Retrofitted Waste Pond Phases 1 and 2 Basis of Design Report

US Magnesium Facility

February 28, 2022

PREPARED FOR

US Magnesium LLC
238 North 2200 West
Salt Lake City, UT 84116

PREPARED BY

Tetra Tech
4750 West 2100 South
Suite 400
Salt Lake City, UT 84120

PROFESSIONAL ENGINEER CERTIFICATION

I hereby certify, as a Professional Engineer in the State of Utah, that the information in this document was assembled under my direct supervisory control. This report is not intended or represented to be suitable for reuse by US Magnesium LLC or others without specific verification or adaptation by the Engineer.

I hereby certify, as a Professional Engineer in the State of Utah, that this document has been prepared in accordance with industry standards and best-practices.

Chad Tomlinson

Chad Tomlinson, P.E.

February 28, 2022
Date

TABLE OF CONTENTS

1. INTRODUCTION 1
- 1.1 Purpose and Scope 1
- 1.2 Project Background 2
  - 1.2.1 Facility Description 2
  - 1.2.2 Historical Waste Pond Operations 2
  - 1.2.3 Groundwater Discharge Permit 3
- 1.3 Supporting Predesign Studies 3
  - 1.3.1 Water Balance Model Addendum 3
  - 1.3.2 Geochemical Evaluation Update 3
  - 1.3.3 Soil Boring Investigation 3
  - 1.3.4 Groundwater Flow Modeling 3
  - 1.3.5 Slurry Wall Compatibility Study 4
- 1.4 Project Phasing 5
- 1.5 Regulatory Requirements 5

2. GENERAL DESIGN CRITERIA FOR PHASE 1 AND 2 6
- 2.1 Survey Data 6
  - 2.1.1 Geodetic Datum 6
  - 2.1.2 Vertical Datum 6
  - 2.1.3 Topographical Survey Data 6
- 2.2 Retrofitted Waste Pond Water Balance Modeling and Sizing 6
  - 2.2.1 Summary of Water Balance Modeling 6
  - 2.2.2 Maximum Operating Water Level 6
  - 2.2.3 Wave Run-Up Allocation 6
- 2.3 Design Life 7
- 2.4 Hydraulic Barrier Wall Performance Criteria 7

3. GEOTECHNICAL INVESTIGATIONS 8
- 3.1 Site Geology 8
- 3.2 Field Investigations 8
  - 3.2.1 Embankment Foundation 8
  - 3.2.2 Borrow Source Area 9

4. EMBANKMENT DESIGN 11
- 4.1 General Embankment Configuration 11
- 4.2 Embankment Foundation 11
- 4.3 Construction Material 11
- 4.4 Slope Stability Assessment 11

5. HBW DESIGN 12
- 5.1 Summary of Compatibility Testing Results 12
- 5.2 HBW Design 12
  - 5.2.1 HBW Alignment 12
  - 5.2.2 HBW Thickness 12
  - 5.2.3 HBW Working Platform 12
  - 5.2.4 HBW Trench Depth 12

5.2.5 Trench Slurry 13
5.2.6 HBW Soil-Clay Backfill 13
5.2.7 HBW Performance Testing 14
5.2.8 Protection of Work 14
6. REFERENCES 15

TABLES

Table 3.1 March 2019 Borehole Generalized Lithology and Details
Table 3.2 Geotechnical Test Results for Undisturbed Samples
Table 3.3 Geotechnical Test Results for Disturbed Samples

FIGURES

Figure 1-1 US Magnesium Location Map
Figure 1-2 Retrofitted Waste Pond Area Map

APPENDICES

Appendix A: Water Balance Modeling Report
Appendix B: Geochemical Evaluation
Appendix C: Embankment Boring Logs and Standard Penetration Test Results
Appendix D: Borrow Source Data
Appendix E: Phase 1 Design Drawings
Appendix F: Earthwork and HBW Specifications
Appendix G: Construction Quality Assurance Plan
Appendix H: Slope Stability Assessment
Appendix I: Soil-Clay Backfill Compatibility Test Report
Appendix J: Phase 2 Design Drawings

ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
bgs	below ground surface
BOD	basis of design
BSA	borrow source area
CWP	Current Waste Pond
CY	cubic yards
cm/s	centimeters per second
DWQ	Division of Water Quality
EPA	U.S. Environmental Protection Agency
Facility	US Magnesium Rowley Facility
ft	foot/feet
GDWP	Groundwater Discharge Permit
GLEI	Great Lakes Environmental and Infrastructure
GSL	Great Salt Lake
H:V	Horizontal to vertical
HBW	hydraulic barrier wall
NAD	North American Datum
NAVD	North America Vertical Datum
MDD	maximum dry density
OMC	optimum moisture content
OWP	Old Waste Pond
PI	plasticity index
Project	Retrofitted Waste Pond Project
RWP	Retrofitted Waste Pond
SB	soil boring
SPT	Standard Penetration Test
Stantec	Stantec Consulting Services Inc.
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
USEPA	United States Environmental Protection Agency
US Magnesium	US Magnesium LLC

1. INTRODUCTION

Tetra Tech, Inc. (Tetra Tech) has prepared this report to present the basis of design (BOD) for the Retrofitted Waste Pond (RWP) at US Magnesium LLC's (US Magnesium's) Rowley facility (Facility). The Facility processing plant produces a low-pH wastewater stream that is currently discharged to unlined evaporation ponds. The RWP is designed for the US Magnesium Facility (Facility) to meet requirements outlined in Utah Administrative Code (UAC) R317-6, Ground Water Quality Protection and the Utah Department of Environmental Quality (UDEQ) Division of Water Quality (DWQ) Groundwater Discharge Permit (GDWP) UGW450012, effective December 18, 2018 and modified August 12, 2020, for the construction of pond embankments and a vertical hydraulic barrier wall (HBW) along the cross-gradient and downgradient sides of the RWP.

