From:	Mayne, Elizabeth
To:	"wniccoli@telesto-inc.com"
Cc:	Hora, Pam; Julie Mikulas
Subject:	Response to Home Office Pit, File No. M-1977-439 – AM04
Date:	Thursday, November 10, 2022 1:33:00 PM
Attachments:	Response_Telesto_LRM.pdf image001.png image002.png image003.png image004.png image005.png

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Dear Mr. Niccoli

Attached is a response to comments that you provided to the Division of Reclamation, Mining and Safety regarding
Martin Marietta's Home Office Pit application. Let me know if you have any questions.

Thank you,

Elizabeth Mayne | Project Administrator
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TETRA TECH

November 9, 2022

Mr. Walter L. Niccoli, PE
Principal/Senior Engineer
Telesto Solutions, Inc.
750 14th St. SW
Loveland, CO 80537

Email: wniccoli@telesto-inc.com

RE: Telesto/LRM comments on DRMS AM-4 application – Home Office Mine, Permit M1977-439

Dear Mr. Niccoli:

This letter is in response to the specific comments and questions in your letter of February 25, 2022, documenting comments on behalf of Loveland Ready-Mix Concrete, Inc. (LRM) on Exhibit G of Martin Marietta's 112c Permit Amendment Application (AM4) for the Home Office Mine, submitted on December 23, 2021, File No. M-1977-439. Below are your comments followed by Martin Marietta's responses.

Section 1- Introduction and Background

Comment

Paragraph 2 indicates that "This Groundwater Monitoring and Mitigation Plan presents the methods for monitoring groundwater during mining and reclamation, and for mitigating any potential groundwater impacts associated with permitted mining at the site." How can monitoring of groundwater during mining and reclamation be completed when monitoring wells were not installed between LRM's property and the Phase 1 pit until after reclamation was complete?

> ***Response***
> *Water level measurements are available as of 2004. Additional wells were installed at various times throughout mining, including 2016, 2018, and 2021. Exhibit G provides updated hydrographs of water levels and we have incorporated Loveland Ready Mix's well data into our analysis.*

Comment

Paragraph 3 states that the discussion is limited to potential changes in the hydrologic balance resulting from the installation of the compacted clay liners. The paragraph refers to Figure G-1, which shows conceptual groundwater flow directions before mining and after reclamation. The focus of the paragraph and Exhibit G is on Stage G, yet the Stage G area is confined to the northeast corner of Figure G-1. It should be central to the figure to show areas surrounding the pit. With lined pits, the potential disruption to the hydrologic balance is "mounding" upgradient of the lined area and "shadow" of the down-gradient areas. Please provide projections of the anticipated changes up- (especially to the north) and down-gradient of the pit area. Also,

- What is the basis of the green flow arrows?

  Response
  A well-understood characteristic of alluvial aquifers is that groundwater flows approximately parallel to river flow. The green flow arrows represent pre-mining groundwater flow patterns.

- How do you depict groundwater flow directions (they may be correct) without a potentiometric surface?

  Response
  A well-understood characteristic of alluvial aquifers is that groundwater flows approximately parallel to river flow.

- Why are there no projections of the pre-pit groundwater flows through the pit area and to the north?

  Response
  A revised Figure G-1 depicts additional groundwater flow arrows.

- Where does the water from the north go?

  Response
  Under pre-mining conditions, water from the north flows approximately parallel to the Cache La Poudre River. Under post-mining conditions, water from the north will flow east along the north side of Area G-I and then return to flowing approximately parallel to the Cache La Poudre River.

- How large will the mounding be on the north side of the Phase 1 pit?

  Response
  Mounding on the north side of the Area G-I pit will likely be on the order of 2-3 feet, as shown in the Koonce and Slatten hydrographs in Chart 6: Nearby Monitoring Well Data.

Section 1.1 – Historical Use

Comment

From our understanding of the timeline and information from site inspections, it appears that Phase 1 is complete with liner installed. It is unclear from the section title if Martin Marietta plans to go back in and install liner over what appears to be a reclaimed and final Phase 1 (See photographs in July 2021 inspection report). What is the timeframe for installing liners and perimeter drains?

> ***Response***
> *An additional liner will not be installed in Area G-I. The G-I liner was installed in Fall 2020. The underdrain, also referred to as the underdrain, was installed in Fall 2021, as shown in Figure F3. An additional portion of underdrain located along the north side of Area G-II is planned to be installed upon completion of Area G-II mining. For clarity, the nomenclature used for the drain will be "underdrain" rather than perimeter and/or underdrain.*

Comment

This section identifies a potential issue with rising water table west of Stage G, and points to Section 2.1 for the mitigation solution. There are no analyses in Section 2.1 confirming the reason for the issue, or the solution. Please provide such analyses.

> ***Response***
> *Groundwater levels rose due to the mounding effect on the upgradient side of the Area G-I compacted clay liner. The solution was the design and installation of an underdrain on the west side of Area G-I. Design and as-built drawings, prepared by Deere & Ault are provided in Exhibit G, Attachment 2.*

Section 1.2

Comment

The first paragraph describes monitoring wells installed in 2005. Which wells are these? Where are they located? Where are the data? These would be very useful in helping LRM understand potential impacts. Please provide a plan view map of their locations and historical data.

> ***Response***
> *Numerous monitoring wells were installed, generally beginning in 2001 through 2021. Monitoring well data is available beginning in 2007 for the nearby wells referred to as "Stegner Cornfield aka MM Near KOA". Monitoring well data is available beginning in 2004 for the nearby wells referred to as "Koonce" and "Slatten". Records from Lafarge indicate these wells were installed in 2001. Figure G-3 shows the locations of the Koonce, Slatten, and Stegner Cornfield aka MM Near KOA wells.*

Comment

Groundwater elevations shown in Charts 1, 2 and 3 are helpful when combined with the location map to help understand groundwater gradients but do little to explain how close the groundwater is to ground surface, and what the potential impacts could be to landowners. Please provide depth to water information for these wells.

> ***Response***
> *Depth to water information for wells discussed in Exhibit G has been added to Exhibit G. Figure G-3 shows the locations of wells discussed in Exhibit G.*

Comment

Chart 1 shows a steep rise that correlates in time to the end of mining in Phase 1. There is almost a 7.25 foot between July 2020 and July 2021 in well HO-01, and the trend is upward. What is the cause of this? Will the trend continue upward? This could be an issue for LRM's ability to farm the field to the north of Phase 1. Could it explain the issue raised by the neighbor?

Response
Chart 1 from the original AM-04 document was renamed Chart 2 because of the addition of information to Exhibit G. Chart 2: Martin Marietta Monitoring Data (HO-1 and HO-6), previously named Chart 1: Martin Marietta Monitoring Data (HO-1 and HO-6) shows the upward trend referred to in the above comment. The increase in water level correlates to the installation of the Area G-I compacted clay liner. Since the original submission of AM-04, water level monitoring has continued. The hydrographs in revised Exhibit G include water level monitoring through March 2022. Additional water level monitoring data indicate that water levels have appeared to stabilize and show responses to local recharge events.

Section 2.1

Comment

This is the paragraph referred by Section 1.1 as mitigation for the observed rising water table west and north of Stage G Phases 1 and 2, respectively. The paragraph references a perimeter drain being designed by Deere and Ault. Anecdotal information from neighbors indicate that Martin Marietta already installed the drain. Given the rising water level in HO-01 and the fact that Martin Marietta is actively dewatering Phase 2 (and thus, lowering the head at the drain outlet creating a large gradient to increase flows), does not bode well for the mitigation solution purposed in the document. Please explain how this is a mitigation solution for rising water levels on the north side of the Phase 1 pit, and how LRM is protected from flooding caused by groundwater rising to flow around the pit liner.

Response
Mitigation does not appear to be necessary at this time. Mounding on the north side of the Area G-I pit will likely be on the order of 2-3 feet as demonstrated by the Koonce and Slatten hydrographs shown in Chart 6: Nearby Monitoring Well Data. Furthermore, it is our understanding that Loveland Ready-Mix intends to mine the area north of Area G-I.

Comment

It is not clear whether the "underdrain" shown in Figure F-3 is the "perimeter drain," or if another drain is planned. Please provide design details (or as-built drawings) for the perimeter drain. Include:

- Plan and profile along the proposed alignment
- An effective hydraulic conductivity analysis
- Hydraulic analysis

These should show the combination of the perimeter drain and liner is equivalent to the pre-mining condition in terms of its carrying capacity. Also, include the area north of the Phase 1 pit in this analysis to show the potential impact to LRM property.

Response
The underdrain and the perimeter drain are the same drain. For clarity, the nomenclature used for the drain will be "underdrain" rather than perimeter and/or underdrain. This language has been clarified in Exhibit G. The underdrain that has already been installed will not be changed. However, upon completion of mining in Area G-II, an additional section of underdrain will be installed. This section of drain is located along the north side of Area G-II and will connect to the existing underdrain at the northeast corner of Area G-II. Construction drawings prepared by Deere & Ault, A Schnabel Engineering Company are provided in Exhibit G, Attachment 2. In addition, Deere & Ault, A Schnabel Engineering Company provided hydraulic analysis calculations which have also been included in Exhibit G, Attachment 2.

Comment

The plan view on Figure F3 labels an "underdrain" perforated pipe skirting the west side of the Phase 1 pit, passing between Phases 1 and 2, turning solid and emptying into the recharge pond on the southeast side of Phase 2. The perforated drainpipe and trench bottom are roughly 5.4 and 6.4 feet, respectively, below the top of the liner, which is essentially at natural grade. Based on water levels taken on LRM's property, the bottom of the drain might intersect the top of the natural water table, and thus, it appears the drains are not planned deep enough. It is our experience that French drains that extend over at least half of the saturated thickness are necessary to efficiently move groundwater around impermeable structures. Please provide an analysis regarding the drain sizing, depth, and location (horizontal and vertical) that efficiently and effectively moves groundwater around the lined pit on all sides and maintains the hydrologic balance. Related, provide methods and infrastructure design to maintain (e.g., cleanouts) and ensure the drain has a long life.

Response
The discharge elevation of the underdrain was installed at 5011.87, which is at or below the historic water level. The underdrain was installed at a slope ranging from approximately 0.16-0.49 % and is therefore located at the maximum feasible depth to be able to convey groundwater along the historic groundwater flow pattern. The upstream-most invert of the drain is approximately 5 feet below ground surface. Construction plans with as-constructed information prepared by Deere & Ault, A Schnabel Engineering Company are provided in Exhibit G, Attachment 2.

Section 2.3

Comment

The mitigation plan is reactive: 1) wait for complaints by neighboring well owners, and 2) then rely on baseline data to determine if there is an effect and develop a mitigation strategy. There is no up-front planning presented to provide an inkling that a workable plan is in place to maintain the hydrologic balance. Please ensure the plan is proactive by providing projections of problem areas, and potential mitigation strategies before something happens.

Mitigation in this section talks solely about impacts to wells. Please elaborate on the mitigation strategy for flooding neighboring properties (e.g, eliminating problematic groundwater in crawl spaces, saturating farm ground or crop root zones with a water table that is too high).

Response
A surface drainage channel is proposed along the west side of Area G-I, adjacent to the underdrain to facilitate surface drainage and maintain historic flow patterns.

Summary

Comment

To ensure the applicant's amendment meets the requirement to maintain the hydrologic balance and not harm LRM's (and neighbor's) properties, LRM humbly requests that the DRMS requires the applicant to be pro-active in revision to the current AM-4 submittal, and provide the requested analyses, engineering plans, clarifications, and address the questions raised in this review, particularly:

- Clarifying the timing of mining, lining and perimeter drain installation

  Response
  Mining of Area G-I was completed by Spring 2017. The installation of the compacted clay liner in Area G-I was completed in Fall 2020. The underdrain that goes from north to south along the west side of Area G-I was installed in January and February of 2022.

  Mining of Area G-II is expected to be complete by the end of 2022. The installation of the portion of the underdrain that will flow west to east along the north side of Area G-II will be performed upon completion of mining in Area G-II.

- Providing baseline information from the monitoring wells installed in 2005

  Response
  Baseline information from the monitoring wells referenced above has been added as an appendix to Exhibit G. The 2005 Groundwater Monitoring Program Interim Report for Home Office includes water level measurements for the Koonce and Slatten wells from 2004 and 2005. These data points were added to Chart 6: Nearby Well Monitoring Data in Exhibit G.

- Providing elevational information and/or depth to groundwater information when presenting all monitoring well information

  Response
  Elevation information and depth to groundwater information for all discussed wells have been added as an appendix to Exhibit G.

- Describe the observed trends in groundwater elevations, their estimated causes, and considerations for the proposed reclamation plan to maintain the hydrologic balance

  Response
  Please reference the updated Exhibit G.

- Providing detailed analysis on the function of the proposed drain and liner combination

  Response
  The function of the proposed underdrain is to control groundwater levels and maintain historic flow patterns.

- Show and justify projected groundwater levels after reclamation including how the perimeter drain will function efficiently long-term

  Response
  Monthly groundwater monitoring will continue through mining and reclamation to assess the functionality of the underdrain. The drain design includes cleanouts to maintain capacity and functionality.

- Extend the perimeter drain to include the north side of Phase 1 and include appropriate discharge

  Response
  An additional portion of the underdrain will be installed along the north side of Area G-II upon completion of mining and reclamation of Area G-II. Installing an underdrain along the north side of Area G-I 1 is not necessary as groundwater will naturally flow to the east along the north side of the liner. Furthermore, it is our understanding that Loveland Ready-Mix intends to mine the area north of Area G-I.

If you have any questions regarding the responses to your comments, please let me know.

Sincerely,

TETRA TECH

Tom Hesemann, PG, CEG
Senior Engineering Geologist/Hydrogeologist

Attachment: Revised Exhibit G with Attachments

cc: Brock F. Bowles, DRMS

EXHIBIT G: WATER INFORMATION

Martin Marietta is amending the existing 112 Reclamation Permit No. M-1977-439 to change the final reclamation for Area G of the Home Office site from one open water lake to two sealed water storage reservoirs using compacted clay embankment liners.

1.0 INTRODUCTION AND BACKGROUND

Martin Marietta owns properties known as the “Home Office” site in Larimer County, Colorado. The properties are located on the west and east sides of North Taft Hill Road, approximately ½ mile south of Larimer County Road 54G, in Sections 33 and 34 of Township 8 North, Range 69 West of the 6th Principal Meridian, and Sections 3 and 4 of Township 7 North, Range 69 West of the 6th Principal Meridian.

This Groundwater Monitoring and Mitigation Plan presents the methods for monitoring groundwater during mining and reclamation, and for mitigating any potential groundwater impacts associated with permitted mining at the site. Martin Marietta is applying to the Colorado Division of Reclamation, Mining and Safety (DRMS) for an Amendment to the existing 112 Reclamation Permit No. N-1977-439 to change the final reclamation for Area G of this site from one open water lake to two sealed water storage reservoirs using a compacted clay embankment liner.

Exhibit B shows the location of the Affected Area and Area G. Exhibits F1 and F2 show all the Affected Area in the permit. Exhibit F3 details Area G, which is located in the northern portion of the Affected Area. The changes within the Affected Area are limited to Area G. Consequently, this discussion is limited to potential changes in the hydrologic balance as a result of the installation of compacted clay embankment liners in Area G-I and Area G-II. Figure G-1, enclosed, shows the Affected Area; Area G; adjacent parcels to Area G and property owners; and conceptual groundwater flows before and after the installation of the compacted clay liners.

1.1 HISTORIC USE

Area G mining and associated dewatering began in Spring 2016 and is currently underway. A compacted clay liner was installed in Area G-I in September 2020 upon completion of mining. A compacted clay liner will be installed in Area G-II upon completion of mining.

Figure G-1 shows the adjacent properties to Area G, lined cells, unlined cells, cells that will be lined in the future, and irrigation ditches in the vicinity of the Affected Area. Agricultural land uses are located north and east of Area G. Loveland Ready Mix owns properties to the north and east of Area G. Irrigation ditches in the area include the New Mercer Canal, the Larimer County Canal No. 2 Ditch, the Arthur Canal, and Taylor & Gill Lateral (owned by Martin Marietta).

Loveland Ready Mix irrigates fields north and east of Area G outside of the permit area. Irrigation field tiles are reported to have been installed in the properties owned by Constance A Fredman located southeast of Area G of the Affected Area (Figure G-2). After reports of poor drainage, the field tiles were repaired by Loveland Ready Mix. Flooding was reported to Martin Marietta on the PKR Farm LLC property located east of the Affected Area (Figure G-2) as part of the field tile issue. In response, Martin Marietta worked with Loveland Ready Mix and PKR Farm LLC and installed drainage ditches between Loveland Ready Mix and PKR Farms LLC and along the east side of Area G-I. The drainage ditches convey irrigation runoff from the area east of the Affected Area to the south to the Cache La Poudre River, similar to the historic drainage patterns. Since the installation of the ditches, there have not been further reports of flooding.

Based on discussions with Seaworth Properties LLC, water is rising on the east side of a parcel owned by Seaworth Properties LLC, on the west side of Area G-I during the irrigation season. Martin Marietta is working with Seaworth Properties LLC and installed a groundwater perimeter drain between January 10, 2022 and

February 4, 2022 to address the groundwater rise and irrigation return flow to the river. Figure F-3 presents the location and design drawings for the perimeter drain (See Section 2.1 Mining Plan). An additional section of perimeter drain is proposed along the north side of Area G-II. This section will connect to the installed perimeter drain at the northeast corner of Area G-II. A swale was installed on Martin Marietta's property on the west side of Area G-I to facilitate surface drainage for landowners located west of Area G-I. Figure G-3 shows the approximate locations of the perimeter drain and swale.

Chart 1 illustrates the mining cells in the vicinity of the Affected Area and the liner status of each cell.

