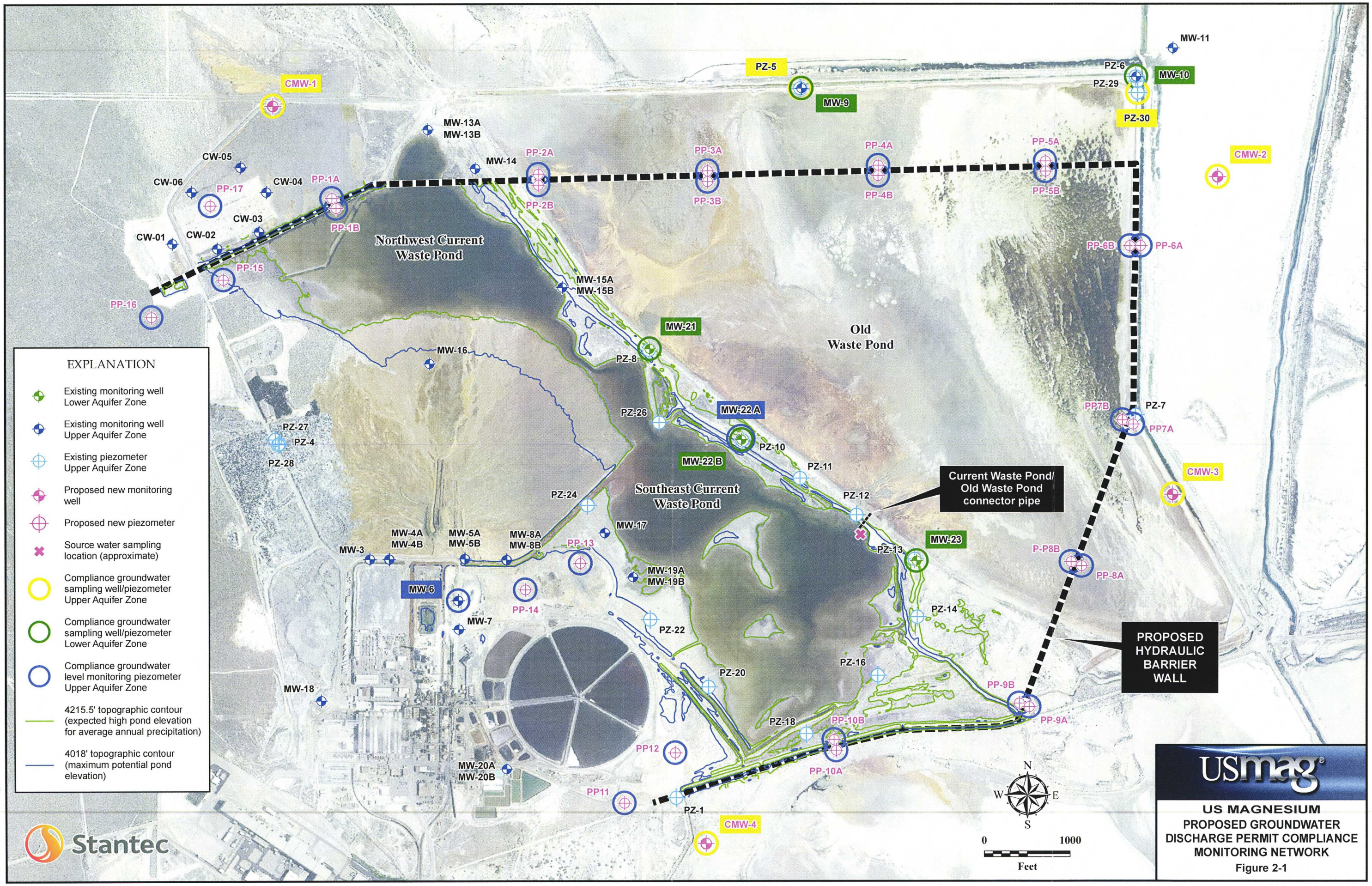
PROPOSED RETROFITTED WASTE POND CONFIGURATION

Figure 1-2

DRAWN BY D. Severson

13 Dec 2017

C:\Data\MWH\PB&L &US Magnesium\FIGURES\Fig 2-1_Prop GW Discharge Permit Compliance Mon Network_13Dec2017.mxd



EXPLANATION

- Existing monitoring well Lower Aquifer Zone
- Existing monitoring well Upper Aquifer Zone
- Existing piezometer Upper Aquifer Zone
- Proposed new monitoring well
- Proposed new piezometer
- Source water sampling location (approximate)
- Compliance groundwater sampling well/piezometer Upper Aquifer Zone
- Compliance groundwater sampling well/piezometer Lower Aquifer Zone
- Compliance groundwater level monitoring piezometer Upper Aquifer Zone
- 4215.5' topographic contour (expected high pond elevation for average annual precipitation)
- 4018' topographic contour (maximum potential pond elevation)

Stantec

USmag®

US MAGNESIUM

PROPOSED GROUNDWATER DISCHARGE PERMIT COMPLIANCE MONITORING NETWORK

Figure 2-1

APPENDIX A – COMPLIANCE WELL/PIEZOMETER BORING AND CONSTRUCTION LOGS

Stantec

MONITORNG WELL ID: **MW-21**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 12

EASTING: 1302098.55 NORTHING: 3499731.09

ELEVATION: 4218.18 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 60.5 GROUNDWATER LEVEL (ft btoc): 6.4

DATE STARTED: 6/17/2017 DATE FINISHED: 6/17/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		FILL-POORLY GRADED SAND (SP): with fine grained oolitic sand and some silt and fine gravel (cemented oolitic), pale brown (10YR						
5		SILTY CLAY (CL): with trace fine sand, greenish gray (GLEY 5/1), medium plasticity with low plasticity where fine grained sands						
		Estimated depth to groundwater in field.						
10		POORLY GRADED SAND WITH GRAVEL (SP): cemented oolitic sand, greenish gray (GLEY 5/1). POORLY GRADED SAND (SP): fine to coarse oolitic sand, with some silt and some fine gravel, greenish gray (GLEY 5/1) to very dar						
15		Cemented oolitic sand.						
		SILTY SAND (SM): fine grained sand, dark gray (GLEY 4/1) to greenish gray (GLEY 5/1), wet, nonplastic, generally loose with som	0	79.2	20.8	SM		
20								
25			0.1	74.6	25.3	SM		
							16.3	1.7E-6
30		Grades to very dense, wet, greenish gray (GLEY 5/1), with thin 0.125 inch to 0.0625 inch silty clay wide stringers.						

WELL CONSTUCTION DIAGRAM

- Above ground protective casing
- Groundwater Level at 6.4 ft btoc in June 2017
- Aqua Grout 0 to 43 ft bgs
- 0 of 50 ft bgs, 4 in dia, Sch 40 PVC solid riser
- Borehole dia, 10 inches from 0 to 35 ft bgs

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-21**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 12

EASTING: 1302098.55 NORTHING: 3499731.09

ELEVATION: 4218.18 BOREHOLE ANGLE: 90 degrees

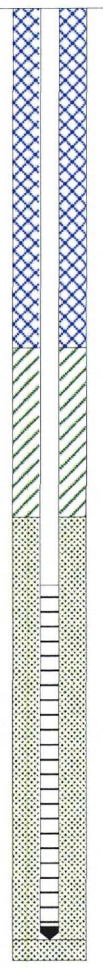
TOTAL DEPTH (ft): 60.5 GROUNDWATER LEVEL (ft btoc): 6.4

DATE STARTED: 6/17/2017 DATE FINISHED: 6/17/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
35		SILTY CLAY (CL): with trace fine grained sand, greenish gray (GLEY 6/1), medium plasticity, low plasticity where sandy, soft gr	0	21	79	CL	26.4	4.8E-8
40		CLAY SAND (SC): with fine grained sand, greenish gray (GLEY 6/1), low plasticity, stiff, wet. SILTY CLAY (CL): with trace fine sand, greenish gray (GLEY 5/1), medium plasticity, soft to medium stiff, wet, strong sulfur od					31.1	2.8E-8
45			0	2.4	97.6	CL		
50		SILTY SAND (SM): fine grained sand, with thinly interbedded clays, dark greenish gray (GLEY 4/1) to greenish gray (GLEY 6/1), n	0	27.3	72.7	CL		
55		SILTY CLAY (CL): greenish gray (GLEY 6/1), medium plasticity, stiff, wet. SILTY SAND (SM): fine grained sand, dark greenish gray (GLEY 4/1) to dark gray (GLEY 4/1), wet, medium dense, nonplastic.	0	73.1	26.9	SM		
60		CLAY(CL): with trace silt, greenish gray (GLEY 5/1), wet, low to medium plasticity, soft, moderate sulfur odor.					22.7	5.7E-5
65		End of borehole at 63 ft below ground surface in clays.						

WELL CONSTUCTION DIAGRAM



Bentonite 43 to 48 ft bgs

Filter Pack Sand 48 to 60.5 ft bgs

50 to 60 ft bgs, 4 in dia, Sch 40 PVC screen

End Cap at 60.4 ft bgs

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-22B**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 14

EASTING: 1303169.4 NORTHING: 3498673.93

ELEVATION: 4218.15 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 65.2 GROUNDWATER LEVEL (ft btoc): 6.38

DATE STARTED: 6/8/2017 DATE FINISHED: 6/8/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)
0		FILL SILTY SAND (SM): fine to medium grained sand, brown (10 YR 5/1), nonplastic, dry grading to slightly moist, loose.						
5		CLAY (CL): light brownish gray (2.5 Y 6/2), slight to low plasticity, wet, medium stiff, grading to soft at 7 ft, slightly mois						
10		POORLY GRADED GRAVEL (GP): cemented oolitic sands broke into angular sand and gravel size material.						
15		POORLY GRADED SAND (SP): fine to medium grained oolitic sand with trace silt, gray (10YR 6/1) grades to light brownish gray (2. With fine and coarse gravel size material of cemented oolitic sand.	12.4	68.6	19	SM		
20		SILTY SAND (SM): fine grained sand with trace silt, gray (GLEY 5/1) to greenish gray (GLEY 6/1), wet, nonplastic, weak sulfur o With thin bedded silty clay, light olive gray (5Y 6/2), slight to low plasticity, medium dense, moist to wet.						
25		Same as previous.	0	72.8	27.2	SM		
30		Increase in silt to 40%, gray (2.5Y 5/1), medium dense to dense, moderate sulfur odor. With thin bedded silty clay.					28.6	7.3E-8
		With thinly interbedded silt (ML) from 35 to 36.2 ft, grades to dry to slightly moist at 35 ft, light greenish						

WELL CONSTUCTION DIAGRAM

- Above ground protective casing
- Groundwater Level at 6.38 ft btoc in June 2017
- Aqua Grout 0 to 46.8 ft bgs.
- 0 of 54 ft bgs, 4 in dia, Sch 40 PVC solid riser
- Borehole Diameter 10 inches from 0 to 39 ft bgs.

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-22B**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 14

EASTING: 1303169.4 NORTHING: 3498673.93

ELEVATION: 4218.15 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 65.2 GROUNDWATER LEVEL (ft btoc): 6.38

DATE STARTED: 6/8/2017 DATE FINISHED: 6/8/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS						WELL CONSTUCTION DIAGRAM
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)	
35		gray (GLEY 7/1).							
		CLAY (CL): with trace fine sand, greenish gray (GLEY 5/1), medium plasticity, moist to wet, stiff.	0	6	94	CL	44.1	1.1E-7	
40									
45		Note: Sonic core interval from 47 to 60 ft fell out of sampler and was retrieved with 15 foot recovery. Lithological interpreta	0	8.9	91.1	CL	53.7	6.2E-8	
		SILTY SAND (SM/ML): fine grained sand with silt, with some clay, greenish gray (GLEY 6/1), wet, low plasticity, soft to medium							
50									
55							50.4	2E-7	
			0	56.2	43.8	SC			
60		CLAY (CL): with trace silt and few thin sand stringers, greenish gray (GLEY 6/1), wet, low to medium plasticity, medium stiff,							
		POORLY GRADED SAND (SP): very dark greenish gray (GLEY 3/1), wet, nonplastic, very loose.							
		CLAY (CL): with trace silt and fine grained sand, medium plasticity, medium stiff to stiff, moist, strong sulfur odor.	0	79.2	20.8	SM			
65		End of borehole at 65.2 ft below ground surface. Stopped drilling in observed clay.							

Borehole Diameter 8 inches from 39 to 65.2 ft bgs.

Bentonite 46.8 to 52 ft bgs.

Filter Pack Sand 52 to 65.2 ft bgs.