The GWDP modified August 12, 2020 included DWQ's authorization to construct ("construction permit") for the earthen embankments associated with Phase 1 of the RWP project. US Magnesium proceeded to contract with a qualified construction contractor (Odin Construction Solutions) and construction quality assurance and engineering contractor (Tetra Tech, Inc.) and commenced mobilization for and construction of the RWP Phase 1 embankments on July 1, 2021. RWP Phase 1 construction is in-progress as of the date of this Basis of Design Report.

On June 30, 2021, the United States District Court for the District of Utah entered a Consent Decree (CD), Case No. 2:01CV0040B, which among other requirements, incorporates the RWP design and construction in CD Section VII (CERCLA Response Action) and Appendix 12 (Statement of Work for the CERCLA Response Action). As of the June 30, 2021 Effective Date of the CD, US Magnesium has and will submit RWP project design and construction documents to DWQ and the USEPA On-Scene Coordinator (OSC) and Alternate OSC.

1.1 Purpose and Scope

The RWP design is divided into three phases, the first phase (Phase 1) includes the RWP perimeter earthen embankment to the top elevation of the planned HBW, the second phase (Phase 2) includes the HBW, and the third phase (Phase 3) will include the additional embankment height to be constructed above the top of the HBW to meet the final crest elevation. RWP project [the Project] phases are described in more detail in Section 1.4.

This document describes the basis on which Phases 1 and 2 of the RWP design have been developed. This document will be updated again when the RWP Phase 3 design is completed. The following topics and RWP Phases 1 and 2 design components have been considered and are outlined in this report:

- Project background
- Supporting predesign studies
- Project phasing
- Applicable standards and regulatory requirements to be considered in the design
- General design criteria including:
    - Topographical survey information
    - RWP water balance modeling and sizing requirements
    - Existing site conditions
    - RWP design life
- Investigation completed in support of the design
- Embankment design (Phase 1)
- HBW Design (Phase 2)

1.2 Project Background

1.2.1 Facility Description

US Magnesium has operated the Facility, located in Tooele County along the west shore of Great Salt Lake (GSL), since 1972. The Facility is situated in Lakeside Valley, an extension of Skull Valley, Utah, at an elevation of approximately 4,220 feet (ft) above mean sea level (amsl) (**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. The production process involves electro-chemically producing 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). Facility wastewater is discharged through a 36-inch conveyance pipe to the Current Waste Pond (CWP).

USM completed construction of its lithium carbonate production plant ("Li2CO3 plant") in June 2020 and began commissioning, start-up and shakedown. The Li2CO3 plant began production during August 2020. Maximum wastewater flow from the Li2CO3 plant at its full production rate remains consistent with the estimated 282 gallons per minute maximum stated in the Updated Water Balance Modeling Report, Stantec, June 25, 2019.

1.2.2 Historical Waste Pond Operations

1.2.2.1 Old Waste Pond

Prior to using the US Magnesium CWP to store wastewater at the Facility, the Old Waste Pond (OWP), located east of the CWP, was utilized for wastewater disposal (**Figure 1-2**). The approximate 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 secondary dike was constructed surrounding the OWP in 1980 in response to observed seepage along its eastern extents. 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 the Great Salt Lake) (GSL) waters due to rising lake levels and wastewater was diverted to a holding area while dike repairs were conducted. 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 OWP dike, flooding the evaporation ponds including Solar Evaporation Pond 1 West. This required wastewater flows to be directed to the current CWP which was developed in low-lying mudflats separated from the GSL lakebed (and OWP) by southeast oriented beach ridges. The OWP was subsequently inundated by GSL waters and remained inundated until the early 1990s when the lake level receded and the dikes surrounding the OWP were repaired. The OWP has occasionally received water from seepage through the eastern dike of the CWP, notably in April 2012 and spring/summer 2015 (ERM, 2016), and GSL water breaches in the mid-1980s. Currently the CWP and OWP are connected through an overflow pipe that was installed in November 2018 at an invert elevation of 4214.5 (**Figure 1-2**). The overflow pipe helps maintain lower water levels in the CWP and limits hydraulic head on the pond dikes, therefore decreasing the possibility for wastewater to escape the ponds by underground or surface flow. Discharges through the overflow pipe to the OWP have since occurred intermittently and primarily in the spring.

1.2.2.2 Current Waste Pond

The Facility currently utilizes the CWP, an approximate 285-acre wastewater impoundment, which receives wastewater flows from Facility processes and stormwater flows that are conveyed through a new 36-inch conveyance pipe installed in February 2019 (**Figure 1-2**). An additional wastewater stream, a gypsum-based slurry, discharges to the northern end of the CWP which, over time, has created a rust-colored delta-shaped gypsum deposit within the impoundment.

