Draft
Cover System and Buttress Alternatives Evaluation–

Marshall Landfill

Prepared for
Washington State Department of Ecology

Prepared by
Herrera Environmental Consultants, Inc.
and
GeoEngineers, Inc.

HERRERA
Science + Planning + Design

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Marshall Landfill

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DRAFT
June 13, 2023

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EXECUTIVE SUMMARY

Washington State Department of Ecology (Ecology) has executed a contract with Herrera Environmental Consultants (Herrera) to provide Architecture/Engineering Services for the Marshall Landfill Cleanup Site, CSID #1022 (Project), located in Marshall, Spokane County, Washington. This Project consists of engineering services for a traditional design-bid-build public works project in conformance with the Revised Code of Washington (RCW) 39.04, along with other additional services necessary for Ecology to achieve the requirements of the remedial action for the Marshall Landfill (Landfill, Site).

The Landfill (consisting of the approximately 25-acre Main Landfill and Five-Acre Landfill) has been assessed for five issues of concern: landfilled waste extends beyond parcel boundaries; slopes exceed stability factors for static seismic conditions at the north and east ends of the Site; the Landfill was closed without an approved cover system; drainage was not installed at the Landfill; and landfill gas (LFG) infrastructure was not assessed at property boundaries.

Herrera has developed recommendations for four of the issues of concern. The recommendations are assessed and evaluated in this Cover System and Buttress Alternatives Evaluation, and summarized below.

- Waste at Parcel Boundaries. Landfilled waste has been observed extending onto adjacent properties to the north, west, and south of the Landfill. Herrera recommends covering waste in place. This will require coordination with adjacent property owners for access and future land use restrictions. Herrera will support this coordination through the design process.

- Steep Slopes. Slopes exceeding safety factors were observed to the north and east of the Landfill. Herrera recommends removing waste from the north slope to achieve a stable slope of 2H:1V. Herrera recommends installing a retaining wall at the toe of the east slope, with soil above to achieve a stable slope of 2.1H:1V. Soils used for slope stability in both areas will serve as soil covers for the Landfill.

- Cover System. Existing cover systems were assessed and determined to be inadequate at the Main Landfill. Soils used for final cover at the Five-Acre Landfill may be reused for final cover following bentonite amendment to achieve required permeability. Herrera recommends installation of an evapotranspiration (low permeability soil) final cover system. Soils for the system may be reused from the Five-Acre Landfill and imported from the neighboring Action Materials. Soils from both locations will require bentonite amendment to achieve required permeability.

- Stormwater Drainage. Available area for stormwater infrastructure is limited to a small area at the northeast corner of the Marshall Landfill. Soil infiltration analysis has been conducted and confirmed the area available can accommodate the anticipated stormwater from the Marshall Landfill for 10- and 100-year storm events. Additional infiltration ponds may be installed throughout the Marshall Landfill to account for geography and conveyance paths. These ponds will be further assessed during the design phase of the Project.

LFG will be further assessed pending decision on management strategies for landfilled waste. LFG monitoring probes will be installed outside the landfilled waste to assess LFG migration and potential impacts to neighboring properties.

Recommendations from this Evaluation will be discussed with Ecology to develop a basis of design for closure of the Landfill. These recommendations will be coordinated to determine a path forward to develop preliminary design for the Project.

INTRODUCTION

In March 2022, the Washington State Department of Ecology (Ecology) executed a contract with Herrera Environmental Consultants (Herrera) to provide Architecture/Engineering Services for the Marshall Landfill Cleanup Site, CSID #1022 (Project), located in Marshall, Spokane County, Washington. This Project consists of engineering services for a traditional design-bid-build public works project in conformance with the Revised Code of Washington (RCW) 39.04, along with other additional services necessary for Ecology to achieve the requirements of the remedial action for the Marshall Landfill (Site).

Key considerations for the Project include waste management strategy, steep slopes to the north and east of the Site, appropriate cover systems for the overall Site, stormwater management strategies, and landfill gas (LFG) management strategies. The Herrera Team (consisting primarily of Herrera, and GeoEngineers, Inc. [GeoEngineers]) has developed this Cover System and Buttress Alternatives Evaluation (Evaluation) to provide an assessment of the various considerations listed, with LFG considerations to follow installation and monitoring of LFG probes contingent upon waste management strategy selected. The Evaluation will be used to determine a preferred approach for cover system selection, steep slope mitigation, and waste management strategy necessary to progress design of the Project.

SITE BACKGROUND

GeoEngineers performed a Remedial Investigation (RI) and Feasibility Study (FS) for the Site in 2018. The RI/FS reports provide background information for the Site, assessment of existing conditions, and provides alternatives for a final cover system. This Evaluation summarizes site background provided in the RI/FS, and provides additional information on current adjacent properties.

Marshall Landfill

The Marshall Landfill is primarily located on four parcels owned by Marshall Properties, where waste is buried in the Main and Five-Acre Landfills:

- <u>The Main Landfill</u> (Parcel Nos. 24214.9018 and 24214.9041): This approximate 25-acre waste disposal area is located within the south-central portion of the site. Sand and gravel removed from the Main Landfill were replaced with waste during the period from 1970 through 1990. The landfilled waste thickness was estimated at 100 feet in the Main Landfill (Fetrow 1991). Waste from the Main Landfill has been observed on neighboring properties (Parcel Nos. 24214.9044 and 24213.9076 to the north, and 24213.9017 to the west).
- <u>The Five-Acre Landfill</u> (Parcel Nos. 24213.9011 and 24213.9009): This approximate Five-Acre waste disposal area is located within the northwest portion of the site. Waste was disposed within the Five-Acre Landfill during the period from 1980 through 1984. The landfilled waste thickness was estimated at 45 feet in the Five-Acre Landfill (Fetrow 1991). Waste from the Five-Acre Landfill has been observed on neighboring properties (Parcel Nos. 24213.9076 to the east, and 24213.9010 to the west).

Neither the Main Landfill nor the Five-Acre Landfill is equipped with a bottom liner. As the Main Landfill and Five-Acre Landfills were filled, daily cover material consisting of 6 to 12 inches of sand was placed on the solid waste (Fetrow 1991). As a result, both landfills consist of alternating layers of waste material and sand of variable thickness.

Disposal operations ceased on-site in 1990. At that time, the Main Landfill and Five-Acre Landfill were closed under Permit No. SCHD SW-MARSH-001 (Fetrow 1991). The Main Landfill was reportedly covered with a layer of fine to medium sand. A passive LFG venting system and a compacted-clay cap was installed in 1990 at the Five-Acre Landfill; however, the as-built condition of the clay cap is not well documented. Observations of the clay cap over the Five-Acre Landfill prior to the RI indicated the cap was not intact over the entire area of the landfill and some waste was exposed.

The southern and southeastern boundaries of the Main Landfill were buttressed with what appears to be a berm constructed of sandy materials from the adjacent gravel pit. The buttress berm reportedly was constructed to add additional capacity to the Main Landfill. The site description and history are described in detail in the RI/FS reports.

Adjacent Properties

The Marshall Landfill is located adjacent to a mix of public- and private-owned properties.

- The former Spokane County Landfill (Parcel No. 24282.9002) is located adjacent to the southern boundary of the Main Landfill. The landfill was operated by Spokane County as a daily-burn landfill from the 1950s until 1970, and has no bottom liner.
- Spokane County Engineers own three parcels to the west of the Marshall Landfill (Parcel Nos. 24213.9010, 24213.9016, and 24213.9017). These parcels are primarily undeveloped and are heavily forested. Waste from the Main Landfill and Five-Acre Landfill has been observed on two of these parcels (Parcel Nos. 24213.9017 and 24213.9010).
- An access road to an active gravel pit and associated offices, laydown area, and parking facilities borders the Five Acre Landfill to the north. The access road separates the Five Acre Landfill from a private property owned by Jongeward (Parcel No. 24212.9074).
- Parcels owned by Randall Gillingham (Parcel Nos. 24213.9076 and 24213.9075) and Castle Materials (Parcel No. 24214.9044) are located to the north of the Marshall Landfill. The Castle Materials property is used by Action Materials for ongoing excavation operations at an active gravel pit (the Gillingham Gravel Pit). Administrative offices, parking, and ongoing operations to support excavation of an active gravel pit are also provided on the property. The Gillingham Property includes additional support facilities for Action Materials (a portion of their administrative offices, parking, and haul road). Waste from the Marshall Landfill has been observed extending into each of these parcels.
- The east side of the Main Landfill is restricted by South Cheney Spokane Road.

INVESTIGATORY FIELD WORK

The RI/FS indicated approximate boundaries of the Main and Five-Acre Landfills based on historical evidence and field work conducted. GeoEngineers performed additional field work to further evaluate the cover thickness over landfilled waste, the lateral extents of landfilled waste, and the properties of soils observed at the landfills. Test pit locations were logged via GPS, and are shown for the Marshall and Five-Acre Landfills in Figures 1 and 2, respectively.

Test Pit Excavations

GeoEngineers excavated test pits of the Main and Five-Acre Landfills in November 2022 to address the following data gaps:

- Delineate waste extents to develop closure strategy of waste consolidation or waste removal beyond parcel limits;
- Delineate and characterize existing cover soils to determine feasible options for final cover design; and
- Determine the infiltration capacity of existing soil for the potential design of stormwater management infrastructure. It is anticipated that infiltration will be maximized on site and augmented with evaporation to meet stormwater management requirements.

Twenty-five and seventeen test pits were excavated in the Main and Five-Acre Landfills, respectively, to ascertain thickness and extent of cover material:

- Twelve test pits were excavated in the middle of the Main Landfill until municipal solid waste (MSW) was encountered to assess the thickness of the cover material.
- Eight test pits were excavated in the middle of the Five-Acre Landfill until MSW was encountered to assess the thickness of the cover material.
- Nine test pits were excavated west and east of the Five-Acre Landfill to assess the lateral extent of the waste at the excavated locations. These test pits were advanced to approximately 10 feet below ground surface (bgs) or until MSW was no longer observed (if shallower than 10 feet bgs).
- Twelve test pits were excavated to the west and north of the Main Landfill to confirm the extent of waste at these locations. These test pits were advanced to approximately 10 feet bgs or until MSW was no longer observed (if shallower than 10 feet bgs).
- One additional test pit was excavated northeast of the Main Landfill to evaluate infiltrations rates for proposed stormwater design.

Test pits were backfilled with the excavation spoils and compacted using the excavation equipment.

Grab Samples

GeoEngineers collected soil samples from the existing cover materials for laboratory testing. At least one grab soil sample was obtained from each soil type observed covering the waste at each test pit location. Select samples were submitted for laboratory analysis including grain-size analyses, and Atterberg limits.

Infiltration Test

GeoEngineers conducted one test pit infiltration test near the northeast corner of the Main Landfill in general accordance with the procedures described in Appendix 4C–Test Pit Method of the *Spokane Regional Stormwater Manual*. Two water trucks were used to supply a constant flow of water for the infiltration test.

FIELD FINDINGS

Field findings were used to update the approximate lateral extents of waste buried at the Landfill and to supplement the preliminary assessment of cover soils used throughout the Site explained in the RI/FS reports. Field findings are described in the ensuing sections.