54 of 64 ft bgs, 4 in dia, Sch 40 PVC screen

End Cap at 64.4 ft bgs

Notes:

K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing

ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe

PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-23**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 15

EASTING: 1305195.27 NORTHING: 3497263.97

ELEVATION: 4219.582 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 67.3 GROUNDWATER LEVEL (ft btoc): 10.28

DATE STARTED: 6/16/2017 DATE FINISHED: 6/16/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS: Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)	WELL CONSTUCTION DIAGRAM
0		SILT WITH SAND (ML): fine grained oolitic sand, light brown gray (10 YR 6/2), low plasticity, soft, slightly moist, few organic							Above ground protective casing
5									
10		SILTY CLAY (CL): gray (2.5 YR 6/1), high plasticity, wet, stiff and grading to very stiff. very dark gray (10 YR 3/1), medium plasticity, wet, weak sulfur odor, banded or very thinly beds, beds are greenish gray (GLEY							Groundwater Level at 10.28 ft btoc in June 2017
15		POORLY GRADED GRAVEL WITH SAND (GP): cemented oolitic sand, light olive brown (2.5 YR 7/1). POORLY GRADED SAND (SP): fine grained oolitic sand with silt, light gray (10YR 7/1) to light brownish gray (10YR 6/2), wet, non	0	3.5	96.5	CH			
20		POORLY GRADED GRAVEL WITH SAND (GP): cemented oolitic sand, light olive brown (2.5 YR 7/1). SILTY SAND (SM): fine grained sand, with some silt, dark greenish gray (GLEY 4/1) to dark gray (GLEY 4/1), wet, nonplastic.							0 of 56.1 ft bgs, 4 in dia, Sch 40 PVC solid riser
25		Dark gray (GLEY 3/1), to dark greenish gray (GLEY 4/1), wet, nonplastic, medium dense.	0	74.7	25.3	SM			Borehole dia, 10 inches from 0 to 67.3 ft bgs
30							34.9	2.1E-6	
35		With interbedded silty clay, greenish gray (GLEY							

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

Stantec

MONITORNG WELL ID: **MW-23**

CLIENT: US Magnesium LLC

PROJECT: Groundwater Discharge Permit Application

SITE LOCATION: US Magnesium Rowley, Utah Plant

DRILLING CONTRACTOR: Cascade Drilling

DRILLING METHOD: Sonic

DRILLING EQUIPMENT: GP24-300 RS

SAMPLING METHOD: Sonic Core Barrel

COORDINATE SYSTEM: NAD 1983 UTM Zone 15

EASTING: 1305195.27 NORTHING: 3497263.97

ELEVATION: 4219.582 BOREHOLE ANGLE: 90 degrees

TOTAL DEPTH (ft): 67.3 GROUNDWATER LEVEL (ft btoc): 10.28

DATE STARTED: 6/16/2017 DATE FINISHED: 6/16/2017

LOGGED BY: Bill Bragdon

DEPTH (ft bgs)	LITHOLOGICAL GRAPHIC	LITHOLOGICAL DESCRIPTION	LABORATORY RESULTS						WELL CONSTUCTION DIAGRAM
			Gravel %	Sand %	Fines %	Group Symbol	Porosity %	K (cm/sec)	
		5/1), slightly to low plasticity, moist.							
		Low sample recovery in silty sand.							
40		Same as previous.							
		CLAY (CL): with trace silt, greenish gray (GLEY 5/1), medium plasticity, wet, very stiff, sulfur odor.							
45			0	5.1	94.9	CH			
							49.8	3.4E-8	
50			0	5.7	94.3	CL	50.7	4.1E-8	
55		CLAY (CL): with silt and interbedded thin fine to medium grained sand, greenish gray (GLEY 6/1) to dark greenish gray (GLEY 4/1							
		SILTY SAND (SM): with trace silt, gray (5Y 5/1), wet, nonplastic, sulfur odor, loose.							
60		SILTY CLAY (CL): greenish gray (GLEY 5/1), slightly to low plasticity, wet.							
		SILTY SAND (SM): with trace silt, dark greenish gray (GLEY 3/1), fine to medium grained, wet, nonplastic, sulfur odor, loose.	0	70.4	29.6	SM			
65		CLAY (CL): with trace silt, dark greenish gray (GLEY 4/1), medium plasticity, stiff to very stiff, sulfur odor.	0	10.9	89.1	CL			
							47.7	8.2E-8	
70		End of borehole at 69 ft below ground surface in clays.							

Bentonite 49 to 54 ft bgs.
Filter Pack Sand 54 to 63.7 ft bgs

56.1 to 66.1 ft bgs, 4 in dia, Sch 40 PVC screen

End Cap at 69.4 ft bgs

Notes:
K = Hydraulic conductivity
cm/sec = centimeters per second
ft btoc = feet below top of casing
ft = feet
UTM = Universal Transverse Mercator
Sch = schedule of a pipe
PVC = polyvinyl chloride pipe
dia = diameter
bgs = below ground surface

US MAGNESIUM, LLC
MONITORING WELL COMPLETION FORM

Project No: 4270163.010103

Drilling Company: Layne

Key Number 3210

3 — Protective Casing Top (ft ags)

4213.87 — Riser Top (Not applied to Flush Mount; ft ags)

GROUND SURFACE

Concrete Bottom/Grout Top Depth (ft bgs) 1

NA — Blank Casing Top Depth (Riser Bottom; ft bgs)

2 — Protective Casing Depth (ft bgs)

Grout Type Bentonite Grout

Comments: Over drilled to 90' pushed sample 90-95. Back filled 75-95 with bentonite grout. 10/20 sand 53-75.

Grout Bottom Depth (Seal Top Depth; ft bgs) _____

Seal Material Bentonite Grout

Top of Sand (seal bottom depth; ft bgs) 53

59 — Blank Casing Bottom (Screen Top; ft bgs)

Coarse Sand Size 10/20

0.010 — Slot Size

69 — Screen Bottom (Foot Top; ft bgs)

Filter Pack Bottom (ft bgs) 75

Borehole Depth (ft bgs) 905

69.5 — Foot/End Cap Bottom (Well Total Depth; ft bgs)

NOT TO SCALE

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

Loc ID/Well ID MW-9

Geologist Bill Bragdon

Date Construction Started 4/13/04

Date Construction Completed 4/13/04

LOC Type (i.e. Monitoring Well) Monitoring Well

Riser Material/Diameter PVC, 4"

Blank Casing Material/Diameter PVC, 4"

Screen Material/Diameter PVC, 4"

Protective Casing Type Metal

Borehole Diameter 9"

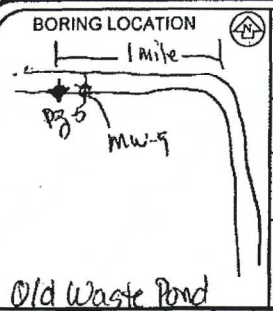
Above Ground Completion [X] Flush Mount [ ]

USCS Classification of Screened Interval SM CL

MONITORING WELL LOG FORM

4270163.010103

BORING LOCATION



Project: USM Project No: ____
Date Drilled: 4/12/04 Date Completed: 4/12/04
Logged By: B. Bragdon
Water Elevation (ft.): 4207.96
Date Measured: 5/6/04
Total Depth (ft.): 90'
Diameter (in.): 4"

Boring ID: MW-9
Northing: 14872254.59 Easting: 1166669.91
Ground Surface Elevation (ft.): 4211.29
Measuring Point (MP) Elevation (ft.): Ground
MP is Top of PVC Casing Datum: NGVD (1929)
Drilling Contractor: Layne
Drilling Method: Percussion Hammer

Screen: Diameter 4" Depth 59-69 Slot Size 0.010
Casing: Diameter 4" Length +7-59 Type PVC
Sand 53-75 Bentonite Seal 1-53 ~~Cement Grout Seal~~

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICATION	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
1											
2								CL/SP		Fill material of mixtures of silty clay and fine to medium sand. moderate yellowish brown 10YR 5/4, slightly moist.	
3								SM/SC		silty fine sand and clayey fine to medium sand, sand is subangular light olive gray 5Y 6/1, slightly plastic to low plasticity locally. stiff, slightly moist	
4											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

* C California Split Spoon Sampler (2.5" I.D.)
S Standard penetration test sampler
c Cuttings
▼ Elevation of ground water

US MAGNESIUM, LLC
MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW-9

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
5											
6											
7											
8	60	40	Ø	Ø				GP		fine to coarse sandy fine & coarse gravel, very light gray N8 to white N9 subangular to angular, dense, wet weak sulfur odor	
9											
10											
11											
12	10	90	Ø	Ø				SP		fine to medium sand w/ fine gravel light gray N7, subangular to subrounded, wet dense	
	60	40	Ø	Ø				SP/GP		AS Above w/ increase in fine gravel to SP/GP	
13	Ø	Ø	100	Ø				CL		silty clay, olive gray 5Y4/1, medium plasticity wet, stiff, sulfur odor	
	Ø	90	10	Ø				SP		fine sand w/ some medium sand, medium dark gray N4, wet, dense, weak sulfur odor	
14											
15											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW-9

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
5	Ø	70	30	Ø				SM		Increase in silt to SM	
6										medium light gray N6 and light olive gray 5Y 6/1 interbedded, non plastic, dense, wet, strong sulfur odor	
7											
8											
9											
20											
21											
22											
23								CL			
								CL		w/ few greenish gray 5GY 6/1 partings	
24								CL		CL - silty clay, medium plasticity	
25								CL			

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____

Boring ID.: MW-9

DEPTH (FEET)	GRAIN SIZE: % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
25								SM			
26											
27										CL w/ clay partings, greenish gray 5GY6/1	
28											
29										CL CL w/ few clay partings, greenish gray, medium plasticity, stiff, sulfur odor greenish gray 5GY6/1	
30											
31											
32										CL CL w/ few clay partings. greenish gray 5GY6/1 CL	
33										grades to slightly moist to moist	
34											
35											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW-9

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
35								SM		SM AS Above	
	Ø	Ø	100							silty clay, greenish gray 5GY4/1 slow to medium plasticity, stiff moist, sulfur odor	
36										w/ moderate yellowish brown 10YR5/4	
								CL		modeling, sulfur odor	
37	Ø	70	30					SM		silty fine sand light olive gray 5Y 6/1 dense, wet, sulfur oder	
38								CL		silty clay greenish gray 5GY 4/1	
										medium plasticity, stiff to very stiff, moist, sulfur odor.	
39											
40	Ø	60	40					SM		sm silty fine sands, as below @ 41.7'	
								CL			
41								CL			
	Ø	60	40					SM		sm silty fine sand greenish gray 5GY4/1 wet, dense, sulfur odor	
42										clay as above @ 38'	
								CL			
43											
44											
45											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____

Boring ID.: MW-9

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
45								CL		Silty clay, greenish gray 5GY4/1, medium plasticity, stiff to very stiff moist, sulfur odor	
46										w/ Moderate Yellowish Brown 10YR5/4 mottling.	
47										sm(1/4") silty fine sand, olive gray 5Y4/1	
48											
49											
50							↓				
51											
52											
53											
54								ML/CL		clayey silt, greenish gray 5G6/1 and olive gray 5Y4/1 layers, low to medium plasticity, stiff to very stiff, moist sulfur odor	
55											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: LSM Project No:
Boring ID.: MW9

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
55								ML		ML as above	
56										Increase in clay to CL/ML medium plasticity	
57											
58											
59	10	70	20					SM		silty fine sand with fine gravel, dark greenish gray 5GY 4/1, angular, NP dense, wet, sulfur odor	
								CL		CL AS Above	
60								SM		SM AS Above, no gravel	
										SM & CL AS Above	
61								CL		silty clay	
								SM		silty fine sand	
62								CL		silty clay	
										silty fine sand	
63								SM		collected TOC & neutralization potential 60-65' @ 1745 4/12/04	
										silty clay	
								CL			
64								SM		silty fine sand w/ few fine angular gravel	
								CL		silty clay	
65								SM		silty fine sand	

PROJECT NO. 427010G.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW9

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
65											4/13 ↓
66	Ø	Ø	100	Ø				ML/CL		silty clay/clayey silt interbeds greenish gray 5GY 6/1, low to medium plasticity stiff to very stiff, strong sulfur oder	
67	Ø	10	30	Ø				SM		grades to med. dark gray N4, moist silty fine sand, olive gray 5Y 4/1, non plastic dense, wet, sulfur odor	
								ML/CL		ML/CL As Above	
68	10	70	20	Ø				SM		As Above with few angular fine gravel	
								ML		clayey silt, greenish gray 5GY 6/1 low to medium plasticity, stiff moist, sulfur oder	
69											
10								ML/CL			
	Ø	10	30					SM		SM silty fine sand, greenish gray 5GY 6/1 non plastic dense, wet, sulfur oder	
11	Ø	Ø	100					ML/CL			
12											
13										grades to greenish black 5GY 2/1 and dark greenish gray 5GY 4/1 low to medium plasticity, moist sulfur oder	
14											
15											

PROJECT NO. 427O106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____

Boring ID.: MW 9

DEPTH (FEET)	GRAIN SIZE: % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
75								ML/CL		silty clay / clayey silt as above	
										sm silty fine sand, olive gray 5Y 4/1 wet, dense, non plastic	
76											
								ML		silt and clayey silt interbedded olive gray 5Y 4/1, low plasticity wet, stiff to very stiff sulfur oder	
77											
										w/ gypsum Xtals ~~or Halite~~	
78											
79											
								SM/ML		silt and silty fine sand medium gray N5, non plastic, ~~dry~~ dense, wet, sulfur oder	
80										w/ few gypsum Xtals.	
81								CL		silty clay, greenish gray 5G 6/1 moist, medium plasticity sulfur oder, ~~dense~~ stiff to very stiff	
82											
										w/ few gypsum Xtals ~~as above~~	
83											
84											
85											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW9

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
85	Ø	Ø	Ø	Ø				CL		silty clay, greenish gray 5G 6/1 moist, stiff to very stiff medium plasticity, sulfur odor	
86									Δ A Δ	few Xtals.	
87											
88	Ø	60	40	Ø				SM		silty fine sand light olive gray 5Y 6/1, wet, dense, sulfur odor	
89								CL		CL As Above	
90							↓				
91											
92								CL		grades to olive gray 5Y 4/1	
93	Ø	70	30					SM		silty fine to medium sand, olive gray 5Y 4/1, wet, dense, NP, sulfur odor	
								CL		silty clay, olive gray 5Y 4/1 medium plasticity, stiff to very stiff, moist, strong sulfur odor	
94											
95							↓			TD 95'	

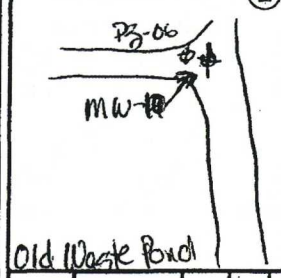
PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