1.2.3 Groundwater Discharge Permit

To address concerns regarding wastewater containment and potential contamination of groundwater resources from ongoing operation of the CWP, US Magnesium submitted a groundwater discharge permit application to DWQ on December 15, 2017. The proposed discharge control system design concept, as presented in the Groundwater Discharge Control Plan (Stantec, 2017a), consists of combining the CWP and OWP into one large RWP by installing a perimeter embankment and a HBW that keys into a low-permeability confining layer, the Deeper Silty Clay Unit (Stantec, 2017a and 2017b).

On December 19, 2018, the DWQ issued GWDP UGW450012, which provided approval to proceed with compliance items identified in the permit application. On August 12, 2020, DWQ issued a renewal of GWDP UGW450012 that was modified to incorporate the RWP Phase 1 design deliverable and includes the Construction Permit for the Retrofitted Waste Pond Phase 1 – Embankment Construction. Consistent with the requirements of the GWDP, the RWP Phase 2 design has been added to this Basis of Design Report and the Phase 2 design package is being submitted for review and approval by the DWQ.

1.3 Supporting Predesign Studies

To support detailed design of the RWP, the following investigations and studies have been performed or are ongoing.

1.3.1 Water Balance Model Addendum

A water balance study was performed to evaluate and verify that the pond area and embankment height of the proposed RWP are sufficiently sized. The water balance model included in the Groundwater Discharge Permit (GWDP) application's Groundwater Discharge Control Plan (Stantec, 2017a) was revised in 2019 to support the detailed design of the RWP, which includes an expanded pond area and additional wastewater discharge flow from the lithium plant. This updated model is reported as an addendum to the 2017 model and is attached to this report as **Appendix A**. Conclusions as they pertain to the RWP design are discussed further in Section 2.2.1 and 2.2.2 of this report.

1.3.2 Geochemical Evaluation Update

Because sediments underlying the RWP area contain materials potentially reactive with the low-pH wastewater, a geochemical evaluation was conducted and included in the 2017 GWDP application's Groundwater Discharge Control Plan (Stantec, 2017a). This evaluation was updated in 2019 as required in the GWDP, and accounts for a revised wastewater discharge rate due to the lithium plant wastewater flows (282 gpm at full lithium plant production rate) as well as an increased RWP area (**Figure 1-2**). The updated 2019 geochemical evaluation is attached to this report as **Appendix B**. Based on this updated evaluation, carbonates in the Upper Aquifer Zone will likely provide neutralization capacity for wastewater that will last for hundreds of years.

1.3.3 Soil Boring Investigation

To augment historical data, nine soil borings were drilled in March 2019 at locations along the proposed HBW alignment to measure the depth to the top of the Deeper Silty Clay Unit (the low-permeability layer, or confining layer, into which the HBW will be keyed). As shown in **Figure 1-2**, depths to the Deeper Silty Clay Unit from the Phase 1 RWP top of embankment design elevation (4218 ft above mean sea level [amsl]) are shown in brown type. Boring logs are included in the Sonic Soil Boring Investigation Summary Report included as **Appendix C**. Standard penetration tests were conducted at seven of the nine locations drilled in March 2019. SPT results are shown in the boring logs included in **Appendix C.** Results as they pertain to the Phase 1 RWP design are discussed further in Section 3.2.1of this report.

1.3.4 Groundwater Flow Modeling

A groundwater flow model was constructed in 2015 to support the conceptual design of the RWP. The model was used to predict the impact of the proposed RWP on groundwater flow. A complete description of the computer groundwater flow model, simulations, and sensitivity analyses is included in **Appendix E** of the Groundwater Discharge Control Plan submitted with the GWDP application on December 15, 2017 (Stantec, 2017). The model indicates that over the 30-year simulation period, groundwater beneath the RWP is not predicted to migrate laterally outside the RWP footprint, or vertically below the confining layer. Consistent with the GWDP, the design and anticipated performance of the RWP barrier wall will be verified with data on the hydrogeological conditions at the site including the ground water flow model and any appropriate modifications to the model.

1.3.5 Slurry Wall Compatibility Study

Due to the acid nature of the wastewater, bench-scale slurry compatibility tests were performed to evaluate the appropriate slurry mix for the HBD. Great Lakes Environmental and Infrastructure (GLEI) was retained by US Magnesium to conduct the study, and results are presented in a letter report from GLEI dated November 28, 2018 which was submitted to DWQ in December 2018 and included as **Appendix I** of this report. Results of this study were used to prepare the HBW slurry specification for the Phase 2 RWP Design, presented in **Appendix G**.

Stantec participated in the planning for the collection of site-specific bulk samples for the compatibility study and performed the subsurface soil sampling, groundwater sampling, waste pond water sampling, and plant water sampling and containerization of the samples on April 5 and 9, 2018. The site-specific sample collection for the compatibility study is summarized below:

Boreholes were advanced utilizing a truck mounted direct push 7800 Geoprobe rig to depths of 50, 45, and 30.5 feet bgs at previously sonic-drilled boring locations SB-2 and SB-3. The Geoprobe boreholes were designated SB-2a and SB-2b, and SB-3a. The direct push rods used had an outer dimeter of 3.25 inch that included a 2-inch by 5-foot clear PVC collection sleeve and the soil column was collected continuously through the total depths of the boreholes. Soil sample volumes for boring locations SB-2a and SB-2b amounted to three (3) full five-gallon buckets.