Main Landfill

The soil cover in the Main Landfill portion of the site generally consists of fine to coarse sand with silt and gravel or fine to coarse gravel with silt and sand to depths ranging from 0 to 5.5 feet bgs (Figure 3), with the following exceptions:

- The soil cover at TP-SC-1 was approximately 9 feet thick. Soil cover thickness at test pits TP-SC-2 and TP-SC-3 to the northwest and northeast of TP-SC-1 was 0.5 feet and 1 foot, respectively, indicating a generally localized area of thick soil cover in the southern portion of the Main Landfill.
- The soil cover at TP-SC-11 was approximately 6 feet thick. Soil cover thickness at test pit TP-SC-11A to the west and explorations from previous investigations (GeoEngineers 2018A) to the east of TP-SC-11 was 3.5 feet and 1 foot thick, respectively, indicating a generally localized area of thick soil cover in the northwest portion of the Main Landfill.

Five-Acre Landfill

The soil cover in the Five-Acre Landfill generally consists of fine to coarse sand with varying amounts of silt underlain by a fine-grained soil cover layer (stiff lean clay with varying amounts of sand). Total soil cover thickness ranges from 0 to 9.5 feet (Figure 4) while the fine-grained soil cover thickness ranges from 0 to 7 feet (Figure 5). The soil cover layer is generally thicker to the west.

Lateral Waste Extents

Perimeter test pits were used to approximate the lateral and vertical extents of waste buried beyond the Main and Five-Acre Landfills. Cross sections were developed to interpolate depth and extent of waste beyond the Marshall Landfill property. Cross sections are included in Figures 6 through 17, with letters referring to cross sections identified in Figures 1 and 2.

Main Landfill

Perimeter test pits excavated at the Main Landfill provided insight to the approximate lateral extent and depth of waste buried beyond the Marshall Properties' parcel lines. Approximate extents are shown in cross-sections, and summarized below:

- Waste extends approximately 25- to 45-feet onto parcel 24213.9076. Interpolated perimeter boundaries show waste extents up to approximately 160 feet onto the north adjacent parcel (24213.9076). Waste was observed in test pits TP-M-1A and TP-SC-16 located approximately 125- and 50-feet beyond the north boundary of parcel 24213.9018, respectively. Approximately 1.09 acres of parcel 24213.9076 is assumed to contain Main Landfill waste. Approximate bottom of waste depths of 6- and 7-feet bgs were observed on the north adjacent parcel. Waste depths of 1.5- and 7.5-feet bgs were observed on the north adjacent property in test pits TP-6 and TP-7, respectively.
- Waste extends approximately 25 feet onto parcel 24214.9044. Interpolated perimeter boundaries show waste extents up to approximately 50 feet onto the north adjacent parcel (24214.9044). Approximately 0.40 acres of parcel 24214.9044 is assumed to contain Main Landfill waste. An approximate bottom of waste depth of at least 10 feet bgs was observed on the north adjacent parcel. Waste depths of 4.5- and 6-feet bgs were observed on the north adjacent property in test pits TP-15A and TP-SC-18, respectively.
- Along the western boundary of the Main Landfill waste extends approximately 15- and 30-feet beyond the west parcel boundary of 24213.9018 and onto the west adjacent parcel (24213.9017). Near the northwest corner of the Main Landfill, waste extents appear to generally follow the west parcel boundary up until about test pit locations TP-11A and TP-11B, where waste begins to generally extend beyond the west perimeter boundary onto the west adjacent parcel. Main Landfill waste was observed approximately 50-, 70-, 160-, and 75-feet beyond the west perimeter boundary in test pits TP-3W, TP-SC-4A, TP-SC-2B, and TP-1, respectively. Approximately 1.32 acres of parcel 24213.9017 is assumed to contain Main Landfill waste. An approximate bottom of waste depth of at least 7 feet bgs was observed on the west adjacent parcel. Waste depths of 4-, 9- and at least 5-feet bgs were observed on the west adjacent property in test pits TP-SC-4, TP-SC-2B and TP-1, respectively.

Five-Acre Landfill

Based upon current exploratory data, the Five-Acre Landfill currently occupies five parcels; two centrally located parcels (24213.9009 and 24213.9011) containing majority of the Five-Acre Landfill are owned by MARSHALL PROP, two east adjacent parcels (24213.9075 and 24213.9076) are privately owned by Randall J Gillingham, and one west adjacent parcel (24213.9010) is owned by Spokane County Engineers.

Along the eastern boundary of the Five-Acre Landfill waste extends onto the southwest corner of parcel 24213.9075 and onto the northwest corner and western portion of parcel 24213.9076.

- Landfilled municipal solid waste terminates near the east boundary of parcel 24213.9009 but accumulation of construction and demolition waste continues approximately 215 feet beyond the east boundary of parcel 24213.9009 onto the northeast adjacent parcel 24213.9075. Approximately 0.74 acres of parcel 24213.9075 is assumed to contain Five-Acre Landfill construction and demolition waste. An approximate bottom of waste depth of at least 7.5 feet bgs was observed on the northeast adjacent property (parcel 24213.9075). The following construction and demolition waste depths were observed on the northeast adjacent property (parcel 24213.9075): 6 feet in TP-FE-1, at least 7.5 feet in TP-FE-3, 5 feet in TP-SC-20, at least 4 feet in TP-SC-22, and 1.75 feet in TP-SC-22A.
- Landfilled waste continues approximately 60 feet beyond the east boundary of parcel 24213.9009 onto the southeast adjacent parcel (24213.9076). Interpolated perimeter boundaries show waste extents up to approximately 230 feet onto the southeast adjacent parcel (24213.9076). Waste was observed in test pit exploration TP-FE-2 located approximately 95 feet beyond the east boundary of parcel 24213.9009. Approximately 1.16 acres of parcel 24213.9076 is assumed to contain Five-Acre Landfill waste. An approximate bottom of waste depth of at least 7.5 feet bgs was observed on the southeast adjacent parcel (24213.9076). The following waste depths were observed on the southeast adjacent property (Parcel 24213.9076): 8 feet in TP-FE-2, 6 feet in TP-M-4A, at least 6 feet in TP-F-11A, at least 3.5' in TP-11B, 4.5 feet in TP-11C, and at least 11 feet in TP-M-1B.
- Along the western boundary of the Five-Acre Landfill waste extends onto the west adjacent parcel (24213.9010). Waste appears to extend approximately 75-, 65-, and 25-feet beyond the west boundary of parcel 24213.9009, at boundary B, C, and D, respectively. Test pits TP-SC-33 and TP-F-12B, show waste extends approximately 50- and 60-feet beyond the west boundary of parcel 24213.9009. Approximately 1.17 acres of parcel is assumed to contain Five-Acre Landfill waste. Approximate bottom of waste depths of at least 3-, 6-, and 7-feet bgs were observed on the west adjacent parcel (24213.9010) at boundary B, C, and D, respectively. The following waste depths were observed on the west adjacent property (Parcel 24213.9010): at least 7 feet in TP-F-16B, at least 10 feet in TP-SC-33, at least 6.5 feet in TP-F-15B, at least 6 feet in TP-F-14B, at least 3 feet in TP-SC-32, and at least 7 feet in TP-F-12B.

Soil Analysis

Select soil samples providing general coverage throughout the Main and Five-Acre Landfills were selected for soil analysis to determine grain size and saturated hydraulic conductivity.

Laboratory and Field Analysis

Seven fine-grained soil samples from interior Five-Acre Landfill test pit locations were selected for Atterberg limits analysis by ASTM Method D4318. Soil samples were selected from the observed fine-grained soil cover unit. Test results indicate that the fine-grained soil cover unit observed throughout the interior of the Five-Acre Landfill consists primarily of lean clay with varying amounts of sand.

Six coarse-grained soil samples were selected from interior Five-Acre Landfill test pit locations for grain size analysis (gradation) by ASTM C136. Soil samples were selected from the coarse-grained sand soil cover unit. Test results indicate that the upper coarse-grained soil cover unit observed throughout the interior of the Five-Acre Landfill consists primarily of fine to coarse sand with varying amounts of silt and gravel.

Two coarse-grained soil cover samples were selected from interior Main Landfill test pit locations (TP-SC-1 and TP-SC-7) for grain size analysis (gradation) by ASTM C136. Test results indicate that the thin to irregular coarse-grained soil cover unit observed throughout the interior of the Main Landfill consists primarily of fine to coarse sand with varying amounts of silt and gravel, and fine to coarse gravel with sand and varying amounts of silt.

Soil Characteristics

Coarse-grained sand and gravel units observed throughout the Five-Acre and Main Landfills, although fill, are consistent with native glaciofluvial deposits. Saturated hydraulic conductivities of coarse-grained soil cover were estimated for test pit soil laboratory data in conjunction with the Massmann 2008 soil grain size analysis method outlined in the Washington Department of Ecology 2019 Stormwater Management Manual for Eastern Washington (SMMEW). The Massmann 2008 grain size analysis method is a laboratory test-based method that estimates saturated hydraulic conductivity using empirical relationships to grain size (WADOE 2019). Estimated saturated hydraulic conductivities are provided in Appendix B, Hydraulic Conductivity Estimates.

Saturated Hydraulic conductivities at the Main Landfill were estimated based upon sand and gravel soil cover grain-size distribution data from test pits TP-SC-1 and TP-SC-7, located interior to the Main Landfill. Using the Massmann 2008 method outlined in the SMMEW, an average saturated hydraulic conductivity of 2.1×10^{-1} (cm/s) was observed.

Saturated Hydraulic conductivities at the Five-Acre Landfill were estimated based upon sand soil cover grain-size distribution data from test pits TP-SC-24, TP-SC-26, TP-SC-30, and TP-SC-31, located interior to the Five-Acre Landfill. Using the Massmann 2008 method outlined in the SMMEW, an average saturated hydraulic conductivity of 8.7×10^{-2} (cm/s) was observed.

Fine-grained soil cover observed throughout the interior of the Five-Acre Landfill consisted primarily of lean clay as determined by Atterberg limits analysis. Fine-grained soil cover appeared to be generally stiff, indicating a degree of compaction. Lean clay soil types exhibit low permeability by nature, and under the optimal soil compaction conditions, soil particles become more closely packed reducing hydraulic conductivity further. General hydraulic conductivity for clay soils range from approximately 1.0×10^{-9} (cm/s) to 1.0×10^{-6} (cm/s).

Soil Suitability for Cap Design

Three bulk samples of local soil that could potentially be used as capping material were collected and submitted to a local laboratory for analyses of hydraulic conductivity. One bulk sample of stockpiled sand was collected from the adjacent Action Materials pit, one sample of surficial soil was collected from test pit TP-23, and one sample of surficial soil was collected from test pit TP-27. The bulk sample from the Action Materials pit consisted of sand with trace silt. The bulk samples from the test pits consisted of silty sand with gravel.

The samples were mixed at the laboratory with various percentages of commercially available bentonite clay, compacted to approximately 90 percent of maximum dry density (MDD) based on the ASTM D1557 (modified proctor) procedure, then tested in accordance with ASTM D 5084 (Hydraulic Conductivity using a Flexible Wall Permeameter). Laboratory results are presented in Appendix C. Initial results indicate that about 10 to 12 percent bentonite by dry weight would be required to achieve target hydraulic conductivity values for amended site soil to meet cover system permeability requirements. That equates to about 11 to 14 pounds of bentonite per cubic foot of amended soil.

Infiltration Area Testing

The Site was reviewed for available infiltration areas outside and downgradient of waste limits, and an infiltration test pit location (IT-1) was selected northeast of the Main Landfill (Figure 1). One test pit infiltration test was conducted in general accordance with the Spokane Regional Stormwater Manual (SRSM), Appendix 4C–Test Pit Method. Test pit IT-1 was excavated to approximately 5.5 feet bgs and backfilled with pea-gravel after a 2-inch PVC screen was installed at the base of the excavation. Two approximately 2,000-gallon water trucks provided a constant flow of water (head pressure) for the infiltration test.