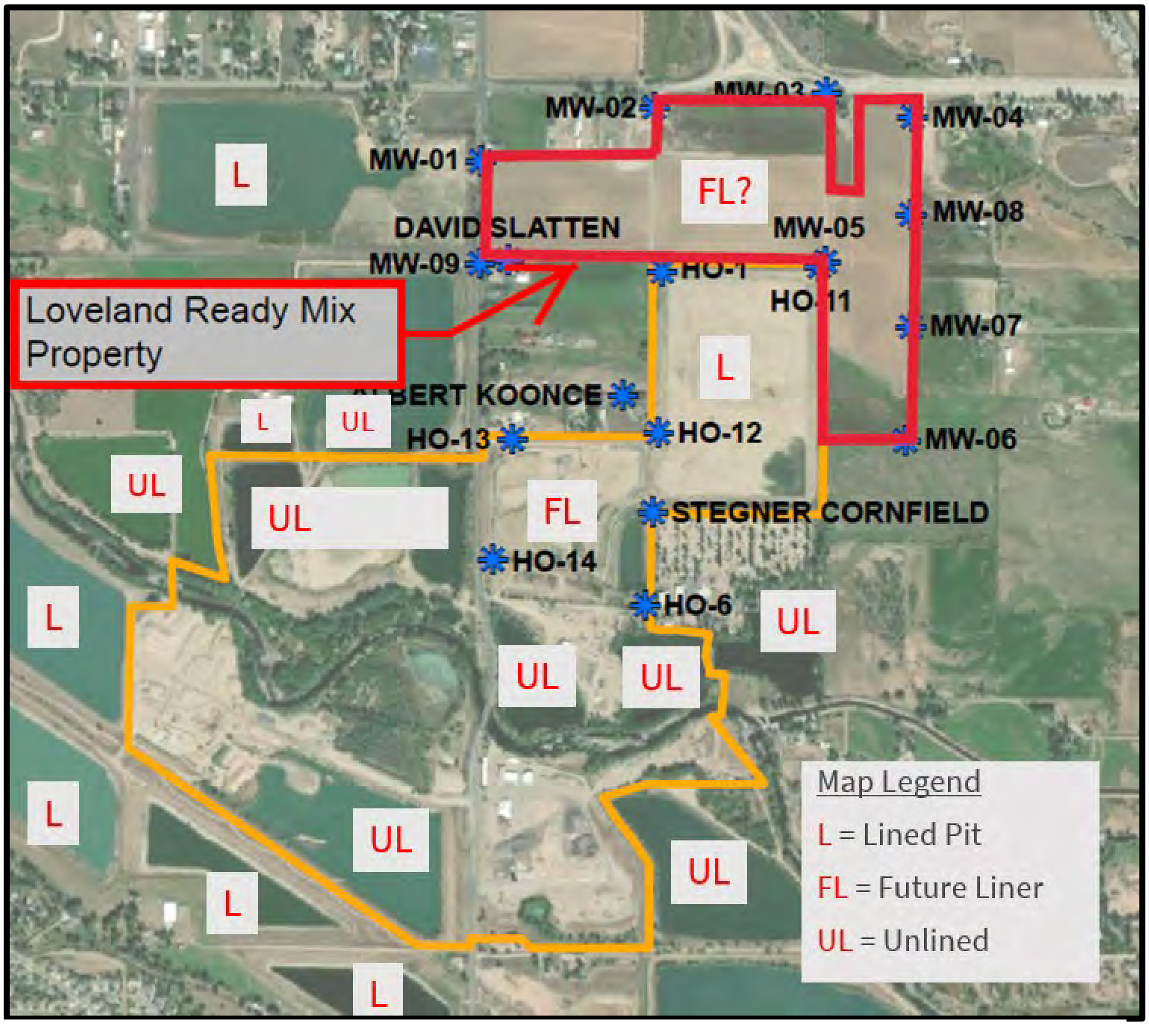


Chart 1: Mining Cells in the Vicinity & Liner Status

1.2 EXISTING WELLS

1.2.1 Monitoring Wells

Six monitoring wells (HO-1, 6, 11, 12, 13 and 14) were installed outside the limits of proposed mining, allowing for groundwater monitoring to occur during and after mining.

Monitoring well HO-1 was installed in the northwest corner of Area G-I. Monitoring well HO-6 was installed in the southeast corner of Area G-II. Both HO-1 and HO-6 were installed in 2018. Monthly groundwater monitoring for wells HO-1 and HO-6 began in May 2018. The well monitoring program documented pre-mining groundwater levels near the project area and seasonable fluctuations.

The following monitoring wells were installed in Area G in 2021:

- HO-11, in the northeast corner of Area G-I
- HO-12, near the southern portion of Area G-I, and near the northeast corner of Area G-II
- HO-13, near the northwest corner of Area G-II
- HO-14, near the southwest corner of Area G-II

Monthly groundwater monitoring for wells HO-11, HO-12, HO-13, and HO-14 began in May 2021. Exhibit F3, dated August 2021, and Figure G-3 show the locations of the wells.

Chart 1 shows water level measurements for HO-1 and HO-6. Chart 2 shows water level measurements for HO-11, HO-12, HO-13, and HO-14. Exhibit G, Attachment 1 shares the raw data for wells HO-1, HO-6, HO-11, HO-12, HO-13, and HO-14.

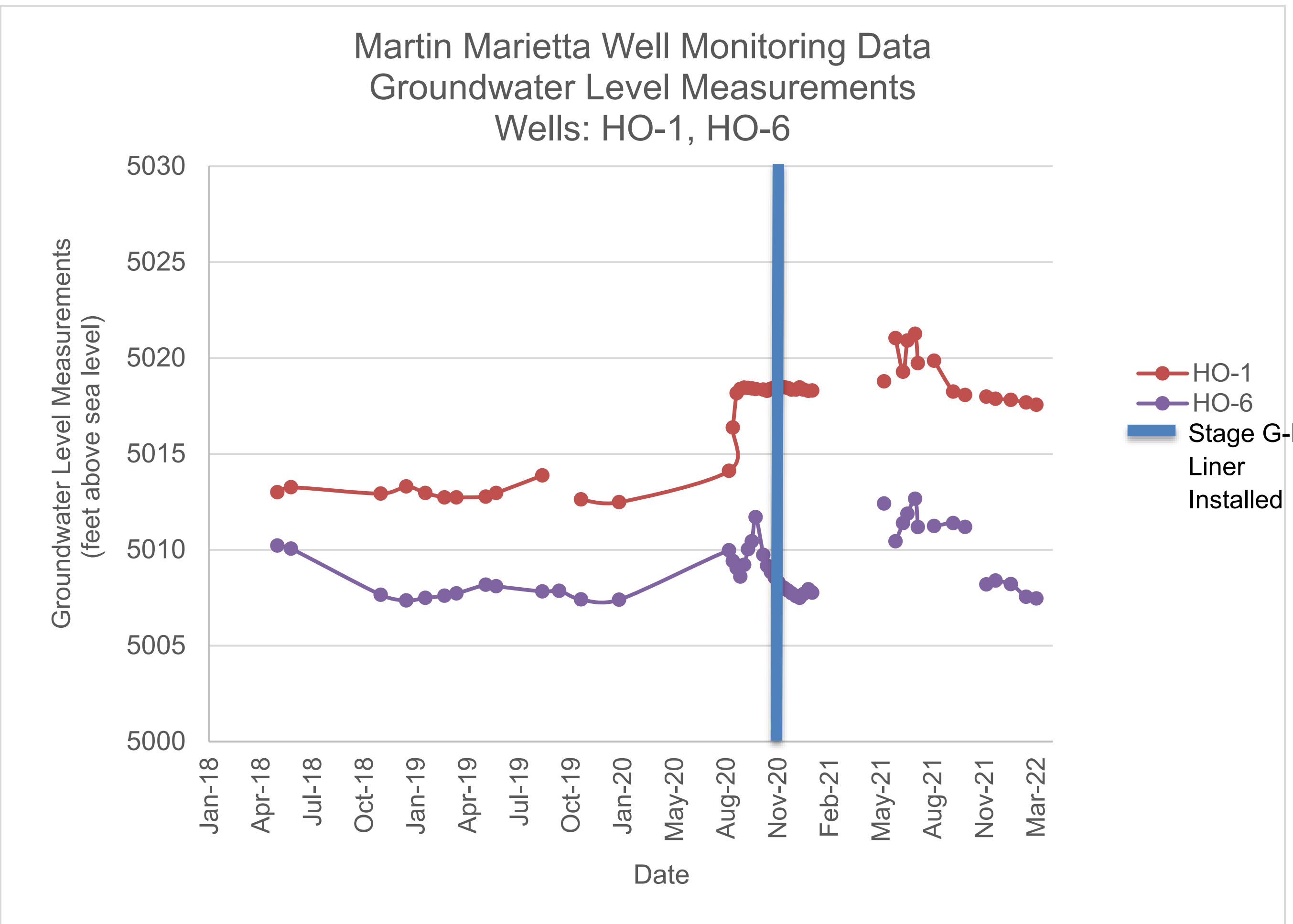


Chart 2: Martin Marietta Monitoring Data (HO-1 and HO-6)

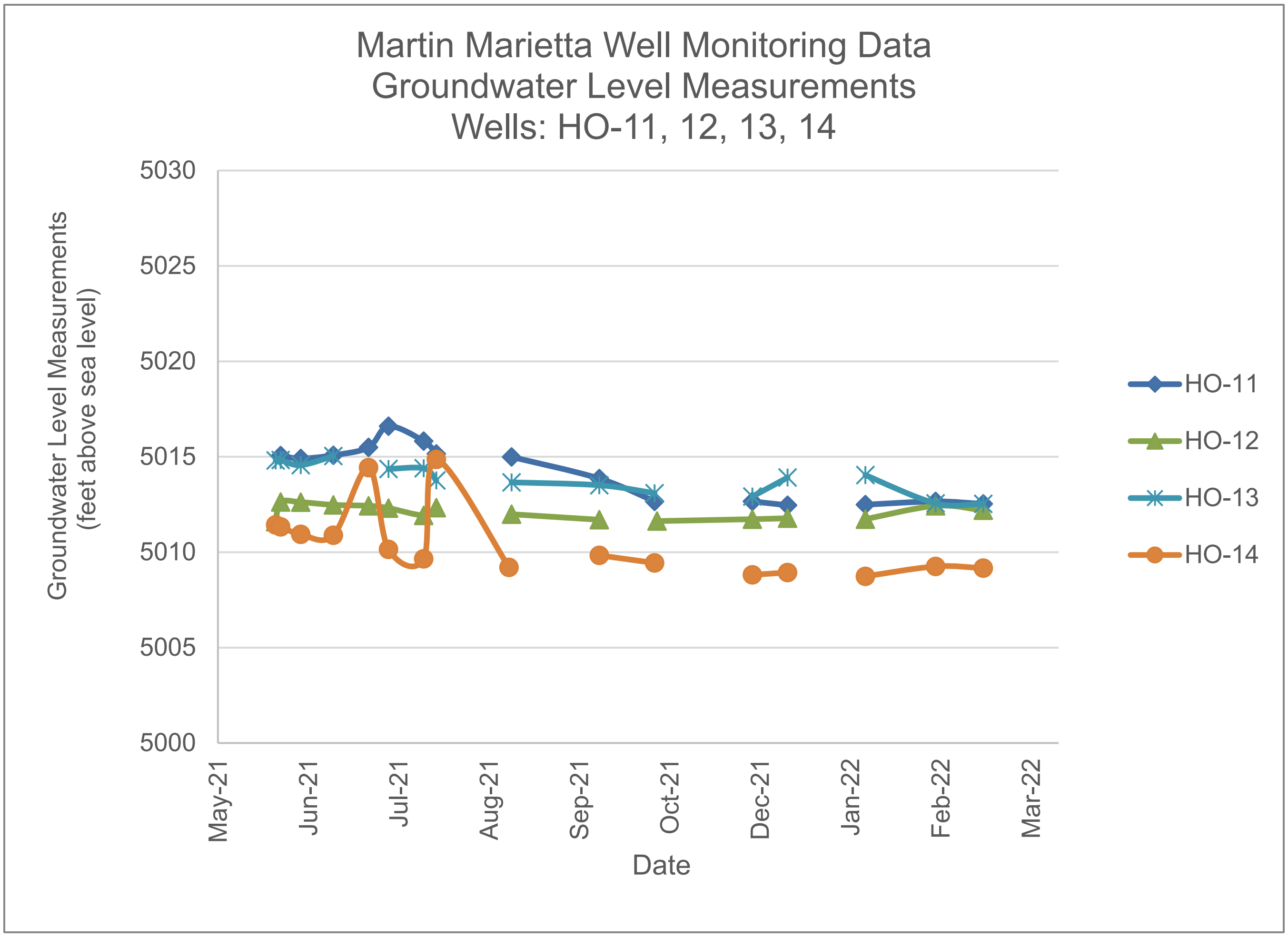


Chart 3: Well Monitoring Data (HO-11, 12, 13, 14)

Loveland Ready Mix installed monitoring wells on their lands in July 2016. Chart 4 and 5 show water level measurements that have been collected monthly since the wells were installed. Monitoring wells MW-02, MW-03 and MW-04 are located north of Area G-I. Monitoring wells MW-05, MW-06, MW-07 are located east of Area G-I. Groundwater monitoring for monitoring wells MW-02 through MW-07 began in July 2016. Groundwater levels fluctuate throughout the seasons. Exhibit G, Attachment 1 presents data provided by Loveland Ready Mix.

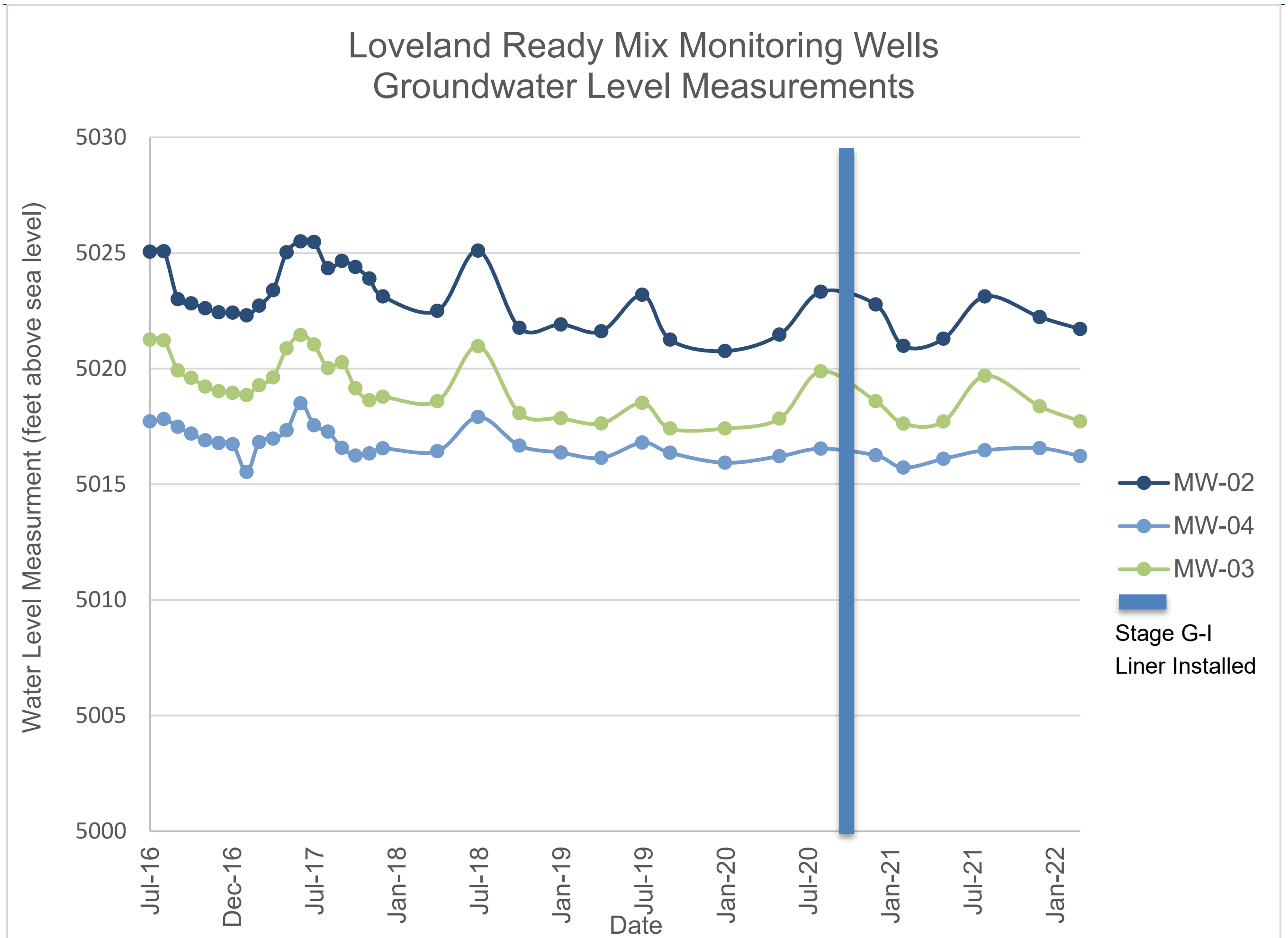


Chart 4: Loveland Ready Mix Monitoring Wells, MW-02, 03, 04

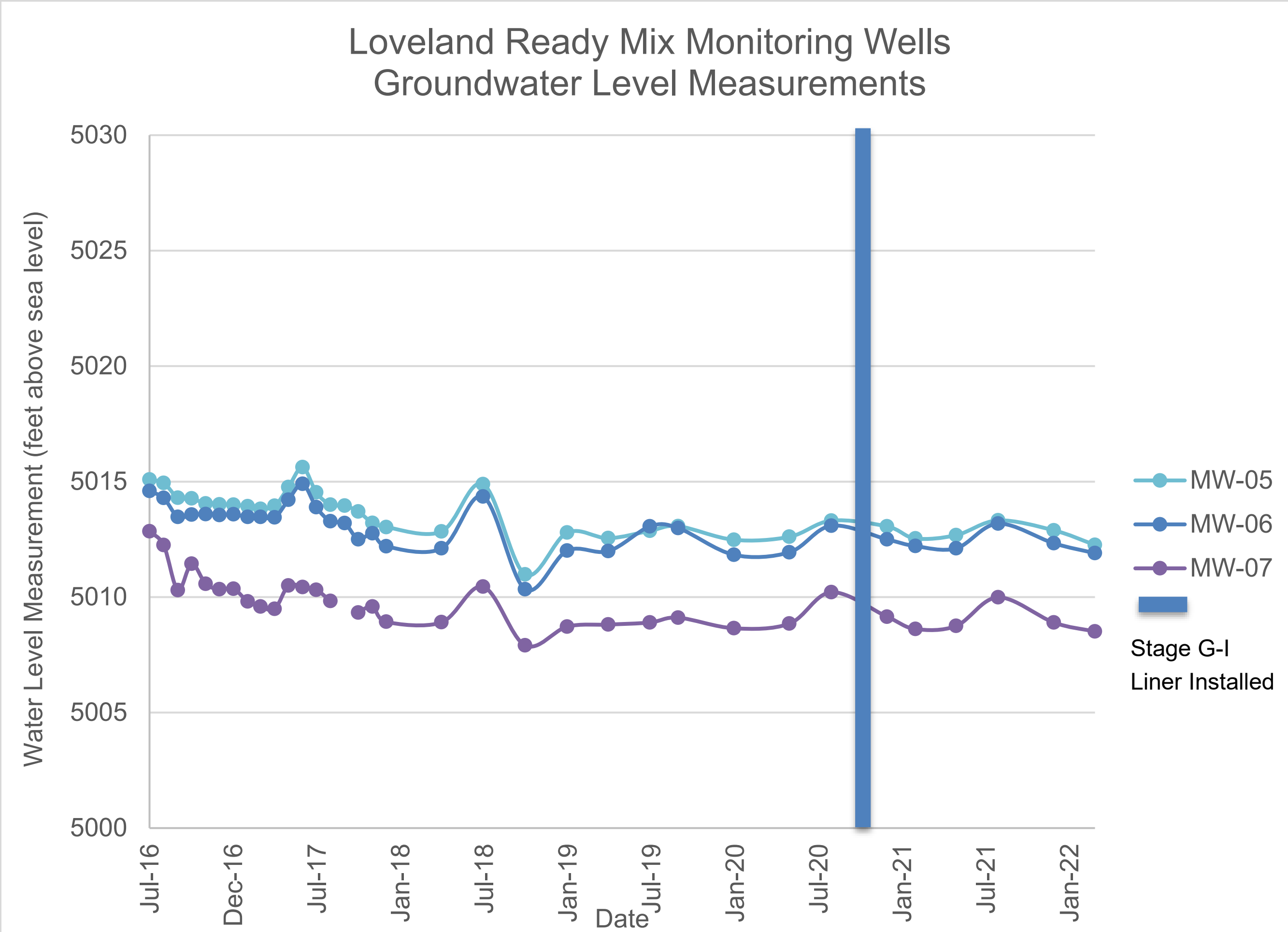


Chart 5: Loveland Ready Mix Monitoring Wells, MW-05, 06, 07

1.2.2 Nearby Wells

Numerous wells were installed in 2001 to establish groundwater baselines to monitor the groundwater conditions before, during, and after mining per the 2005 Well Monitoring Program Interim Report for Home Office. Water level measurements from 2004 and 2005 are included in the 2005 Well Monitoring Program Interim Report Well locations are shown on Figure G-3. Well owners, David L and Virginia S Slatten's property is located west of Area G-I at the northernmost portion of Area G-I (Figure G-1). Well Owners, Albert R and Sharon E Koonce's property is located west of Area G-I, just north of Area G-II. A well owned by Martin Marietta, referred to as "MM near KOA" is located east of Area G-II and south of Area G-I. Groundwater monitoring for the Slatten, Koonce and MM near KOA wells began in April 2007. Groundwater levels fluctuate throughout the seasons. The range of water level measurements for the Slatten well is 6.6 feet. The range of water level measurements for the Koonce well is 8.5 feet. The range of water level measurements for the MM near KOA well is 7.7 feet. Table 1 presents the maximum, minimum and average saturated thickness for the monitoring well data set. Mining and associated dewatering began in Spring 2016. A shift in water level measurements is shown in Chart 3, which presents historical well monitoring data from the Slatten, Koonce and MM near KOA wells. Exhibit G, Attachment 1 presents raw data for the nearby wells.