EarthProbe personnel experienced refusal at borehole location SB-3a due to a tightly compacted silty sand layer, encountered at a depth of 30.5 bgs. Several additional attempts were made to push through the tight silty sand layer, including moving the Geoprobe rig several feet in the opposite direction and repositioning it with smaller diameter push rods to try to gain a 45-foot depth profile of this location. All attempts to push (hammer the sampling rod) through the tight silty sand layer to the desired total depth of 45-feet were unsuccessful. A review of the available lithological data of the surrounding area near and adjacent to the SB-3a boring suggests that the silty sand layer is monolithic and far extends the proposed boring alignment. EarthProbe personnel and the Stantec technician determined that the direct push method could not be used effectively to collect a continuous core ample to the desired depth. Subsequently, only one (1) five gallon bucket of soil was collected from this location.

Groundwater samples were collected from monitoring wells PZ-10 and MW-22a by utilizing a peristaltic pump and following low-flow sampling procedures. A purged volume of 2.5 gallons of groundwater from each well were collected in two separate five-gallon clear plastic carboy containers for a total of 10 gallons of groundwater.

Water collected at the discharge point of the then-recently completed wastewater discharge piping system was completed by using a new five-gallon plastic bucket and a large plastic funnel that were rinsed three times with the source water. After rinsing, two (2) five gallon clear plastic carboy containers were filled with the combined plant wastewater discharge to the current waste pond.

Plant water (from USM’s groundwater wells in Skull Valley approximately 20 miles south of the site) was collected directly into three (3) plant water rinsed, five gallon clear carboy containers.

On April 12, 2018, a USM employee delivered the site-specific bulk samples to the Geo-Logic Associates material testing laboratory in Grass Valley, California, toured the laboratory facility and reviewed the testing program with the lab’s owner and principal. The Geo-Logic Associates testing program and results are included in the GLEI Soil-Clay Backfill Compatibility Test report, dated November 28, 2018, which is included as **Appendix I** of this report.

The design of the HBW is discussed in detail in Section 5.0.

1.4 Project Phasing

The RWP is being designed in three phases and will be constructed in the following four phases:

- Phase 1 will consist of constructing the perimeter embankment to an initial crest elevation of 4218 ft amsl. Phase 1 will take between one and two construction seasons to complete. The Phase 1 BOD Report was finalized and submitted in March 2020 (Stantec, 2020).
- Phase 2 will consist of installing the HBW. Designs for both RWP Phases 1 and 2 are presented in this version of the BOD Report.
- Phase 3 (future phase) will consist of raising the embankment to the final design elevation including freeboard requirements, installing embankment erosion protection, and placing crest surface material. Phase 3 is scheduled to be designed in 2022.
- Phase 4 (future phase) will consist of completion of installation of the final compliance monitoring system.

The design package for Phase 1 was finalized and submitted to the UDEQ DWQ on March 3, 2020. The design for Phase 2 is presented in this version of the Basis of Design Report along with the Phase 1 design. Phase 3 is anticipated to be completed in fall 2022. An updated RWP BOD Report that will include Phase 3 will be submitted for review and approval prior to implementation.

1.5 Regulatory Requirements

This Project is being executed according to the GWDP under the jurisdiction of UDEQ DWQ and the design as approved by DWQ will dictate the work. Any changes to the approved design will be coordinated with the DWQ prior to implementing the change.

2. GENERAL DESIGN CRITERIA FOR PHASE 1 AND 2

2.1 Survey Data

2.1.1 Geodetic Datum

The survey datum used for the design is in U.S. State Plane, North America Datum (NAD) 1983, Utah Central Zone.

2.1.2 Vertical Datum

The vertical datum used for the design is the North American Vertical Datum (NAVD) 88 U.S. ft.

2.1.3 Topographical Survey Data

The topographical information used for the design was based on an aerial topographic survey performed by NM Group in November 2015. The aerial topographic survey was based on an accuracy of ±50mm horizontally and ±150mm vertically, and a topographic map was created with 6-inch vertical contours. Updated ground-based topographic information collected for the northern CWP dike on March 27, 2019 was provided by Robinson Biehn & Biehn Inc. Subsequent to the survey being used for the design, maintenance of the existing OWP berms was completed in November 2019 to repair damaged due to wave erosion. The average OWP embankment crown elevation across the OWP sections that were within the maintenance project scope were reestablished to 4,210 AMSL which is consistent with the 2015 topographic survey.

2.2 Retrofitted Waste Pond Water Balance Modeling and Sizing

2.2.1 Summary of Water Balance Modeling

The water balance model included in the US Magnesium GWDP application was updated in 2019 for the RWP Phase 1 design to reflect an increased RWP area and anticipated additional future wastewater discharges. Since the application was submitted, the northern embankment of the RWP was moved further north to align with the north edge of the OWP boundary to improve constructability and to utilize existing pond berms as a base for the new RWP embankment. US Magnesium completed construction of its lithium processing plant at the Facility which is now contributing to wastewater flows to the RWP. As a result, updates to the initial water balance model (Appendix D of the Groundwater Discharge Control Plan [Stantec, 2017a]), were implemented during the RWP Phase 1 design in 2019 to evaluate the effects on required storage capacity and maximum operating water level due to the additional flows from the lithium process plant as well as likely impacts to evapoconcentration on future evaporation rates. The 2019 memorandum is presented in **Appendix A**. The 2017 water balance model and 2019 updated water balance model and memos were based on the original (2017) RWP configuration with a new diagonal embankment cross-cutting the southeastern portion of the OWP. As specified in the RWP Phase 1 final design and Phase 1 and 2 designs, the RWP embankment encompasses the entire footprint of the OWP which adds approximately 75 acres of pond area that was not included in the 2017/2019 water balance model / memos.