The flow rate near the end of the constant head portion of the test was approximately 10.4 gallons per minute (gpm), which equates to about 0.023 cubic feet per second (cfs), under a constant head of about 1.45 feet. This resulted in a normalized test pit outflow rate of about 0.16 cfs per foot of head (cfs/ft). Using the normalized outflow rate in conjunction with the test pit equation $q_{nd}=0.9242K^{0.8601}$ contained in the SRSM, a hydraulic conductivity (K) was estimated at about 1.5×10^{-2} cm/sec (21.2 in/hr).

Using the procedures outlined in the SRSM, design outflow rates for Spokane County standard Type A (single-depth) and Type B (double-depth) drywells are 0.1 cfs and 0.17 cfs, respectively. These outflow rates include a safety factor of 2.5 in accordance with the SRSM.

WASTE MANAGEMENT APPROACH

The FS identified seven alternatives to manage the waste for the Main and Five-Acre Landfills. Management strategies ranged from enforcement of institutional controls, in-place containment, and complete excavation. The FS identified in-place containment as the preferred approach.

Waste Beyond Landfill Boundaries

During exploratory work performed in November 2022, waste was observed beyond the boundaries of each landfill (described earlier in this document). This waste needs to be considered as part of the overall closure for the project. Although in-place containment is the preferred approach for the overall landfill closure, different disposal options for the waste buried outside of the landfills are considered to evaluate a preferred approach.

Three disposal options have been identified as feasible strategies to manage the landfilled waste beyond the landfill boundaries (off-site waste):

- **Option 1–Excavate and Consolidate.** Excavate waste from beyond landfill boundaries and consolidate within the final covers of the Main and Five-Acre Landfills.
- **Option 2–Excavate and Dispose Off-Site.** Excavate waste beyond landfill boundaries, characterize the material, and transport for final disposal at nearby permitted waste facilities accepting the waste. Cover the balance of waste within the Main and Five-Acre Landfills.
- **Option 3–Cover in Place.** Coordinate with neighboring properties to perform boundary line adjustments or property acquisition to bury landfilled waste in place. Cover the balance of waste within the Main and Five-Acre Landfills.

Volume of Waste

Approximate volumes of landfilled waste within the boundaries of the landfills are included in the FS. Through exploratory excavations conducted by GeoEngineers, approximate extents of waste landfilled beyond the Main and Five-Acre Landfill property boundaries were identified. Those lateral extents were reviewed and compared with existing topography to develop conservative volumes of landfilled waste. The conservative volumes are developed to provide an assessment for the overall volume of waste landfilled beyond property boundaries. The approximate volume of waste is included below.

Table 1. Approximate Volume of Waste Landfilled.		
Location	**Volume (cubic yards)**	**Volume (tons)[b]**
Main Landfill[a]	2,001,500	1,601,200
Five-Acre Landfill[a]	268,700	215,000
Area Between Main and Five-Acre Landfills[a]	24,300	19,500
Waste within Gillingham and Castle Material properties[c]	100,000	80,000
Waste within Spokane County Properties	144,000	115,000
Total Volume of Waste Landfilled	2,538,500	2,030,800

[a] Approximate volume of waste from the Marshall FS (GeoEngineers, 2018), rounded up to nearest 100 cubic yards or tons.

[b] Assumed 0.8 tons per cubic yard for all landfilled waste.

[c] An average depth of 15 feet was assumed for the waste observed extending into the Gillingham and Castle Material Properties.

Option 1–Waste Consolidation

Option 1 consists of in-place containment of the Main Landfill, Five-Acre Landfill, and the area between the two landfills with a final cover system. Waste at the edges of each landfill, and along the perimeter of each landfill, would be excavated and consolidated within the boundary of the two landfills to accommodate construction of the final cover. Waste would be consolidated to accommodate minimum offsets of 6 feet from the adjacent Spokane County properties, 10 feet from the privately owned properties, and 10 feet from the 60-foot road right of way (ROW) along South Cheney Spokane Road.

Soils excavated above the buried waste could be beneficially reused to support closure if properly separated from waste. These soils, contingent upon their characteristics, could be used as fill or cover material. For assessment purposes, Option 1 assumes waste excavated is classified as non-hazardous, not dangerous, and can be disposed of at an approved Subtitle D facility. Since the Five-Acre Landfill was observed to have a fairly consistent cover system, Option 1 assumes soils removed at and beyond the boundary of the Five-Acre Landfill will be left on-site for fill/cover following excavation of waste. This assessment assumes soils used for cover at the Main Landfill and for waste beyond the boundary of each landfill cannot be appropriately separated from waste during excavation, and would be landfilled within the final closure for the Main and Five-Acre Landfills.

Option 2–Waste Consolidation and Off-Site Disposal

Comprehensive removal and off-site disposal is the most effective remedial action for managing risk and provides the highest level of permanence and long-term effectiveness by removing the source material. Option 2 involves excavating waste located at and beyond the boundary of each landfill, characterizing the exhumed materials, and transporting them off-site for disposal at a permitted facility. Similar to Option 1, waste would be consolidated to accommodate offsets from adjacent property boundaries.

For assessment purposes, Option 2 assumes waste excavated is classified as non-hazardous, not dangerous, and can be disposed of at an approved Subtitle D facility. The closest Subtitle D facility that could accept materials from the landfills is located in Medical Lake, Washington, 10 miles from the site. Since the Five-Acre Landfill was observed to have a fairly consistent cover system, this Option assumes soils removed at and beyond the boundary of the Five-Acre Landfill will be left on-site for fill/cover following excavation of waste. This assessment assumes soils used for cover at the Main Landfill and for waste beyond the boundary of each landfill cannot be appropriately separated from waste during excavation, and would be landfilled at the Medical Lake facility.

Option 3–Cover in place

Option 3 considers covering waste in place beyond the landfill boundaries. Covering waste in place minimizes risk of releasing constituents that could be harmful to human health and the environment as part of the construction process. Option 3 provides adjacent property owners with improved controls of landfilled materials, including groundwater and LFG monitoring and improved waste containment (i.e., landfill gap) from existing conditions.

Option 3 will require coordination with adjacent property owners to either implement an access agreement including restrictive convents or may require property acquisition. Property acquisition would require lot line adjustments as well as environmental restrictive convents.

For waste is covered in place, a cover system would be constructed such that a minimum 10-foot offset is provided for edge of cover and lateral extent of waste adjacent to the ROW and behind buildings on private property, and a minimum 6-foot offset for the balance of the cover area.

Summary of Off-Site Waste Management Options

Waste management on-site can be accomplished through a variety of cover systems. Management of off-site waste requires assessment of where the waste is placed and how the properties in which waste is observed are treated. The table below describes the preliminary approximate costs for each of the waste management options described in this section. Costs do not include the overall landfill construction (infrastructure, cover system, stormwater treatment, etc.), nor do they include costs associated with each option (filling in existing land where waste has been excavated, permitting costs to expand the property boundary, etc.), rather, these high-level costs assess the estimates for excavating, hauling (and, as appropriate, compacting) off-site waste.

Table 2. Preliminary Approximate Costs for Waste Management Options.

Option	Approximate Cost	Items Included in Cost
Option 1–Waste Consolidation	$4,880,000	Excavate, haul, and compact waste from off-site to on-site. Assumes approximately $20 per cubic yard.
Option 2–Waste Consolidation and Off-Site Disposal	$25,000,000	Excavate and haul waste to Subtitle D Facility. Assumes approximately 50 miles round trip, $114 per ton for tip fees.
Option 3–Cover in Place	$600,000	Access agreement; restrictive convents; Potential property acquisition and boundary line adjustment. If property requires acquisition (up to 6 acres), an estimated property value $100k per acre is assumed.

COVER SYSTEM ALTERNATIVES

The FS identified a variety of cover system alternatives, with Alternative 3–In Place Containment with Soil Cover System Cover Main Landfill and Five-Acre Landfill; Stabilize Existing Buttress Berm; Install LFG Collection System; Implement a Restrictive Covenant on the Deed being identified as the preferred cover system strategy.

Alternative 3 consists of the following waste management strategies:

- In-place containment of Main and Five-Acre Landfill waste, and the area between the two landfills, with soil cover system (herein referred to as an Evapotranspiration Cover).
- Soil cover system would consist of, from bottom to top, approximately two feet of low permeability material, 0.5 feet of topsoil, and hydroseed.
- Main Landfill buttress berm would be regraded to a stable slope of 2.1:1 or less.
- Additional site grading would be completed to control and mitigate stormwater run-on and run-off.
- LFG collection system would be constructed to reduce buildup and potential offsite migration of gases.
- Disturbed areas would be seeded and left to naturally revegetate over time.

Through discussion with Ecology and internal coordination, Alternative 5–In-Place Containment with Low-Permeability Geosynthetic Cover System; Cover Main Landfill and Five-Acre Landfill; Stabilize Existing Buttress Berm; Install LFG Collection System; Implement a Restrictive Covenant on the Deed was identified as a second waste management strategy for consideration. Alternative 5 consists of the same features described above as Alternative 3, with a revision of the cover system:

- In-place containment of Main and Five-Acre Landfill waste, and the area between the two landfills, with low-permeability geosynthetic cover system (herein referred to as a Prescriptive Cover).
- Cover system would consist of, from bottom to top, 2 feet of cover soil, 0.5 feet of bedding sand, a geosynthetic liner, 0.5 feet of topsoil, and hydroseed.

Relevant and Appropriate Cover Systems

Although Alternatives 3 and 5 are assessed for the main cover system strategy, recommended waste cover strategies vary throughout the landfill based on the geometry of the area:

- In flatter areas (sloped 2.1:1 or less), the cover systems described for Alternatives 3 and 5 are appropriate. Alternatives 3 and 5 are assessed further to evaluate the costs for a Prescriptive (Alternative 3) or Evapotranspiration (Alternative 5) cover system. Soil and geosynthetic cover systems will be considered for the top deck and shallow slope areas for the landfills.
- In steeper areas (sloped 2.1:1 or greater), the cover systems described for Alternatives 3 and 5 are not stable unless structurally augmented or the slopes excavated and regraded requiring waste relocation. Geostructural cover systems and or slope regrading and waste relocation are assessed to accommodate cover for these areas, specifically the east slope of the Main landfill (buttress) and the north slope of the Main Hill landfill (adjacent to the Castle Materials, Inc. and Gillingham parcels.

The ensuing sections discuss cover systems for flatter areas and for steep slope areas. The features of the various cover systems are described, and high-level costs are included to assess each proposed approach.

Evapotranspiration Cover

Alternative 3 includes the use of an Evapotranspiration (ET) cover. ET covers use vegetation and fine-grained soils to store precipitation until it is naturally evaporated, or it is transpired by the vegetative cover. The ET cover would consist of, from bottom to top, approximately two feet of low permeability soil, 0.5 feet of topsoil, and hydroseed.

Design and Construction Considerations

As described in WAC 173-304, low permeability soil needs to have a permeability of 1x10-6 centimeters per second or lower. Per soil assessment described above, existing cover soils used at the Five-Acre Landfill require at least 6 percent bentonite amendment, locally available gravel pit soils from Action Materials require approximately 10 percent bentonite amendment, to accommodate permeability requirements. A pug mill would be required to provide bentonite amendment to the soils from both Five-Acre and Action Materials. Material costs are anticipated be fairly minimal to transport soils from Action Materials and process soils from the Five-Acre Landfill, though costs would be incurred to import bentonite material.