MONITORING WELL LOG FORM

4270163.010103

BORING LOCATION



Project: USM Project No: ____
Date Drilled: 4/14/04 Date Completed: 4/15/04
Logged By: B. Bragdon
Water Elevation (ft.): 4203.7
Date Measured: 5/6/04
Total Depth (ft.): 80
Diameter (in.): 9"

Boring ID: MW-10
Northing: 14872367.41 Easting: 1167147.38
Ground Surface Elevation (ft.): 4210.61
Measuring Point (MP) Elevation (ft.): Ground
MP is Top of PVC Casing Datum: NGVD (1929)
Drilling Contractor: Layne
Drilling Method: Percussion Hammer

Screen: Diameter 4" Depth 68-78 Slot Size 0.010
Casing: Diameter 4" Length +2-68 Type PVC
Sand 63-80 Bentonite Seal 1-63 Cement Grout Seal ____

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICATION	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
1										Fill Material 0-5' mixture of 1) silty clay (CL) light olive gray 5Y 6/1, medium plasticity, stiff, moist	
2										2) fine sand (SP) light olive gray 5Y 6/1 to moderate reddish brown 10R 4/6, NP, dense, moist	
3										3) fine to coarse sandy fine gravel w/ gypsum xtals, moderate reddish brown 10R 4/6, dense moist.	
4											

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366308

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

* C California Split Spoon Sampler (2.5" I.D.)
S Standard penetration test sampler
c Cuttings
▼ Elevation of ground water

US MAGNESIUM, LLC
MONITORING WELL LOG FORM

Project: ASM Project No: _____
Boring ID.: MW-10

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
5	Ø	90	10	Ø				SP		fine sand w/ trace silt light olive gray 5Y 6/1, non plastic dense, wet, weak sulfur oder	
6											
7										grades to dark greenish gray 5GY 4/1 with strong sulfur oder	
8											
9										grades to very light gray N8	
10						▼				?	
11	Ø	Ø	100	Ø				CL		silty clay ~~green~~, dark greenish gray 5GY 4/1, medium plasticity stiff to very stiff, slightly moist to moist, sulfur oder	
12											
13											
14	Ø	15	100	Ø				ML		silt/clayey silt, light ~~gray~~ olive gray 5Y 6/1, wet, slightly to low plasticity, stiff, sulfur oder	
15				Ø		▼				few partings of brownish gray 5YR 4/1 organic oder and grayish black 5YR 2/1	

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366309

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW-10

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
15											
								ML			
16										?. contact for ML SP/GP estimated.	
17	40	60	LS	Ø				SP/GP		fine to coarse sand and fine and coarse gravel, light olive gray 5Y 5/2	
										to yellowish gray 5Y 7/3, angular	
18										non plastic, dense, wet, sulfur oder.	
19										"oolitic sand"	
20											
21											
	10	90	LS					SP		grades to fine to medium sand	
22										light gray N7, wet, dense to	
										very dense, some grains	
										are white N9 to very light gray N8	
23											
24										w/ few coarse gravel, angular	
25											

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366310

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____

Boring ID.: MW-10

DEPTH (FEET)	GRAIN SIZE: % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
25										oolitic sand as above	
26										very dense.	
27											
28											
29											
30										w/few angular coarse gravel	
31											
32											
33										oolitic sand	
34	0	60	40	0				SM		grades to silty fine sand, olive gray 5Y 4/1, dense, wet, sulfur odor	
35											

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

F II

M366311

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: GSM Project No:
Boring ID.: MW-10

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
35								SM		silty fine sand, dark greenish gray 5G 4/1 dense, wet, sulfur odor	
								GP		w/ some fine and coarse gravel	
36								GP		w/ fine and coarse gravel	
										CL silty clay, low to medium plasticity	
37	Ø	Ø	100	Ø				SM		dark greenish gray 5GY 4/1, wet, stiff sulfur odor	
	Ø	60	40	Ø						silty fine sand greenish gray 5GY 6/1 wet, dense, sulfur odor	
38											
39											
40											
41								SM		SM as above	
42											
43								CL		CL w/ thin interbeds of silty clay (≈ 1/8 - 1/4" thick)	
44	Ø	15	100	Ø				CL		silty clay, greenish gray 5G 6/1 medium plasticity, stiff to very stiff, moist, sulfur odor	
45											

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366312

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: MW-10

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
45								CL			
	Ø	60	40	Ø				SM		silty fine sand, greenish gray 5 G 6/1 wet, dense, sulfur oder, non plastic	
46											
										CL with 1/16" clay partings	
47										CL	
48										silty clay, greenish gray 5G 6/1	
	Ø	15	100	Ø				CL		medium plasticity, stiff to very stiff moist, sulfur oder	
49											
										wi few gypsum X tals	
											4/14/04
50											4/15/04
	Ø	Ø	100	Ø				CL		silty clay, greenish gray 5G 6/1 medium plasticity, stiff, moist sulfur odor	
51											
	Ø	6	100	Ø				ML		silt slightly plastic, greenish gray 5G 6/1 wet, sulfur odor, stiff	
								CL		silty clay CL As Above	
52											
	~~Ø~~	~~6~~	~~100~~	~~Ø~~				~~CL~~		silt ML As Above	
	Ø	6	100	Ø							
	Ø	Ø	100	Ø				CL		silty clay CL As Above	
53											
54											
55											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366313

MONITORING WELL LOG FORM

Project: USM Project No:
Boring ID.: MW-10

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
55	Ø	Ø	100	Ø				CL		Silty clay greenish gray 5GY 6/1 medium plasticity, vugy locally with water in vugs, moist, stiff weak sulfur oder.	
56											
57											
58											
59											
60								CL		CL As Above	
61				Ø							
62											
63											
64											
65											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366314

MONITORING WELL LOG FORM

Project: USM Project No:

Boring ID.: VMW-10

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
65	Ø	Ø	100					CL		silty clay, greenish gray 5G6/1 medium plasticity, stiff to very stiff, moist with wet vugs	
66											
67											
										sm grades to CL as above with	
68										sm partings silty fine sand partings and upto ½", light olive gray 5Y6/1 to Brownish gray 5YR 4/1, wet at partings, weak sulfur odor	
69											
10										sm	
11								CL	A	few gypsums xtals	
12										sm partings	
										sm silty fine sand as below @ 13'	
13	Ø	60	40					SM		silty fine sand, greenish gray 5GY 6/1, wet, dense, sulfur odor non plastic.	
14											
15											

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

M366315

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

Project: Rusin Project No:

Boring ID.: MW-10

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
75								SM		SM As Above	
76	Ø	Ø	100	Ø				CL		silty clay, greenish gray 5G 6/1 medium plasticity, stiff to very stiff, moist to wet locally	
77	Ø	45	55					ML/CL		grades to clayey silt, moist low plasticity, sulfur oder	
78	Ø	60	40	Ø				SM		silty fine sand, greenish gray 5G 6/1, wet, sulfur oder dense	
	Ø	Ø	100	Ø				CL		CL as above	
79											
80										collected TOC & Neutralization Potential 73-75 SM and 76-78 CL @ 1015 @ 949 time TD 80' both 4/15/04	
11											
12											
13											
14											
15											

CONFIDENTIAL SETTLEMENT COMMUNICATIONS SUBJECT TO FED R. EVID. 408

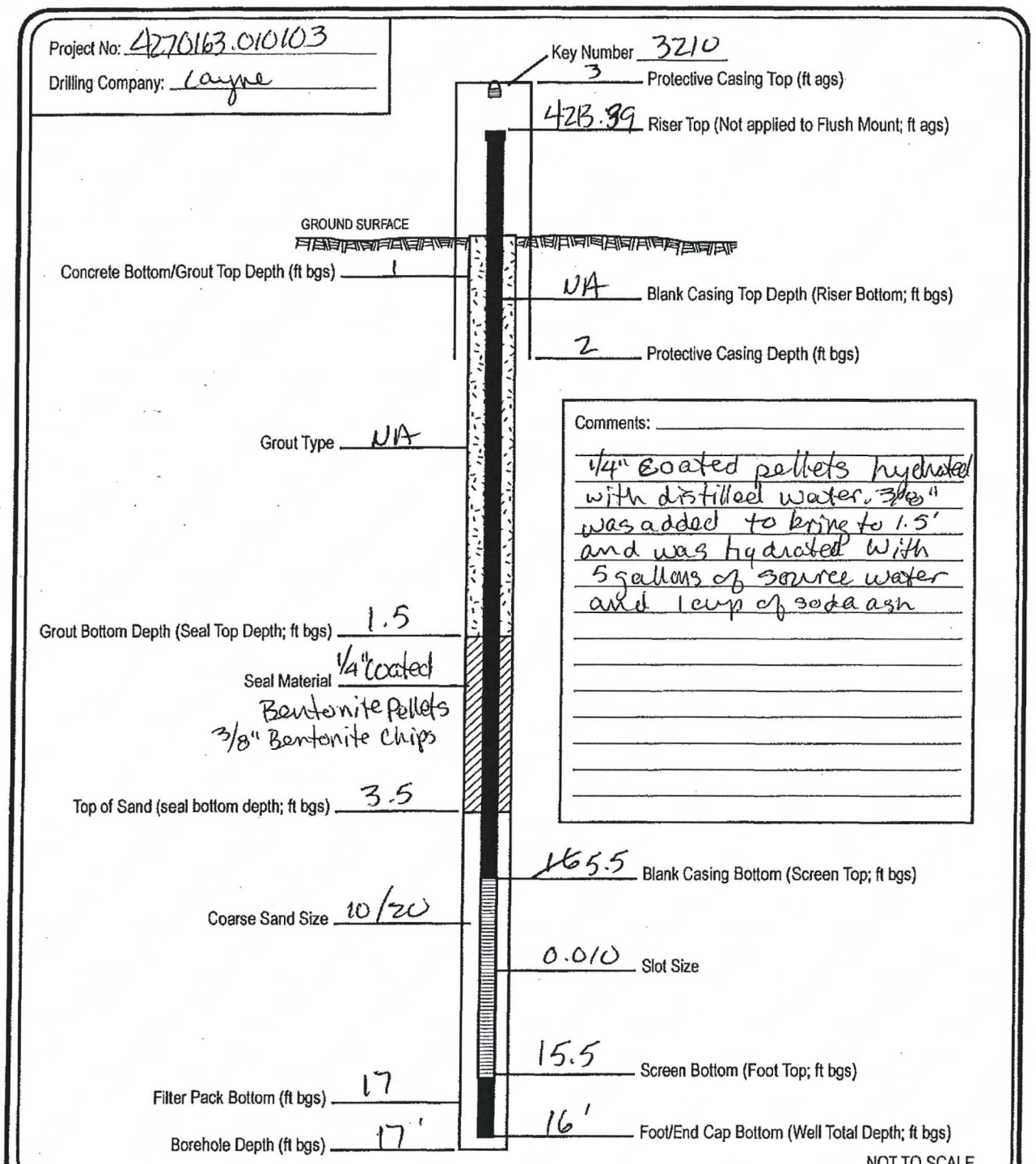
M366316

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

US MAGNESIUM, LLC
MONITORING WELL COMPLETION FORM

Project No: 4270163.010103
Drilling Company: Layne



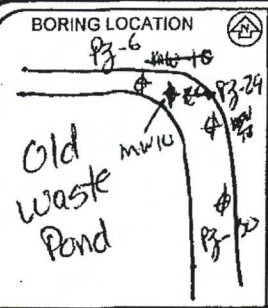
Loc ID/Well ID P3-30
Geologist Bill Bragdon
Date Construction Started 4/19/04
Date Construction Completed 4/19/04
LOC Type (i.e. Monitoring Well) Piezometer
Riser Material/Diameter PVC, 4"
Blank Casing Material/Diameter PVC, 4"
Screen Material/Diameter PVC, 4"
Protective Casing Type Metal
Borehole Diameter 10.25
Above Ground Completion ☒ Flush Mount ☐
USCS Classification of Screened Interval SP/CL/GP/GC

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

4270163.010103

BORING LOCATION



Project: USM Project No: _____
Date Drilled: 4/May Date Completed: _____
Logged By: B Bragdon
Water Elevation (ft.): 4203.63
Date Measured: 5/6/04
Total Depth (ft.): 17'
Diameter (in.): ~~10.75~~ 9"

Boring ID: PZ-30
Northing: 14872180.25 Easting: 1169762.42
Ground Surface Elevation (ft.): 4210.61
Measuring Point (MP) Elevation (ft.): Ground
MP is Top of PVC Casing Datum: NGVD (1929)
Drilling Contractor: Layne
Drilling Method: Hollow Stem Auger

Screen: Diameter 4.0" Depth 5.5-15.5 Slot Size 0.010
Casing: Diameter 4.0" Length 2-5.5 Type PVC
Sand 3.5-5.5 Bentonite Seal 1.5-3.5 Cement Grout Seal NA

DEPTH (FEET)	GRAIN SIZE % GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICATION	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
1										mixture of CL, SP & GP that is imparted fill material (0-5.5')	
2										CL silty clay, light olive gray 5Y 6/1, medium plasticity	
3										SP fine sand, light olive gray 5Y 6/1 to moderate reddish brown 10R 4/6	
4										GP fine to coarse sandy fine gravel w/ few gypsum x-tals, moderate reddish brown 10R 4/6	

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

*C California Split Spoon Sampler (2.5" I.D.)
S Standard penetration test sampler
c Cuttings
▼ Elevation of ground water