2.2.2 Maximum Operating Water Level

Based on the results of the water balance modeling, the predicted design maximum operating water level is 4218 ft amsl with a surface area of 1025 acres, assuming a recurring annual precipitation data set of 75% of the highest annual record. The maximum average annual pond water level is approximately 4215.5 ft amsl with a surface area of 856 acres, assuming average annual rainfall for the Project site.

2.2.3 Wave Run-Up Allocation

Additional freeboard (embankment height) is required to protect the embankment against wind-generated waves (combination of wave run-up and wave setup). The freeboard required and resulting embankment crest elevation will be determined as part of the Phase 3 design.

2.3 Design Life

The RWP is being designed to achieve the performance objectives of the Project for a period of 30 years. The 30-year design life for the RWP was selected based on consultation with US Magnesium and is supported by the updated water balance model results. If in the future the design life of the pond needs to be increased beyond 30 years and the RWP modifications are required to accommodate an increased design life, US Magnesium will submit a design modification or amendment for any required modifications to DWQ for approval.

2.4 Hydraulic Barrier Wall Performance Criteria

The overall purpose of the HBW is to protect groundwater outside off the RWP. The HBW was designed to be compatible with the pond water (pH<1) over the proposed design life of 30 years. The primary performance criterion for the HBW will be to achieve a maximum hydraulic conductivity of 1×10^{-6} cm/sec to limit the flux of pond water into the groundwater located outside the RWP.

3. GEOTECHNICAL INVESTIGATIONS

3.1 Site Geology

The stratigraphy in the vicinity of the proposed RWP includes a variety of sediments deposited during historical lake periods dating back to ancient Lake Bonneville. The deposits consist of continuous and discontinuous layers of oolite-containing sands, silty sands, and fine-grained sands; clays and silty clays; and both cemented and uncemented gravel. Stratigraphic units generally dip toward the east (Stantec, 2017b).

Underlying the proposed RWP area are two units of silty clay, a discontinuous shallow unit (located approximately 5 to 10 ft below ground surface [bgs]) and the deeper, thicker, and laterally continuous Deeper Silty Clay Unit (confining layer).

Along the alignment of the proposed RWP embankment, oolitic sand material is present within silty/fine-grained sand layers, typically between 3 and 30 feet bgs. Oolites have been observed within fine to medium grained silty sands, sometimes described as cemented or partially cemented material, and often observed as thin interbedded layers within thicker silty sand or poorly graded sand layers (**Appendix C**).

Across the site, the top of the Deeper Silty Clay Unit is encountered approximately 31 to 55 ft bgs and has been observed to vary between approximately 10 and 18 ft in thickness in the area of the proposed RWP with thickness increasing from west to east across the site (Stantec, 2017b). Depth from current ground surface to the top of the Deeper Silty Clay Unit along the HBW alignment ranges from 30 to 46.5 ft bgs (Stantec, 2019). This unit acts as a confining layer, dividing the shallow aquifer beneath the RWP area into two zones, the Upper Shallow Aquifer Zone (Upper Aquifer Zone) and the Lower Shallow Aquifer Zone (Lower Aquifer Zone).

3.2 Field Investigations

This section presents the investigations that have been completed in relation to characterization of foundation soils that will underly the embankment and material from the borrow source area (BSA) that will be used to generate soils for the construction of the RWP perimeter embankment. The existing BSA and the proposed extension of this borrow area to be used for RWP embankment construction are shown in **Figure 1-2**.

3.2.1 Embankment Foundation

3.2.1.1 Soil Boring Investigation

The objective of the soil boring investigation was to obtain additional data and a more uniform spacing of borings along the proposed RWP HBW alignment to confirm the depth to the Deeper Silty Clay Unit. Between March 11, 2019 and March 14, 2019, a track-mounted sonic drill rig completed nine vertical soil borings (SB-8 through SB-16) along the HBW alignment (**Figure 1-2**), as documented in the Sonic Boring Investigation Report (Stantec, 2019). The soil borings were advanced into the Deeper Silty Clay Unit (a confining layer) but did not penetrate below this layer. A Stantec professional geologist licensed in the state of Utah provided full-time drilling oversight and logged the extracted core.

The investigation included visual observations of representative core samples, logging the borings, and recording Standard Penetration Test (SPT) results. SPTs were performed at seven of nine soil boring locations (SB-8 through SB-14), at 2.5 ft below ground surface (bgs), 7.5 ft bgs, and 12.5 ft bgs. SPTs were not performed at SB-15 and SB-16 due to the unavailability of equipment on the day these boreholes were drilled. During the SPTs, blow counts were recorded to evaluate the associated relative densities of in-situ soils within the associated ranges. The relative densities were used to evaluate the subsurface conditions in support of the HBW design. Generalized borehole lithology for the nine soil borings and SPT results are presented in **Table 3.1** and detailed borehole logs are presented in **Appendix C**.

3.2.1.2 Interpretation of Results

Data collected during the subsurface investigation provides data to evaluate the extent of the Deep Silty Clay Unit and assess the strength of embankment foundation material. SPT data collected within the upper 15 ft of the boreholes range between 1 and 18, with the majority of measurements being below 4 blows per 6-inches. Based on this information, the soils in this area are generally characterized as very soft to soft. These results are conservative for depths below the groundwater table which ranged from approximately 4 to 9 ft bgs. As such, preparation of the embankment foundation will require over-excavation of unsuitable material and placement and compaction of suitable material from the borrow area.