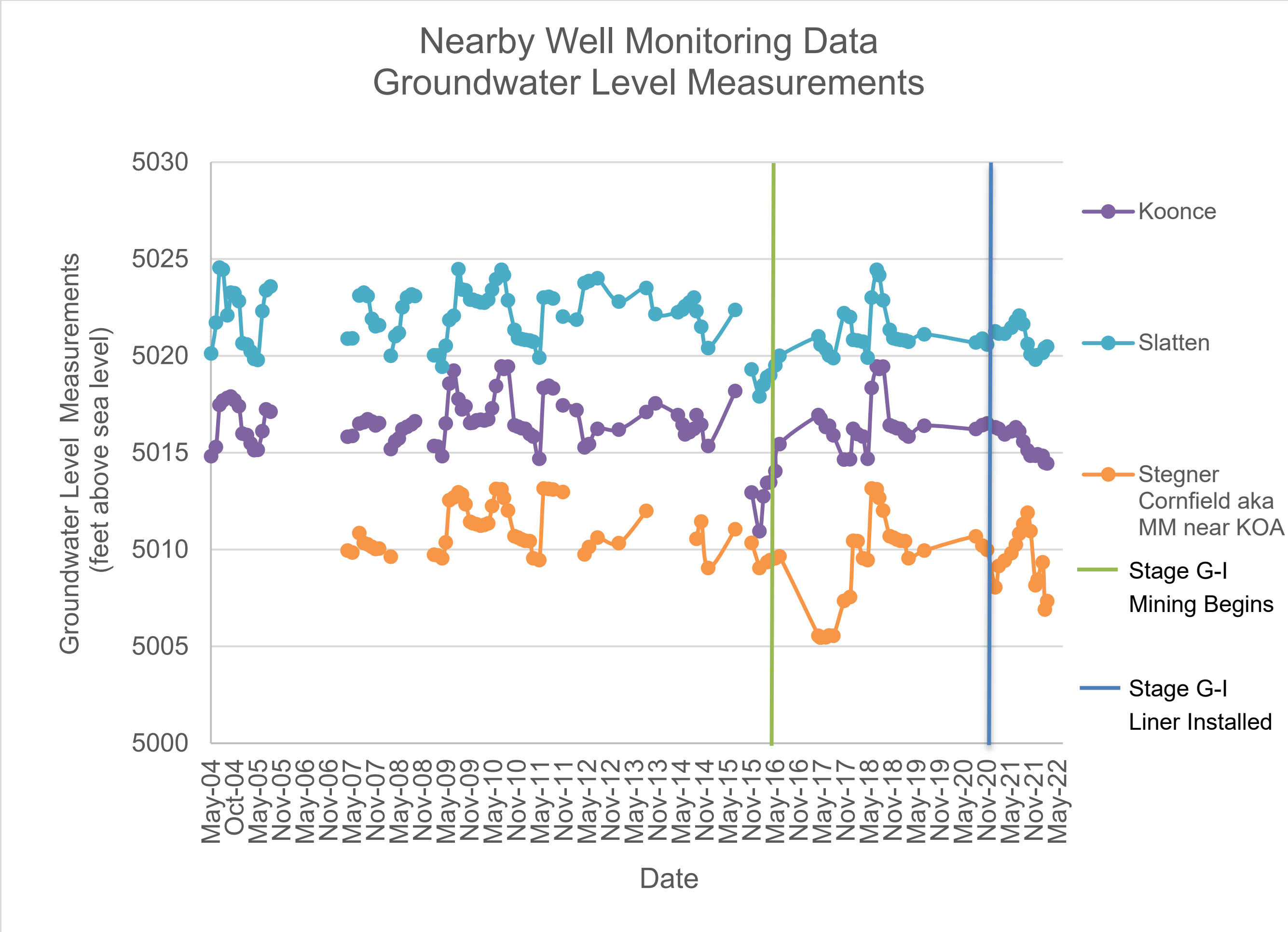


Chart 6: Nearby Well Monitoring Data

1.3 WELL INVENTORY

In December 2021, a well inventory of the Affected Area and adjacent areas was conducted to identify domestic wells near the project site. The inventory involved a review of constructed well records on file with the Colorado Division of Water Resources, located within ½ mile plus 200 feet of the Affected Area. The well inventory identified 98 constructed wells within ½ mile plus 200 feet, of the Affected Area. Figure G-2 enclosed shows the Affected Area and the constructed well locations on file with the Colorado Division of Water Resources.

1.4 HISTORIC AND FUTURE GROUND WATER LEVELS, AND IMPACTS TO WELLS

The presence of lined and unlined cells near Area G and previous dewatering of Area G demonstrates that the revised reclamation plan, i.e. lining of Area G cells will result in changes, but manageable changes, to the hydrologic balance.

The principal change to the hydrologic balance will be mounding on the upgradient (west) side of Area G. Martin Marietta has been preemptive in addressing the mounding on the east side by installing a perimeter drain. Exhibit G, Attachment 2 presents the location and design of the perimeter drain.

Regarding the down gradient impacts, monitoring well data demonstrates minimal impacts to wells will occur on the down gradient shadow effect (east and southeast) sides of Area G. Table 1 presents the historic range of saturated thickness in the monitoring wells. The period or record for the data includes the time when the Area G cells were being actively dewatered. The impacts from dewatering are greater than the shadow effect of the lined cells. Monitoring wells HO-6 and Stenger Cornfield/MM Near KOA are adjacent to the dewater cells yet they had minimum statured thickness of 6.9 feet and 4.6 feet respectively. Chart 7 presents the hydrograph of wells HO-6 and the Stegner Cornfield/MM Near KOA wells. The impacts of dewatering and subsequent recovery of the water levels after installation of the liner in the northern Area G cell.

The saturated thickness in the shadow zone after installation of the liner will be on the order of five to six feet. Water wells completed in sand and gravel aquifers typically provide approximately 25 to 30 gallons per minute per foot of drawdown or saturated thickness in the well. The wells on the down gradient side of Area G are domestic with permitted maximum pumping rates of 15 gallons per minute (gpm). Consequently, five to six feet of saturated thickness will provide the allowed pumping rates of 15 gpm. Wells located further from Area G will have even more saturated thickness and hence will be able to pump the permitted rates.

Table 1: Saturated Thickness

Saturated Thickness (feet)				
Well	**Minimum**	**Maximum**	**Delta**	**Average**
HO-1	5.8	14.6	8.8	10.3
HO-6	6.9	12.2	5.3	8.6
HO-11	10.0	14.2	4.1	11.7
HO-12	6.4	7.5	1.0	6.9
HO-13	5.8	8.3	2.5	7.1
HO-14	3.2	9.3	6.1	4.9
Koonce	5.5	14.0	8.51	10.8
Slaten	7.9	14.5	6.57	11.6
Stegner Cornfield/MM Near KOA	4.6	12.4	7.7	9.5
MW-01	9.1	16.8	7.7	11.4
MW-02	11.8	16.5	4.7	14.0
MW-03	10.4	14.4	4.0	12.1
MW-04	11.5	14.5	3.0	12.7
MW-05	7.5	12.1	4.6	10.0
MW-06	6.3	10.9	4.6	9.0
MW-07	8.9	13.9	4.9	10.7
MW-08	6.8	16.0	9.2	10.5
MW-09	6.0	12.8	6.8	8.2

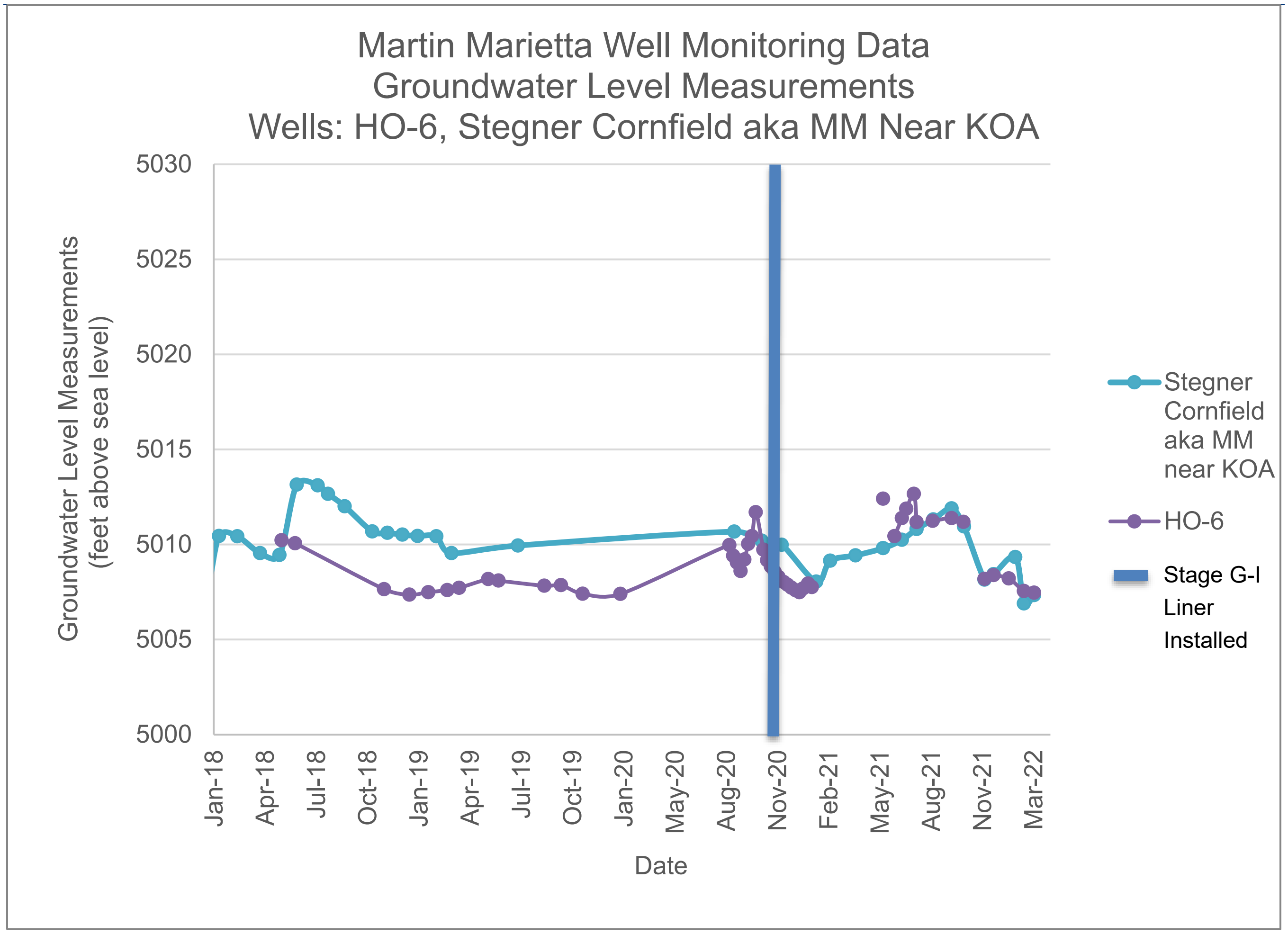


Chart 7: Monitoring Well Data (HO-6, Stegner Cornfield aka MM Near KOA)

2.0 MONITORING AND MANAGEMENT

2.1 MINING PLAN

The Reclamation Plan has been designed to reduce potential groundwater impacts to adjacent properties. A perimeter drain was designed by Deere and Ault to mitigate groundwater rise and to allow irrigation return flow off of the properties being irrigated west of Area G-I. The perimeter drain is installed along the west Area G-I. An additional portion of perimeter drain is proposed along the north side of Area G-II. Mining is expected to be completed in Area G-II by the end of 2022. The portion of the perimeter drain north of Area G-II will be installed upon completion of mining. The perimeter drain discharges through the berm between Area G-II and II to an unlined pond that is tributary to the Cache la Poudre River.

2.2 MONITORING

2.2.1 Martin Marietta Monitoring Wells

Monthly water level monitoring at HO-1, HO-6, HO-11, HO-12, HO-13, and HO-14 will continue during mining. When mining is complete, quarterly water level monitoring at HO-1, HO-6, HO-11, HO-12, HO-13, and HO-14 will continue until reclamation is complete and the DRMS releases the financial warranty bond.

2.2.2 Domestic Water Wells

Monthly water level monitoring at the Slatten and Koonce wells will continue during mining. When mining is complete, quarterly water level monitoring at the Slatten and Koonce wells will continue until reclamation is complete and the DRMS releases the financial warranty bond.

2.3 MITIGATION

The available monitoring well data will be used to identify changes in alluvial groundwater flow associated with mining and reclamation activities. Baseline data collected from the monitoring program will provide a range of relative water levels associated with pre-mining groundwater conditions. These data will be utilized to evaluate the nature and extent of the change to the prevailing hydrologic balance and if necessary, provide for the development of corrective actions.

In the event of a well owner complaint within 600 feet of the Affected Area, Martin Marietta will review the available monitoring information and submit a report to the DRMS within 30 days. The report will include discussions with any well owner who has contacted Martin Marietta regarding a concern and a review of baseline data from the well and vicinity to evaluate whether changes may be due to seasonal variations, climate, mining, or other factors. The report will identify the extent of potential or actual impacts associated with the changes. If the extent of groundwater changes due to mining or reclamation activities is determined to be a significant contributing factor that has or may create adverse impacts, the mining-associated impacts will be addressed to the satisfaction of the DRMS.

If the DRMS determines that the impact on a well for which temporary mitigation has been initiated is not a result of Martin Marietta's activities, or is not solely a result of Martin Marietta's activities, Martin Marietta will reduce or cease mitigation accordingly.

If a well goes dry due to mining or reclamation activities, Martin Marietta will implement mitigation measures within 7 days. Mitigation measures would include providing a temporary alternative water supply that meets the documented historic well production or need, until further investigation can be conducted to determine if the well condition is due to the mining operation.

Martin Marietta will begin to implement one or more mitigation measures if mining or reclamation activity is determined to be a significant contributing factor to groundwater changes requiring mitigation.

Temporary mitigation measures may include, but are not limited to:

- Compensation for well owners to use their existing treated water system to replace the well production loss.
- Provide a water tank and deliver water as necessary to meet documented historic well production or need.
- Other means acceptable to both the well owner and Martin Marietta.

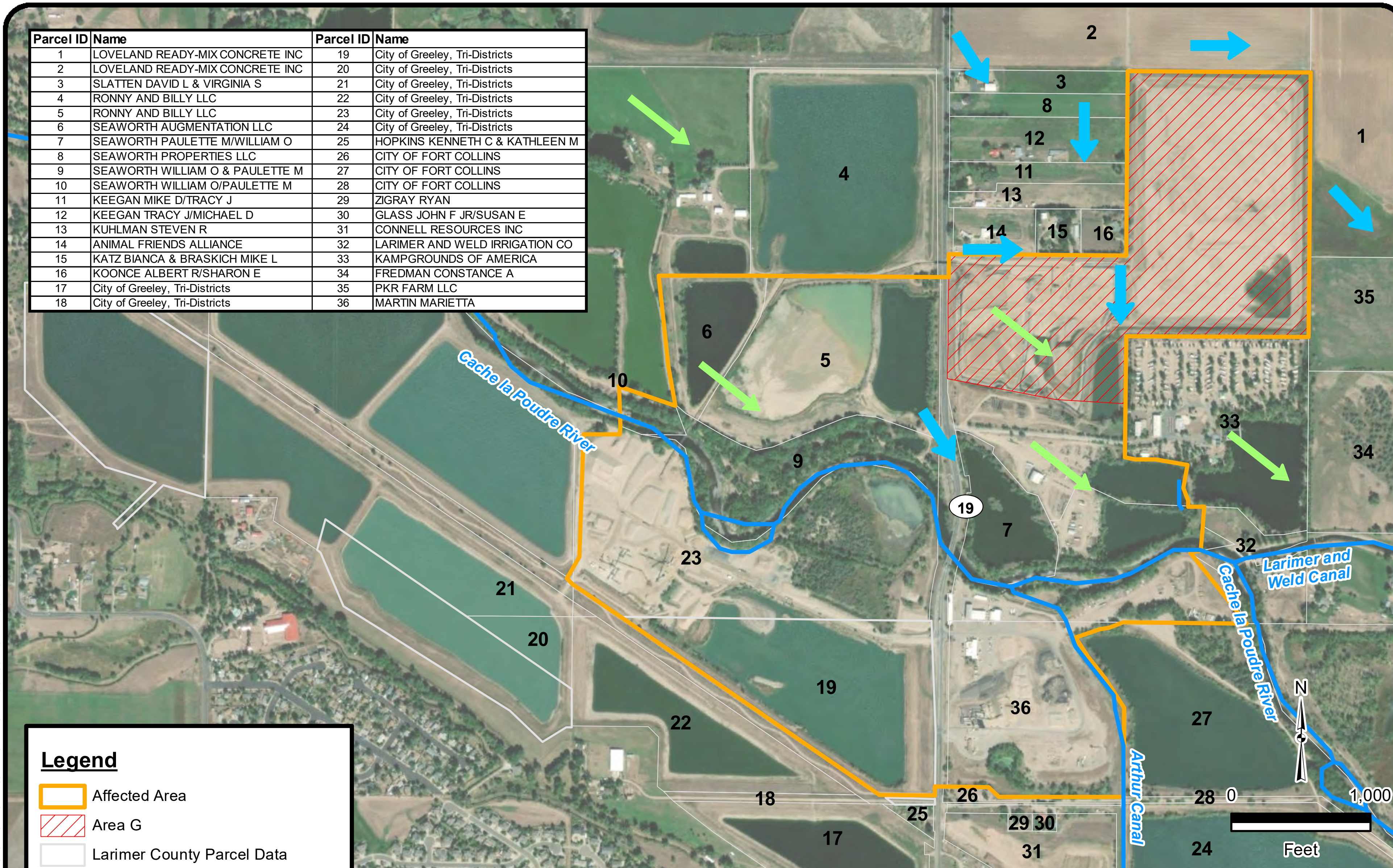
Long-term mitigation measures may include, but are not limited to:

- Cleaning a well to improve efficiency.
- Providing an alternative source of water or purchasing additional water to support historic well use with respect to water quantity and quality. If needed, water quality parameters will be checked in affected wells to ensure alternative sources support the historic use.
- Modifying a well to operate under lower groundwater conditions. This could include deepening existing wells or lowering the pumps. All work would be done at Martin Marietta's expense with the exception of replacing equipment that was non-functional prior to mining.
- If existing wells cannot be retrofitted or repaired, replacing the impacted well with a new replacement well.
- Design and installation of a cistern.