US MAGNESIUM, LLC
MONITORING WELL LOG FORM

Project: USM Project No: _____
Boring ID.: B3-30

DEPTH (FEET)	% GRAVEL	% SAND	% FINES	MAX. PID READING (ppm)	BLOWS (6 IN.)	SAMPLE TYPE*	SAMPLE RECOVERY	USCS/ASTM CLASSIFICAT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION (USCS name; color; size and angularity of each component or plasticity; density; moisture content; additional facts)	ELEVATION (FEET)
5											
								SP		fine sand w/ trace silt, light Olive Gray 5Y 6/1, non plastic, wet ≈7.5, dense, weak sulfur odor	
6	0	90	10	Ø							
										grades to very light gray N8	
7										wet 7-7.5'	
8											
9										oolitic sand w/ gypsum Xtals	
										TOC and neutralization potential	
										7.5-10' @ 1533 on 4/19/04	
10											
11	Ø	25	100	Ø				CL		silty clay, Olive gray 5Y 4/1	
										medium plasticity, stiff to very stiff	
12										moist, no odor	
	60	40	Ø					GP		fine ~~and~~ to coarse sandy fine and coarse gravel, Olive gray 5Y 4/1 and very light gray N8, some oolitic sand, wet, no odors	
13											
	60	10	30	Ø				GC		grades to clayey gravel	
14										Olive gray N8, low plasticity stiff, wet	
										TOC & NP @ 1559 12.5-15	
15											

PROJECT NO. 4270106.010101.ai 03/04/03 SLC

MONITORING WELL LOG FORM

APPENDIX B – STANDARD OPERATING PROCEDURES FOR FIELD ACTIVITIES

STANDARD OPERATING PROCEDURE 20

GROUNDWATER SAMPLING FOR CHEMICAL ANALYSES

STANDARD OPERATING PROCEDURE 20

GROUNDWATER SAMPLING FOR CHEMICAL ANALYSES

TABLE OF CONTENTS

1.0 INTRODUCTION 2

2.0 DEFINITIONS 2

3.0 RESPONSIBILITIES 5

4.0 MONITORING WELL SAMPLE COLLECTION PROCEDURES 6

- 4.1 SAMPLING EQUIPMENT 6
- 4.2 PRE-SAMPLING PROCEDURES 6
- 4.3 GENERAL CRITERIA FOR SAMPLE COLLECTION 12
- 4.4 MONITORING WELL PURGING AND SAMPLING EQUIPMENT 15
- 4.5 MONITORING WELL LOW-FLOW SAMPLING 21

5.0 GROUNDWATER SAMPLE COLLECTION PROCEDURES FOR EXTRACTION OR PRODUCTION WELLS 23

6.0 PURGE WATER HANDLING AND DISPOSAL 24

7.0 REFERENCES 25

1.0 INTRODUCTION

This standard operating procedure (SOP) is intended to serve as a reference for the proper equipment and techniques for collecting groundwater samples for chemical analysis. The purpose of this SOP is to enable the user to collect representative and defensible groundwater samples, and to plan the field sampling effort. The techniques presented will be followed whenever applicable, although site-specific conditions or project-specific requirements may warrant adjustments in methodology.

To be valid, a groundwater sample must represent the water-bearing unit being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from collection to analysis in order to minimize changes in water quality. Acceptable equipment for sample collection from completed wells includes bailers and various types of pumps. In order to obtain a representative sample of the groundwater, the sampler must accomplish the following:

- avoid collecting stagnant (standing) water in the well casing;
- avoid physically or chemically altering the water due to improper sampling techniques, sample handling, or transport; and;
- document that proper sampling procedures have been followed.

This SOP describes groundwater sample collection methods only.

2.0 DEFINITIONS

Annular Space: The space between the casing or well screen and the wall of the drilled hole, or between the drill pipe and casing, or between two separate strings of casing. The annular space may also be referred to as the annulus.

Aquifer: A geologic formation, group of formations, or part of a formation that is capable of yielding economic quantities of water to a well or spring.

Bailer: A long, narrow, tubular device with an open top and a bottom check valve that is used to remove water from a well during purging or sampling. Bailers may be made of Teflon®, polyethylene, or stainless steel. Disposable bailers are available and are made of polyethylene.

Bladder Pump: A pump consisting of a flexible bladder usually made of Teflon® contained within a rigid cylindrical body (commonly made of stainless steel or PVC) that is operated using compressed air and a pump controller. The lower end of the bladder is connected through a check valve to the intake port, while the upper end is connected through a second check valve to a sampling line that leads to the ground surface. A second line, the gas line, leads from the compressed air source to the space between the bladder and the outer body of the pump. After filling under hydrostatic pressure, application of gas pressure forces the groundwater to the surface through the sample line. An air compressor or compressed air tank provides gas pressure. The pump controller automatically switches the gas pressure off and on at specific intervals.

Centrifugal Water-Supply Pump: A pump that creates a vacuum and moves liquid by accelerating it radially outward and upward in an impeller to a discharge line.

Chain-of-Custody: Method for documenting the history and possession of a sample from the time of its collection through its analysis, data reporting and final disposition.

Check Valve: Ball and spring valves on bailers and pumps that are used to allow water to flow in one direction only.

Conductivity (electrical): A measure of the quantity of electricity transferred across a unit area, per unit potential gradient, per unit time. It is the reciprocal of resistivity.

Datum: An arbitrary surface (or plane) used in the measurement of heads (i.e., National Geodetic Vertical Datum [NGVD], commonly referred to as mean sea level [msl]).

Decontamination: A variety of processes used to clean equipment that contacted formation material or groundwater that is known to be or suspected of being contaminated.

Dissolved Oxygen (DO): A measure of the quantity of oxygen dissolved in groundwater. DO data is collected in the field using direct measure probes. DO is used to assess the balance between oxygen-consuming and oxygen-producing processes.

Downgradient: In the direction of decreasing hydrostatic head.

Drawdown: The lowering of the potentiometric or piezometric surface in a well and aquifer due to the discharge of water from the well.

Electric Submersible Pump: A pump that consists of a rotor contained within a chamber and driven by an electric motor. The entire device is lowered into the well with the electrical cable and discharge tubing attached. A portable power source and control box remain at the surface. Electrical submersible pumps used for groundwater sampling are constructed of inert materials such as stainless steel and teflon, and are sealed to prevent sample contamination by lubricants.

Filter-Pack: Sand or gravel that is generally uniform, clean, and well-rounded that is placed in the annulus of the well between the borehole wall and the well screen to prevent formation material from entering the well screen, and to stabilize the adjacent formation.

Groundwater Sample: A sample collected from an aquifer for chemical analysis to support remedial investigation, feasibility studies, treatability studies, remediation design and performance assessment, waste characterization, etc.

Head-Space: The empty volume in a sample container between the water level and the cap.

Hydropunch®: An in-situ groundwater sampling system in which a hollow steel rod is driven into the saturated zone and a groundwater sample is collected via a stainless steel bailer.

In Situ: In the natural or original position; in place.

Monitoring Well: A well that is constructed by one of a variety of techniques for the purpose of extracting groundwater for physical, chemical, or biological testing, or for measuring water levels.

Oxidation-Reduction Potential (ORP): ORP is a measurement of the potential of a given system to oxidize or reduce. ORP data are collected in the field using direct measure probes. Positive potentials indicate the system is oxidizing, while negative potentials indicate the system is reducing.

Packer: A transient or dedicated device placed in a well or borehole that isolates or seals a portion of the well, well annulus, or borehole at a specific level.

Peristaltic Pump: A low-volume suction pump. The compression of a flexible tube by a rotor results in the development of suction.

pH: A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.

Piezometer: A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface.

Preservative: An additive (usually an acid or a base) used to protect a sample against decay or spoilage, or to extend the holding time for a sample.

Static Water Level: The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby groundwater extraction.

Temperature: A measure of the thermal energy contained in a solid or fluid.

Turbidity: Cloudiness in water due to suspended and colloidal organic and inorganic material.

Upgradient: In the direction of increasing hydrostatic head.

3.0 RESPONSIBILITIES

This section presents a brief definition of field roles, and the responsibilities generally associated with them. This list is not intended to be comprehensive and often, additional personnel may be involved. Project team member information will be included in project-specific plans (e.g., work plan, field sampling plan, quality assurance plan, etc.), and field personnel will always consult the appropriate documents to determine project-specific roles and responsibilities. In addition, one person may serve in more than one role on any given project.

STANTEC Project Manager: Develops the groundwater sampling program with input from key project staff and project stakeholders.

STANTEC Quality Control Manger: Performs project audits. Ensure that the project-specific data quality objectives are met.

STANTEC Field Team Leader (FTL) and/or Geologist, Hydrogeologist, or Engineer: Implements the groundwater sampling program and supervises other sampling personnel. Insure that proper chain-of-custody procedures are observed and that samples are collected, packaged, transported, and shipped in a correct and timely manner. Also prepares daily logs of field activities.

STANTEC Field Sampling Technician (or other designated personnel): Assists the FTL and/or geologist, hydrogeologist, or engineer in the implementation of tasks and is responsible for the proper use, and maintenance of groundwater sampling equipment.

4.0 MONITORING WELL SAMPLE COLLECTION PROCEDURES

4.1 SAMPLING EQUIPMENT

There are several types of equipment available for well purging and sampling. Several factors that will be considered when choosing purging and sample collection equipment include the depth and diameter of the well, availability of the equipment, the recharge capacity of the well, and the analytical parameters of interest. Few sampling devices are suitable for the complete range of groundwater parameters. For example, a peristaltic pump is acceptable for collecting major ion and trace metal samples, but it may lead to erroneous analytical results if used for the collection of samples for volatile organics analysis or dissolved gases.

In many cases pumps such as bladder and electric submersible pumps are used for sample collection. These pumps minimize the aeration of the groundwater as it is sampled, and therefore provide the most representative samples. The use of other types of sample collection equipment, such as bailer, or gas lift pumps, is not recommended, especially when analyzing for parameters that are sensitive to geochemical changes that can occur due to the aeration of the water within the well such as VOC's. In addition, the use of these sampling devices may entrain suspended materials, such as fine clays and colloids that are not representative of mobile chemical constituents in the formation of interest (Puls and Barcelona, 1989).

4.2 PRE-SAMPLING PROCEDURES

Well Inspection: Upon arrival at the well, prior to groundwater purging or sampling, sampling personnel will document any signs of tampering or well deterioration. These observations will be recorded in the field logbook or on a field form. A plastic sheet will be placed around the well head to prevent contamination of the surface around the well during purging/sampling, and to keep decontaminated sampling equipment from contacting the ground surface.

Field Measurements — Water Level and Water-Quality Parameters: Water level measurements and water-quality parameters including pH, conductivity, temperature, turbidity, ORP, and DO will be collected in the field during groundwater purging and sampling. The

sensitivity of the water-quality parameters to changes as a result of exposure of groundwater to surface level conditions (e.g., changes in the partial pressure of dissolved gases or the conditions of the purging system) make in-situ monitoring desirable. If possible, water-quality parameter measurements should be conducted in a closed, flow-through cell attached to the discharge line of the pump system.

The accuracy, precision, and usefulness of these measurements are dependent on the proper use and care of the field instruments. All meters will be calibrated in accordance with the manufacturer's directions. The instruments will be handled carefully at the well site and during transport to the field and between sampling sites. All information regarding meter calibration will be described in the field log book or field log form. All meters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following paragraphs describe the general procedures for field parameter measurement.

Water Level: A full round of water levels will be measured in all relevant wells prior to the sampling of any wells and used to calculate the purge volumes. Water levels will be monitored before, during, and after sampling if following low flow or standard purge sampling procedures are used.

pH: pH will be measured during purging and immediately prior to sample collection using a meter with an accuracy of $\pm$ 0.1 pH units. . Prior to use of the pH meter, it will be established that the meter is providing accurate measurements. All information regarding meter calibration will be described in the field log book or field log form. All meters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following procedures will be followed for field measurement of pH:

1. Immerse the probe in the sample. Allow for sufficient flow past the probe membrane either by stirring the sample or placing the probe in a flow-through cell.
2. Allow the meter to stabilize and record the pH to the nearest 0.1 pH units in the field logbook or on the field form.

Specific Conductivity: Specific conductivity will be measured during purging and immediately prior to sample collection. For passive sampling, specific conductivity will be measured

immediately following sample collections, dependent of sample volume requirements. Prior to use of the specific conductivity meter, it will be established that the meter is providing accurate measurements. All information regarding meter calibration will be described in the field log book or field log form. All meters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following procedures will be followed for field measurement of specific conductivity:

1. Immerse the specific conductivity probe in the sample. Allow for sufficient flow past the probe membrane either by stirring the sample or placing the probe in a flow-through cell.
2. Allow the meter to stabilize and record the specific conductivity and unit of measurement (e.g. micromhos/centimeter [µm/cm] or millimhos/cm).

Temperature: Temperature will be measured during purging and immediately prior to sample collection with either a mercury or electronic thermometer capable of accurately reading to 0.1 degrees Celsius (°C). Prior to use of the temperature meter, it will be established that the meter is providing accurate measurements. All temperature meters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following procedures will be followed for field measurement of specific temperature:

1. Immerse the temperature probe or thermometer in the sample.
2. Allow the temperature to stabilize and record the temperature and unit of measurement (e.g. degrees Fahrenheit or Celsius) to the nearest 0.1 degrees in the field log book or on the field form.

Dissolved Oxygen: Dissolved oxygen will be measured during purging and immediately prior to sample collection. Whenever possible, in-situ measurements of DO will be collected to minimize sample handling. If this is not possible, care will be taken during DO measurement to minimize turbulence that may lead to increased oxygen solubilization in the sample and unreliable results. Non-in-situ DO measurements should be indicated as such in field log books. Prior to use of the DO meter, it will be established that the meter is providing accurate measurements. All DO meters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following procedures will be followed for field measurement of DO:

1. Immerse the probe in the sample and allow sufficient time for the meter to stabilize.
2. Read and record the dissolved oxygen content and unit of measurement to the nearest 0.1% for percent oxygen readings or 0.1 milligrams per liter (mg/l) for mg/l readings in the field logbook or on the field form. Note that DO is affected by temperature and it is important that the associated temperature measurements are accurate.