3.2.2 Borrow Source Area

The soils used for construction of the RWP embankment have been and will be generated from an expansion of the borrow area on site. For the Phase 1 RWP design, approximately 369,000 cubic yards (CY) of soil will be required for construction of the RWP embankment to an elevation of 4218 ft amsl.

3.2.2.1 Subsurface Investigation

An investigation within the vicinity of the current BSA was conducted in 2015 as part of evaluating the feasibility of constructing a proposed evaporation pond in an upland area (north and west of the Facility) to replace the CWP (MWH, 2015). As part of the investigation, soil borings and test pits were completed in the BSA as shown in **Figure 1-2**.

In general, the primary units observed consisted of silt and clayey silt material from the surface to depths of approximately two to five ft bgs, followed by a lower-permeability silty clay layer that extends to approximately 10 to12 ft bgs, and a 5 to 10 ft thick oolitic sand layer that is underlain by a silty sand or silty clay layer.

Observed soil types and lithologies were recorded during drilling of soil borings and monitoring wells, and excavation of test pits. Test pits were typically excavated to depths of 10 to 12 ft bgs (typically to depth of groundwater) and soil borings were drilled to approximately 20 ft deep. Test pit and soil boring logs from the BSA were recorded in the field and are included in **Appendix D**. In general, lithologic logs for the test pits and soil borings indicate very fine-grained clay soils within the first 10 to 15 ft bgs, and typically oolitic sands were observed below the fine-grained layer to the bottom of the soil boring/test pit. Laboratory results of samples collected from the fine-grained clay soils and the oolitic sand material indicate high calcium carbonate content, 18 to 26% and over 62%, respectively (MWH, 2015).

Undisturbed soil samples from eight soil borings were classified and analyzed at a geotechnical laboratory for particle size distribution, Atterberg Limits, hydraulic conductivity (flexible wall permeameter), and water content as listed in **Table 3.2**. Soil boring locations are shown in **Figure 1-2**.

The first seven soil samples were collected between three and 11 ft bgs and represent soils that would likely comprise the proposed pond foundation. These samples were classified as lean and fat clays (Unified Soil Classifications of CL/CH). Hydraulic conductivity results for five of the samples selected for this analysis are relatively low, ranging between 10^{-4} and 10^{-7} centimeters per second (cm/s). Results for one additional soil sample, collected near the surface of a historic evaporation pond bottom (identified as PDS-1), resulted in a hydraulic conductivity result of 8.0×10^{-5} cm/s, a value consistent with sediment on the bottom of a naturally-lined wastewater pond at the site that has been exposed to high acid wastewater.

Disturbed soil samples were collected from several test pits and were sent to a geotechnical laboratory for soil classification and analyses, as listed in **Table 3.3**. Test pit samples were collected from depths between 0.1 and 15 ft bgs, and represent fine-grained native material proposed to be used to construct the pond embankment. Hydraulic conductivity results for the disturbed soil samples ranged between 1.3×10^{-6} to 3.1×10^{-5} cm/s, consistent with hydraulic conductivity values anticipated for the embankment. Note that the hydraulic conductivity testing was not performed with low-pH wastewater, and therefore results do not take into consideration the potential for dissolution of the calcium carbonate content of soils and associated expected increases in hydraulic conductivity.

Based on the results of the 2015 geotechnical investigation, the majority of soils adjacent to the existing BSA are characterized as fine-grained material. Additionally, a zone of oolitic sands was encountered between 9.7 and 16.5 ft bgs.

3.2.2.2 Interpretation of Results

Based on the geotechnical data collected, the native soils (with the exception of oolitic sands) at the proposed BSA are suitable as embankment material due to their fine-grained nature and relatively high plasticity. Given the potential for encountering oolitic sands at a depth of greater nine ft, the borrow depth within the existing and future expansion of the BSA should be limited to seven ft bgs. This translates to a surface area of approximately 42 acres in order to obtain the estimated 369,000 CY of RWP embankment material. The approximate extents of the BSA for construction of the embankments is shown in **Figure 1-2**, and a grading plan is presented in **Appendix E**.

4. EMBANKMENT DESIGN

This section presents the design of the embankment to be constructed as part of Phase 1. Engineering drawings, technical specifications for earthwork, and the Construction Quality Assurance Plan for the Phase 1 portion of work are provided in **Appendix E**, **Appendix F**, and **Appendix G**, respectively.

4.1 General Embankment Configuration

The embankment will be constructed of homogenous earthen fill with 4H:1V (horizontal to vertical ratio) inboard and a 3H:1V outboard slopes. As part of Phase 1 and to provide sufficient room for installation of the HBW, the majority of the embankment crest will be constructed as a split pad consisting of a trenching pad and a mixing pad. The trenching pad will be constructed to the maximum predicted RWP operating water level of 4218 ft amsl and will have a minimum crest width of 22.5 ft to provide a sufficient working platform for excavation of the HBW trench to be installed during Phase 2. The mixing pad will be constructed to an elevation of 4213.5 ft amsl and will be constructed to a width of 23 and 27 feet depending on the depth of the HBW trench. Following construction of the HBW the trenching pad portion of the embankment will be raised to the final design elevation, to be determined during Phase 3 design activities, to accommodate for necessary pond freeboard.