If a groundwater mitigation action is required, Martin Marietta will notify the DRMS of the condition, action taken and report the results and present a plan for monitoring the mitigation.

O:\Projects\Longmont\8741\117-8741002\Docs\Permits\DRMS Adequacy Review 1\ExhG\ExhGWaterInformation.docx

FIGURES



Parcel ID	Name	Parcel ID	Name
1	LOVELAND READY-MIX CONCRETE INC	19	City of Greeley, Tri-Districts
2	LOVELAND READY-MIX CONCRETE INC	20	City of Greeley, Tri-Districts
3	SLATTEN DAVID L & VIRGINIA S	21	City of Greeley, Tri-Districts
4	RONNY AND BILLY LLC	22	City of Greeley, Tri-Districts
5	RONNY AND BILLY LLC	23	City of Greeley, Tri-Districts
6	SEAWORTH AUGMENTATION LLC	24	City of Greeley, Tri-Districts
7	SEAWORTH PAULETTE M/WILLIAM O	25	HOPKINS KENNETH C & KATHLEEN M
8	SEAWORTH PROPERTIES LLC	26	CITY OF FORT COLLINS
9	SEAWORTH WILLIAM O & PAULETTE M	27	CITY OF FORT COLLINS
10	SEAWORTH WILLIAM O/PAULETTE M	28	CITY OF FORT COLLINS
11	KEEGAN MIKE D/TRACY J	29	ZIGRAY RYAN
12	KEEGAN TRACY J/MICHAEL D	30	GLASS JOHN F JR/SUSAN E
13	KUHLMAN STEVEN R	31	CONNELL RESOURCES INC
14	ANIMAL FRIENDS ALLIANCE	32	LARIMER AND WELD IRRIGATION CO
15	KATZ BIANCA & BRASKICH MIKE L	33	KAMPGROUNDS OF AMERICA
16	KOONCE ALBERT R/SHARON E	34	FREDMAN CONSTANCE A
17	City of Greeley, Tri-Districts	35	PKR FARM LLC
18	City of Greeley, Tri-Districts	36	MARTIN MARIETTA

Legend

- Affected Area
- Area G
- Larimer County Parcel Data
- Pre-Mining Groundwater Flow
- Post-Mining Groundwater Flow

TETRA TECH
www.tetratech.com
351 Coffman Street, Suite 200
Longmont, Colorado 80501
Tel: (303) 772-5282

MARTIN MARIETTA

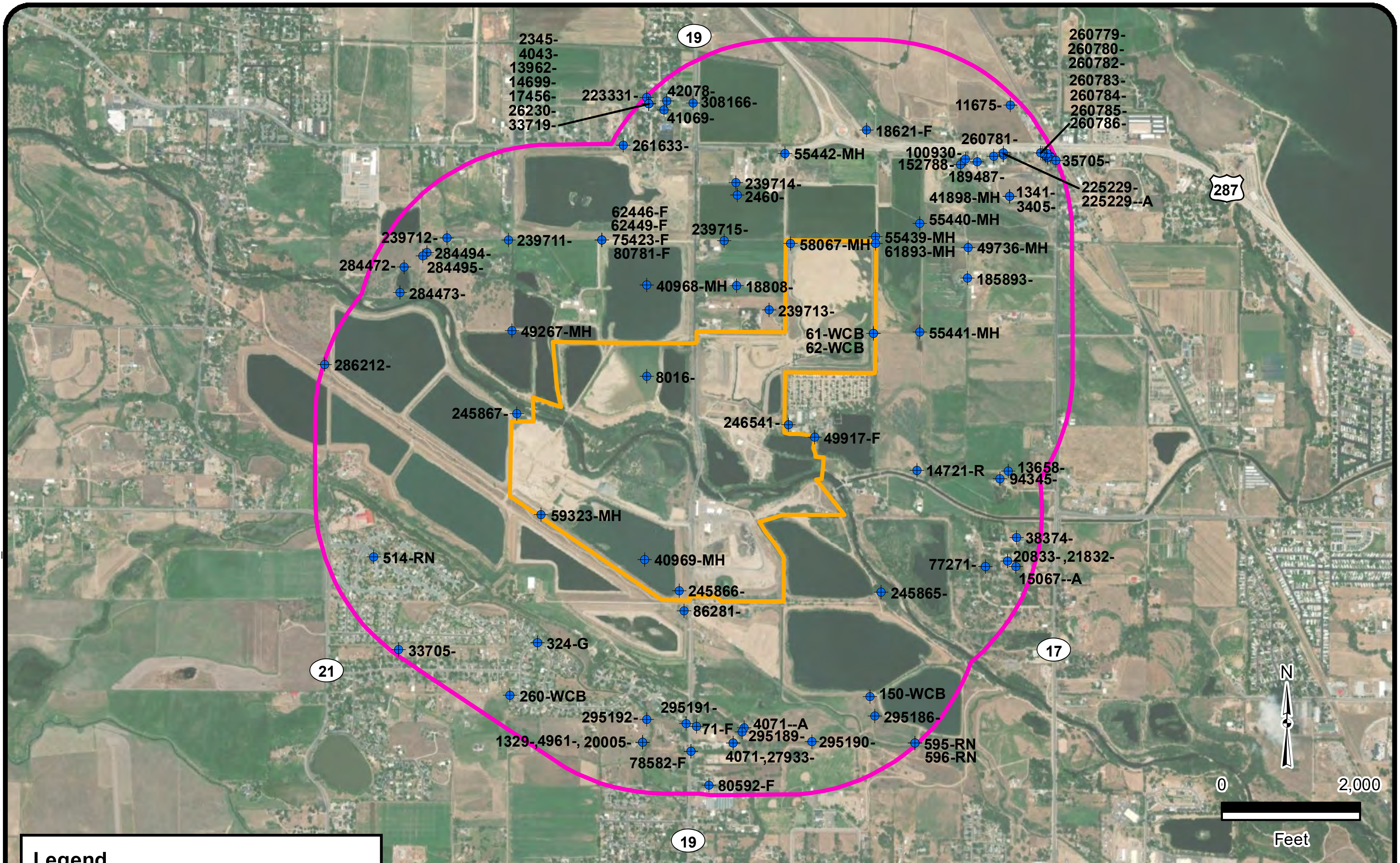
TAFT HOME OFFICE AMENDMENT
EXHIBIT G

GROUNDWATER FLOW MAP

Project No.:	117-8741002
Date:	JUN 06, 2022
Designed By:	JJA

Figure
G-1

6/6/2022 - O:\PROJECTS\LONGMONT\8741\117-8741002\GIS\MXD\GROUNDWATERMAP.MXD - JEREMY.ANDRYAUSKAS



Legend

- Constructed Well Location with Permit No.
- Affected Area
- Affected Area Offset (1/2 Mile Plus 200 Feet)

TETRA TECH

www.tetratech.com

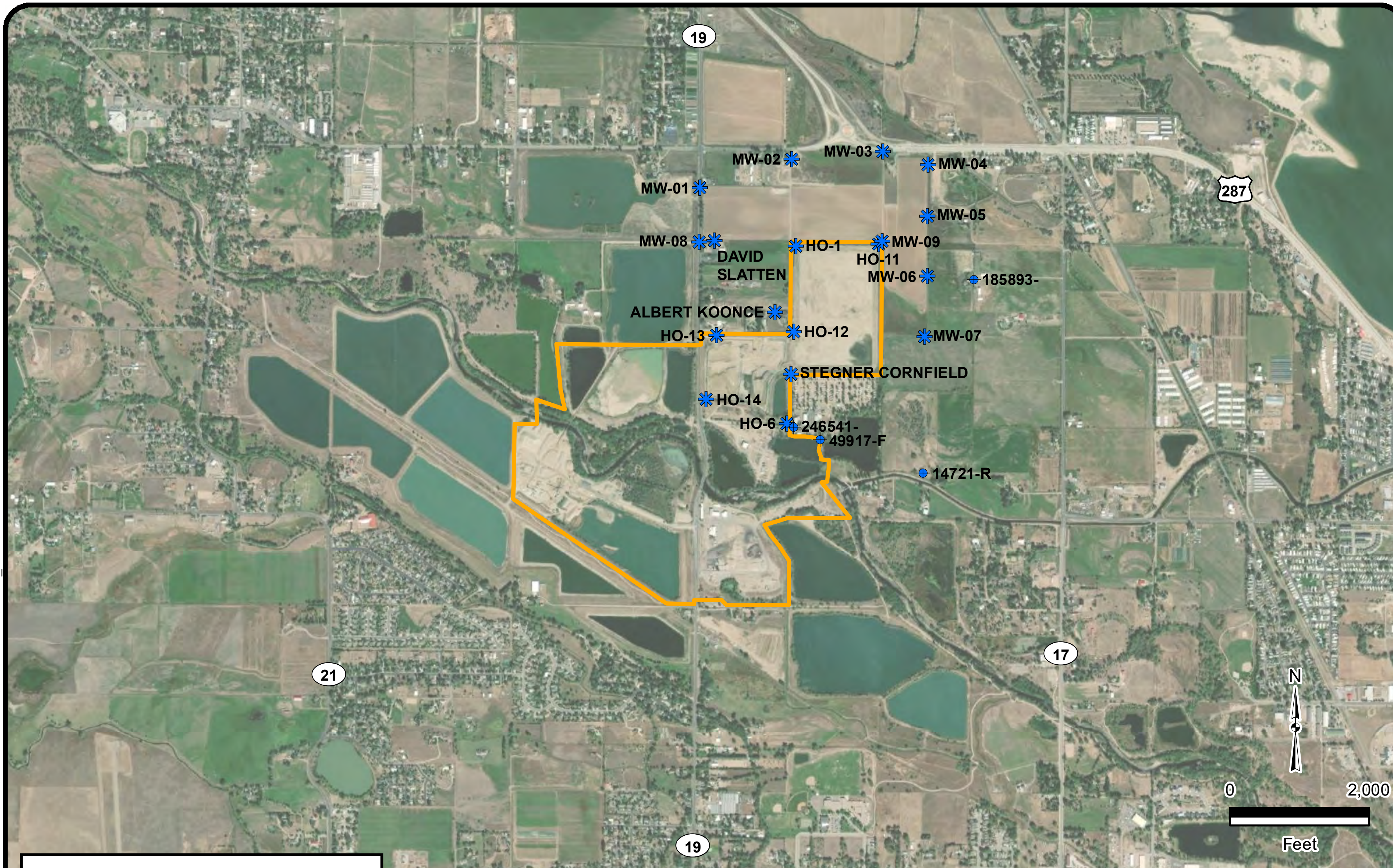
1900 S. Sunset Street, Ste. 1-E
Longmont, Colorado 80501
PHONE: (303) 772-5282 FAX: (303) 772-7039

MARTIN MARIETTA

TAFT HOME OFFICE AMENDMENT
EXHIBIT G

**DWR WELL SEARCH RESULTS (DEC 20, 2021)
CONSTRUCTED WELL APPROXIMATE LOCATION
WITHIN 1/2 MILE OF AFFECTED AREA**

Project No.:	117-8741002
Date:	DEC 21, 2021
Designed By:	JJA
Figure	G-2



Legend

- Estimated Well Location
- Constructed Well Location with Permit No.
- Affected Area