Oxidation-Reduction Potential: Oxidation reduction potential will be measured during purging and immediately prior to sample collection using direct measure instruments. . Prior to use of the ORP meter, it will be established that the meter is providing accurate measurements. All ORP meters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following procedures will be followed to obtain ORP readings:

1. Immerse the probe in the sample. Allow for sufficient flow past the membrane either by stirring the sample or placing the probe in a flow-through cell.
2. Allow the meter to stabilize and record the reading (in millivolts) in the field log book or on the field form.

Turbidity: Turbidity will be measured during purging and immediately prior to sample collection using a direct read meter. Turbidity is a measure of the interaction of light with suspended solid particles in the sample, and is reported in Nephelometric Turbidity Units (NTUs). Prior to use of the turbidimeter, it will be established that the meter is providing accurate measurements. All turbidimeters will be used in accordance with the manufacturer's directions and no meters will be used unless they are functioning properly. The following provides general guidance for collecting turbidity data:

1. Place the meter probe into the sample, or place the cuvette containing the sample into the measuring chamber of the meter. .
2. Allow the meter to stabilize and record the turbidity measurement in the field log-book or on the field form.

Pre-Sampling Purging Criteria The recommended amount of purging before sampling is dependent on many factors including the characteristics of the well, the hydrogeological

properties of the aquifer, the type of sampling equipment being used, and the proposed analytical parameters.

For all standard sampling techniques, determination of the total pre-sampling purge volume will be volume-based (sampling procedures are discussed in Section 4.5). A minimum of three borehole volumes will be purged prior to sampling for all wells that do not bail or pump dry at a purge rate of $\geq$ 1 liter per minute. It is recommended that a flow rate as close to the actual groundwater recharge rate (steady state flow) as possible be used to avoid further well development, well damage, or the disturbance of accumulated corrosion or reaction products in the well (Puls and Barcelona, 1989).

During purging, water-quality parameters including pH, turbidity, specific conductivity, temperature, DO, and ORP will be measured. Pre-sampling purging will be considered complete when three borehole volumes have been removed from the well, and the final three consecutive measurements (collected at time intervals equal to or greater than the required time to purge ½ of the borehole volume) do not change by more than the following:

Conductivity	±3%
pH	±0.1 units
Temperature	±1 degree Celsius
Dissolved Oxygen	±0.3 milligrams per liter (mg/l)
ORP	±10 millivolts
Turbidity	<5 NTU

If the parameters have not stabilized after three borehole volumes have been purged from the well, up to three additional borehole volumes (resulting in a total of six borehole volumes) will be removed. If the parameters are not stable after a maximum or six borehole volumes have been purged, the sample will be collected and the non-stabilized parameters will be recorded. In some cases turbidity requirements may not be met for some wells, or if methods other than pumps are used for groundwater evacuation. If the turbidity exceeds 5 NTUs after three borehole volumes have been removed and the turbidity is continuing to decrease, purging should continue until turbidity stabilizes. If the stable turbidity measurements (i.e., three measurements within ±10%) exceed 5 NTUs, the Project Manager will be contacted to determine what corrective actions, if any, will be taken prior to sampling.

Borehole volumes will be calculated following the steps described below. Calculations and the total purge volumes will be entered in the field logbook or groundwater sampling log form.

1. Obtain all available information on well construction (e.g., casing diameter, borehole diameter, screened interval, total well depth, etc.).
2. Measure and record static water level (depth below ground level or top of casing reference point).
3. Determine depth of well by sounding using a clean, decontaminated weighted tape measure or an electronic water-level probe.
4. Calculate the purge water volume using the following formula:

Total Purge Volume: $V_t = 3(V_c + V_a n) \times 7.48\ gal/ft^3$

where:	V_t	=	Total Purge Volume (gals)
	V_c	=	Volume of water in well casing (ft^3)
	V_a	=	Volume of water in well annulus (ft^3)
	n	=	Estimated porosity of sand pack (usually 30%)
	7.48	=	Conversion factor from cubic feet to gallons

Casing Volume: $V_c = \pi r_1^2 h_1$

where:	V_c	=	Casing Volume (ft^3)
	r_1	=	Inside radius of monitoring well casing (ft)
	h_1	=	Height of water column (i.e., total well depth minus static water level depth) (ft)

Annular Volume: $V_a = \pi(r_2^2 - r_1^2)\ h_2$

where:	V_a	=	Annular volume (ft^3)
	r_2	=	Radius of borehole (ft)
	r_1	=	Outside radius of well casing (ft)
	h_2	=	Total vertical saturated thickness of sand pack (ft)

Alternatively, the casing volume can be calculated by multiplying the linear feet of water in the well by the volume per linear foot taken from Table 20-2 or other similar tables. The units used for all calculations will be consistent.

When evacuating low yield wells (wells that pump or bail dry at a purge rate ≥ 1 liter per minute) the well will be purged to dryness once (USEPA, 1986, 1992). Sampling will be conducted when the well recovers to 90 percent of the pre-purge water column thickness. If under special circumstances the well does not recover to 90 percent within a normal workday, the well may be allowed to recover overnight and be sampled the following morning. When a well is to recover overnight, the Project Manager will be notified. At no time will the well be pumped or bailed dry if the recharge rate causes the formation water to vigorously cascade down the sides of the screen, which may cause the loss of volatiles.

4.3 GENERAL CRITERIA FOR SAMPLE COLLECTION

As discussed in Section 4.1, several types of equipment may be used for groundwater sample collection. Regardless of the type of equipment used, the following procedures will be observed during groundwater sampling:

- When using non-dedicated sampling equipment, monitoring wells will be sampled in the order of increasing contamination.
- After well development, adequate time must be allowed for the formation to equilibrate before the well should be sampled. The length of time between well development and sampling depends on the hydraulic conductivity and gradient of the formation around the well. For wells with higher hydraulic conductivities and/or gradients, one to two days may be sufficient for the formation to return to equilibrium. Wells with lower hydraulic conductivities and/or gradients may require significantly more time to come to equilibrium.
- All purging and sampling equipment will be decontaminated prior to purging and sampling, and between sampling locations (non-dedicated equipment).
- All samples for dissolved metals analysis will be field filtered and preserved.
- Temperature, pH, specific conductance, DO, ORP, and turbidity will be measured immediately prior to sample collection.
- Preserved sample bottles will be checked daily for the proper pH using litmus paper test strips. When checking VOA vials, a vial will be filled with sample water and a strip of litmus paper will be used to test the solution; the test vial will not be used for sample

collection. The pH of other preserved bottles can be checked by pouring a drop of sample solution out of the cap onto the litmus test strip; the bottle can be used for sample collection. Acids will have a pH of less than or equal to 2 and bases will have a pH of greater than or equal to 13.

- In accordance with EPA guidance powder-free gloves and "low-particulate" paper towels will be used by personnel during sample collection.
- All groundwater sample data and information collected in the field will be recorded in the field log book or on a field form..
- Sample bottles will be filled in order of the volatility of the analytes to be tested so that containers for analysis of volatile organic compounds (VOCs) will be filled first, and those for analyses that are not pH-sensitive or subject to loss of volatile or semi-volatile components will be filled thereafter. The sample collection order that will be followed is based on U.S. EPA guidance (U.S. EPA, 1986) and is as follows:
  - VOCs
  - Total petroleum hydrocarbons (TPH)
  - Total organic halogens (TOX)
  - Total organic carbon (TOC)
  - Extractable organics (e.g., semi-volatile organic compounds, pesticides, herbicides, explosives)
  - Total metals
  - Dissolved metals
  - Phenols
  - Cyanide
  - Sulfate and chloride
  - Nitrate and ammonia
  - Radionuclides.

Dissolved Metals Filtering Procedures: Groundwater samples for dissolved metals will be filtered in the field using a disposable 0.45-micron (µm) filter prior to filling the sample

containers. If the samples are collected with a pump, an in-line disposable filter will be placed on the pump discharge line and the groundwater sample will be collected directly into the sample container from the filter discharge. If the samples are collected with a bailer, the sample will first be transferred to a clean container. This sample will then be filtered using either a peristaltic pump equipped with Teflon® tubing and an in-line 0.45 µm disposable filter or a hand vacuum filtration system (e.g., Nalgene ™ disposable filtration units). The inlet of the pump tubing will be placed in the groundwater sample and the sample will be pumped through the filter and collected into the sample container from the filter discharge. All filtered groundwater samples will be field preserved with nitric acid to a pH of <2. Note that the samples will not be preserved prior to filtering. The filters will be discarded after each use.

VOC Sample Collection Procedures: Regardless of the sampling equipment type, the following procedures will be used for VOC sample collection. It should be noted that bailers are not recommended for the collection of VOC samples . Bailers should only be used as a last resort in the collection of VOC samples and approval from the Project Manager must be obtained prior to using a bailer to collect samples for VOC analysis.

- If a pump is used for sampling, the pump discharge rate will be reduced to 100 milliliters per minute (ml/min) or less. If a bailer is used for sampling, a VOC sampler will be attached to the bottom of the bailer. The VOC sampler will be inserted in such a manner as to allow a streamlined flow of water into the sample bottle. The contents of the bailer will be discharged slowly through the VOC sampler to the sample container to minimize aeration of the sample. During direct-push groundwater sampling, sample water may be slowly poured from the top of the stainless steel bailer, thus reducing the amount of sediment collected in the vial.
- The sample container will be completely filled so that a convex meniscus forms over the neck of the opening to eliminate head-space.
- Position the Teflon® side of the septum (in the vial cap) against the meniscus, and screw the cap on tightly.
- Invert the sample bottle and tap lightly to check for air bubbles. The absence of an air bubble indicates an airtight seal. If an air bubble is observed, recollect the sample

following the procedures described above using a new sample vial. This process will be continued until the VOC sample vials contain no head space.

- Collected VOC samples will be checked for effervescence (sparging). If sparging is observed, the VOC sample will be recollected in unpreserved volatile organic analysis (VOA) vials to prevent the loss of VOCs from the sample.

Non-VOC Sample Collection Procedures: The following procedures will be followed for the collection of samples for analyses other than VOCs or dissolved metals:

- If a pump is used, the pump discharge will be reduced to minimize agitation or aeration of the sample.
- The sample containers will be filled in order from the least to the most stable compounds as described previously.
- Sufficient volume will be collected so that the scheduled analysis can be performed. The sample containers do not need to be filled so that there is no head-space.

4.4 MONITORING WELL PURGING AND SAMPLING EQUIPMENT

Several types of equipment may be used for purging and sampling. Equipment that may be used for purging includes bailers, and bladder, electric submersible, water supply, and peristaltic pumps. The types of equipment that may be used for sampling include bailers, and bladder, electric submersible, and peristaltic pumps. Centrifugal water-supply pumps will not be used for sample collection. Specific instructions for the use of several types of equipment for purging and for sample collection are presented in the paragraphs that follow.

Bailers: Bailers represent the simplest method of purging or collecting a sample from a well. However, they may not be suitable for the collection of samples for certain analyses. The advantages associated with bailer use are:

- Relatively inexpensive to purchase and use.
- Disposable bailers minimize decontamination and potential for cross-contamination.

The limitations associated with bailer use are:

- Labor-intensive, particularly in deep wells (> 30 ft)

- Rope used to lower and raise bailer may introduce surface contaminants into well.
- Bailers are not preferable for the collection of samples for VOC analysis, but in some cases (e.g., small-diameter piezometer) bailing may be the best means available.

The following general procedures will be followed when using a bailer for well purging and sampling:

- Non-disposable bailers will be decontaminated prior to use and between sampling each subsequent well.
- Stainless steel, Teflon®-coated stainless steel wire, or disposable nylon rope is recommended for lowering and retrieving the bailer from the well. At no time should the bailer or the line touch the ground during the sampling process. This can be done by coiling the line in a bucket or on a sheet of polyethylene. Polypropylene line may be substituted for the stainless steel wire, but should be discarded after each use. Nylon rope should be discarded and wire should be decontaminated after use.
- When lowering the bailer into the well, care should be taken to minimize agitation in the well, such as when the bailer contacts the water-table surface. The bailer should be lowered to a depth below the top of the screened interval during purging and sampling to ensure that the collected sample water is obtained directly from the screened interval of the well.
- Once pre-sampling purging criteria have been met, lower the bailer slowly into the well and fill with groundwater. Retrieve the bailer to the surface and attach a VOC sampler to the bottom of the bailer. The VOC sampler should be inserted in such a manner as to allow a streamlined flow of water into the sample bottle. Sample groundwater will be dispensed from the bottom of the bailer, through the VOC sampler, into the sample container. Care will be taken to minimize aeration of the sample during filling. As previously mentioned, direct-push groundwater samples may be dispensed from the top of the bailer, thus reducing the amount of sediment collected in the vial.
- If VOC samples are scheduled for collection, fill sample vials so that there is no head-space, following the guidance under Section 4.3 VOC Sample Collection Procedures.

- Collect the remaining sample fractions by discharging the contents of the bailer into the sample containers. The sample bottles need to be filled so that there is sufficient volume for the scheduled analysis; however, the sample containers do not need to be filled so that there is no head-space.

Peristaltic/Centrifugal Water-Supply Pumps: Peristaltic and centrifugal water-supply pumps are widely used for purging wells with shallow water levels (less than 30 feet). Peristaltic pumps are only suitable for the collection of certain environmental samples Centrifugal water-supply pumps will not be used for sample collection. The advantages associated with these pumps are:

- They are light, portable and easily adaptable.
- Minimal downhole equipment is required.
- They are capable of delivering large quantities of water against low head conditions.
- Disposable tubing minimizes lengthy decontamination procedures.

The limitations associated with the use of these pumps are:

- Electricity is needed
- Both pumps are not suitable for purging wells deeper than 30 feet.
- If new tubing is not available, decontamination may be time consuming.