4.2 Embankment Foundation

Improvements to the soil underlying the embankment are required to provide a suitable foundation of sufficient strength to limit the potential for settlement. In some areas along the alignment, the embankment are being constructed over previously constructed dikes. In these areas, the dikes will be scarified to a shallow depth (approximately 2-inches) and recompacted with the first lift of embankment fill to the required specifications. In areas along the alignment where the embankments are constructed within the existing RWP footprint, foundation improvement will consist of surface roughening of the existing OWP soils and then placing an initial 3 foot loose lift of soil obtained from the BSA and compacting in accordance with the project specifications presented in **Appendix G**.

4.3 Construction Material

Soils used for the construction of the embankment will be generated from the BSA. Embankment soils will be placed and compacted to 95% of the maximum dry density (MDD) and within 0 to +4% of the optimum moisture content (OMC), as determined by Standard Proctor testing.

4.4 Slope Stability Assessment

A slope stability assessment was performed to evaluate the long-term stability of the RWP embankment and is provided in **Appendix H**. Based on the stability assessment conducted, the embankment meets the required minimum factors-of-safety for long-term static conditions of 1.5.

5. HBW DESIGN

5.1 Summary of Compatibility Testing Results

Compatibility testing (refer to Section 1.3.5 and **Appendix I**) was performed to assist in selecting the most appropriate soil-clay backfill for use in constructing the HBW. Soil-clay backfills consisting of both alkalized and non-alkalized samples using sepiolite, saponite, and bentonite clays were assessed in the study. Samples were tested using site-specific pond water permeate and the soils used to develop the backfill samples were from the boring drilled within the existing dike (refer to Section 1.3.5).

The results indicated that although the alkalized soil-clay backfills provided additional buffering capacity, they resulted in higher hydraulic conductivities due to their resultant lower densities and higher porosity. As such, a non-alkalized backfill using a saponite or sepiolite admix was identified as the best mix for design and construction of the HBW.

Stantec has selected the use of the soil-sepiolite backfill for use in this design. This is mainly due to the fact that it had similar performance to saponite and is available locally in Nevada.

5.2 HBW Design

This section presents the basis of design for the HBW. Refer to **Appendix F** for the HBW construction specification and **Appendix J** for design drawings including plan and profile sections of the HBW.

5.2.1 HBW Alignment

The centerline alignment of the HBW will be located approximately 13.25 ft from the upstream (wastewater pond side) crest of the embankment or 16.75 ft from the downstream crest of the embankment. The HBW will extend around the entire perimeter of the RWP excluding the western side. Based on water balance modeling (**Appendix A**), the maximum predicted water level in the RWP will be 4218 ft amsl with a maximum average annual pond water level of approximately 4215.5 ft amsl. Therefore, the HBW will extend on its northwestern end and southwestern end to locations where the natural ground elevation is 4218 ft amsl or higher.

5.2.2 HBW Thickness

The HBW design is currently based on a minimum nominal width of 30-inches. This design width was selected to accommodate readily available excavator bucket widths. The width of the HBW may be increased to accommodate the selected contractor’s excavation equipment.

5.2.3 HBW Working Platform

The construction of the Phase 1 RWP embankment will result in a working platform width of 30-ft. This platform width was selected is based on discussions with construction contractors and on previous project experience to provide sufficient space for excavation of the HBW trench, soil mixing and emplacement of the soil-sepiolite backfill to be performed as an essentially continuous side-by side operation.

5.2.4 HBW Trench Depth

The HBW will extend from an elevation of 4218 (top elevation of working platform) to a depth a minimum of one bucket depth (approximately 3 feet) into the confining clay layer, referred to in Table 3.1 as the Deeper Silty Clay Unit. Based on a top of HBW elevation of 4218, total HBW trench excavation depths will likely vary between approximately 29 feet and 58 feet below the top of the working platform. The CQAP, presented in **Appendix G**, requires that the HBW Construction Contractor and US Magnesium Representative perform field observations and sampling to confirm the depth of the confining layer. Any changes to the HBW depth based on field observations will be documented in the as-built drawings.

The slurry trench method of construction allows the contractor and quality control engineer/technician to visually observe and inspect the cuttings (for each excavator bucket) that come out of the trench during excavation. Even though the trench is filled with slurry to provide short-term stability of the trench, the excavation cuttings that come out of the bucket are naturally consolidated soils that can be classified and logged according to ASTM 2488. Once the contractor reaches the target design depth by soundings, continuing observation of soil cuttings will identify the top of the low-permeability confining layer (Deeper Silty Clay Unit) within one or two feet vertically depending on the profile of the cuttings presented in the bucket at the target design depth. The contractor will “tag” the depth of the excavation upon confirmation of interception of the confining layer and note this as the top-of-key. The contractor will continue excavation, soundings and observation of soil cuttings to assure consistent full-bucket height (minimum 3-foot and up to 5-foot) penetration into the key material prior to placing the soil-sepiolite admix backfill to construct the HBW.

5.2.5 Trench Slurry

A sepiolite based slurry will be used to support the HBW trench excavation to reduce the potential for trench wall sloughing prior to placement of the backfill mixture in accordance with the HBW specification presented in **Appendix I**. The sepiolite trench slurry (i.e., higher density “drilling mud”) provides short-stability to the trench by imposing a hydrostatic force to the sidewalls of the trench. By ensuring that the sepiolite slurry is maintained with a minimum of 3-feet of head above the top of groundwater level, the contractor will assure short-term trench stability until the soil-sepiolite admix backfill is placed to construct the HBW.