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MARTIN MARIETTA

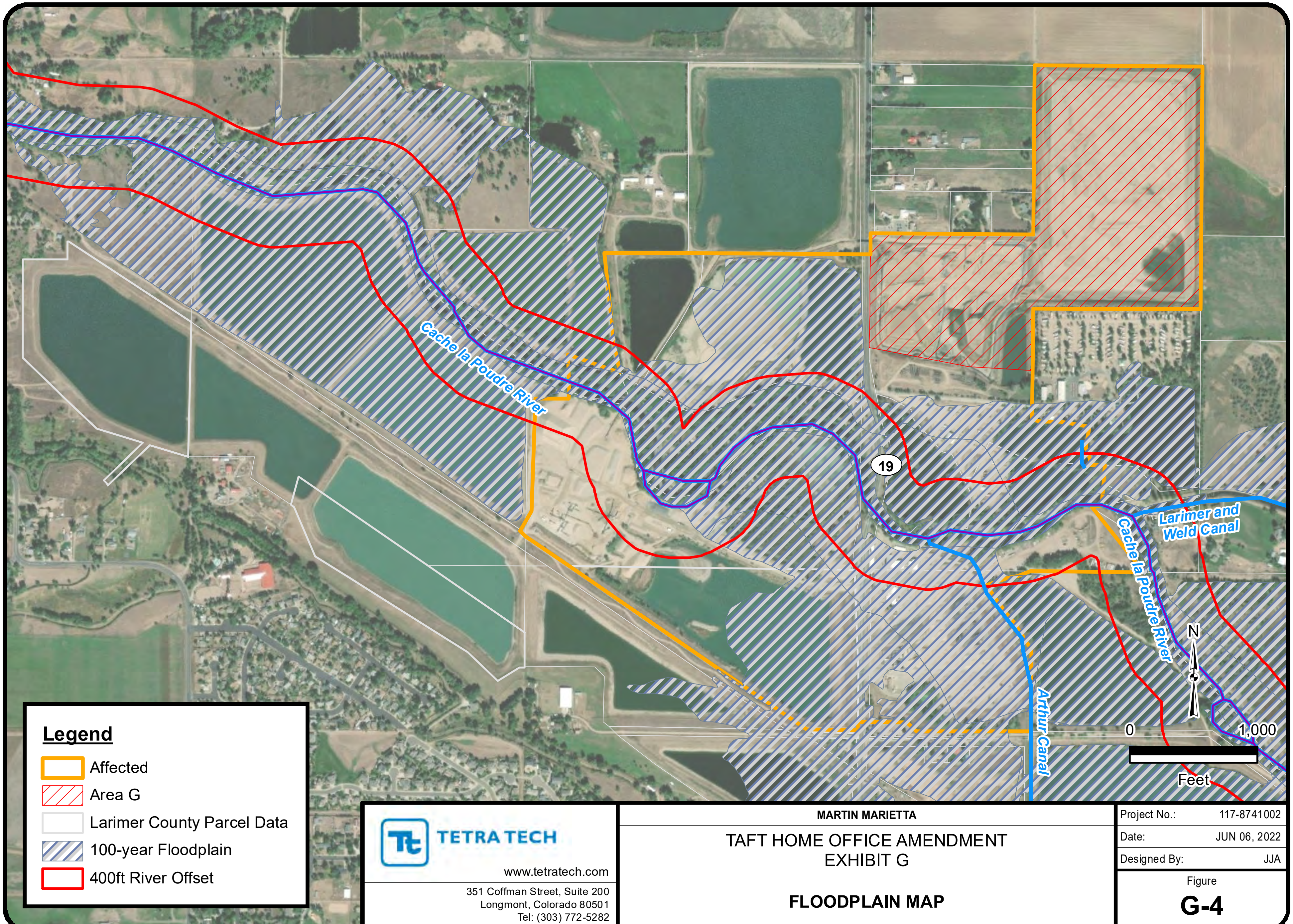
TAFT HOME OFFICE AMENDMENT
EXHIBIT G

ESTIMATED WELL LOCATIONS

Project No.:	117-8741002
Date:	APR 06, 2022
Designed By:	JJA

Figure
G-3

4/6/2022 - O:\PROJECTS\LONGMONT\8741\117-8741002\GIS\MXD\WELL_MAP3.MXD - JEREMY.ANDRYAUSKAS



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Tel: (303) 772-5282

MARTIN MARIETTA

TAFT HOME OFFICE AMENDMENT
EXHIBIT G

FLOODPLAIN MAP

Project No.: 117-8741002
Date: JUN 06, 2022
Designed By: JJA

Figure
G-4

6/6/2022 - O:\PROJECTS\LONGMONT\8741\117-8741002\GIS\MXD\FLOODPLAINMAP.MXD - JEREMY.ANDRYAUSKAS

ATTACHMENT 1
RAW MONITORING WELL DATA

HOME OFFICE MONITORING WELLS (COMBINED MEASUREMENTS PROVIDED BY DEERE & AULT AND MARTIN MARIETTA)																		
Monitoring Well Name	HO-1			HO-6			HO-11			HO-12			HO-13			HO-14*		
Well Location	1469960, 3109282			1467379, 3109131			1469954, 3110451			1468699, 3109239			1468646, 3108123			1467725, 3107980		
Top of PVC Casing Elevation (ft.)	*5024.08*			*5019.39*			*5021.36*			*5023.53*			*5026.66*			*5023.84*		
Ground Elevation of Well (ft.)	*5021.21*			*5016.45*			*5018.43*			*5021.17*			*5023.74*			*5021.58*		
PCV Stickup (approx.)	*2.87*			*2.94*			*2.93*			*2.36*			*2.92*			*2.20*		
Bottom Elevation of Well (ft.)	4996.21			4987.45			5004.43			5004.17			5008.74			5004.53		
Estimated Bedrock Elevation (ft)	5006.71			5000.45			5002.43			5005.17			5006.74			5005.58		
Total Well Depth Ground-Bottom (ft.)	25.00			29.00			14.00			17.00			15.00			17.00		
Date	Water Depth from Top of PVC (ft.)	Saturated Thickness	Ground Water Elevation (ft.)	Water Depth from Top of PVC (ft.)	Saturated Thickness	Ground Water Elevation (ft.)	Water Depth from Top of PVC (ft.)	Saturated Thickness	Ground Water Elevation (ft.)	Water Depth from Top of PVC (ft.)	Saturated Thickness	Ground Water Elevation (ft.)	Water Depth from Top of PVC (ft.)	Saturated Thickness	Ground Water Elevation (ft.)	Water Depth from Top of PVC (ft.)	Saturated Thickness	Ground Water Elevation (ft.)
Monday, May 7, 2018	11.08	6.29	5013.00	9.17	9.77	5010.22												
Friday, June 1, 2018	10.82	6.55	5013.26	9.33	9.61	5010.06												
Tuesday, November 13, 2018	11.15	6.22	5012.93	11.74	7.20	5007.65												
Sunday, December 30, 2018	10.78	6.59	5013.30	12.03	6.91	5007.36												
Sunday, February 3, 2019	11.12	6.25	5012.96	11.90	7.04	5007.49												
Sunday, March 10, 2019	11.35	6.02	5012.73	11.79	7.15	5007.60												
Monday, April 1, 2019	11.35	6.02	5012.73	11.67	7.27	5007.72												
Saturday, May 25, 2019	11.31	6.06	5012.77	11.21	7.73	5008.18												
Thursday, June 13, 2019	11.12	6.25	5012.96	11.29	7.65	5008.10												
Friday, September 6, 2019	10.20	7.17	5013.88	11.56	7.38	5007.83												
Monday, October 7, 2019				11.53	7.41	5007.86												
Saturday, November 16, 2019	11.45	5.92	5012.63	11.98	6.96	5007.41												
Saturday, January 25, 2020	11.60	5.77	5012.48	11.99	6.95	5007.40												
Friday, August 14, 2020	9.96	7.41	5014.12	9.42	9.52	5009.97												
Friday, August 21, 2020	7.71	9.66	5016.37	9.98	8.96	5009.41												
Friday, August 28, 2020	5.91	11.46	5018.17	10.34	8.60	5009.05												
Friday, September 4, 2020	5.70	11.67	5018.38	10.79	8.15	5008.60												
Friday, September 11, 2020	5.63	11.74	5018.45	10.18	8.76	5009.21												
Friday, September 18, 2020	5.64	11.73	5018.44	9.36	9.58	5010.03												
Friday, September 25, 2020	5.67	11.70	5018.41	8.95	9.99	5010.44												
Friday, October 2, 2020	5.70	11.67	5018.38	7.69	11.25	5011.70												
Friday, October 16, 2020	5.73	11.64	5018.35	9.66	9.28	5009.73												
Friday, October 23, 2020	5.79	11.58	5018.29	10.22	8.72	5009.17												
Friday, October 30, 2020	5.68	11.69	5018.40	10.55	8.39	5008.84												
Friday, November 6, 2020	5.61	11.76	5018.47	10.83	8.11	5008.56												
Friday, November 13, 2020	5.61	11.76	5018.47	11.10	7.84	5008.29												
Monday, November 23, 2020	5.60	11.77	5018.48	11.37	7.57	5008.02												
Monday, November 30, 2020	5.64	11.73	5018.44	11.51	7.43	5007.88												
Monday, December 7, 2020	5.73	11.64	5018.35	11.66	7.28	5007.73												
Tuesday, December 15, 2020	5.73	11.64	5018.35	11.80	7.14	5007.59												
Tuesday, December 22, 2020	5.62	11.75	5018.46	11.90	7.04	5007.49												
Tuesday, December 29, 2020	5.73	11.64	5018.35	11.70	7.24	5007.69												
Thursday, January 7, 2021	5.79	11.58	5018.29	11.45	7.49	5007.94												
Thursday, January 14, 2021	5.78	11.59	5018.30	11.63	7.31	5007.76												
Monday, May 24, 2021										11.93	6.43	5011.60	11.85	8.07	5014.81	12.30	5.86	5011.43
Wednesday, May 26, 2021	5.3	12.07	5018.78	6.98	11.96	5012.41	6.3	12.63	5015.06	10.90	7.46	5012.63	11.83	8.09	5014.83	12.40	5.76	5011.33
Thursday, June 3, 2021							6.45	12.48	5014.91	10.91	7.45	5012.62	12.10	7.82	5014.56	12.79	5.36	5010.94
Wednesday, June 16, 2021	3.04	14.33	5021.04	8.95	9.99	5010.44	6.28	12.65	5015.08	11.05	7.31	5012.48	11.62	8.30	5015.04	12.84	5.32	5010.89
Wednesday, June 30, 2021	4.80	12.57	5019.28	8.00	10.94	5011.39	5.87	13.06	5015.49	11.10	7.26	5012.43				9.30	8.85	5014.43
Thursday, July 8, 2021	3.17	14.20	5020.91	7.51	11.43	5011.88	4.76	14.17	5016.60	11.22	7.14	5012.31	12.30	7.62	5014.36	13.58	4.57	5010.15
Thursday, July 22, 2021	2.82	14.55	5021.26	6.73	12.21	5012.66	5.54	13.39	5015.82	11.60	6.76	5011.93	12.26	7.66	5014.40	14.08	4.07	5009.65
Tuesday, July 27, 2021	4.35	13.02	5019.73	8.21	10.73	5011.18	6.21	12.72	5015.15	11.2	7.16	5012.33	12.9	7.02	5013.76	8.97	9.29	5014.87
Wednesday, August 25, 2021																14.63	3.63	5009.21
Thursday, August 26, 2021	4.22	13.15	5019.86	8.15	10.79	5011.24	6.37	12.56	5014.99	11.54	6.82	5011.99	13	6.92	5013.66			
Thursday, September 30, 2021	5.83	11.54	5018.25	8	10.94	5011.39	7.5	11.43	5013.86	11.83	6.53	5011.70	13.15	6.77	5013.51	14	4.26	5009.84
Friday, October 22, 2021	6.01	11.36	5018.07	8.2	10.74	5011.19	8.7	10.23	5012.66				13.57	6.35	5013.09	14.4	3.86	5009.44
Saturday, October 23, 2021										11.9	6.46	5011.63						
Tuesday, November 30, 2021	6.1	11.27	5017.98	11.2	7.74	5008.19	8.7	10.23	5012.66	11.8	6.56	5011.73	13.74	6.18	5012.92	15.02	3.24	5008.82
Tuesday, December 14, 2021							8.9	10.03	5012.46	11.75	6.61	5011.78	12.75	7.17	5013.91	14.9	3.36	5008.94
Friday, December 17, 2021	6.21	11.16	5017.87	11	7.94	5008.39												
Friday, January 14, 2022	6.26	11.11	5017.82	11.18	7.76	5008.21	8.87	10.06	5012.49	11.8	6.56	5011.73	12.62	7.30	5014.04	15.1	3.16	5008.74
Friday, February 11, 2022	6.4	10.97	5017.68	11.84	7.10	5007.55	8.7	10.23	5012.66	11.1	7.26	5012.43	14.1	5.82	5012.56	14.58	3.68	5009.26
Wednesday, March 2, 2022	6.52	10.85	5017.56	11.93	7.01	5007.46	8.83	10.10	5012.53	11.33	7.03	5012.20	14.13	5.79	5012.53	14.67	3.59	5009.17

Home Office Nearby Wells Water Level Monitoring

LOCATION	ALBERT KOONCE			DAVID SLATTEN			STEGNER CORNFIELD/MM Near KOA		
LATTITUDE	40 37'08.6 N			40 37'18.8 N			40 36'59.8 N		
LONGTITUDE	105 06'37.4 W			105 06'48.6 W			105 06'34.5 W		
DESCRIPTION	2" CASE-BY NORTH FENCELINE			2"CASE-CENTER NORTH FENCE			PVC BY RV PARK		
ELEVATION OF BENCHMARK	5023.4			5028.0			5018.5		
ELEVATION OF GROUND SURFACE	5022.4			5027.0			5017.8		
ESTIMATED BEDROCK ELEVATION	5005.4			5010.0			5000.8		
DATE	READING (Measurement from Benchmark to Water Level, ft)	WATER ELEV	SATURATED THICKNESS (ft)	READING (Measurement from Benchmark to Water Level, ft)	WATER ELEV	SATURATED THICKNESS (ft)	READING (Measurement from Benchmark to Water Level, ft)	WATER ELEV	SATURATED THICKNESS (ft)
05/04/04	8.62	5014.82	9.4	7.88	5020.12	10.1			
06/10/04	8.15	5015.29	9.9	6.29	5021.71	11.7			
07/08/04	5.98	5017.46	12.0	3.45	5024.55	14.6			
08/03/04	5.75	5017.69	12.3	3.55	5024.45	14.4			
09/07/04	5.62	5017.82	12.4	5.91	5022.09	12.1			
10/04/04	5.55	5017.89	12.4	4.74	5023.26	13.3			
11/01/04	5.73	5017.71	12.3	4.77	5023.23	13.2			
12/06/04	6.04	5017.40	12.0	5.18	5022.82	12.8			
01/03/05	7.46	5015.98	10.5	7.36	5020.64	10.6			
02/07/05	7.53	5015.91	10.5	7.42	5020.58	10.6			
03/07/05	7.96	5015.48	10.0	7.77	5020.23	10.2			
04/04/05	8.31	5015.13	9.7	8.16	5019.84	9.8			
05/02/05	8.3	5015.14	9.7	8.22	5019.78	9.8			
06/07/05	7.33	5016.11	10.7	5.7	5022.3	12.3			
07/06/05	6.21	5017.23	11.8	4.62	5023.38	13.4			
08/10/05	6.33	5017.11	11.7	4.42	5023.58	13.6			
01/01/07									
02/01/07									
03/01/07									
04/02/07	7.62	5015.82	10.4	7.12	5020.88	10.9	8.6	5009.95	9.1
05/09/07	7.58	5015.86	10.4	7.1	5020.9	10.9	8.71	5009.84	9.0
06/01/07									
07/02/07	6.94	5016.50	11.1	4.89	5023.11	13.1	7.7	5010.85	10.1
08/06/07	6.87	5016.57	11.1	4.74	5023.26	13.3	8.21	5010.34	9.5
09/05/07	6.72	5016.72	11.3	4.92	5023.08	13.1	8.28	5010.27	9.5
10/08/07	6.84	5016.60	11.2	6.1	5021.9	11.9	8.41	5010.14	9.3
11/05/07	7.04	5016.40	11.0	6.48	5021.52	11.5	8.52	5010.03	9.2
12/03/07	6.92	5016.52	11.1	6.42	5021.58	11.6	8.5	5010.05	9.3
01/01/08									
02/01/08									
03/03/08	8.26	5015.18	9.7	8	5020	10.0	8.92	5009.63	8.8
04/07/08	7.85	5015.59	10.1	6.99	5021.01	11.0			
05/05/08	7.71	5015.73	10.3	6.82	5021.18	11.2			
06/01/08	7.23	5016.21	10.8	5.5	5022.5	12.5			
07/07/08	7.11	5016.33	10.9	4.99	5023.01	13.0			
08/11/08	6.98	5016.46	11.0	4.84	5023.16	13.2			
09/08/09	6.82	5016.62	11.2	4.92	5023.08	13.1			
10/01/08									
11/01/08									
12/01/08									
01/01/09									
02/03/09	8.1	5015.34	9.9	7.98	5020.02	10.0	8.82	5009.73	8.9
03/03/09	8.13	5015.31	9.9	7.98	5020.02	10.0	8.85	5009.70	8.9
04/07/09	8.62	5014.82	9.4	8.57	5019.43	9.4	9	5009.55	8.8
05/05/09	6.93	5016.51	11.1	7.48	5020.52	10.5	8.18	5010.37	9.6
06/02/09	4.88	5018.56	13.1	6.15	5021.85	11.9	6	5012.55	11.8
07/07/09	4.21	5019.23	13.8	5.94	5022.06	12.1	5.86	5012.69	11.9
08/12/09	5.67	5017.77	12.3	3.53	5024.47	14.5	5.6	5012.95	12.1
09/08/09	6.21	5017.23	11.8	4.58	5023.42	13.4	5.71	5012.84	12.0
10/06/09	6.05	5017.39	11.9	4.62	5023.38	13.4	6.21	5012.34	11.5
11/11/09	6.91	5016.53	11.1	5.1	5022.9	12.9	7.12	5011.43	10.6
12/01/09	6.89	5016.55	11.1	5.11	5022.89	12.9	7.19	5011.36	10.6
01/01/10	6.77	5016.67	11.2	5.18	5022.82	12.8	7.25	5011.30	10.5
2/1/2010	6.74	5016.70	11.3	5.24	5022.76	12.8	7.32	5011.23	10.4
3/1/2010	6.78	5016.66	11.2	5.26	5022.74	12.7	7.28	5011.27	10.5
4/1/2010	6.72	5016.72	11.3	5.11	5022.89	12.9	7.2	5011.35	10.6
5/1/2010	6.15	5017.29	11.9	4.59	5023.41	13.4	6.31	5012.24	11.4
6/1/2010	5	5018.44	13.0	4.05	5023.95	13.9	5.42	5013.13	12.3
7/13/2010	3.99	5019.45	14.0	3.56	5024.44	14.4	5.44	5013.11	12.3
8/1/2010	4.12	5019.32	13.9	3.84	5024.16	14.2	5.88	5012.67	11.9
9/1/2010	4	5019.44	14.0	5.14	5022.86	12.9	6.54	5012.01	11.2
10/22/2010	7.03	5016.41	11.0	6.66	5021.34	11.3	7.86	5010.69	9.9
11/19/2010	7.1	5016.34	10.9	7.09	5020.91	10.9	7.93	5010.62	9.8

12/17/2010	7.18	5016.26	10.8	7.14	5020.86	10.9	8.03	5010.52	9.7
1/14/2011	7.21	5016.23	10.8	7.18	5020.82	10.8	8.1	5010.45	9.6
2/18/2011	7.48	5015.96	10.5	7.21	5020.79	10.8	8.12	5010.43	9.6
3/18/2011	7.61	5015.83	10.4	7.28	5020.72	10.7	9	5009.55	8.8
5/3/2011	8.76	5014.68	9.2	8.1	5019.9	9.9	9.1	5009.45	8.6
6/6/2011	5.1	5018.34	12.9	5	5023	13.0	5.4	5013.15	12.4
7/16/2011	4.99	5018.45	13.0	4.96	5023.04	13.0	5.42	5013.13	12.3
8/19/2011	5.12	5018.32	12.9	5.04	5022.96	13.0	5.45	5013.10	12.3
9/30/2011									
11/4/2011	6	5017.44	12.0	5.98	5022.02	12.0	5.58	5012.97	12.2
2/17/2012	6.25	5017.19	11.8	6.14	5021.86	11.9			
4/20/2012	8.17	5015.27	9.8	4.25	5023.75	13.8	8.8	5009.75	8.9
5/25/2012	8	5015.44	10.0	4.14	5023.86	13.9	8.42	5010.13	9.3
7/30/2012	7.21	5016.23	10.8	4	5024	14.0	7.93	5010.62	9.8
1/11/2013	7.25	5016.19	10.8	5.2	5022.8	12.8	8.22	5010.33	9.5
8/13/2013	6.34	5017.10	11.7	4.5	5023.5	13.5	6.55	5012.00	11.2
10/23/2013	5.9	5017.54	12.1	5.85	5022.15	12.1			
4/17/2014	6.5	5016.94	11.5	5.75	5022.25	12.3			
5/23/2014	7	5016.44	11.0	5.62	5022.38	12.4			
6/11/2014	7.5	5015.94	10.5	5.44	5022.56	12.6			
7/16/2014	7.38	5016.06	10.6	5.24	5022.76	12.8			
8/20/2014	7.21	5016.23	10.8	5	5023	13.0			
9/8/2014	6.5	5016.94	11.5	5.7	5022.3	12.3	8	5010.55	9.8
10/16/2014	7	5016.44	11.0	6.5	5021.5	11.5	7.1	5011.45	10.6
12/9/2014	8.1	5015.34	9.9	7.6	5020.4	10.4	9.5	5009.05	8.3
7/7/2015	5.26	5018.18	12.7	5.63	5022.37	12.4	7.5	5011.05	10.3
8/18/2015									
11/12/2015	10.5	5012.94	7.5	8.7	5019.3	9.3	8.2	5010.35	9.6
1/12/2016	12.5	5010.94	5.5	10.1	5017.9	7.9	9.5	5009.05	8.3
2/12/2016	10.7	5012.74	7.3	9.5	5018.5	8.5			
3/12/2016	10	5013.44	8.0	9.1	5018.9	8.9	9.2	5009.35	8.6
4/5/2016	9.97	5013.47	8.0	9	5019	9.0	9.1	5009.45	8.6
5/15/2016	9.4	5014.04	8.6	8.5	5019.5	9.5	9	5009.55	8.8
6/16/2016	8	5015.44	10.0	8	5020	10.0	8.9	5009.65	8.9
4/15/2017	6.5	5016.94	11.5	7	5021	11.0	13	5005.55	4.8
5/2/2017	6.68	5016.76	11.3	7.43	5020.57	10.6	13.1	5005.45	4.6
6/12/2017	7.12	5016.32	10.9	7.67	5020.33	10.3	13.08	5005.47	4.7
7/7/2017	7.05	5016.39	10.9	7.99	5020.01	10.0	12.99	5005.56	4.8
8/10/2017	7.55	5015.89	10.4	8.12	5019.88	9.9	13	5005.55	4.8
11/1/2017	8.8	5014.64	9.2	5.8	5022.2	12.2	11.2	5007.35	6.6
12/17/2017	8.78	5014.66	9.2	6	5022	12.0	11	5007.55	6.8
1/11/2018	7.21	5016.23	10.8	7.18	5020.82	10.8	8.1	5010.45	9.6
2/14/2018	7.48	5015.96	10.5	7.21	5020.79	10.8	8.12	5010.43	9.6
3/28/2018	7.61	5015.83	10.4	7.28	5020.72	10.7	9	5009.55	8.8
5/3/2018	8.76	5014.68	9.2	8.1	5019.9	9.9	9.1	5009.45	8.6
6/4/2018	5.1	5018.34	12.9	5	5023	13.0	5.4	5013.15	12.4
7/13/2018	3.99	5019.45	14.0	3.56	5024.44	14.4	5.44	5013.11	12.3
8/1/2018	4.12	5019.32	13.9	3.84	5024.16	14.2	5.88	5012.67	11.9
9/1/2018	4	5019.44	14.0	5.14	5022.86	12.9	6.54	5012.01	11.2
10/22/2018	7.03	5016.41	11.0	6.66	5021.34	11.3	7.86	5010.69	9.9
11/19/2018	7.1	5016.34	10.9	7.09	5020.91	10.9	7.93	5010.62	9.8
12/17/2018	7.18	5016.26	10.8	7.14	5020.86	10.9	8.03	5010.52	9.7
1/14/2019	7.21	5016.23	10.8	7.18	5020.82	10.8	8.1	5010.45	9.6
2/18/2019	7.48	5015.96	10.5	7.21	5020.79	10.8	8.12	5010.43	9.6
3/18/2019	7.61	5015.83	10.4	7.28	5020.72	10.7	9	5009.55	8.8
7/19/2019	7.05	5016.39	10.9	6.89	5021.11	11.1	8.6	5009.95	9.1
8/23/2020	7.22	5016.22	10.8	7.32	5020.68	10.7	7.87	5010.68	9.9
10/13/2020	7.02	5016.42	11.0	7.12	5020.88	10.9	8.35	5010.20	9.4
11/19/2020	6.93	5016.51	11.1	7.42	5020.58	10.6	8.56	5009.99	9.2
1/22/2021	7.13	5016.31	10.9	6.74	5021.26	11.3	10.5	5008.05	7.3
2/17/2021	7.21	5016.23	10.8	6.85	5021.15	11.1	9.4	5009.15	8.4
4/5/2021	7.5	5015.94	10.5	6.86	5021.14	11.1	9.12	5009.43	8.6
5/26/2021	7.34	5016.10	10.7	6.55	5021.45	11.4	8.74	5009.81	9.0
6/30/2021	7.13	5016.31	10.9	6.19	5021.81	11.8	8.3	5010.25	9.4
7/27/2021	7.34	5016.10	10.7	5.93	5022.07	12.1	7.73	5010.82	10.0
8/27/2021	7.87	5015.57	10.1	6.37	5021.63	11.6	7.23	5011.32	10.5
9/30/2021	8.32	5015.12	9.7	7.4	5020.6	10.6	6.65	5011.90	11.1
10/23/2021	8.6	5014.84	9.4	7.93	5020.07	10.1	7.6	5010.95	10.1
11/30/2021	8.6	5014.84	9.4	8.2	5019.8	9.8	10.4	5008.15	7.4
12/17/2021	8.53	5014.91	9.5	7.97	5020.03	10.0	10.11	5008.44	7.6
1/26/2022	8.61	5014.83	9.4	7.85	5020.15	10.1	9.21	5009.34	8.5
2/11/2022	8.96	5014.48	9.0	7.6	5020.4	10.4	11.65	5006.90	6.1
3/2/2022	9	5014.44	9.0	7.52	5020.48	10.5	11.21	5007.34	6.5

Data Source Notes:
Coordinates provided by Martin Marietta, 2021-08-19
Elevations provided by Martin Marietta, 2021-08-19
Water level measurements provided by Martin Marietta
Ground Surface for Koonce and Slatten approximated as 1 foot below BM.
Bedrock depth estimated as 17 feet below ground surface