Above the low permeability soil, topsoil would need to be imported. Hydroseed would also need to be imported and sprayed above topsoil.

A high order cost of about $42/square yard (SY) is approximated for the ET Cover System.

Prescriptive Cover

Alternative 5 from the FS includes use of a prescriptive geosynthetic cover system. Rather than the ET cover system, the conventional geosynthetic cover uses a mix of natural materials and manufactured materials to provide required controls. The conventional geosynthetic cover would consist of, from bottom to top, 2 feet of low permeability soil, 0.5 feet of bedding sand, a geosynthetic liner, 0.5 feet of topsoil, and hydroseed.

Design Considerations

Bedding sand, LLDPE/HDPE geomembrane, geotextile, geonet, bentonite, borrow soil, topsoil, and hydroseed would need to be imported to accommodate the prescriptive cover. Similar to the ET cover, a pug mill would need to be used to process soils from the Five-Acre Landfill and Action Materials for use in the cover system.

A high order cost of about $103/SY is approximated for the Prescriptive Cover System.

Main Landfill North Steep Slope Cover Options

The existing Main Landfill north slope generally varies in inclination between 1.25H:1V (horizontal to vertical) to 2.4H:1V, with slope heights ranging from about 18 to 40 feet. The steepest portion of the north slope is located behind structures associated with the Action Materials borrow pit operation. The toe of the slope immediately abuts some of the buildings. Several test pits were excavated near the top of the slope and at the bottom of the slope in November 2022, including TP-SC-17, TP-SC-17A, TP-SC-18 and TP-SC-34. Based on the results of the test pits, subsurface conditions along the slope generally consist of a mixture of reworked on-site soil (sand and gravel) and MSW, with soil comprising over 50 percent of the material volume. Soil conditions at the toe of the slope and to the north appear to consist of native sand and gravel deposits.

Parameters used in the stability analyses were based on the results of test pits, laboratory testing, and empirical relationships with similar MSW materials in the literature, and are summarized in Table 3.

Table 3. Stability Analysis Parameters.

Soil	Unit Weight (pcf)	Friction Angle (deg)	Cohesion (psf)
North Slope (MSW/Sand Mixture)	115	32	50
Soil along Bottom of Slope (Glacial Flood Deposits)	120	36	0

For seismic (pseudo-static) conditions, a horizontal acceleration coefficient of 0.106g was used, which is consistent with slope stability analyses conducted for the buttress and is based on Site Class D and 10 percent probability of exceedance in 250 years. Given the presence of existing buildings along the bottom of the slope, we recommend a minimum safety factor (SF) of 1.5 against slope instability for static conditions and a minimum SF of 1.1 for seismic conditions. Critical cross sections were evaluated near the buildings where the slope is inclined between about 1.25H:1V to 1.5H:1V. Based on the results of analyses, the existing slope has a static safety factor ranging from 1.1 to 1.2 and a seismic safety factor ranging from 0.9 to 1.0.

To achieve a minimum static safety factor of 1.5 along the north slope, analyses indicates that a slope inclination of 2H:1V or flatter is required to satisfy the minimum global safety factors for static and seismic conditions. This will require flattening the north slope where inclinations are steeper than 2H:1V through regrading the slope, or a combination of regrading and constructing retaining walls to increase stability of the existing slope.

Grading and Cover System Options

Based on the results of the stability analyses, three preliminary options for regrading the north slope to achieve the required long-term stability for the final cover system were evaluated:

- Option 1–Regrading the existing slope to no steeper than 2H:1V and placement of an ET soil cover.
- Option 2–Regrading the existing slope to no steeper than 3H:1V and installing a Prescriptive (geomembrane) cover system.
- Option 3–Regrading the existing slope to no steeper than 2H:1V and installing a geomembrane with an anchored geoweb soil cover system.

Additional discussion for these options is presented below.

The feasibility of constructing a gravity retaining wall along the bottom of the slope was also considered. However, constraints and limited space between the toe of the slope and existing buildings would make construction of a retaining wall challenging and significantly more expensive, in our opinion. Therefore, stability of gravity wall options was not evaluated.

Option 1–2H:1V slope with soil cover

This option consists of excavating existing soil and MSW along the north slope and regrading the slope to no steeper than 2H:1V. The excavated material would need to be incorporated into the main landfill. Excavation should be relatively straight-forward from a construction standpoint using conventional equipment. The existing overhead power line would need to be relocated before commencing earthwork activities.

Potential areas to relocate the excavated MSW and soil on the existing landfill include the northwest or central portions of the landfill where existing grades are relatively level or where depressions exist.

After regrading the north slope to no steeper than 2H:1V, the slope should be covered with clean soil that is placed as engineered cover soil meeting minimum hydraulic conductivity criteria and to achieve the required minimum soil cover thickness. Nearby native sand and gravel deposits such as the glaciofluvial sand and gravel within and surrounding the project site area may be used and amended with bentonite. laboratory direct shear testing must be conducted on the engineered soil to confirm the soil will be stable. The cover soil may require amendments for sustaining vegetation. A stormwater drainage collection system may need to be installed along the base of the slope.

Costs for Option 1 are anticipated to be similar to costs for the ET cover system.

Option 2–3H:1V slope with geomembrane and cover soil

This option consists of excavating existing soil and MSW along the north slope and regrading the slope to no steeper than 3H:1V. This inclination will support design and construction of a final cover system that may include a textured geomembrane (such as LLDPE or HDPE). A cushion geotextile will be needed below the geomembrane. A drainage layer (sand or a geocomposite) and soil cover can be placed over the geomembrane for permanent conditions. Typically, a minimum of 2 feet of clean cover soil is needed over the geomembrane. Space will be required to construct the geomembrane anchor trench and stormwater drainage swale along the toe of the slope.

Laboratory interface shear testing should be completed on the selected geomembrane, geocomposite drainage layer (if needed), and proposed cover soil to confirm the cover system will be stable.

Costs for Option 2 are anticipated to be similar to costs for the Prescriptive cover system.

Option 3–2H:1V slope with geomembrane and anchored geoweb soil cover system

This option consists of excavating existing soil and MSW along the north slope and regrading the slope to no steeper than 2H:1V. This final inclination will support design and construction of a final cover system that may include a textured geomembrane (such as LLDPE or HDPE, or possibly PVC), drainage layer, and an anchored geoweb soil cover system. The drainage layer and soil cover can be placed over the geomembrane for permanent conditions, but the soil cover will not be stable over the geomembrane unless supported by a system such as a geoweb.

Conceptual design of an anchored geoweb cover system for the north slope may include a cushion geotextile under the geomembrane, textured geomembrane, geocomposite drainage layer, and a minimum 6-inch-deep geoweb infilled with suitable topsoil. The anchored geoweb system may only allow for a 6-inch deep soil cover over the geomembrane and this may not be suitable for establishing suitable vegetation. The geoweb would be supported by a tendon system anchored along the top of the slope and in the geomembrane anchor trench.

A geomembrane cover system will require a drainage layer over the geomembrane that discharges to a collection system. Additional space will be needed to construct the geomembrane anchor trench and a stormwater collection system along the toe of the slope.

Option 3 requires install of a 6-inch geoweb. Per vendor quote received in March 2023, the cost would be approximately $81,100 for the area for materials, with an additional 250 percent added for the cost of construction. Adding the geoweb to the other materials required for cover, Option 3 is anticipated to cost approximately $140/SY.

Main Hill East Steep Slope Cover Options (Buttress)

GeoEngineers previously evaluated the slope stability along the existing buttress in the RI/FS, which indicated the existing safety factors against potential slope instability for static and seismic conditions were less than 1.5 and 1.1, respectively. Analyses indicated that widening the buttress to a 2.1H:1V slope was required to meet these safety factors.

Design and Construction Considerations

Based on updated topographic data the toe of the existing buttress slope was determined to be immediately adjacent to the Cheney Spokane Road Right of Way (ROW). Encroachment of the buttress fill into the ROW was deemed not feasible. An additional constraint is the top of the buttress slope is benched and serves as the only access road on the east side of the Main Landfill.

Due to constraints in buttress footprint (restricted at toe by Cheney Spokane Road ROW and at the top by the existing access road), reducing the slope will require adding a wall at the toe and adding fill or regrading and cutting the slope back into the waste mass which would require removal of the access road and significant waste excavation and relocation.

Based on the results of the stability analyses, and the limited footprint restrictions, three preliminary options for regrading the buttress slope to achieve the required long-term stability for the final cover system were evaluated:

- Option 1–Excavation of 2.1H:1V slope with soil cover
- Option 2–Wall with 2.1H:1V slope and soil cover

Additional discussion for these options is presented below.

Option 1–Excavation of 2.1H:1V slope with soil cover

This option consists of excavating the buttress slope and backfilling with soil cover to a stable condition. To accommodate the 2.1H:1V slope, the access road would need to be removed or modified. The excavated material would need to be hauled and incorporated into the western half of the Main Landfill. With the required revisions to the access road, access would be eliminated on the east half of the landfill.

Option 2–Wall with 2.1H:1V slope and soil cover

This option consists of installing a wall with a 10-foot horizontal offset between the toe of the existing slope and the existing property line and ROW. It is estimated the wall will extend for approximately 766 lineal feet, have a wall face area of about 6,400 square feet, with a maximum wall height of about 12 feet. The approximate retaining wall area is included in Appendix E. Fill would be placed behind the wall and extend to the top of the buttress at the access road. Excavation of along the outside edge of the access road would be required to place a soil cover.

Rough order of magnitude costs

Option 1 costs include removal and transport of soils and refuse, fill and compact borrow soil with bentonite amendments for soil cover, and hydroseeding the new slope surface. Option 2 costs include construction of the retaining wall, installation of soil cap, and hydroseeding.

Each Option assumes approximately 750 linear feet of rework of the existing buttress. Rough order of magnitude costs do not include tree removal and other vegetative stripping, construction management, and design support for either Option. Rough order of magnitude costs are summarized in the table below:

Table 4. Preliminary Approximate Costs for Waste Management Options.

Option	Cost
Option 1–Excavation of 2.1H:1V slope with soil cover	$3,360,000
Option 2–Wall with 2.1H:1V slope and soil cover	$1,160,000

The feasibility of regrading the buttress slope by excavation and waste relocation without a wall poses significant concern with the resulting extensive slope length, and removal of the access bench on the east half of the landfill. Access road removal increases fire suppression risk by removing a natural fire break, limits access for fire suppression and control, and removes drainage conveyance infrastructure on the east side of the Landfill necessary to convey water to the north and east (the only available area for stormwater infiltration).

INFILTRATION AREA ASSESSMENT

The entire 43-acre site was evaluated for stormwater management options. Based on an assumed pervious land cover of short prairie grass and Group B soils, a curve number value of 71 (herbaceous, fair) was selected for the evaluation. Stormwater runoff volumes for the 10-year and 100-year storm event were calculated for the entire site and are summarized in Table 4.

Table 5. Stormwater Runoff Volume for the Entire Marshall Landfill Site.