After meeting pre-sampling purging criteria, the following procedures will be followed when sampling with a peristaltic pump:

1. Reduce the flow of the peristaltic pump to minimize aeration of the groundwater sample.
2. Collect the sample fractions into the appropriate sample containers. The sample bottles need to be filled so that there is sufficient volume for the scheduled analysis; however, the sample containers do not need to be filled so that there is no head-space.

Electric Submersible Pumps: Electric submersible pumps may be used for both purging and sampling, and along with bladder pumps, are often the preferred method of groundwater sample collection. Submersible pumps take in the sample and push the sample up a discharge tube to the surface. The power source for these pumps is electricity. Electric submersible pumps are available for 2-inch-diameter wells and larger, and can lift water up to two hundred feet. These

pumps should be dedicated, wherever possible, and used in wells with high purge volume requirements.

The advantages of these pumps are:

- They allow for collection of low turbidity samples.
- They are easy to install as dedicated systems.
- Limitations of these pumps are:
- Certain models may be expensive.
- Electricity is needed.
- Sediment in water may cause clogging of the pump and deterioration of the impellers.
- Decontamination of non-dedicated electric submersible pumps may be difficult and time consuming.

The procedures outlined below will be followed for purging with electric submersible pumps.

For wells with high recharge rates (≥ 1 liter per minute), purge as follows:

1. Set the pump intake within the screened interval, adjacent to the most impacted hydrogeologic zone. In some cases (e.g., screened intervals 10 feet long or less) the pump intake may be placed approximately two feet above bottom of well.
2. Record water level and potential subsequent drawdown continuously with an electric water level indicator.
3. If the static water level prior to purging is above the screened interval, acceptable drawdown will be defined as the lowering of the water level to the top of the screened interval. If continued drawdown occurs below the top of the screened interval, the pump rate will be decreased to stabilize the water level to prevent atmospheric contact with the filter pack and formation.
4. If the static water level prior to purging is within the screened interval, the drawdown due to purging will not exceed a distance of 25 percent of the length of the saturated screened interval. This will prevent cascading and the potential loss of volatiles, excessive turbidity, and entrapment of air in the filter pack. The well should not be pumped dry.

5. If the pump seizes up during purging, the pump may be jiggled within the well in an attempt to free clogged sediment and resume pump operation.

For wells with low recharge rates (≤ 1 liter per minute), the following procedures will be used to purge the wells:

1. Set the pump intake at approximately two feet above the bottom of the well. Measure the depth to water.
2. Purge the well at a rate of approximately one liter per minute (this flow rate may not be possible in deeper wells) until the water level drops to the pump intake.
3. Allow the static water level to recover to 90 percent of the original static level. If under special circumstances the well does not recover to 90 percent within a normal workday, the well may be allowed to recover overnight and be sampled the following morning. When a well is to recover overnight, the Project Manager will be notified. At no time will the well be pumped or bailed dry if the recharge rate causes the formation water to vigorously cascade down the sides of the screen, which may cause the loss of volatiles.
4. After sufficient recharge has occurred, pump at a low flow rate (e.g., 100 ml/min.) and collect water-quality parameter measurements if adequate water volume is present. Continue purging and monitoring until three consecutive readings meet the stabilization criteria. The drawdown will be monitored continuously to ensure the water level does not drop to a level less than one foot above the pump intake. If adequate water volume is not present, sample without field parameter stabilization.

The following procedures will be followed when collecting groundwater samples using a submersible pump:

1. Once purging requirements have been met, adjust the flow rate to maintain a steady streamlined flow from the discharge tube into the sample container. Sample collection flow rates will be approximately 100 ml/min. In between filling containers, care will be taken to ensure that well water does not flow onto the ground.
2. Collect samples in order of volatility. Samples for VOC analysis will always be collected first.

3. Fill VOC sample bottles so that there is no head-space, following the guidance under Section 4.3 VOC Sample Collection Procedures.
4. Collect the remaining sample fractions. The sample bottles need to be filled so that there is sufficient volume for the scheduled analysis. However, the sample containers do not need to be filled so that there is no head-space.

Bladder Pumps: Bladder pumps are positive displacement pumps that can be used for both purging and sample collection, and along with electric submersible pumps, are often preferred for sample collection. Groundwater is displaced and forced up the pump discharge line by an inflatable bladder. The advantages of these pumps are:

- They allow for the collection of low turbidity samples.
- They are adjustable to very low flow rates.
- They are relatively inexpensive and easy to install as dedicated systems.

Limitations of these pumps are:

- An air compressor or another source of compressed air are required to operate the pumps
- They cannot be used at depths greater than 150 feet below ground surface unless specially designed pumps are used.
- Pump efficiency decreases with depth.
- Sediment in water may cause clogging of the valves in the pump.

For wells with high recharge rates (≥ 1 liter per minute), purge as follows:

1. Set the pump intake one foot from the bottom of the screened interval for low yield wells or in the middle of the screened interval for high yield wells. Begin purging at approximately one liter per minute.
2. Once purging requirements have been met, adjust the flow rate to maintain a steady streamlined flow from the tube into the sample container during each discharge cycle of the bladder pump. Sample collection flow rates will be 100 ml/min or less for VOC samples. VOC sample vials will be filled completely during a bladder pump discharge

cycle. In between filling containers, care will be taken to ensure that well water does not flow onto the ground.

For wells with low recharge rates (≤ 1 liter per minute), the following procedures will be used to purge the wells:

1. Set the pump intake at approximately two feet above the bottom of the well. Measure the depth to water.
2. Purge the well at a rate of approximately one liter per minute (this flow rate may not be possible in deeper wells) until the water level drops to the pump intake.
3. Allow the static water level to recover to 90 percent of the original static level. If under special circumstances the well does not recover to 90 percent within a normal workday, the well may be allowed to recover overnight and be sampled the following morning. When a well is to recover overnight, the Project Manager will be notified. At no time will the well be pumped or bailed dry if the recharge rate causes the formation water to vigorously cascade down the sides of the screen, which may cause the loss of volatiles.
4. After sufficient recharge has occurred, pump at a low flow rate (e.g., 100 ml/min.) and collect water-quality parameter measurements. Continue purging and monitoring until three consecutive readings meet the stabilization criteria. The drawdown will be monitored continuously to ensure the water level does not drop to a level less than one foot above the pump intake. If adequate water volume is not present, sample without field parameter stabilization.

4.5 MONITORING WELL LOW-FLOW SAMPLING

To limit the disposal of large volumes of purged water, monitoring wells can be sampled with pumps using lower flow rates (i.e. electrical submersible, bladder, peristaltic). Studies have shown that groundwater in the screened interval of a standard monitoring well can be representative of groundwater in the formation, even though stagnant water lies above in the casing. This occurs when flow is generally horizontal and naturally purges the screened interval. However, the insertion of a sampling device, such as a bailer or pump, can disrupt this equilibrium and cause mixing of the screened and cased interval waters. The mixture of stagnant and screened interval water can even be forced into the aquifer, resulting in chemical and

microbiological effects that may affect data quality. Therefore, low-flow sampling techniques are most accurate using dedicated sampling devices and tubing that can be left in place within a monitoring well. Considerations also need to be made for switching between standard purge volume and low-flow sampling methods.

The objective of low-flow sampling is to minimize the velocity/stress on the sample water as it exits the formation into the screened interval of the well and as it enters the pump. Flow rates from 0.1 to 0.5 liter/minute (l/min) are typical for this sampling procedure. When performed correctly, water sampled using the low-flow technique is produced from the screened interval without disturbing stagnant water in the well casing. By using low flow rates to stabilize drawdown at less than the goal of 0.30 feet, only screened interval water will be sampled. Project-specific work plans should be developed in cases where low-flow sampling with less than 0.30 feet of drawdown cannot be achieved. Under these cases, the individual Project Manager must approve of alternative sampling methods prior to sampling.

The following procedures will be used while performing low-flow purging and sampling:

1. Install a pump and tubing in the well (if one does not already exist). Slowly lower the devise and tubing into the well to minimize disturbance of the stagnant water within the well. Place the pump/tubing inlet in the screened interval at the appropriate depth, which should be near the midpoint of the screened interval unless site-specific conditions dictate placing the inlet at a different point within the screened interval. Wait at a sufficient amount of time for well to stabilize after pump/tubing installation before purging and sampling.
2. Before initiating purging, place an electric water level indicator down to the top of the static water table and record the depth to groundwater.
3. Begin purging groundwater at a rate between 100 to 500 ml/min, making sure to minimize drawdown to less than 0.3 feet as a goal. Rates up to approximately 1 l/min may be feasible in high hydraulic conductivity formations, only if the drawdown continues to be less than 0.3 feet. Measure drawdown at intervals of five minutes or less during purging. Adjust the purge rate to balance the desired (low) purge rate and water level drawdown. If the recharge to the well is less than 100 ml/min (i.e., excessive drawdown is occurring), proceed to Step 6.

4. The minimum volume to be purged from the well is the volume of the tubing and pump (available from the manufacturer). The tubing volume will be determined by multiplying the volume per foot of tubing (available from the manufacturer) by the total length of tubing.

5. During purging, measure the following groundwater quality parameters: pH, temperature, electrical conductivity, turbidity, DO, and ORP will be recorded every three to five minutes. After purging of one tubing and pump volume, three successive reading of the water quality parameters must be stabilized prior to sampling as outlined in the *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers* (EPA, 2002). The parameters will be considered stable when three consecutive readings, collected at intervals of at least five minutes, are within:

Conductivity	±3%
pH	±0.1 units
Temperature	±1 degree Celsius
Dissolved Oxygen	±0.3 mg/l
ORP	±10 millivolts
Turbidity	<5 NTU.

However, if the turbidity is not ≤ 5 NTU, but is stable (within ± 10 percent between readings) within a four-hour period, and all other parameters are stable, the samples will be collected. Once the parameters have stabilized begin to collect the samples.

6. If the well produces water at an extremely slow rate and excessive drawdown is occurring (> 0.30 feet.), even at a pumping rate of 100 ml/min, low-flow procedures may not be the best sampling method for the well.

5.0 GROUNDWATER SAMPLE COLLECTION PROCEDURES FOR EXTRACTION OR PRODUCTION WELLS

Extraction wells will be sampled in a similar manner to monitoring wells, although allowances must be made for the type of pumping equipment already installed in the well. The following steps will be taken in collecting samples from extraction or production wells:

1. Inspect the well.

2. Sample from the sampling ports located inside the Site groundwater treatment system building.
3. Open the valve and allow three borehole volumes of water to be purged.
4. Prior to collecting samples intended for VOC analyses, reduce the flow rate to approximately 100 ml/min. .

Fill sample containers with water directly from the sampling port as described under Section 4.3.

6.0 PURGE WATER HANDLING AND DISPOSAL

Because of the potential for spreading environmental contamination, proper purge water disposal is a necessary part of well monitoring. All purge water will be contained in either buckets or a portable storage tank (water wagon). It is acceptable to contain small amounts of purge water in small sampling containers (e.g., covered 5-gallon buckets, 5-gallon plastic distilled water bottles). For most groundwater sampling activities, purge water will be disposed of as stipulated in project-specific plans at the US Magnesium Facility.

7.0 REFERENCES

Puls, R.W. and M.S. Barcelona, 1989. Ground Water Sampling for Metals Analyses, Superfund Ground Water Issue, EPA/540/4-89/001, March 1989.

Puls, R.W. and M.S. Barcelona, 1996. Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures, Ground Water Issue, EPA/540/S-95/504, April 1996.

U.S. Environmental Protection Agency (USEPA), 1986. RCRA Ground-water Monitoring: Technical Enforcement Guidance Document, November 1992.

SOP-21
Collection of Surface Water Samples

Note: This document is proprietary, revision controlled, and is intended strictly for use by Stantec and its teaming partners or subcontractors in support of specific contractual responsibilities. Copying and further dissemination in any manner is not permitted without written authorization by the responsible Stantec Project Manager, except as may be agreed upon by Stantec and its clients in the terms and conditions of applicable contracts.

1.0 SCOPE

The purpose of this document is to define the standard operating procedures (SOP) for the collection and handling of surface water samples. This SOP applies to any work performed by Stantec or subcontractor personnel for any portion of surface water sampling and is intended for use in conjunction with site-specific workplans or sampling and analysis plans (SAPs). Modifications to this SOP may be made with approval of the Project Manager or Task Leader and the Quality Assurance (QA) Manager. Sampling locations shall be as specified in the governing workplan or SAP.

2.0 RESPONSIBILITIES

2.1 Field Sampling Engineer

The Field Sampling Engineer is responsible for sample collection, sample custody in the field, sample preservation, field testing, total and accurate completion of data sheets, sample shipment and delivery of data to the Project Manager, as described in this technical procedure. All staff are responsible for reporting deviations or nonconformance of the procedure to the Field Team Leader, Project Manager, or Quality Assurance (QA) Manager, in compliance with the governing workplan or SAP requirements.

2.2 Field Team Leader

The Field Team Leader is responsible for supervising the Field Sampling Engineers. Supervision includes ensuring that samples are collected, documented, preserved, field analyzed, handled and shipped to the appropriate laboratory as specified in project work documents and this technical procedure.

2.3 Project Manager

The Project Manager has overall management responsibilities for the project, is responsible for designing the sampling program, for arranging the logistics of the program, and for providing any required clarifications in the use of this procedure. The Project Manager may assume the responsibilities of the Field Team Leader on smaller projects.

The Project Manager is also responsible for maintaining project files and filing project documents, project correspondence, chain of custody forms, sediment sampling forms, generated data, and other associated and pertinent project information.

2.4 QA Manager

The QA Manager is responsible for developing and managing procedures outlined in the SOPs and in site specific SAPs, QA plans, and/or workplans.