Stegner - Monitoring Well Measurements									
Depth To Water from Surface (Feet)									
Date Measured	**MW-01**	**MW-02**	**MW-03**	**MW-04**	**MW-05**	**MW-06**	**MW-07**	**MW-08**	**MW-09**
July-16	2.62	0.95	1.75	2.28	2.91	2.41	3.15	6.41	2.92
August-16	4.15	0.93	1.78	2.18	3.06	2.71	3.75	7.38	3.56
September-16	6.89	3.00	3.08	2.52	3.70	3.53	5.70	9.28	5.09
October-16	-0.29	3.18	3.40	2.81	3.73	3.43	4.56	9.99	5.27
November-16	7.01	3.39	3.78	3.10	3.95	3.41	5.43	10.23	5.37
December-16	7.21	3.57	3.98	3.22	3.99	3.45	5.66	10.56	5.45
January-17	7.18	3.58	4.05	3.27	4.00	3.42	5.64	10.63	5.42
February-17	7.19	3.70	4.15	4.47	4.07	3.53	6.19	10.73	5.57
March-17	7.16	3.28	3.72	3.18	4.18	3.53	6.41	10.62	5.62
April-17	5.56	2.61	3.38	3.03	4.05	3.55	6.51	8.95	5.53
May-17	1.76	0.97	2.13	2.67	3.24	2.79	5.50	3.11	3.41
June-17	0.44	0.50	1.55	1.50	2.38	2.10	5.57	1.51	2.20
July-17	1.75	0.53	1.96	2.45	3.47	3.11	5.69	2.18	3.64
August-17	2.60	1.66	2.98	2.73	4.00	3.72	6.17	3.07	6.25
September-17	2.31	1.35	2.73	3.43	4.04	3.80		3.64	6.44
October-17	2.62	1.61	3.85	3.76	4.30	4.50	6.67	4.26	7.81
November-17	2.72	2.11	4.37	3.67	4.79	4.24	6.41	5.23	8.42
December-17	5.63	2.88	4.22	3.45	4.97	4.80	7.07	7.18	8.57
April-18	6.69	3.50	4.41	3.57	5.16	4.89	7.09	8.93	8.74
July-18	2.67	0.90	2.03	2.09	3.11	2.65	5.55	4.71	6.49
October-18	6.94	4.24	4.93	3.33	7.02	6.66	8.09	3.87	8.98
January-19	6.14	4.09	5.15	3.63	5.21	4.99	7.28	7.85	8.84
April-19	6.98	4.39	5.37	3.86	5.45	5.01	7.19	9.31	8.94
July-19	5.84	2.81	4.48	3.20	5.13	3.94	7.10	6.63	8.76
September-19	6.32	4.75	5.59	3.64	4.93	4.01	6.89	6.58	8.39
January-20	7.43	5.24	5.59	4.07	5.52	5.17	7.35	9.59	8.97
May-20	7.03	4.53	5.16	3.79	5.39	5.06	7.15	9.24	8.78
August-20	4.59	2.68	3.12	3.46	4.69	3.91	5.79	4.16	7.18
December-20	6.45	3.23	4.41	3.75	4.94	4.50	6.85	5.78	7.73
February-21	6.69	5.02	5.38	4.28	5.46	4.79	7.38	8.07	8.56
May-21	6.94	4.71	5.29	3.90	5.32	4.89	7.25	9.04	8.74
August-21	4.58	2.88	3.31	3.53	4.68	3.82	6.01	4.06	7.28
December-21	6.51	3.77	4.63	3.44	5.11	4.67	7.10	6.86	8.46
March-22	6.96	4.29	5.28	3.78	5.74	5.10	7.49	7.61	8.98

Legend

Stegner Monitoring Wells

Stegner Parcels

0 400

SCALE IN FEET

N

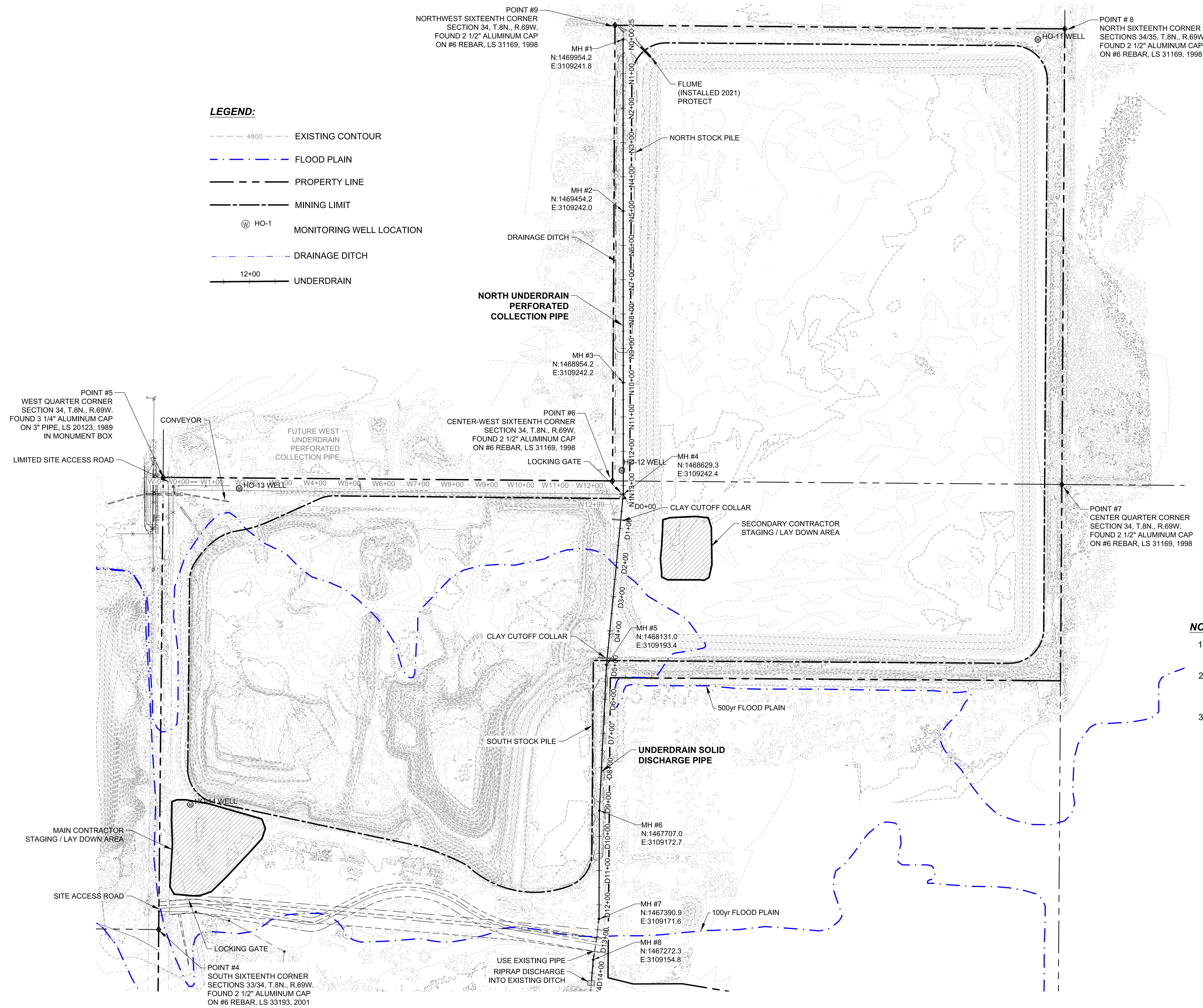
COORDINATE SYSTEM
NAD 83 COLORADO NORTH

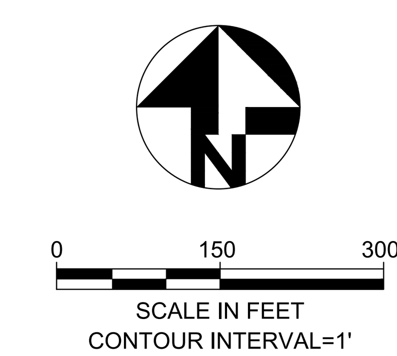
STEGNER BASEMAP

TELESTO SOLUTIONS INCORPORATED

LOVELAND READY-MIX CONCRETE

ATTACHMENT 2
UNDERDRAIN DESIGN





NOTES:

1. ALL UTILITIES TO BE LOCATED, VERIFIED & POT HOLED AS NECESSARY BY CONTRACTOR.
2. TRAFFIC ON LIMITED SITE ACCESS ROAD TO BE COORDINATED WITH ADJACENT PROPERTY OWNERS & ONLY ALLOWED DURING STANDARD WORK HOURS.
3. SURVEY CONTROL PROVIDE BY KING SURVEYOR'S. COORDINATE VALUES ARE THAT OF THE COLORADO STATE PLANE COORDINATE SYSTEM, NORTH ZONE, NORTH AMERICAN DATUM 1983/92. TO CONVERT TO GROUND (MODIFIED) SCALE ABOUT POINT 0,0 AT A FACTOR OF 1.00026675 (0.99973332 CF) VERTICAL DATUM: NAVD 88.

EXISTING SURVEY POINT TABLE

POINT #	NORTHING	EASTING	DESCRIPTION
1	1466019.4650	3110502.4980	S. 1/4 COR, SEC
2	1466033.7797	3109189.4328	W. 1/16 COR, SEC34
3	1466042.3880	3107875.3510	SW. COR, SEC34
4	1467360.3495	3107888.3763	S. 1/16 COR, SEC 34
5	1468678.1520	3107901.4000	W. 1/4 COR, SEC 34
6	1468667.8170	3109210.9885	CENTER W. 1/16 COR, SEC 34
7	1468657.4820	3110520.5770	CENTER 1/4 COR, SEC 34
8	1469985.2060	3110529.0260	N. 1/16 COR, SEC 34
9	1469995.6070	3109218.1910	NW. 1/16 COR, SEC 34

NOTE: POINT # 1,2,3 ARE NOT SHOWN ON THIS PAGE. THEY ARE SOUTH OF THE SITE.

REV	DESCRIPTION	BY	DATE
1	60% DESIGN - NOT FOR CONSTRUCTION	WK	11-4-21
2	FOR CONSTRUCTION	SR	11-29-21

IRECK 11/29/2021 11:32:13 AM

DESIGNED BY: SAR
DRAWN BY: ITR
CHECKED BY: CJH

SUSAN A. RAINEY
STATE PROFESSIONAL ENGINEER NO. XXXXX
DATE:

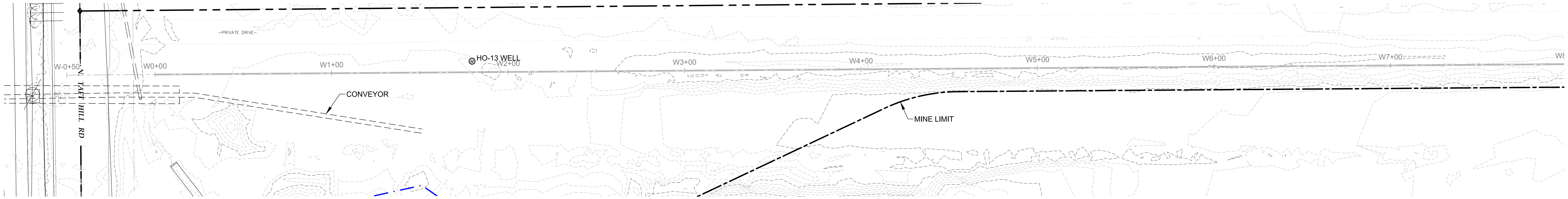
DEERE & AULT
A SCHNABEL ENGINEERING COMPANY
600 S. AIRPORT RD., BLDG. A, SUITE 205
LONGMONT, CO 80503
TEL 303.651.1468 FAX 303.651.1469

HOME OFFICE MINE
UNDERDRAIN CONSTRUCTION

GENERAL PLAN

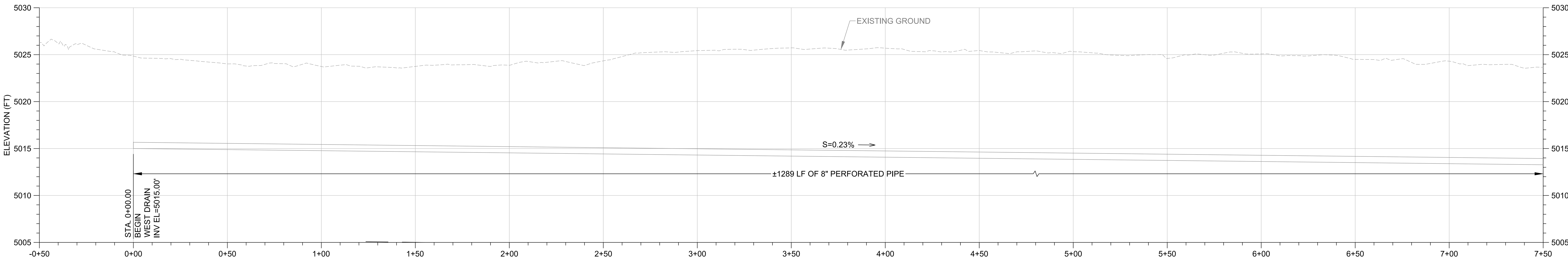
PROJECT: 0494.019.00
DATE: 11/29/21
SHEET 5 OF 9

U:\0494 MARTIN MARIETTA\0494.019 HOME OFFICE MINE\CAD\WORKING\UNDERDRAIN\HO UNDERDRAIN_PIPE PROFILES.DWG



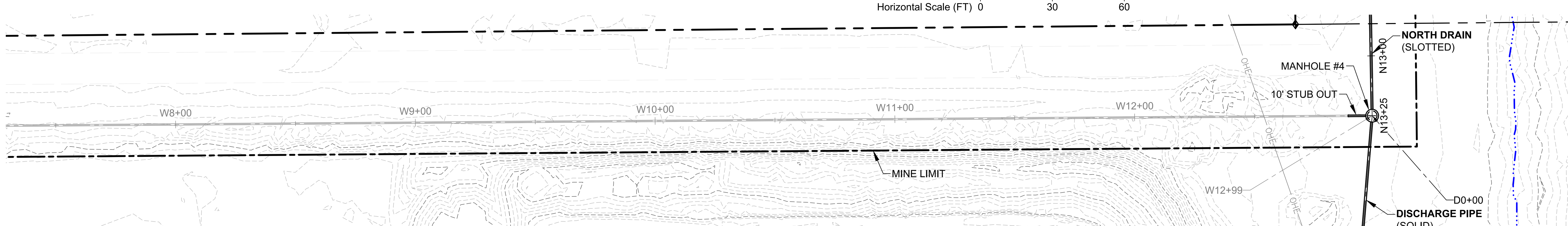
FUTURE WEST DRAIN PLAN (STA 0+00 TO 7+50)

SCALE IN FEET 0 30 60



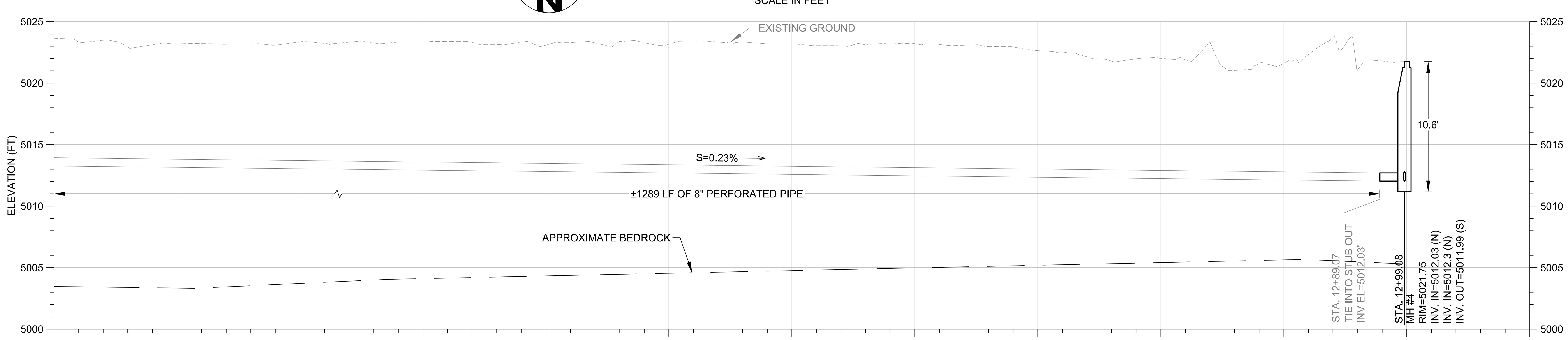
FUTURE WEST DRAIN PROFILE (STA 0+00 TO 7+50)

Vertical Scale (FT) 0 6 12
Horizontal Scale (FT) 0 30 60



FUTURE WEST DRAIN PLAN (STA 7+50 TO 13+00)

SCALE IN FEET 0 30 60



FUTURE WEST DRAIN PROFILE (STA 7+50 TO 13+00)

Vertical Scale (FT) 0 6 12
Horizontal Scale (FT) 0 30 60

REV.	DESCRIPTION	BY	DATE
1	60% DESIGN - NOT FOR CONSTRUCTION	WK	11-4-21
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LONGMONT, CO 80503
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HOME OFFICE MINE
UNDERDRAIN CONSTRUCTION

WEST DRAIN PLAN AND PROFILE

PROJECT: 0494.019.00
DATE: 11/29/21
SHEET
6 OF 9

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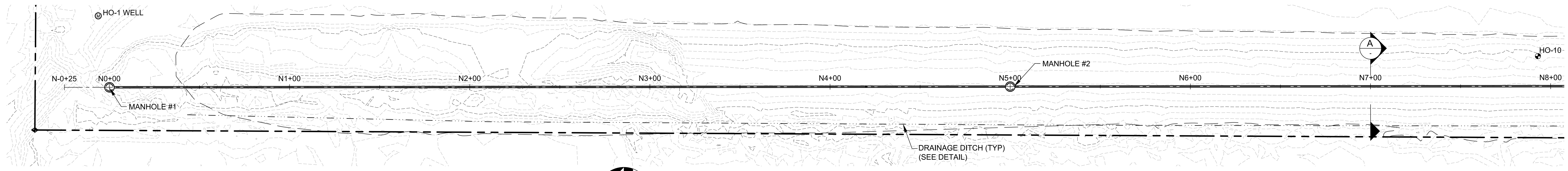
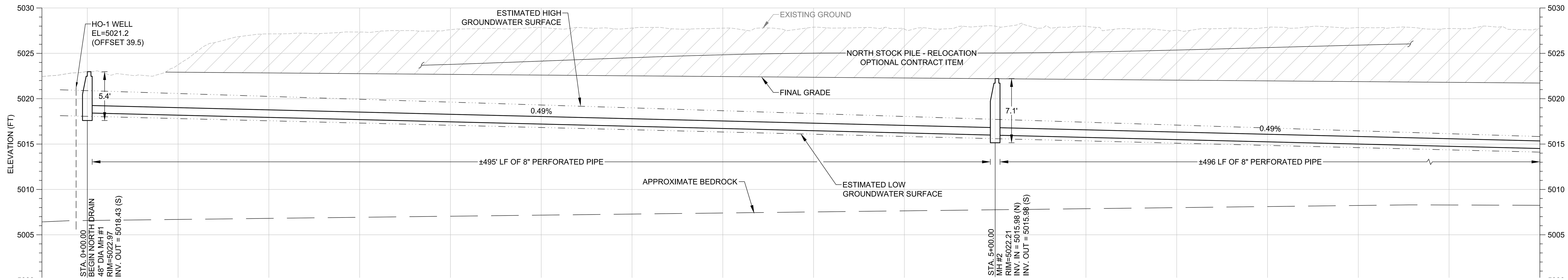