Design Storm	Rainfall (inches)	Volume (acre-feet)	Volume (cubic feet)	Depth (inches)
10-year	1.80	0.683	29,751	0.19
100-year	2.80	2.323	101,190	0.65

There is approximately 10,000 square feet available in the northeast corner of the site for an infiltration pond. Assuming that a majority of the site runoff can be routed to this pond, a pond with the characteristics summarized in Table 5 was assumed for the initial sizing evaluation. Infiltration pond depths are not specified in the Spokane Regional Stormwater Manual (SRSM) or the Stormwater Management Manual for Eastern Washington, so the proposed ponding depth (range of 2 to 6 feet), freeboard, and side slopes were based on design recommendations included in the Stormwater Management Manual for Western Washington.

Table 6. Initial Infiltration Pond Sizing Assumptions.

Pond Characteristic	Sizing Assumption
Bottom area	3,600 square feet (60 feet x 60 feet)
Depth	5 feet
Storage volume	0.654 acre-feet
Freeboard	1 foot
Side Slopes	3:1
Invert Elevation	0 feet
Design Infiltration Rate	8.48 in/hr

Infiltration pond sizing in the Spokane region is based on the 10-year design storm event and the SRSM. An overflow path with the capacity to convey the 100-year storm event must also be provided. The performance of the infiltration pond for the 10-year event and 100-year event evaluated using a single event model (HydroCAD) is summarized in Table 6.

Table 7. Infiltration Pond Performance.

Design Storm	Inflow (cfs)	Infiltrated (cfs)	Elevation (feet)	Storage (acre-feet)
10-year	0.61	0.61	0.04	0.004
100-year	3.48	1.49	4.32	0.533

Based on these initial modeling results, the infiltration pond in the northeast corner of the site should have sufficient capacity to manage the 10-year as well as the 100-year storm event.

RECOMMENDATIONS

This Evaluation has been developed to provide a basis of design for closure of the Marshall Landfill. The Evaluation considers waste management, cover system options, steep slope modifications, and stormwater control for the Site. LFG will be further evaluated pending waste management strategy selected. Recommendations for the various elements are included in the following sections.

Waste Management

Herrera recommends landfilled waste be covered in place. Rough order of magnitude costs to cover waste in place are less expensive than the alternatives considered (waste consolidation and off-site disposal), risks of exposing workers and the environment to harmful landfill-related constituents are minimized, and existing landfill cover is improved. Access Agreement forms will need to be coordinated with adjacent property owners to grant access to Ecology and its representatives to properties to investigate extents of waste, install groundwater monitoring wells and LFG compliance probes, sample and monitor ground water wells and LFG probes, and to construct a new cover. An outreach strategy will be coordinated between Ecology and Herrera to discuss this option with neighboring property owners throughout the project.

Cover System

Consistent with the RI/FS, Herrera recommends an ET cover be used for landfill final cover. The ET cover avoids cost of importing geosynthetics and utilizes natural features to maintain control of infiltration and runoff. The ET cover can be used throughout shallow sections of the Site, and in steep slope sections where the slope has been modified to accommodate the ET cover.

Main Landfill North Steep Slope Modifications

Based on the existing footprint and restrictions within the Site, Herrera recommends excavating existing soil and MSW along the north slope and regrading the slope to no steeper than 2H:1V. The excavated material would need to be incorporated into the main landfill. Excavation should be relatively straight-forward from a construction standpoint using conventional equipment. The existing overhead power line would need to be relocated before commencing earthwork activities. An ET cover system could be installed resulting in the lowest construction cost alternative with a stable slope and low maintenance.

Main Hill East Steep Slope Buttress Modifications

Based on the existing footprint and restrictions within the Site, Herrera recommends the buttress be covered with an ET cover at 2.1H:1V slope, and a retaining wall be installed at toe of slope to accommodate the cover. Vegetation will need to be further evaluated to determine tree protection in place versus tree removal. This will be further vetted through the design process.

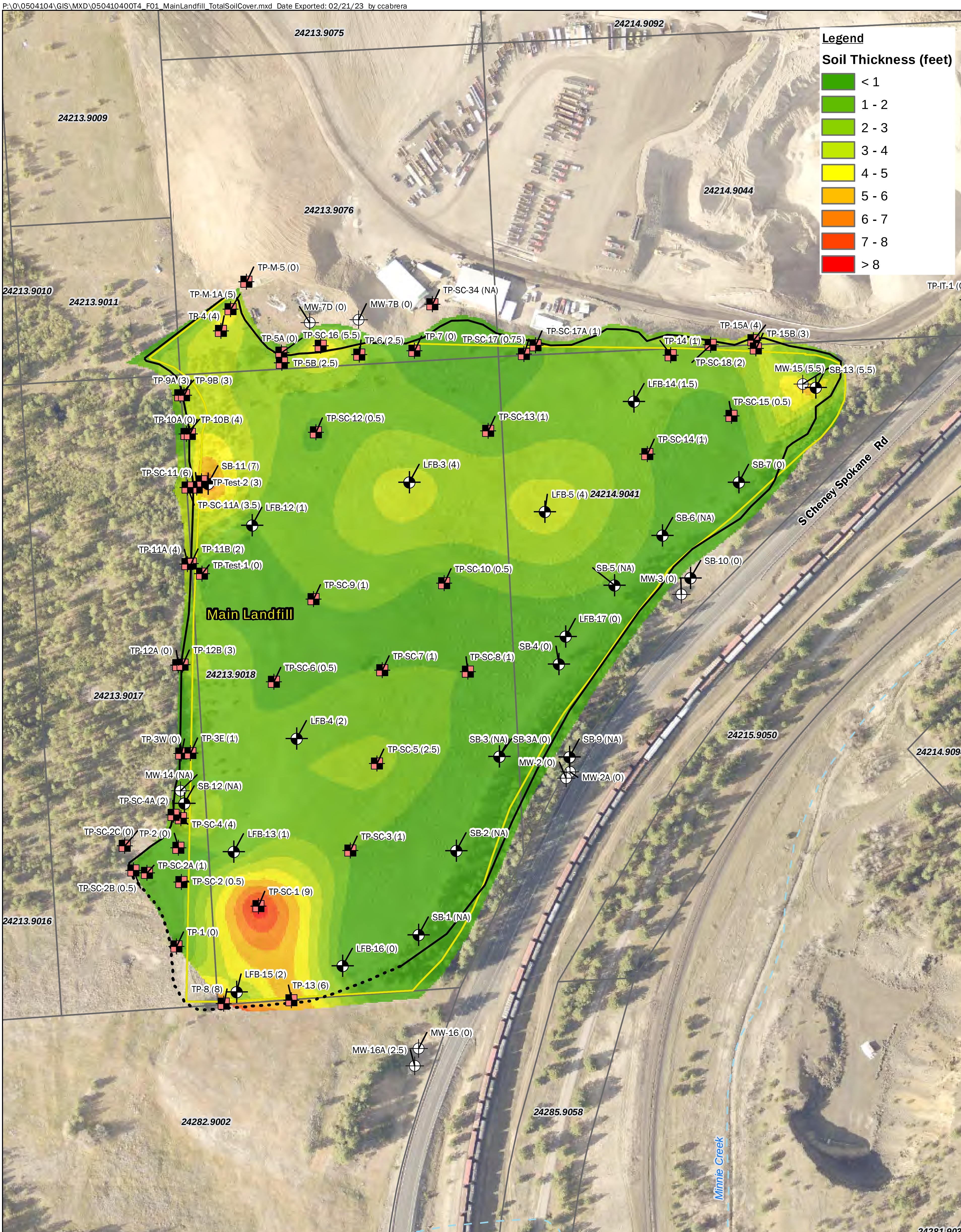
Infiltration Area

The available footprint of approximately 10,000 square feet should have sufficient capacity to manage the 10-year as well as the 100-year storm event, assuming all captured stormwater can be conveyed to the infiltration area. Further evaluation of stormwater routing will be conducted throughout the design process. Areas that are unable to convey stormwater to the infiltration pond will utilize lined evaporation ponds throughout the Landfill.

APPENDIX A

Landfill Figures

P:\0\0504104\GIS\MXD\050410400T4_F01_MainLandfill_TotalSoilCover.mxd Date Exported: 02/21/23 by ccabrera



Legend

- MW-1A — Groundwater Monitoring Well Designation and Approximate Location
- LFB-13 — Landfill Gas Monitoring Well and Approximate Location
- TPC-1 — Test Pit Designation and Approximate Location
- Approximate Landfill Boundaries[3]
- 2022 Approximate Municipal Solid Waste Boundary of Main Landfill
- 2022 Approximate Estimated Municipal Solid Waste Boundary of Main Landfill
- Ephemeral Stream
- Parcel Boundary

(0) Approximate Total Soil Cover Thickness in Feet

(NA) Not Applicable, data point not representative of in-situ soil cover conditions

N W E S

200 0 200

Feet

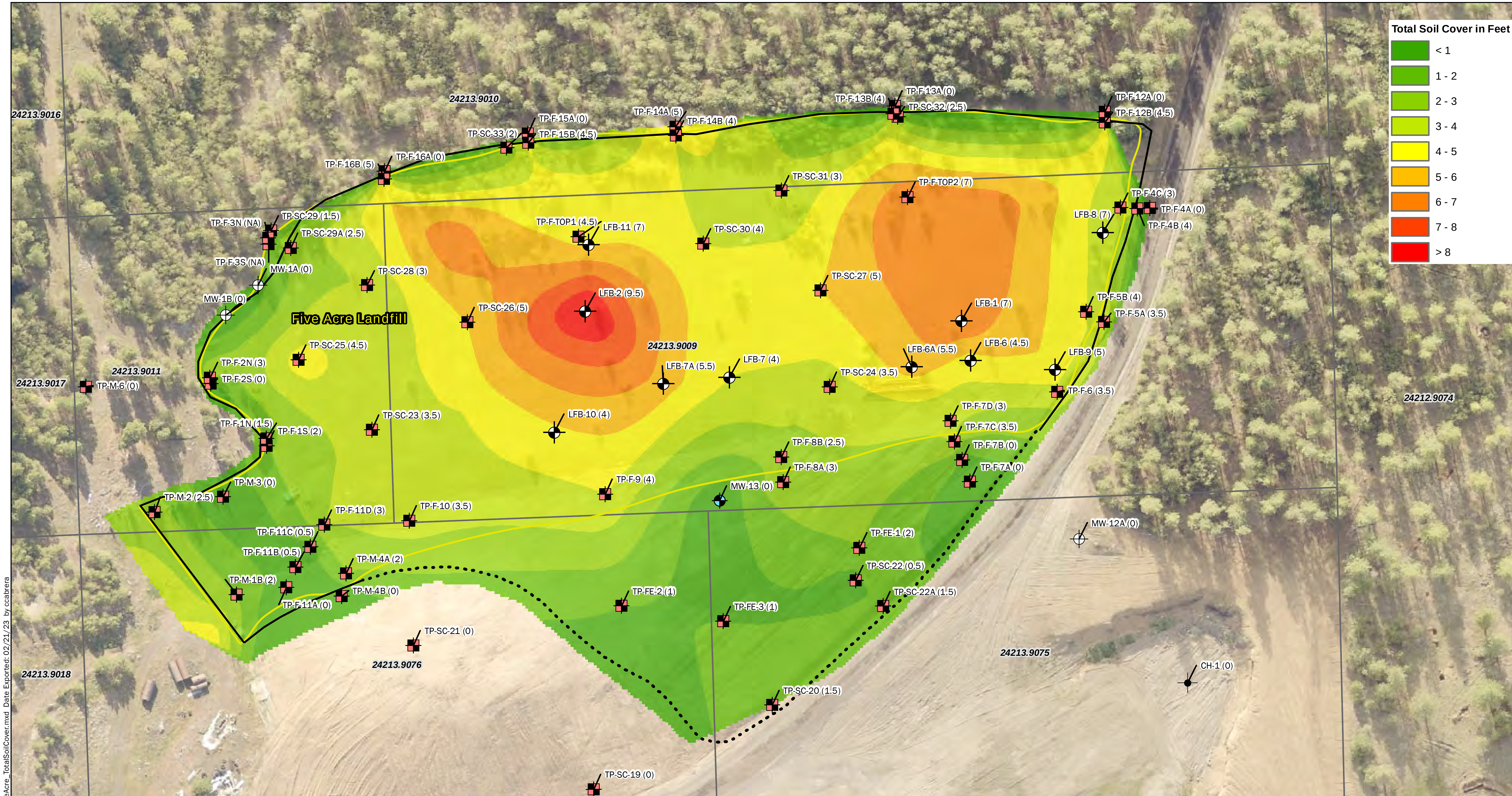
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Landfill boundaries have been modified with respect to Fetrow Engineering (1991) based on Remedial Investigation explorations.
Data Source: Street labels and parcels from Spokane County GIS.
Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Main Landfill Total Soil Thickness

Marshall Landfill
Spokane County, Washington

GEOENGINEERS

Figure 1



P:\0\0504104\GIS\MXD\0504104000T4_F02_FiveAcre_TotalSoilCover.mxd Date Exported: 02/21/23 by ccabrera

Data Source: Street labels and parcels from Spokane County GIS.
Boundary Lines from TD&H survey (May, 2015)

Notes:
1. The locations of all features shown are approximate.
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4. Landfill boundaries have been modified with respect to Fetrow Engineers (1991) based on Remedial Investigation explorations.