5.2.6 HBW Soil-Clay Backfill

The HBW will be constructed using a soil-sepiolite backfill based on the results of the compatibility testing presented in **Appendix I**. The soil-clay mixtures evaluated in the compatibility study utilized soil cuttings obtained from boreholes collected within the existing dikes associated with the Waste Pond. As such, soil excavated from the trench during construction of the HBW will be used as backfill soils that will be blended with the sepiolite to create a low-permeability HBW in accordance with the HBW specification presented in **Appendix F**.

The soil-sepiolite backfill is created out of the trench cuttings and mixed with sepiolite clay. The contractor will stage the spoils along the side of the trench as the excavation progresses. A dozer and smaller excavator lag the excavation and mix the soil cuttings with additional sepiolite clay into a homogenous matrix by tracking back and forth. The smaller excavator will also sluice the soil-sepiolite backfill with trench slurry until the desired slump, usually in the range of 3-inch to 6-inch slump, is achieved. The soil-sepiolite admix backfill is then placed in the slurry filled trench and, by ensuring that the backfill is at least 15 pounds per cubic feet heavier than the trench slurry, the backfill will displace the slurry forward into the advancing open trench. The soil-sepiolite backfill is then what forms the permanent HBW.

It should be noted that oolitic sands are likely to be encountered at varying depths during excavation of the trench. Boring logs presented in appendix C provide an indication of the depth and thickness of the oolitic gravel/sand that may be encountered during trenching of the soil column. Although oolitic gravel/sand were identified in the majority of borings, the oolitic gravel/sand horizons were generally encountered within 10 to 15 feet below ground surface and the oolitic lenses were generally less than a couple feet in thickness. Based on an average CWP trench depth of 50 feet, it is likely that oolitic gravel/sand will only comprise at most 15 to 20% of the total volume of material excavated from the trench.

Although the soil intervals containing oolitic sands represent a very small percentage of the total trench depth and the oolitic sands were retained in the compatibility study soil samples and, thus, will not have an appreciable effect on the performance of the HBW, the HBW specification and CQAP includes requirements that the horizons potentially containing oolitic gravels/sands will be preferentially wasted and placed inside the RWP to account for the swell of the soil-sepiolite backfill.

If additional soil is required for HBW construction than is available from the trench excavation spoils, it will be obtained from the on-site borrow area (refer to Section 3 for discussion on the characteristics of the onsite borrow soil). This borrow area soil has significantly more fine-grained material than the soil used during the compatibility testing; therefore, the soil-sepiolite mix ratios may need to be modified based on the amount of additional soil required. However, routine samples of the HBW mix is required as part of the CQAP to confirm that any changes in the soil-sepiolite mix proportions meet project specifications for hydraulic conductivity.

5.2.7 HBW Performance Testing

The main performance specification for the HBW will be hydraulic conductivity. The results of the compatibility testing indicated that a hydraulic conductivity of 1×10^{-6} cm/sec or lower can be achieved. Routine testing on samples of the soil-sepiolite backfill, per the requirements presented in the CQAP, will be conducted. Hydraulic conductivity is primarily influenced by the index properties and density of the HBW mix material, therefore; density and particle size testing will be performed with greater frequency as indicator tests, and hydraulic conductivity testing will be performed less frequently to confirm that the specifications are being met.

5.2.8 Protection of Work

A 2-ft thick clay soil cap will be installed over completed sections of the HBW to protect the HBW from drying, desiccation and other potential damage. The soil for the clay cap will be obtained from the side of the embankment (outboard side) that will be outside of the final trafficable width of the final embankment surface to be designed as part of Phase 3. This clay cap will protect the surface of the HBW until the final embankment raise is completed as part of Phase 3 of the RWP construction.

6. REFERENCES

Bureau of Reclamation, 2012. Design Standards No.13 Embankment Dams Chapter 6: Freeboard, Us Department of Interior Bureau of Reclamation. September 2012.

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

Great Lakes Environmental & Infrastructure, 2018. Soil-clay Backfill Compatibility Test, US Magnesium. Letter report dated November 28, 2018.

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

Stantec, 2017a. Groundwater Discharge Control Plan, Groundwater Discharge Permit Application, US Magnesium Facility, Rowley, Utah. December 2017.

Stantec, 2017b. Hydrogeologic Report, Groundwater Discharge Permit Application, US Magnesium Facility, Rowley, Utah. December 15, 2017

Stantec, 2019. Addendum to the CPT/HPT Investigation Work Plan, US Magnesium Facility, Rowley, Utah. January 9, 2019.

Stantec, 2020. Retrofitted Waste Pond Phase 1 Basis of Design Report, US Magnesium Facility, Rowley, Utah. March 3, 2020,

TABLES

FIGURES

APPENDIX A:
Water Balance Modeling Report

(unchanged since prior submittal)

APPENDIX B:
Geochemical Evaluation

(unchanged since prior submittal)

APPENDIX C:
Embankment Boring Logs and Standard Penetration Test Results

(unchanged since prior submittal)

APPENDIX D:
Borrow Source Data

(unchanged since prior submittal)

APPENDIX E:
Phase 1 Design Drawings

(unchanged since prior submittal)

APPENDIX F:
Earthwork and HBW Specifications

APPENDIX G:
Construction Quality Assurance Plan

APPENDIX H:
Slope Stability Assessment

(unchanged since prior submittal)

APPENDIX I:
Soil-Clay Backfill Compatibility Test Report

(unchanged since prior submittal)

APPENDIX J:
Phase 2 Design Drawings