NORTH DRAIN PLAN (STA 0+00 TO 8+00)

0 30 60
SCALE IN FEET



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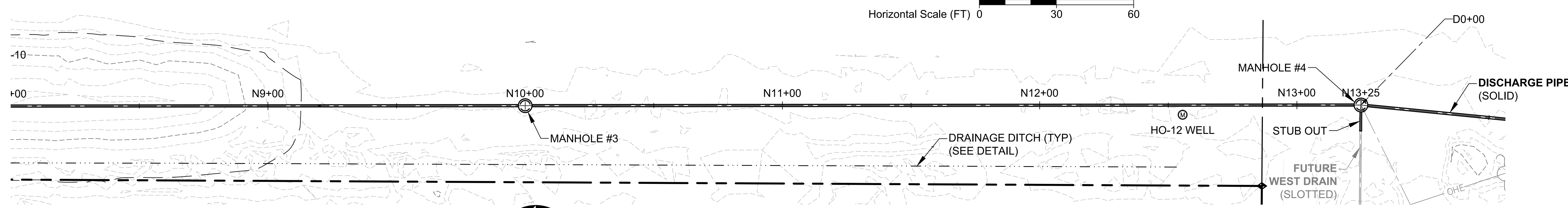
Horizontal Scale (FT) 0 30 60



NORTH DRAIN PLAN (STA 8+00 TO 14+00)

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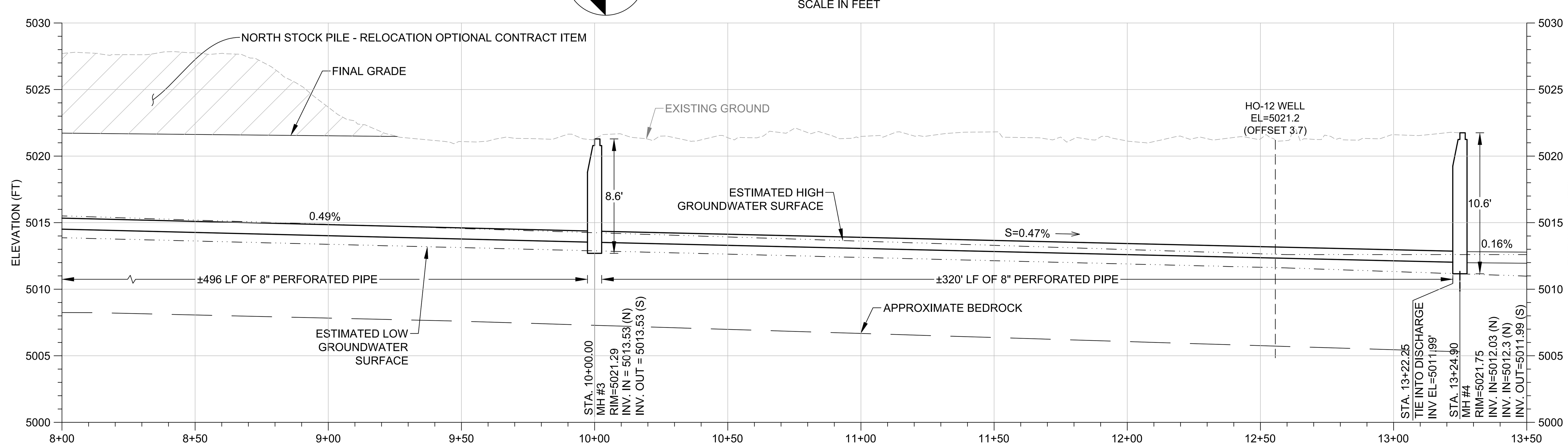
SCALE IN FEET



NORTH DRAIN PROFILE (STA 8+00 TO 13+50)

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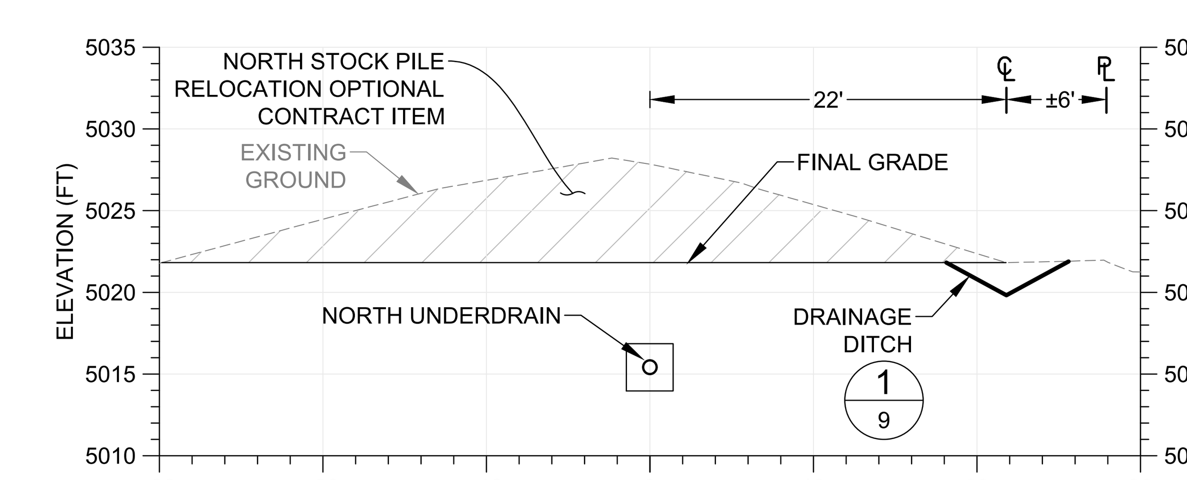
Horizontal Scale (FT) 0 30 60



A - **DITCH SECTION STATION 7+00**

0 10 20
SCALE IN FEET

REV	DESCRIPTION	BY	DATE
1	60% DESIGN - NOT FOR CONSTRUCTION	WK	11-4-21
2	FOR CONSTRUCTION	SR	11-29-21

DESIGNED BY: SAR
DRAWN BY: ITR
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SUSAN A. RAINEY
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HOME OFFICE MINE
UNDERDRAIN CONSTRUCTION

NORTH DRAIN PLAN AND PROFILE

PROJECT: 0494.019.00
DATE: 11/29/21
SHEET 7 OF 9

U:\0494 MARTIN MARIETTA\0494.019 HOME OFFICE MINE\CAD\WORKING\UNDERDRAIN\HO UNDERDRAIN_PIPE PROFILES.DWG

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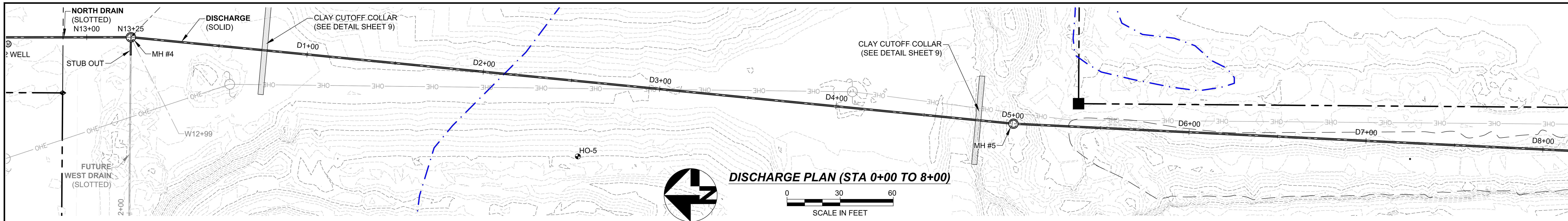
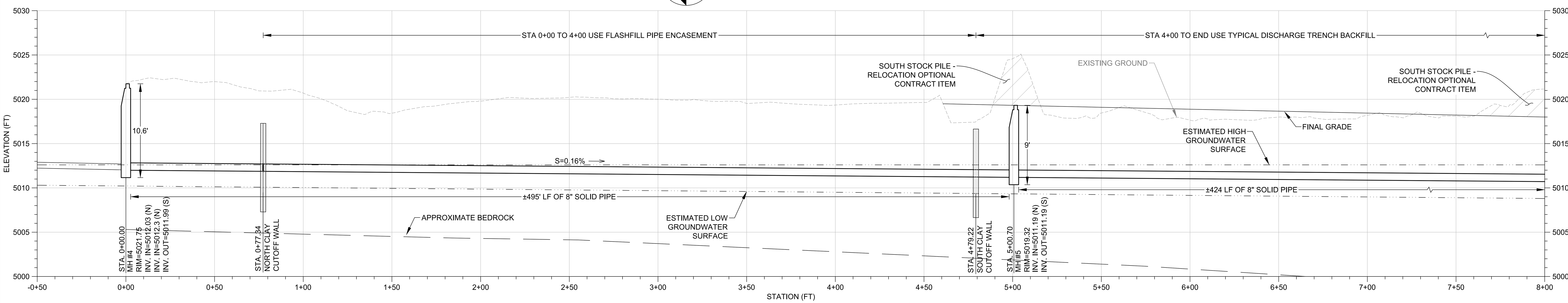


DISCHARGE PLAN (STA 0+00 TO 8+00)



DISCHARGE PROFILE (STA 0+00 TO 8+00)

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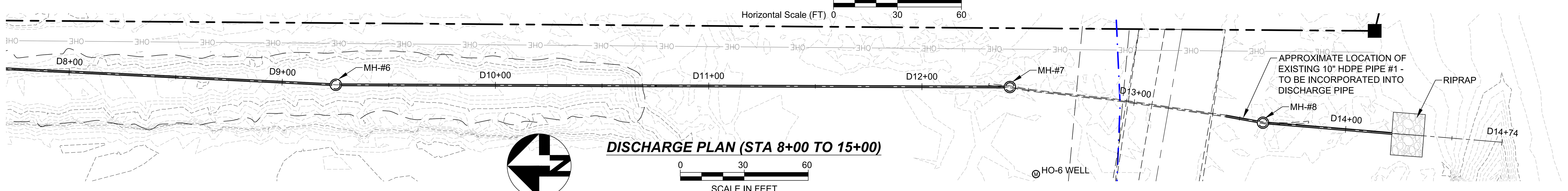
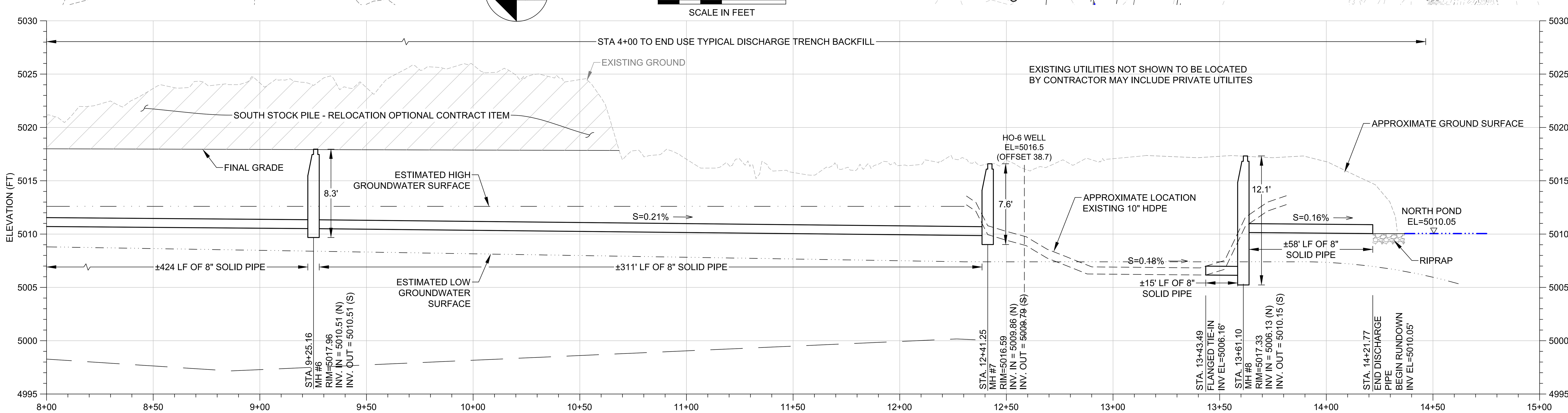
Horizontal Scale (FT) 0 30 60



DISCHARGE PLAN (STA 8+00 TO 15+00)



DISCHARGE PROFILE (STA 8+00 TO 15+00)

Vertical Scale (FT) 0 6 12

Horizontal Scale (FT) 0 30 60

REV	DESCRIPTION	BY	DATE
1	60% DESIGN - NOT FOR CONSTRUCTION	WK	11-4-21
2	FOR CONSTRUCTION	SR	11-29-21

IRECK 11/29/2021 11:32:13 AM

DESIGNED BY: SAR

DRAWN BY: ITR

CHECKED BY: CJH

SUSAN A. RAINEY

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HOME OFFICE MINE

UNDERDRAIN CONSTRUCTION

DISCHARGE PIPE PLAN AND PROFILE

PROJECT: 0494.019.00

DATE: 11/29/21

SHEET 8 OF 9

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DEERE & AULT
A SCHNABEL ENGINEERING COMPANY

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TECHNICAL MEMORANDUM

TO:	Julie Mikulas Britney Guggisberg	**DATE:**	6/21/2022
COMPANY:	Martin Marietta	**SUBJECT:**	Underdrain Calculations
ADDRESS:	1800 North Taft Hill Road Fort Collins, CO 80521	**PROJECT NAME/NO.:**	Home Office DA494019.00
FROM:	Susan A. Rainey, PE	**CC:**	Pam Hora – Tetra Tech

This document presents the calculations performed as part of the groundwater underdrain design at the Home Office Mine.

PROJECT BACKGROUND

The Home Office Mine is located in Larimer County, Colorado in the northwest portion of the city of Fort Collins. As mining progressed at the site, Martin Marietta plans to construct a slope liner in stages around the perimeter of the mined area. The slope liner and berm in the center of the site will create two cells. Phase I, or the first cell and dividing berm, was constructed from August to October in 2020. Phase II is scheduled to be constructed in approximately the same time frame this year. Martin Marietta elected to construct a groundwater collection system or underdrain to deal with possible groundwater mounding that could occur due to the liner configuration. The first section of underdrain (the north drain and discharge) was constructed at the beginning of 2022. The remainder of the underdrain (the west drain) will be constructed as part of Phase II.

CALCULATIONS

Seepage analyses were performed using Seep/W, a finite element computer model software program, to estimate the possible groundwater flow into the underdrain. The seepage analyses were performed using two different K values for the native sand and gravel. The first value (2.54×10^{-3} cm/s) was selected using the NAVFAC DM 7.2 Table 1 typical coefficient of permeability for SW (well-graded sand) soil type as a guideline. This table lists a permeability of greater than 1×10^{-3} ft/min. We selected 5×10^{-3} ft/min or 2.54×10^{-3} cm/s for a possible lower end value, which is greater than the minimum (1×10^{-3} ft/min) typical permeability for well graded sand. This value was selected due to the presence of gravel and cobble on the site. A second seepage analysis was performed with a considerably higher permeability (1×10^{-2} cm/s) for a possible higher end value. This value was selected based off the typical permeability on the NAVFAC DM 7.2 Table 1 for GW (well-graded gravel) of 5×10^{-2} ft/min. Our value of 1.00×10^{-2} cm/s or 1.97×10^{-2} ft/min is less than this maximum permeability.

We performed analyses for each K value with two different groundwater heights for a range of possible flows into the underdrain system. The resulting flows were entered into FlowMaster, a general purpose 1D computational fluid dynamics simulation software, along with other design parameters (pipe size, slope, length, etc.) to calculate how full the pipe would be. An additional flow of 100 gallons per minute or more than double the highest Seep/W flow rate was entered into FlowMaster, as a high-end extreme flow. This was done for the two sections of perforated pipe (north and west drain). A cumulative flow of 200 gallons per minute for the discharge section was also entered into FlowMaster. The resulting percent of pipe full of flow is shown on the attached calculations summary table.

A final check of water velocity through the slots in the perforated pipe was performed for the anticipated flows to confirm the open area of the perforated pipe was sufficient for the estimated possible, and high-end extreme flows.

Home Office Underdrain
Seep W Analysis
Drain pipe sizing.

North Drain

Inputs

Length:	1370	ft. - from drawings
Slope	0.0047	ft./ft.
Pipe Diame	8	in
Manning's	0.0009	
Slots	1.5	in2/ft specified minimum slot area

Outputs

Seep W Input						Seep W Results			Pipe		
Sand and Gravel (k)	Model Ground Surface	Model Groundwater Elevation	Groundwater depth below ground	Drain Elevation	Drain Depth	q	Total flow	Total flow	Flow height - solved in Flowmaster	% of diameter	Water velocity through slots
cm/sec	ft.	ft.	ft.	ft.	ft.	cfs/ft.	cfs	gpm	in		ft/sec
2.54E-03	5,024	5,019	5	5017	7	8.77E-06	1.20E-02	5.392287	0.6	7.1%	8.42E-04
2.54E-03	5,024	5,021	3	5017	7	1.85E-05	2.53E-02	11.37484	0.8	10.1%	1.78E-03
1.00E-02	5,024	5,019	5	5017	7	3.50E-05	4.80E-02	21.51996	1.1	13.7%	3.36E-03
1.00E-02	5,024	5,021	3	5017	7	7.39E-05	1.01E-01	45.43786	1.6	19.6%	7.09E-03
High flow check - 100 gpm, greater than 200% of model						1.63E-04	2.23E-01	100	2.3	29.3	1.56E-02

West Drain

Inputs

Length:	1326	ft. - from drawings
Slope	0.0023	ft./ft.
Pipe Diame	8	in
Manning's	0.0009	
Slots	1.5	in2/ft specified minimum slot area

Outputs

Seep W Input						Seep W Results			Pipe		
Sand and Gravel (k)	Model Ground Surface	Model Groundwater Elevation	Groundwater depth below ground	Drain Elevation	Drain Depth	q	Total flow	Total flow	Flow height - solved in Flowmaster	% of diameter	Water velocity through slots
cm/sec	ft.	ft.	ft.	ft.	ft.	cfs/ft.	cfs	gpm	in		ft/sec
2.54E-03	5,024	5,019	5	5017	7	8.77E-06	1.16E-02	5.219104	0.7	8.2%	8.42E-04
2.54E-03	5,024	5,021	3	5017	7	1.85E-05	2.45E-02	11.00951	0.9	11.8%	1.78E-03
1.00E-02	5,024	5,019	5	5017	7	3.50E-05	4.64E-02	20.82881	1.3	16.0%	3.36E-03
1.00E-02	5,024	5,021	3	5017	7	7.39E-05	9.80E-02	43.97854	1.8	23.1%	7.09E-03
High flow check - 100 gpm, greater than 200% of model						1.68E-04	2.23E-01	100	2.8	35.3%	1.61E-02

Discharge

Length:	1400	ft. - from drawings
Slope	0.0012	ft./ft.
Pipe Diame	8	in
Manning's	0.0009	

Seep W Input						Seep W Results				Pipe
Sand and Gravel (k)	Model Ground Surface	Model Groundwater Elevation	Groundwater depth below ground	Drain Elevation	Drain Depth	q	Total flow	Total flow	Flow height - solved in Flowmaster	% of diameter
cm/sec	ft.	ft.	ft.	ft.	ft.	cfs/ft.	cfs	gpm	in	
2.54E-03	5,024	5,019	5	5017	7		2.36E-02	10.61139	1.1	13.5%
2.54E-03	5,024	5,021	3	5017	7		4.99E-02	22.38435	1.6	19.4%
1.00E-02	5,024	5,019	5	5017	7		9.44E-02	42.34877	2.1	26.7%
1.00E-02	5,024	5,021	3	5017	7		1.99E-01	89.4164	3.2	39.5%
High flow check - 200 gpm, greater than 200% of model							4.46E-01	200	5.1	63.9%

Notes:

See USBR DS-15(5) - Filter Drsign. Paragraph 5.5.2 - "Drains sould be sized so that the depth of water in the drain pipe is less than 50% of the inside diameter.