Projection: NAD 1983 UTM Zone 11N

Legend

- MW-1A — Groundwater Monitoring Well Designation and Approximate Location
- LFB-8 — Landfill Gas Monitoring Well Designation and Approximate Location
- (NA) — Not Applicable, data point not representative of in-situ soil cover conditions
- LFB-1 — Landfill Gas Monitoring Well and Approximate Location
- TP-4 — Test Pit Designation and Approximate Location
- CH-1 — Abandoned Boring Location
- 2022 Approximate Municipal Solid Waste Boundary of Five Acre Landfill
- 2022 Approximate Estimated Municipal Solid Waste Boundary of Five Acre Landfill
- Parcel Boundary
- (0) — Approximate Total Soil Cover Thickness in Feet

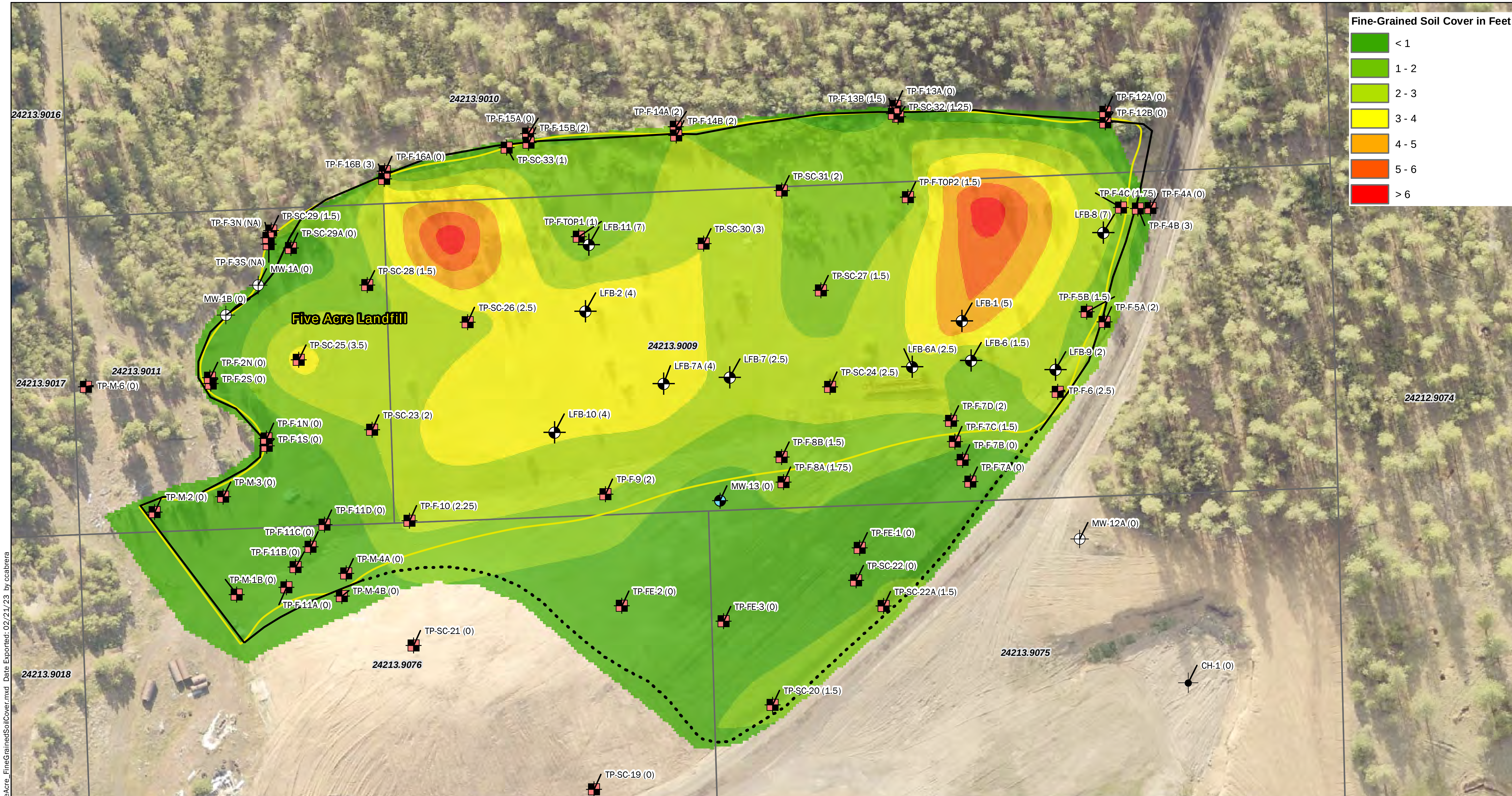
0 100
Feet

Five-Acre Landfill Total Soil Cover

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 2



P:\0\0504104\GIS\MXD\0504104000T4_F03_FiveAcre_FineGrainedSoilCover.mxd Date Exported: 02/21/23 by ccabrera

Data Source: Street labels and parcels from Spokane County GIS.
Boundary Lines from TD&H survey (May, 2015)

Notes:
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4. Landfill boundaries have been modified with respect to Fetrow Engineers (1991) based on Remedial Investigation explorations.

Projection: NAD 1983 UTM Zone 11N

Legend

- MW-1A — Groundwater Monitoring Well Designation and Approximate Location
- LFB-8 — Landfill Gas Monitoring Well Designation and Approximate Location
- (NA) — Not Applicable, data point not representative of in-situ soil cover conditions
- LFB-1 — Landfill Gas Monitoring Well and Approximate Location
- TP-4 — Test Pit Designation and Approximate Location
- CH-1 — Abandoned Boring Location
- 2022 Approximate Municipal Solid Waste Boundary of Five Acre Landfill
- 2022 Approximate Estimated Municipal Solid Waste Boundary of Five Acre Landfill
- Parcel Boundary
- (0) — Approximate Fine-Grained Soil Cover Thickness in Feet

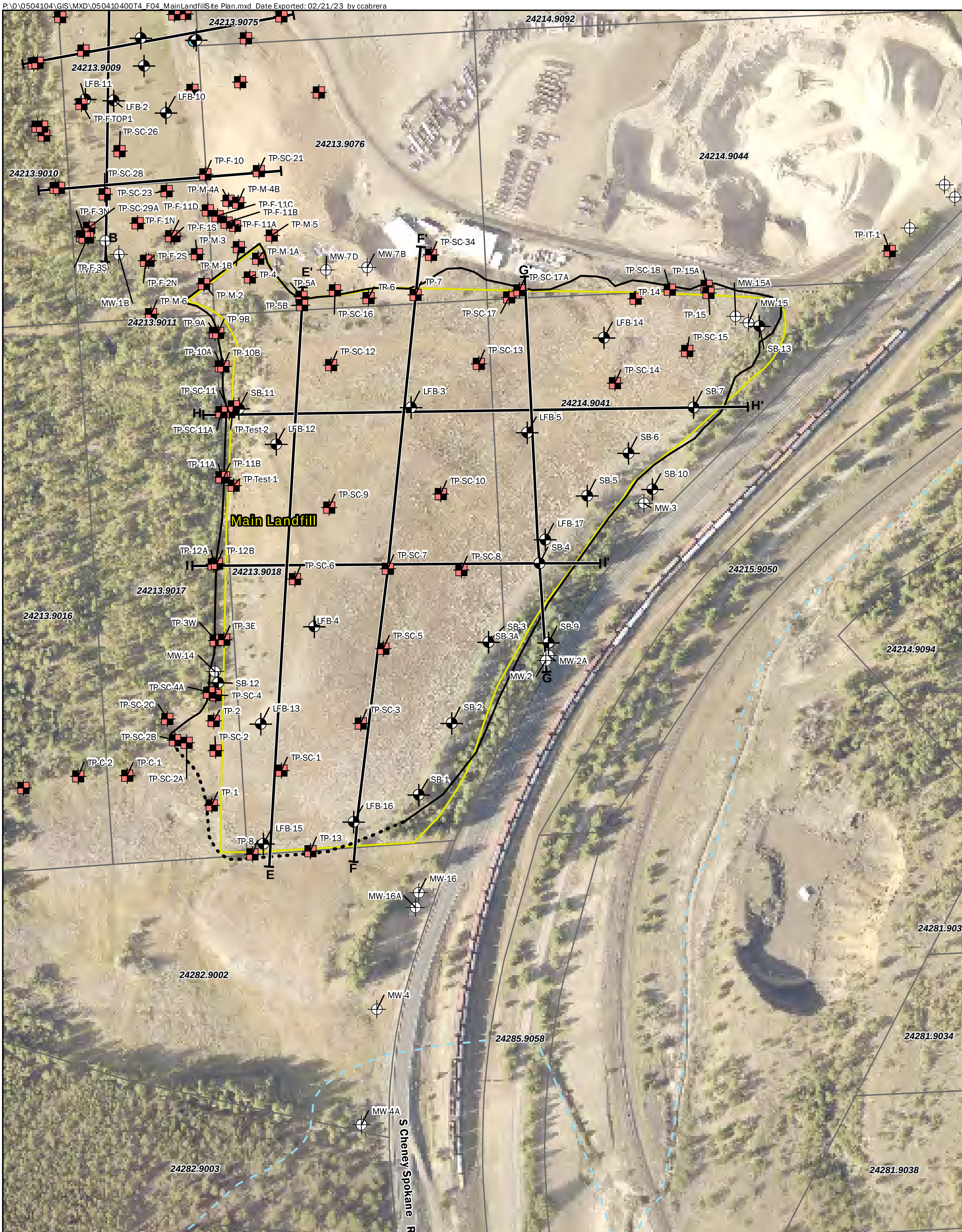
0 100
Feet

Five-Acre Landfill
Fine-Grained Soil Cover Thickness

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 3



Legend

MW-1A	Groundwater Monitoring Well Designation and Approximate Location
LFB-13	Landfill Gas Monitoring Well and Approximate Location
TPC-1	Test Pit Designation and Approximate Location
	Landfill Gas Monitoring Well Designation and Approximate Location
	Approximate Landfill Boundaries[3]
	2022 Approximate Boundary of Main Landfill
	2022 Approximate Estimated Boundary of Main Landfill
	Cross Section Transect
	Ephemeral Stream
	Parcel Boundary

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Notes:

1. The locations of all features shown are approximate.
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3. Landfill boundaries have been modified with respect to Fetrow Engineering (1991) based on Remedial Investigation explorations.