3.0 DISCUSSION

The methods described by this procedure may be used to acquire water samples for chemical or radiological analysis. Methods should be selected at the discretion of the Field Team Leader or Project Manager in accordance with any specific provisions of governing SAPs, QA plans, and/or workplans.

4.0 PROCEDURES

This SOP describes collecting surface water samples at four different types of water bodies, streams, seeps, reservoir or lakes, and standing water locations (ponds). Sample documentation and labeling, as well as, sampling frequency, locations, volumes and analyses shall be as specified in the governing workplan or SAP.

4.1 Decontamination

Before sampling at a new location, all water sample collection equipment will be decontaminated by rinsing the water collection equipment three times with source water, or as specified in the governing workplan or SAP.

4.2 Instrument Calibration

Electronic equipment used during sampling to obtain field parameters will include, but is not limited to, a pH meter with automatic temperature compensation, a specific conductivity meter, a dissolved oxygen meter, a turbidity meter, and an oxidation-reduction potential meter (ORP or eH). Before going into the field, the field team leader will verify that all equipment is operating properly. Calibration, times and appropriate readings will be recorded in the field notebook and as specified in the governing workplan or SAP. Meters will be calibrated according to manufacturer's instructions.

4.3 Filtering

Samples to be analyzed for dissolved state will be filtered during the field sampling event by using a disposable 0.45

micron filter apparatus and peristaltic pump, vacuum pump, syringe, or equivalent equipment. Other samples for a particular analysis may require filtering as specified in the governing workplan or SAP. Filtered samples will be collected according to the following procedure:

- Assemble filter device according to manufacturer's instructions.
- Filter sample either by pouring sample in the top portion of filter unit or pumping it through an in-line filter using the pump or syringe.
- Transfer filtered sample to appropriate sample bottle with required preservative.
- Dispose of the used filter and tubing.
- Decontaminate any reusable filtering equipment. Place decontaminated equipment in a clean plastic bag or container for transportation between sampling locations.

4.4 Obtaining Water Samples

The following general procedures will be used before collecting surface water samples:

- Describe physical characteristics of the water source to be sampled, including type (seep, pond, waste pond, stream, reservoir, lake, etc.), any visual discoloration of water, odor, clarity, or any other notable characteristic of the water source.
- Collect field measurements of water quality parameters.
- Assemble all necessary sample collection and filtering equipment.

- Make sure that the sample labels have been correctly filled out for the sampling location. Assemble bottles for filling.
- Decontaminate sample collection equipment by rinsing the equipment three times with source water.
- Collect water sample. Ideally, the sample will be taken from a point away from where the rinsing of collection equipment occurred when sampling standing water or upstream of the rinsing point when collecting flowing water. The water collection container will be lowered into the water, taking care to avoid collecting items floating in the water and disturbing any sediment during sample collection. After the container is filled, carefully lift it out of the water and empty it into a clean sample composite container. Repeat the process at the sampling location until a sufficient amount of sample has been placed into the composite container as described below. The amount of sample to be composited shall be as specified in the governing workplan or SAP.
- Transfer to appropriately labeled containers

4.4.1 Seeps

Water samples will be collected by immersing the sample transfer container as described above, or for a raw sample, the sample container in the water source. This collection method results in a grab sample that characterizes the medium at a point in space and time, and assumes that the water body sampled (seep) is homogeneously mixed and has no stratification. Water sample collection from seeps will be done closest to the point of discharge as possible, to minimize contamination from surficial contact.

4.4.2 Ponds

Water samples will be collected by immersing the sample transfer container as described above, or for a raw sample, the sample container in the water source. This collection method results in a grab sample that characterizes the medium at a point in space and time, and assumes that the water body sampled (pond) is homogeneously mixed and has no stratification due to its small size. Collecting water samples from standing water will have the emphasis placed upon the sampler limiting disturbance to the water to be sampled, and the use of a sampler that can collect a sample as far from the shoreline as possible. This method will be especially important when collecting samples from ponds that have loose material and high gradient slopes that define the pond shoreline. This will also be important to minimize the immersion risk of sampling personnel. Water samples for ponds may be collected from any point along the shoreline.

4.4.3 Channels and Ditches

Samples will be collected from the same cross section of the ditch or channel as that which is used for the discharge (flow) measurement, if discharge is measured. Samples can be collected with a peristaltic pump or dipper cup using extension rods. Samples will always be collected prior to making discharge measurements if discharge measurements are required. If sampling multiple stations on the same ditch or channel, downstream samples will always be collected first. Prior to sampling, the ditch or channel will be observed for any upstream activities or events that may affect the sample quality. If such events are occurring, the sample will not be collected until the flow clears and the occurrence will be recorded in the field notes.

Selection of sampling methods and equipment based on flow conditions is as follows:

- If the ditch or channel is less than 10 ft wide, the sample will be collected from the center of the flow at mid-depth.
- If the ditch or channel is greater than 10 ft wide, one composite, consisting of three samples will be collected. The water samples will be taken at ¼, ½, and ¾ of the distance across the river or stream cross-section. These samples should be taken at mid-depth in the water column at each location across the stream channel. All three samples will be composited into one larger container, and apportioned as necessary, into the appropriate sample containers.

Water will be collected from smaller ditches and channels using a peristaltic pump or dipper cup. The dipping cup is a Teflon® or stainless steel cup with an extendable handle that allows for sample collection without the sampler having to enter the water body.

The water inside the dipper cup will then be transferred to a clean composite container. The process will be repeated at the sampling location until a sufficient amount of sample has been placed into the composite container. When a sufficient amount has been collected, transfer the water from the composite container into the appropriate sample containers. The method of sample collection shall be recorded in the field notebook.

4.5 Sampling Documentation

A field sampling data sheet will be completed at each sample location. Items not applicable to the sampling will be labeled as not applicable (NA). Sampling information will also be recorded in a bound field notebook. The information recorded on the data sheet and in the field notebook will include the following:

- Sampling location
- Date and time of sampling
- Persons performing the sampling
- Field water quality parameter measurements (specific conductivity, temperature, dissolved oxygen, pH, oxidation-reduction potential, etc.)
- Physical description of the water body to be sampled (color, odor, etc.)
- Sample identification numbers
- Number of samples taken- note containers, analytes, filtering and preservation methods
- Identification numbers of any QC samples from the site
- Any irregularities or problems which may have a bearing on sample quality

4.6 Equipment List

Sample bottles and preservatives (ultra-pure or metal grade nitric acid) will be obtained from the laboratory selected to perform the chemical analyses of the samples. Extra sample bottles with appropriate preservatives will be obtained in case of breakage or other problems.

Equipment used during surface water sample collection includes:

- Camera
- Chain of custody
- Coolers with ice/blue ice
- Copy of this SOP (if applicable) and the governing workplan or SAP
- Filtering apparatus with disposable 0.45 micron filters
- Hand pump, peristaltic pump, vacuum pump, or equivalent equipment
- Plastic HDPE sample containers
- Spray bottle filled with distilled water
- Plastic trash bags
- pH/eH meter (with automatic temperature compensation)
- Rope if obtaining deep samples
- Rite-in-the-Rain™ field notebook or equivalent
- Laboratory provided sample containers
- Sample labels
- Strapping and clear tape
- Turbidity meter if required
- Silicon tubing
- Writing instruments
- Measuring tape

The governing workplan or SAP may require the use of other equipment based on the scope and objective of an individual project. Project personnel will review the workplan or SAP for any equipment not listed in this SOP.

4.7 Field Quality Assurance/Quality Control Samples

Field QA/QC sample requirements shall be as specified in the governing workplan or SAP.

4.8 Sample Containers

All sample bottles must be properly cleaned and prepared. Coordinate with selected analytical laboratory for appropriate sample bottle types and preparation requirements. Plastic, such as PVC, polyethylene, polypropylene, and Tygon, is an acceptable material for contacting samples when the analyses are for inorganic analytes (metals, radionuclides, anions, and cations). Stainless steel and fluorocarbon resin (Teflon, PTFE, FEP, HDPE, or PFA) are acceptable materials that may contact surface water samples. Glass is an acceptable material for contacting samples except when silica or fluoride analyses are to be performed.

4.9 Sample Handling

Sample handling procedures and chain of custody requirements shall be as specified in the governing workplan or SAP. Typical handling procedures for surface water samples are as follows:

- Store sample containers in coolers for transportation in compliance with the sample handling and chain of custody requirements specified in the workplan or SAP.
- Sample documentation and labeling requirements shall be as specified in the governing workplan or SAP.

All surface water samples shall be labeled and sealed and immediately placed in ice-filled coolers with securely closed lids for storage and transport. The analytical laboratory must receive samples in sufficient time to conduct the requested analyses within the specified holding time.

During surface water sampling operations, the proper personal protective equipment will be worn, as described in the applicable workplan or site safety and health plan, to minimize cross-contamination and to ensure the safety of the field sampling personnel.

Closure and Post-Closure Plan

Groundwater Discharge
Permit Application – Part C

Stantec

Prepared for:
US Magnesium

Prepared by:
Stantec

December 15, 2017

Sign-off Sheet

This document entitled Closure and Post-closure Plan was prepared by Stantec Inc. ("Stantec") for the account of US Magnesium LLC (US Magnesium). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the US Magnesium. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

Susan Eyzaguirre, PE, PG

Reviewed by _____

F. Michael DeDen, PG

Approved by _____

Hhan Olsen, PG

Table of Contents

1.0 INTRODUCTION 1

2.0 CLOSURE PLAN CONCEPT 1

2.1 SALT CAP BARRIER CONCEPT 2

2.2 SALT CAP BARRIER CONSIDERATIONS 3

3.0 POST-CLOSURE PLAN CONCEPT 3

3.1 POST-CLOSURE GROUNDWATER MONITORING 4

3.2 POST-CLOSURE FACILITY INSPECTIONS 4

3.3 POST-CLOSURE REPORTING 4

4.0 REFERENCES 4

Acronyms and Abbreviations

%	percent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	contaminant of potential concern
DWQ	Division of Water Quality
Facility	US Magnesium facility
FS	Feasibility Study
gpm	gallons per minute
GSL	Great Salt Lake
GWDP	Groundwater Discharge Permit
PCB	polychlorinated biphenyl
PCDF	polychlorinated dibenzofuran
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation and Feasibility Study
RWP	Retrofitted Waste Pond
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality

1.0 INTRODUCTION

This Closure and Post-closure Plan fulfills one of the requirements of Part C (Accompanying Reports and Plans) of the Groundwater Discharge Permit (GWDP) application for the US Magnesium facility (Facility) located in Rowley, Utah. The state of Utah requires a GWDP for facilities that may result in discharge of pollutants to groundwater. This plan complies with requirements outlined in Utah Administrative Code (UAC) R-317-6-6.3 and follows guidelines presented in the Utah Department of Environmental Quality (UDEQ) Division of Water Quality (DWQ) Ground Water Quality Protection Permitting Information Document (UDEQ, 2006).

The overall purpose of closure and post-closure activities for a facility that has been permitted under the Utah Groundwater Discharge Permit program is to limit long-term potential for groundwater to be impacted by the Facility after it is no longer in operation.

The groundwater discharge control system proposed for the GWDP is a Retrofitted Waste Pond (RWP) that includes installation of a hydraulic barrier wall. The RWP will be approximately 800 acres in size and has been designed to accommodate an average pond inflow of approximately 1100 gallons per minute (gpm). The Facility's plant wastewater will be treated for organic contaminants (with filtration technology) before it is discharged into the pond. Closure and post-closure plans will be implemented once US Magnesium decides to cease operations of the RWP.

Conceptual descriptions of anticipated closure and post-closure activities are described in this plan and are subject to change based on results of ongoing actions with EPA under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). The final closure and post-closure requirements for the pond will be selected under one of those programs. Once that occurs, a revised, and more detailed, Closure and Post-closure Plan will be submitted to the Utah DWQ to ensure that closure and post-closure requirements under the GWDP align with the final remedy selected under CERCLA or RCRA.

2.0 CLOSURE PLAN CONCEPT

Proposed methods to limit potential migration of impacted groundwater outside the RWP boundaries during the closure period are discussed in this section at a conceptual level. Final closure plan details will be presented in a revised Closure and Post-closure Plan to be submitted after final closure requirements are selected under the CERCLA or RCRA program.

Because much of the RWP area has been impacted by Facility wastewater discharged prior to construction of the RWP and issuance of the GWDP, closure activities will include implementation of a barrier technology to prevent low-pH wastewater, as well

as other constituents of concern that may be identified during the Remedial Investigation (RI) currently being conducted under CERCLA, from infiltrating into groundwater and migrating away from the RWP. As part of the RI, a risk assessment will be completed to assess environmental risks associated with impacts to groundwater and surface water across the proposed RWP area.

Also included in the CERCLA program, alternative remedies will be evaluated in a Feasibility Study (FS) and will include utilization of a hydraulic barrier wall and cap barrier technologies. A salt cap barrier treatability study, using naturally precipitated salts from Great Salt Lake (GSL) brine, is currently underway.

US Magnesium is not presenting a final closure plan for the RWP in this application because, as discussed above, decisions concerning final Facility closure will be made under federal RCRA or CERCLA programs. However, ongoing studies performed as part of a salt cap treatability study (ERM, 2016) suggest that a salt cap, utilizing GSL brine, would be a suitable solution to protect human and ecological receptors from exposure to pond sediments.

2.1 SALT CAP BARRIER CONCEPT

Closure of the RWP would begin with cessation of low-pH wastewater discharges, preferably at the start of the evaporation season (May). Surface wastewaters remaining in the pond will evaporate over the course of one or more years, at which point brine would be added to the pond and allowed to evaporate, creating over several years a three to five feet thick salt cap over the RWP area. Once the design thickness is established, the salt cap is expected to be durable, and any potential cracks created would heal naturally during precipitation events.