Slot velocity not specified by design standard. Calculated to check, maintin below 0.06 ft/sec, which the maximum orfice velocity at 100 gpm as calculated in Flow Master

CALCULATION COVER SHEET

Project Home Office Mine Underdrain	**Project Number** DA0494.019
Title Toe drain filter selection and pipe selection	
Computer Programs Used Excel Flow Master Geostudio - SeepW	**Version/Release No.**

Purpose and Objective

Select toe drain filter that is compatible with native soils at the depth of the toe drain. Using USBR Deign Standard No. 13, Embankment Dams, Chapter 5: Protective Filters
Select toe drain pipe slot size that is compatible with filter material.
Select pipe size based on anticipated toe drain flow and pipe slope that meets USBR criteria.
Check water velocity through toe drain slots based on area per foot in specifications.

Summary of Conclusions

Use of ASTM C33 #67 aggregate will be an acceptable filter for the native soils at this site.
A maximum slot size of 1/4 inch is acceptable for the selected filter material.
8 inch slotted pipe will not flow more than 50% full for drains at design slopes, meets USBR.
8 inch solid discharge pipe will discharge anticipated flow from both toe drains without pressurizing.
Acceptable velocity across slots using a minimum opening of 1.5 sq.in. per foot.

Originator

Print	Sign	Date
Walter Kramb		Dec 14, 2021

Checked

Print	Sign	Date

Base Material

Determine the gradation curves of the base soil. Use enough samples to define the range of grain size for the base soil. Design the filter gradation based on the base soil that requires the smallest D_{15F} size. If soil has particles larger than the #4 sieve, an adjusted gradation is calculated. Input values below for the base soil (original) gradation (in red):

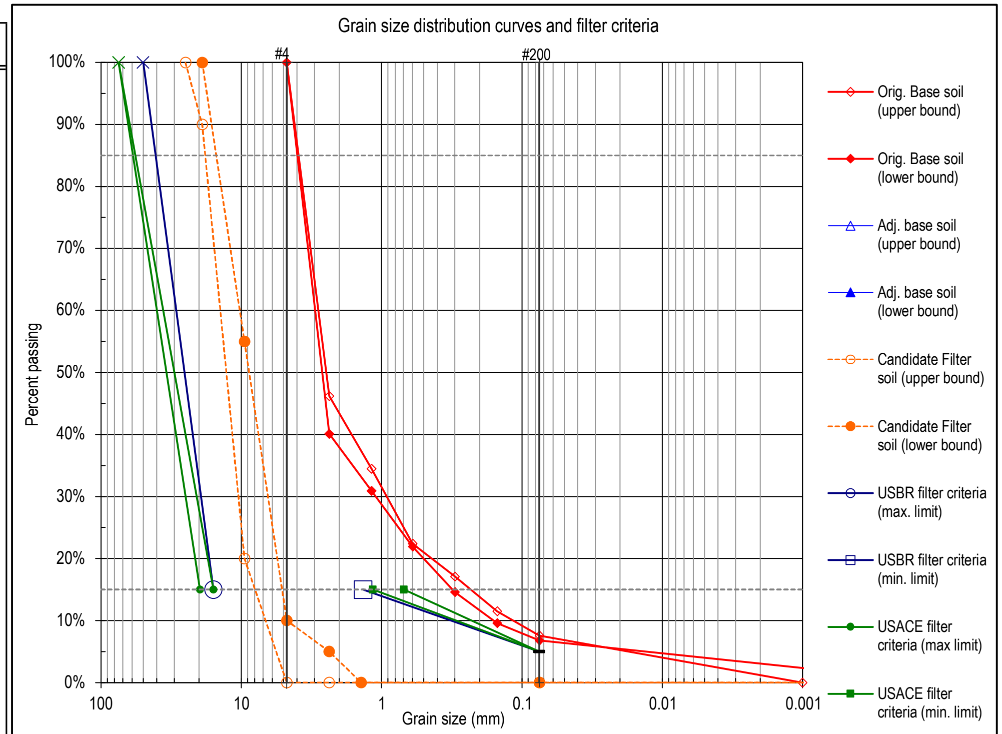
Project: Home Office Underdrain
ASTM #67 Gravel Filter

Name: W. Kramb
Date: 10/5/2021

Particle size (mm)	Sieve #	Base soil (original), % passing (upper bound)	(lower bound)	Adjusted gradation, % passing upper bound	lower bound
75	-				
37.5	-			*(No adjustment needed)*	
19.0	-				
9.5	-				
4.75	4	100.0%	100.0%		
4.00	5				
3.35	6				
2.80	7				
2.36	8	46.2%	40.1%		
2.00	10				
1.70	12				
1.40	14				
1.18	16	34.5%	30.9%		
1.00	18				
0.850	20				
0.710	25				
0.600	30	22.4%	21.9%		
0.500	35				
0.425	40				
0.300	50	17.1%	14.6%		
0.250	60				
0.212	70				
0.180	80				
0.150	100	11.5%	9.6%		
0.125	120				
0.106	140				
0.090	170				
0.075	200	7.6%	6.8%		
0.053	270				
0.037	-				
0.019	-				
0.009	-				
0.005	-				
0.002	-				
0.001	-	0.0%			
0.0001	-	0.0%	0.0%		

Required entry values are defined below. *

Average % passing #200 after regarding (if any) = A = 7.2%



Properties of base soil	Upper bound		Lower bound	
D_{85B} of original base soil =	3.908	mm	3.987	mm
D_{85B} of adjusted base soil =	---	mm	---	mm
D_{15B} of original base soil =	0.2313	mm	0.3116	mm
D_{15B} of adjusted base soil =	---	mm	---	mm
D_{60B} of original base soil =	2.824	mm	2.977	mm
D_{10B} of original base soil =	0.1149	mm	0.1586	mm
C_u of original base soil =	24.6		18.8	

Fixed points on graph:

- <5% passing #200
- × 50mm max. grain size (USBR)
- × 75mm max. grain size (USACE)

Filter Material

Filter criteria required by the USBR as published in *Design Standards - Embankment Dams No. 13 (1994):*

D_{85B} used in filter design	3.948
Average Passing #200 sieve of base soil	7.2%
Base soil category	4
Base soil description	Sands and gravels
Filter criteria (mm)	Maximum: $D_{15F} \le$ 15.79 To ensure sufficient permeability: Minimum: $D_{15F} \ge$ 1.36
Maximum particle size of filter (mm)	50
Maximum % passing # 200 sieve	5%
PI of material passing #40	0 when tested in accordance with USBR 5360, <u>Earth Manual</u>, on material passing #40

*Required entry values for base soil & candidate filter gradations:

1. Particle size for 100% passing.
2. % Passing the #4 sieve.
3. % Passing the #200 sieve.
4. One point in the 85% - 90% range and another point in the 80% - 85% range, or the 85% point.
5. One point in the 15% - 20% range and another point in the 10% - 15% range, or the 15% point.
6. No duplicate entries; if D100<#4, enter 101% for #4 and 100% for appropriate size.

USBR filter gradation limits:

Maximum limit	
Grain size (mm)	% Passing
50.00	100.0%
15.79	15.0%

Minimum limit	
Grain size (mm)	% Passing
1.36	15.0%
0.075	5.0%

Candidate filter soil gradation. Values shown in red in the left column, and all values in the two right columns, can be changed.

Particle size *mm*	Sieve #	% Passing (upper bound)	% Passing (lower bound)
150.0	-		
100.0	-		
90.0	-		
75.0	-		
63.0	-		
50.0	-		
37.5	-		
25.0	-	100.0%	
19.0	-	90.0%	100.0%
12.5	-		
9.5	-	20.0%	55.0%
4.75	4	0.0%	10.0%
3.35	6		
2.36	8	0.0%	5.0%
2.00	10		
1.70	12		
1.40	14		(0.0%)
1.18	16		
0.850	20		
0.600	30		
0.425	40		
0.300	50		
0.250	60		
0.212	70		
0.180	80		
0.150	100		
0.125	120		
0.106	140		
0.090	170		
0.075	200	(0.0%)	(0.0%)
0.053	270		
0.037	-		
0.019	-		
0.009	-		
0.0001	-	0.0%	0.0%

Acceptibility of candidate filter (CF) soil:

USBR criteria	Upper bound	Lower bound
Max % passing #200:	OK	OK
Max particle size (mm):	OK	OK
Maximum D_{15CF}:	OK	OK
Minimum D_{15CF}:	OK	OK
To minimize segregation (from *Table 2*)***		
Max allowable D_{90CF} =	40	OK
Max D_{90CF} =	19.00	

USACE criteria	Upper bound	Lower bound
Max % passing #200:	OK	OK
Max particle size (mm):	OK	OK
Maximum D_{15CF}:	OK	OK
Minimum D_{15CF} ($3 \times D_{15B}$):	OK	OK
Minimum D_{15CF} ($5 \times D_{15B}$):	OK	OK
To minimize segregation (from *Table B-3*)***		
Max allowable D_{90CF} =	40	OK
Max D_{90CF} =	19.00	

Filters should be relatively uniform (see the C_U value of the candidate filter soil.). Also, filters should not be gap-graded.

*** Generally, this requirement is only necessary for coarse filters and gravel zones that serve as both filters and drains. For sand filters with D_{90} < ~20mm, these limitations are usually not necessary.

Filter criteria required by the US Army Corps of Engineers as published in EM 1110-2-2300 (31 Jul 94):

D_{85B} used in filter design	3.948
Average Passing #200 sieve of base soil	7.2%
Base soil category	4**
Filter criteria (mm)	Maximum: $D_{15F} \le$ 15.79 to 19.74 To ensure sufficient permeability: Minimum: $D_{15F} \ge$ 0.69 to 1.16
Maximum particle size of filter (mm)	75
Maximum % passing # 200 sieve	5%
PI of material passing #40	0 when tested in accordance with EM 1110-2-1906

**If the base soil is in category 4, use the lower of the two 'max. D_{15F}' values when the filter is beneath riprap subject to wave action or beneath drains which may be subject to violent surging and/or vibration.

USACE filter gradation limits:

Maximum limit	
Grain size (mm)	% Passing
75.00	100.0%
19.74	15.0%
15.79	15.0%

Minimum limit	
Grain size (mm)	% Passing
0.69	15.0%
1.16	15.0%
0.075	5.0%

Required entry values are defined above. *

Properties of candidate filter soil (CF). D sizes are in mm:

	D_{85CF}	D_{15CF}	D_{60CF}	D_{10CF}	C_u
upper bound	18.08	7.99	14.12	6.72	2.10
lower bound	15.08	5.13	10.26	4.75	2.16

Home Office underdrain
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of D15F to D85B over that used for protecting a natural or unprocessed soil. The ratio can be as high as 9, but 5 is generally found to meet the practical requirements of the situation. This increase is sometimes possible because the first-stage filter: (1) is a material processed to stringent gradation requirements and placed and compacted under controlled conditions, (2) is inspected and tested to verify that material properties conform to those that are specified, (3) usually has seepage gradients that are much less than those of a foundation material or impervious zone that needs filter protection, and (4) has D_{85} particles in the first stage filter material that are larger than those in materials that are usually being protected and, therefore, less likely to move. However, this increase should be made with caution.

5.5.2 Drain Pipe Perforation Size

The maximum pipe perforation dimension[19] should be no larger than the finer side of the $D_{50}E$ where $D_{50}E$ is taken from the gradation of the envelope (drain) material that surrounds the drainpipe. That is:

$D50_{min}$ for
Astm C33 #57 gravel – ~15mm = 0.59 in
#67 gravel – ~12mm = 0.47 in

Max Perforation Dimension $\leq D_{50}E$

It is emphasized that inaccessible drainpipes beneath embankment dams should be avoided. Drainpipes should be sized and located, and inspection wells should be provided so that access for inspection, maintenance, and repair, if necessary, is easy. It is recommended that each pipe segment be accessible from both ends. In order to provide a margin of safety for the pipe capacity, drains should be sized so that the depth of water in the drainpipe is less than 50 percent of the inside diameter of the drainpipe at the maximum expected discharge. If it is anticipated that the drainpipe will collect a large amount of flow from a pervious foundation or embankment, the maximum depth of water should not exceed 25 percent of the inside pipe diameter due to uncertainties in predicting the amount of flow.

Use ½" slots max
¼" more reasonable
also consider drilled pipe
Review size!
slope

5.6 Laboratory Test Procedures

In the following section, test procedures for laboratory tests are presented. The procedures have been separated into two categories: particle retention and material quality. The particle retention tests evolved from the original test procedures used during research into particle movement. The material quality tests come mainly from industry standard tests, although one stems from research work.

[19] The maximum dimension as used in this standard is the width for a slot and the diameter for a hole.

Home Office Underdrain
Seep W Analysis
Drain pipe sizing.

North Drain

Inputs

Length:	1370	ft. - from drawings	
Slope	0.0047	ft./ft.	
Pipe Diame	8	in	
Manning's	0.0009		
Slots	1.5	in2/ft	specified minimum slot area

				Outputs							
		Seep W Input				Seep W Results				Pipe	
Sand and Gravel (k)	Model Ground Surface	Model Groundwater Elevation	Groundwater depth below ground	Drain Elevation	Drain Depth	q	Total flow	Total flow	Flow height - solved in Flowmaster	% of diameter	Water velocity through slots
cm/sec	ft.	ft.	ft.	ft.	ft.	cfs/ft.	cfs	gpm	in		ft/sec
2.54E-03	5,024	5,019	5	5017	7	8.77E-06	1.20E-02	5.392287	0.6	7.1%	8.42E-04
2.54E-03	5,024	5,021	3	5017	7	1.85E-05	2.53E-02	11.37484	0.8	10.1%	1.78E-03
1.00E-02	5,024	5,019	5	5017	7	3.50E-05	4.80E-02	21.51996	1.1	13.7%	3.36E-03
1.00E-02	5,024	5,021	3	5017	7	7.39E-05	1.01E-01	45.43786	1.6	19.6%	7.09E-03
High flow check - 100 gpm, greater than 200% of model						1.63E-04	2.23E-01	100	2.3	29.3	1.56E-02

West Drain

Inputs

Length:	1326	ft. - from drawings	
Slope	0.0023	ft./ft.	
Pipe Diame	8	in	
Manning's	0.0009		
Slots	1.5	in2/ft	specified minimum slot area

				Outputs							
		Seep W Input				Seep W Results				Pipe	
Sand and Gravel (k)	Model Ground Surface	Model Groundwater Elevation	Groundwater depth below ground	Drain Elevation	Drain Depth	q	Total flow	Total flow	Flow height - solved in Flowmaster	% of diameter	Water velocity through slots
cm/sec	ft.	ft.	ft.	ft.	ft.	cfs/ft.	cfs	gpm	in		ft/sec
2.54E-03	5,024	5,019	5	5017	7	8.77E-06	1.16E-02	5.219104	0.7	8.2%	8.42E-04
2.54E-03	5,024	5,021	3	5017	7	1.85E-05	2.45E-02	11.00951	0.9	11.8%	1.78E-03
1.00E-02	5,024	5,019	5	5017	7	3.50E-05	4.64E-02	20.82881	1.3	16.0%	3.36E-03
1.00E-02	5,024	5,021	3	5017	7	7.39E-05	9.80E-02	43.97854	1.8	23.1%	7.09E-03
High flow check - 100 gpm, greater than 200% of model						1.68E-04	2.23E-01	100	2.8	35.3%	1.61E-02

Discharge

Length:	1400	ft. - from drawings
Slope	0.0012	ft./ft.
Pipe Diame	8	in
Manning's	0.0009	

	Seep W Input					Seep W Results				Pipe
Sand and Gravel (k)	Model Ground Surface	Model Groundwater Elevation	Groundwater depth below ground	Drain Elevation	Drain Depth	q	Total flow	Total flow	Flow height - solved in Flowmaster	% of diameter
cm/sec	ft.	ft.	ft.	ft.	ft.	cfs/ft.	cfs	gpm	in	
2.54E-03	5,024	5,019	5	5017	7		2.36E-02	10.61139	1.1	13.5%
2.54E-03	5,024	5,021	3	5017	7		4.99E-02	22.38435	1.6	19.4%
1.00E-02	5,024	5,019	5	5017	7		9.44E-02	42.34877	2.1	26.7%
1.00E-02	5,024	5,021	3	5017	7		1.99E-01	89.4164	3.2	39.5%
High flow check - 200 gpm, greater than 200% of model							4.46E-01	200	5.1	63.9%

Notes:

See USBR DS-15(5) - Filter Drsign. Paragraph 5.5.2 - "Drains sould be sized so that the depth of water in the drain pipe is less than 50% of the inside diameter.

Slot velocity not specified by design standard. Calculated to check, maintin below 0.06 ft/sec, which the maximum orfice velocity at 100 gpm as calculated in Flow Master

TABLE 5.5 Coarse Aggregate Grading Requirements for Concrete (Reprinted, with permission, from ASTM C33, Table 2, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428).

Size No.	Nominal Size	Amounts Finer Than Each Laboratory Sieve (Square Openings), Weight Percent												
		4 in. (100 mm)	3 1/2 in. (90 mm)	3 in. (75 mm)	2 1/2 in. (63 mm)	2 in. (50 mm)	1 1/2 in. (37.5 mm)	1 in. (25.0 mm)	3/4 in. (19.0 mm)	1/2 in. (12.5 mm)	3/8 in. (9.5 mm)	No. 4 (4.75 mm)	No. 8 (2.36 mm)	No. 16 (1.18 mm)
1	3 1/2 to 1 1/2 in. (90 to 37.5 mm)	100	90 to 100	...	25 to 60	...	0 to 15	...	0 to 5	...	...	...	...	...
2	2 1/2 to 1 1/2 in. (63 to 37.5 mm)	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...
3	2 to 1 in. (50 to 25.0 mm)	...	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...
357	2 in. to No. 4 (50 to 4.75 mm)	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	...	0 to 5	...	...
4	1 1/2 to 3/4 in. (37.5 to 19 mm)	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	0 to 5	...	...	...
467	1 1/2 in. to No. 4 (37.5 to 4.75 mm)	...	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	0 to 5	...	...
5	1 to 1/2 in. (25.0 to 12.5 mm)	...	...	...	...	...	100	90 to 100	20 to 55	0 to 10	0 to 5	...	...	...
56	1 to 3/8 in. (25.0 to 9.5 mm)	...	...	...	...	...	100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5	...	...
57	1 in. to No. 4 (25.0 to 4.75 mm)	...	...	...	...	...	100	95 to 100	...	25 to 60	...	0 to 10	0 to 5	...
6	3/4 in. to 3/8 in. (19.0 to 9.5 mm)	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	0 to 5	...	...
67	3/4 in. to No. 4 (19.0 to 4.75 mm)	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5	...
7	1/2 in. to No. 4 (12.5 to 4.75 mm)	...	...	...	...	...	...	...	100	90 to 100	40 to 70	0 to 15	0 to 5	...
8	3/8 in. to No. 8 (9.5 to 2.36 mm)	...	...	...	...	...	...	...	...	100	85 to 100	10 to 30	0 to 10	0 to 5