Data Source: Street labels and parcels from Spokane County GIS.

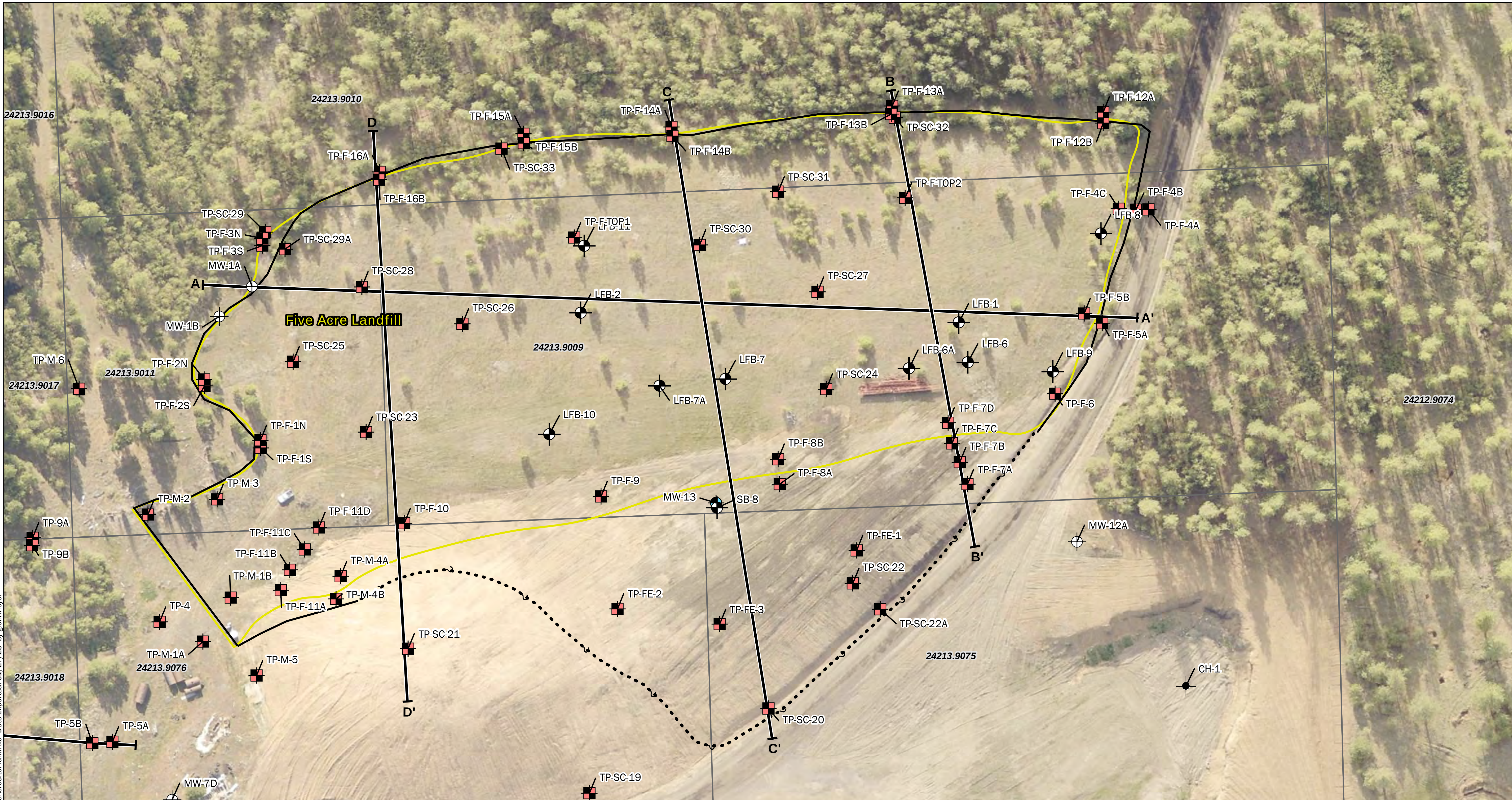
Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Main Landfill Explorations and Cross Section Location

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 4



P:\0\0504104\GIS\MXD\050410400T4_F05_FiveAcreSitePlan.mxd Date Exported: 01/27/23 by glohrmeyer

Data Source: Street labels and parcels from Spokane County GIS.
Boundary Lines from TD&H survey (May, 2015)

Notes:
1. The locations of all features shown are approximate.
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4. Landfill boundaries have been modified with respect to Fetrow Engineers (1991) based on Remedial Investigation explorations.

Projection: NAD 1983 UTM Zone 11N

Legend

- MW-1A — Groundwater Monitoring Well Designation and Approximate Location
- LFB-8 — Landfill Gas Monitoring Well Designation and Approximate Location
- LFB-1 — Landfill Gas Monitoring Well and Approximate Location
- TP-4 — Test Pit Designation and Approximate Location
- CH-1 — Abandoned Boring Location
- Approximate Boundary of Five Acre Landfill[4]
- 2022 Approximate Boundary of Five Acre Landfill
- Cross Section Transect
- Spokane County Parcels Boundary

W N E S

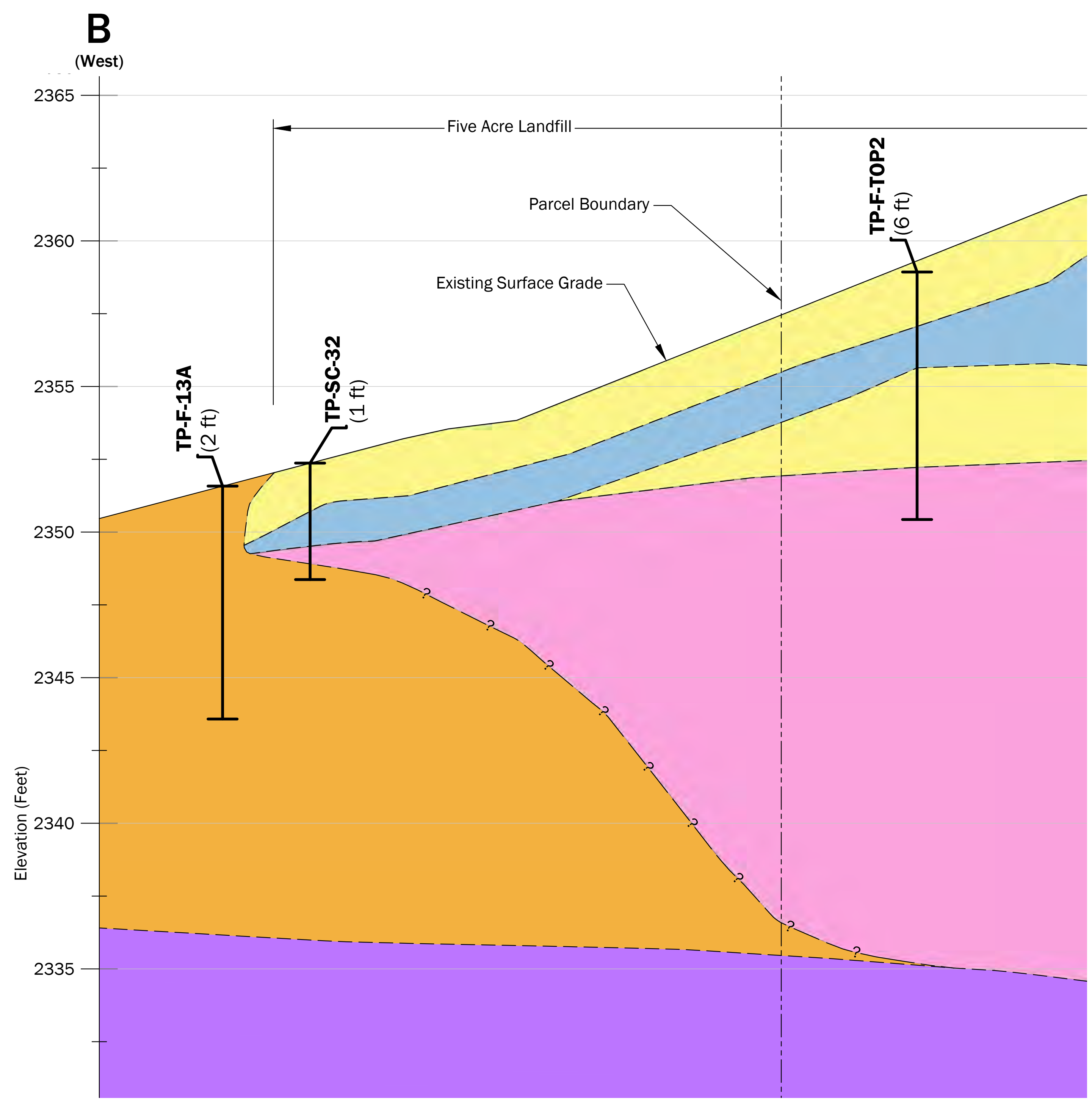
0 100
Feet

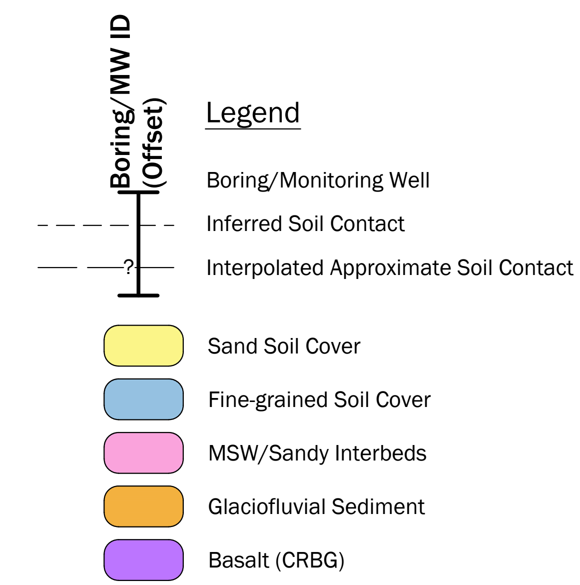
Five Acre Landfill Explorations and Cross Section Location

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 5





Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. CRBG = Columbia River Basalt Group; MSW = Municipal Solid Waste.
4. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