Final design of a salt cap barrier system would be conducted following completion of ongoing studies and approval by the governing agencies as described above. Preliminary studies suggest that use of a brine that is more concentrated than GSL water will result in higher salt accumulation rates and that the accumulated salt generally forms a level surface via preferential salt accumulation in depressions (ERM, 2017a). Less concentrated brines (i.e. GSL waters) may be used in the final season of salt cap construction as preliminary studies suggest such waters provide a smoothing effect due to some dissolution of deposited salt (which is offset by greater salt accumulation throughout the evaporative season)(ERM, 2017a).

Following closure, groundwater within the footprint of the RWP will be neutralized through interactions with high carbonate content sediments beneath the RWP and mixing with circum-neutral waters from infiltration of precipitation (direct and surface runoff) and inflow of upgradient groundwater. Groundwater beneath the RWP would be inhibited from migrating to the surrounding aquifer by the hydraulic barrier wall and the low-permeability Deeper Silty Clay Unit into which the barrier wall will be keyed (at approximately 40 feet below ground surface).

Seasonal accumulation of precipitation on the salt cap is expected; however, these surface waters will be contained within the footprint of the RWP until climatic conditions allow for evaporation or they infiltrate into the contained groundwater. Infiltrating precipitation is not expected to mobilize organic contaminants of potential concern (COPCs) in the unsaturated zone into the underlying groundwater (refer to more detailed discussion below in Section 2.2).

2.2 SALT CAP BARRIER CONSIDERATIONS

A potential issue with a salt cap barrier for the RWP area is that COPCs found within the sediments of the pond may migrate (leach) into the brine during initial application, causing the COPCs to be present in the salt cap itself. Preliminary results of the ongoing Salt Cap Chemical Compatibility study indicate that the only COPCs that have potential to migrate into the salt cap are polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans (PCDF). PCBs and PCDFs leached at values of 0.05% by weight (sediment concentration compared to brine concentration) or less with the exception of monochlorobiphenyl homologs, which leached at 2% by weight (ERM, 2017b). Even at the high end this would result in extremely low concentrations of COPCs within the salt cap itself, and these COPCs would be deposited into a crystalline halite salt matrix that would function effectively as a barrier to ingestion by ecological receptors (ERM, 2017b). Additionally, infiltrating precipitation is not expected to transport COPCs within sediments of the unsaturated zone into the underlying groundwater because interaction of precipitation with the salt cap will increase the salt content of the infiltrating water, thus decreasing the solubility of the large, non-polar organic COPCs via the 'salting-out effect' (ERM, 2017b).

Another issue may be the potential for groundwater to flow out of the upgradient (west) side of the RWP during the closure and post-closure periods. While the regional groundwater recharge into the RWP footprint is minimal (50 gpm) considering the size of the pond, there remains potential for groundwater to discharge near the upgradient side of the barrier wall. This scenario will be evaluated during the detailed design of the groundwater discharge control system. If groundwater discharge out of the upgradient side of the RWP is identified as an issue, a mitigation system, such as addition of a drainage trench to direct a portion of the groundwater inflow around the RWP, will be considered.

3.0 POST-CLOSURE PLAN CONCEPT

Post-closure activities will begin after US Magnesium has ceased operation of the RWP, and will include groundwater quality monitoring in the area immediately downgradient of the RWP.

3.1 POST-CLOSURE GROUNDWATER MONITORING

Annual groundwater sampling is proposed for the first five years of the post-closure period. A network of groundwater monitoring wells located downgradient of the RWP will be maintained and will include a subset of the monitoring wells used for compliance groundwater sampling as described in the Compliance Monitoring Plan (Stantec, 2017).

Identification of post-closure groundwater sampling points and sampling parameters/analytes will be presented in a revised Closure and Post-closure Plan to be submitted after final post-closure requirements are selected under the CERCLA or RCRA program.

3.2 POST-CLOSURE FACILITY INSPECTIONS

Regular facility inspections will be conducted, and findings will be reported in routine post-closure reports. Completed inspection forms will be attached to the reports.

Ongoing inspections of groundwater monitoring facilities will be conducted on a semiannual basis. The condition of compliance monitoring wells and piezometers will be inspected and findings will be recorded.

The general condition of the RWP berms also will be inspected semiannually, and significant erosion or evidence of animal burrowing will be noted.

3.3 POST-CLOSURE REPORTING

An annual reporting frequency is proposed for the first five years of the post-closure period. After five years of post-closure monitoring, data will be reviewed and revisions to the post-closure groundwater monitoring plan will be recommended as appropriate.

4.0 REFERENCES

ERM, 2016. Final Tier 1 Salt Cap Treatability Study Work Plan. US Magnesium, LLC, Rowley, Utah. April 2016.

ERM, 2017a. Post-2017 Evaporation Season Monitoring at Salt Cap Accumulation Test Pond Technical Memorandum. US Magnesium, LLC, Rowley, Utah. November 16, 2017.

ERM, 2017b. Salt Cap Chemical Compatibility Technical Memorandum. US Magnesium, LLC, Rowley, Utah. May 26, 2017.

Stantec, 2017. US Magnesium Groundwater Discharge Permit Compliance Monitoring Plan. December 2017.

UDEQ, 2006. Ground Water Quality Protection Permitting Information Document. Utah Department of Environmental Quality Division of Water Quality Ground Water Protection Section. December 2006.

Contingency and Corrective Action Plan

Groundwater Discharge
Permit Application – Part C

Stantec

Prepared for:
US Magnesium

Prepared by:
Stantec

December 15, 2017

Sign-off Sheet

This Groundwater Discharge Permit application document entitled Contingency and Corrective Action Plan was prepared by Stantec for the account of US Magnesium LLC (US Magnesium). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and US Magnesium. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

Susan Eyzaguirre, PE, PG

Reviewed by _____

F. Michael DeDen, PG

Approved by _____

Hhan Olsen, PG

Table of Contents

1.0 INTRODUCTION 1

2.0 CONTINGENCY PLAN 1

2.1 CONTINGENCY PLAN IMPLEMENTATION CRITERIA 1

2.2 CONTINGENCY RESPONSE ACTIONS 2

2.2.1 Notifications 2

2.2.2 Compliance Investigation 2

2.2.3 Contingency Response Action Options 3

3.0 CORRECTIVE ACTION PLAN 4

4.0 REFERENCES 4

LIST OF TABLES

Table 2-1 Contingency Response Action Options

Acronyms and Abbreviations

AOC	Agreement and Order on Consent
BAT	best available technology
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DWQ	Division of Water Quality
Facility	US Magnesium facility
GWDP	Groundwater Discharge Permit
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RWP	Retrofitted Waste Pond
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality

1.0 INTRODUCTION

This Contingency and Correction Action Plan describes the contingency responses and corrective actions to be followed under the US Magnesium Retrofitted Waste Pond Groundwater Discharge Permit (GWDP). This plan fulfills one of the requirements of Part C (Accompanying Reports and Plans) of the GWDP application for the US Magnesium facility (Facility) located in Rowley, Utah. This plan complies with requirements outlined in Utah Administrative Code (UAC) R-317-6-6.3, and follows guidelines presented in the Utah Department of Environmental Quality (UDEQ) Division of Water Quality (DWQ) Ground Water Quality Protection Permitting Information Document (UDEQ, 2006).

The remainder of this plan is divided into two primary sections:

- Section 2.0, Contingency Plan. This section presents response options to be implemented if GWDP limits are exceeded.
- Section 3.0, Corrective Action Plan. This section summarizes historical Facility impacts to groundwater and discusses potential remedial actions that may be conducted under the Federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or under the Resource Conservation and Recovery Act (RCRA).

2.0 CONTINGENCY PLAN

In the event permit compliance limits are exceeded, decision logic and response options for US Magnesium to regain and maintain compliance with the established GWDP limits are presented in this section. Contingency plan response action options will be selected and implemented to confirm that best available technology (BAT) is implemented, as necessary, based on evaluation of compliance monitoring data.

2.1 CONTINGENCY PLAN IMPLEMENTATION CRITERIA

Contingency plans will be implemented when either of the following noncompliance conditions are observed:

1. Groundwater Protection Level Exceedance. This condition is indicated when groundwater sampling data for one or more compliance sampling points do not meet GWDP groundwater protection levels for three consecutive monitoring rounds.
2. Loss of Hydraulic Containment. Loss of hydraulic containment may be indicated based on one or both of the following conditions:
   - When groundwater level data from compliance monitoring points suggest potential loss of pond water hydraulic containment for three consecutive monitoring rounds.

- When a RWP wastewater release to the surface outside the RWP boundary is observed due to a breach in, lateral leakage through, or overtopping of the embankment.

As indicated in the Compliance Monitoring Plan (Stantec, 2017), groundwater protection levels will be established as the mean plus two times the standard deviation of baseline data for each groundwater sampling compliance well/piezometer.

2.2 CONTINGENCY RESPONSE ACTIONS

2.2.1 Notifications

US Magnesium will notify the DWQ within 24 hours of detecting/observing a criterion that triggers the contingency plan as described above in Section 2.1. Specifically, notification within 24 hours will be made if a Groundwater Protection Level is exceeded at a given compliance point for three consecutive monitoring rounds, if loss of hydraulic containment is indicated by groundwater level data at the same location for three consecutive monitoring rounds, or if a RWP wastewater release to the surface outside the RWP boundary is observed.

A letter from US Magnesium outlining a plan to address a noncompliance condition will be submitted to the DWQ within 30 days of US Magnesium's detection of a noncompliance condition (UAC R317-6-6.17). The letter will include the following:

- A time schedule for completion of a Compliance Investigation (see Section 2.2.2 for a detailed description), during which an assessment of the source or cause of the noncompliance condition will be conducted
- An initial assessment of the extent of impacts to groundwater
- Identification and evaluation of potential response actions to address the noncompliance condition.

All exceedances of permit protection levels at any compliance point, or indications of hydraulic containment loss stemming from groundwater level data, also will be reported in the next regular monitoring report.

2.2.2 Compliance Investigation

If any noncompliance condition occurs (Section 2.1), a Compliance Investigation will be conducted. A Compliance Investigation report will be submitted to DWQ within 120 days of US Magnesium's detection of the noncompliance condition. The Compliance Investigation may include additional data collection (i.e., groundwater sampling, source water sampling, groundwater-level monitoring, or other investigation methods).

The primary objectives of the Compliance Investigation will be to:

- Assess the cause(s) of the observed noncompliance condition

- Identify the groundwater discharge control system component, including location and extent of that component, that may not be functioning as designed
- Evaluate the areal extent and potential future migration/dispersion of impacted groundwater
- Identify the most appropriate next step(s).

The most practicable and feasible response action will be proposed, which may include a human health and/or environmental risk assessment.

2.2.3 Contingency Response Action Options

Based on Compliance Investigation results, an appropriate response action(s) will be selected, and upon approval by DWQ will be implemented by US Magnesium. Potential contingency response actions are listed in **Table 2-1** below.

Table 2-1
Contingency Response Action Options

Response Action Options	Applicable to the following Noncompliance Condition:		Comment
	Exceedance of Groundwater Protection Level	Loss of Hydraulic Containment	
Monitor natural attenuation of impacted groundwater	X		To be implemented in the affected area
Pump impacted groundwater back into waste pond	X	X	To be implemented in the affected area
Reinforce hydraulic barrier wall	X	X	To be implemented along the barrier wall length identified as compromised
Evaluate performance of wastewater treatment system and improve as appropriate	X		
Propose alternate groundwater protection levels that would reduce risk(s) to acceptable levels	X		Based on human health and/or environment risk assessment results (UAC R317-6-6.15 G)
Propose an alternative best available technology (BAT), or modification of the BAT prescribed in the GWDP	X	X	

3.0 CORRECTIVE ACTION PLAN

UDEQ guidance (UDEQ, 2006) indicates actions to address groundwater impacts in the vicinity of the proposed Retrofitted Waste Pond (RWP) caused by Facility operations that occurred prior to GWDP issuance are to be addressed in this GWDP Corrective Action Plan. However, for the US Magnesium GWDP, pre-existing groundwater impacts from historic activities conducted at the Facility outside the hydraulic containment system of the RWP will be addressed under the federal CERCLA program. Pre-existing groundwater impacts and impacts associated with continued discharge of process wastewater within the hydraulic containment system of the RWP are addressed in the Closure and Post-Closure Plan or under the RCRA program.

As outlined in UAC R317-6-6.15 Part C, the DWQ may at their discretion call for a Contamination Investigation and Corrective Action Plan to be submitted; however, Part A-3 of this regulation indicates that corrective actions implemented under other federal or state programs may be accepted if they meet the substantive requirements of the rule.

> *"The procedural provision of R-317-6.15 shall not apply to any facility where a corrective or remedial action for groundwater contamination, that the Director determines meets the substantive standards of this rule, has been initiated under any other state or federal program."*
> *--UAC R-317-6.15 Part A-3*

Remedial Investigation and Feasibility Study (RI/FS) activities are currently ongoing at the Facility as required in an August 2011 Agreement and Order on Consent (AOC) under CERCLA. The RI is currently addressing impacts to groundwater and surface water across the proposed RWP area, and the final remedy selected for areas regulated under CERCLA will be based on FS conclusions and described in a Record of Decision. In addition, US Magnesium and EPA are attempting to settle an ongoing RCRA enforcement action. A Consent Decree resolving the RCRA action may contain requirements for corrective action related to groundwater impacts within the hydraulic containment system of the RWP.

4.0 REFERENCES

Stantec, 2017. US Magnesium Groundwater Discharge Permit Compliance Monitoring Plan. December 2017.

UDEQ, 2006. Ground Water Quality Protection Permitting Information Document. Utah Department of Environmental Quality Division of Water Quality Ground Water Protection Section. December 2006.