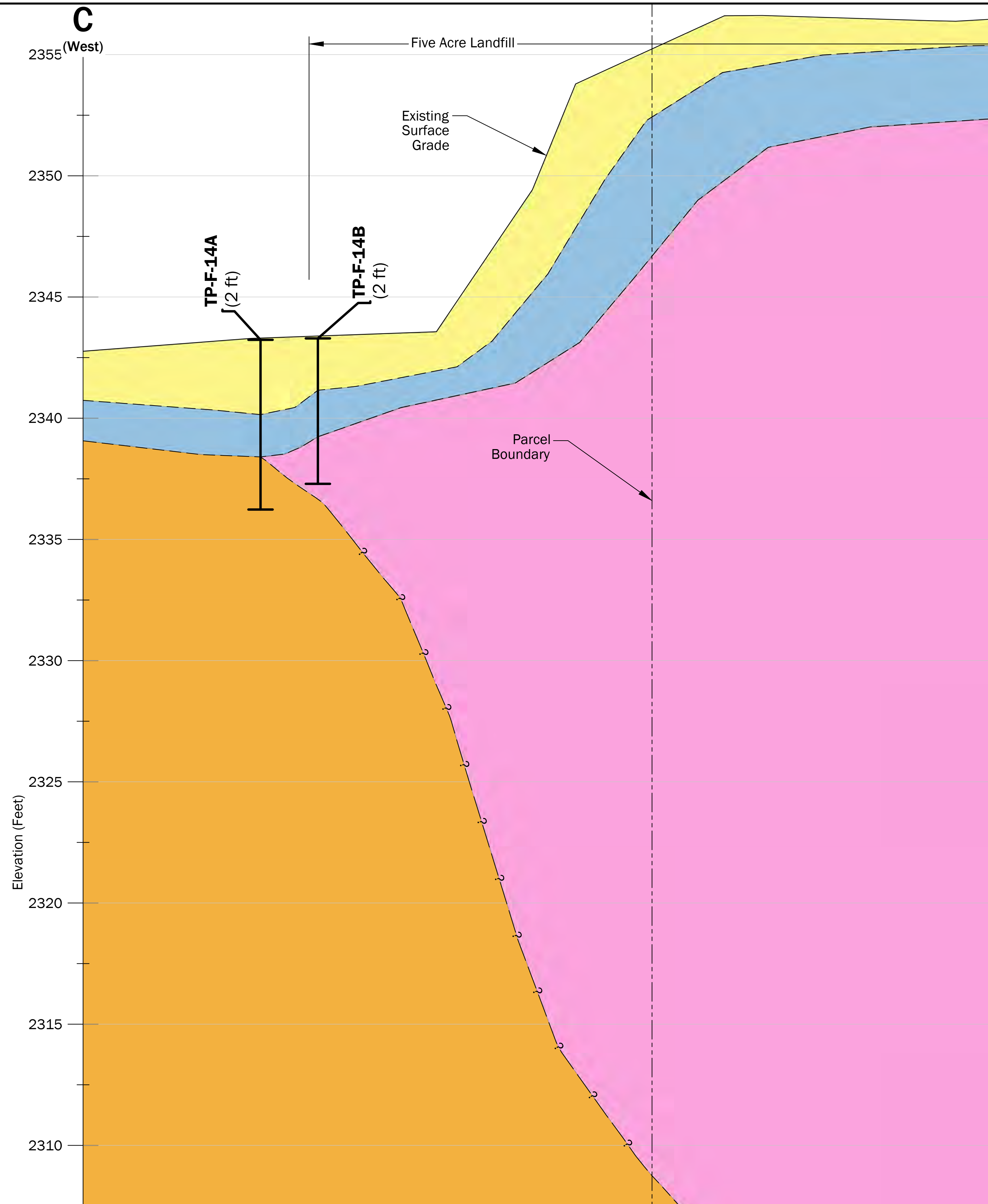
Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet
5 0 5
Vertical Scale in Feet
Vertical Exaggeration = 4X

Cross Section Perimeter Boundary at B

Marshall Landfill
Spokane County, Washington

GEOENGINEERS | **Figure 6**



Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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3. CRBG = Columbia River Basalt Group; MSW = Municipal Solid Waste.
4. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

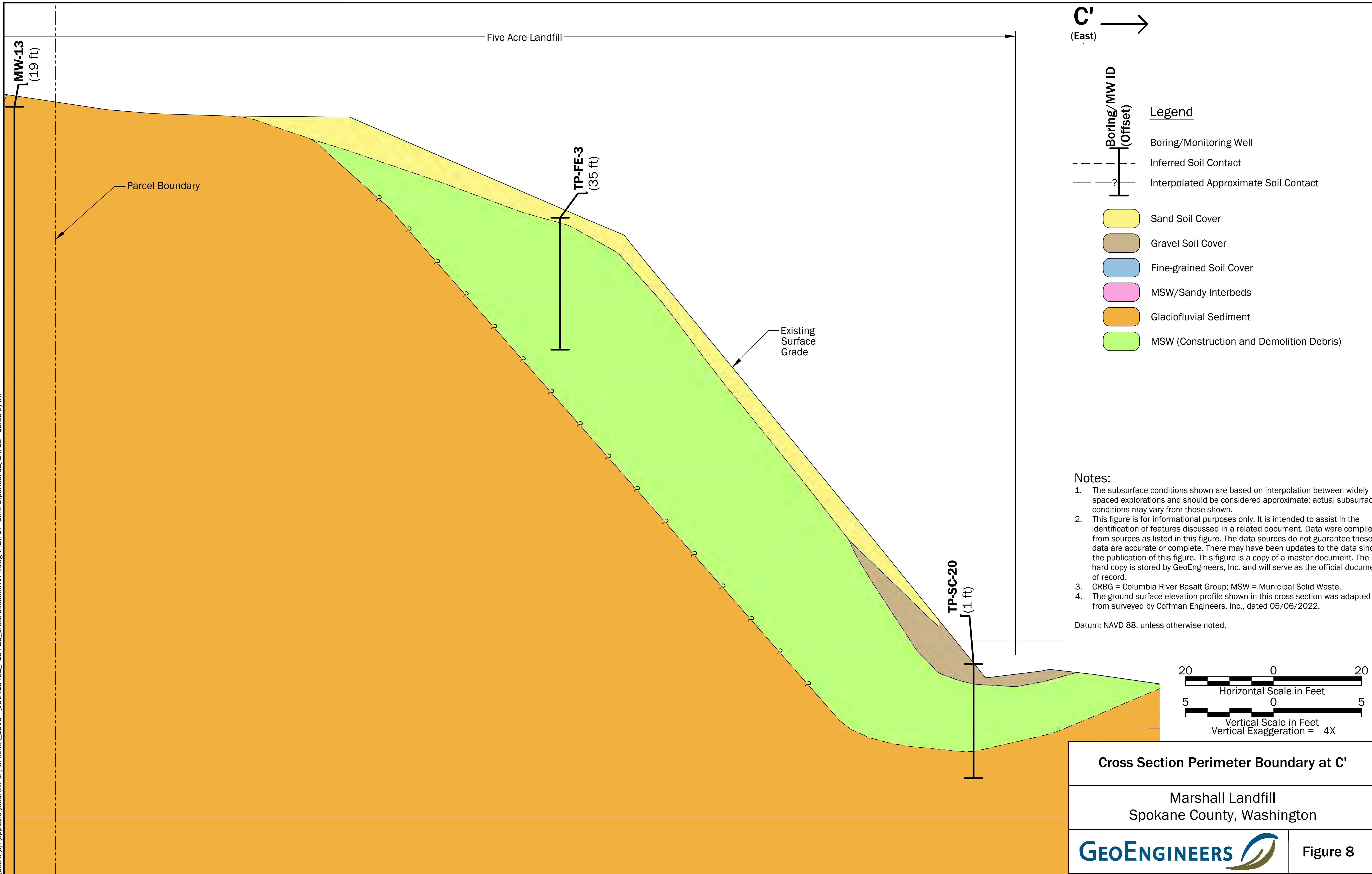
Cross Section Perimeter Boundary at C

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 7

C:\Users\syi\appdata\local\temp\AcPublish_19004\050410401_F15-F26_Cross Sections AA-II.dwg TAB:F16 Date Exported: 02/24/23 - 13:39 by syi



Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
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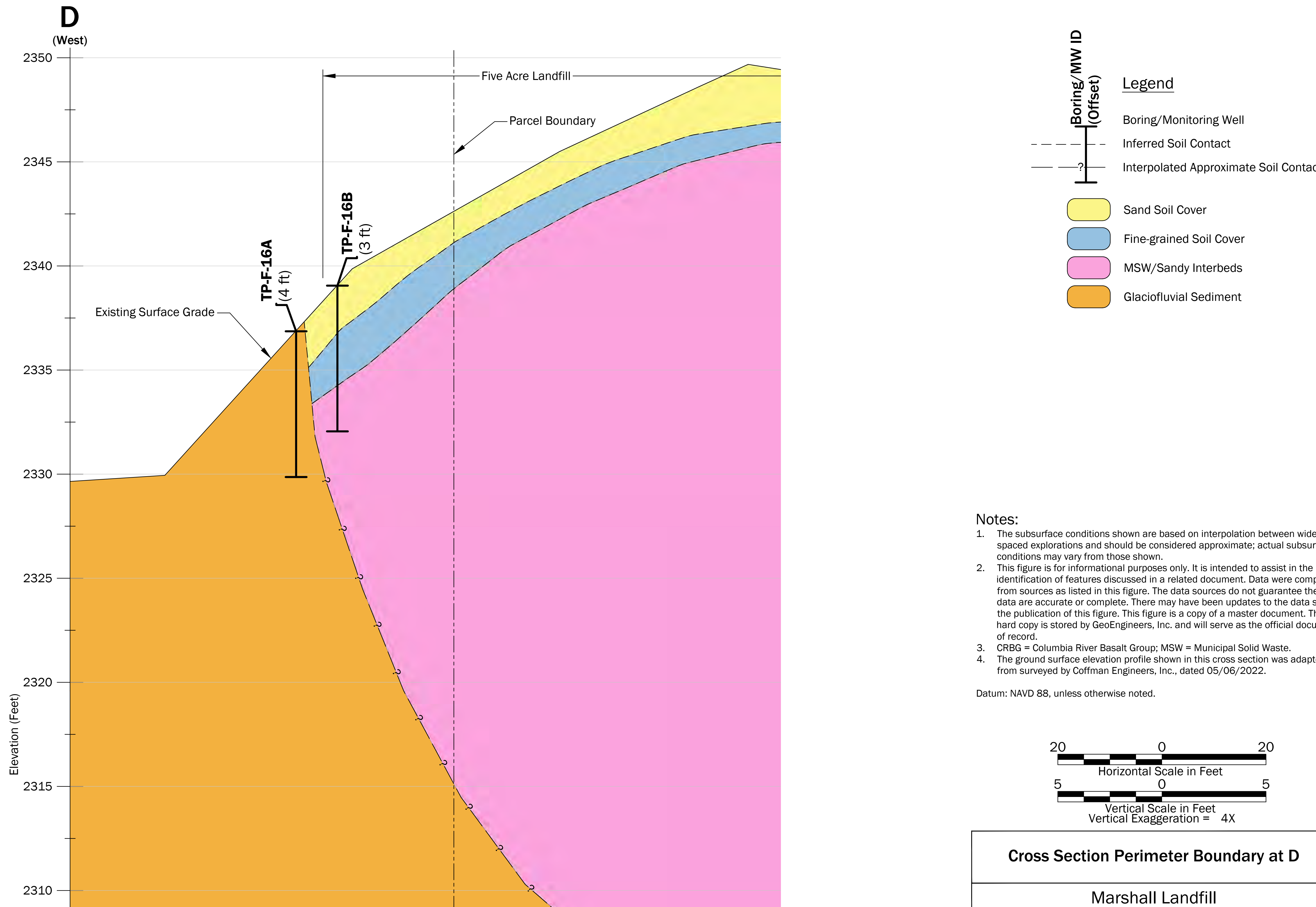
Datum: NAVD 88, unless otherwise noted.

Cross Section Perimeter Boundary at C'

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 8



Notes:

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4. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet
5 0 5
Vertical Scale in Feet
Vertical Exaggeration = 4X

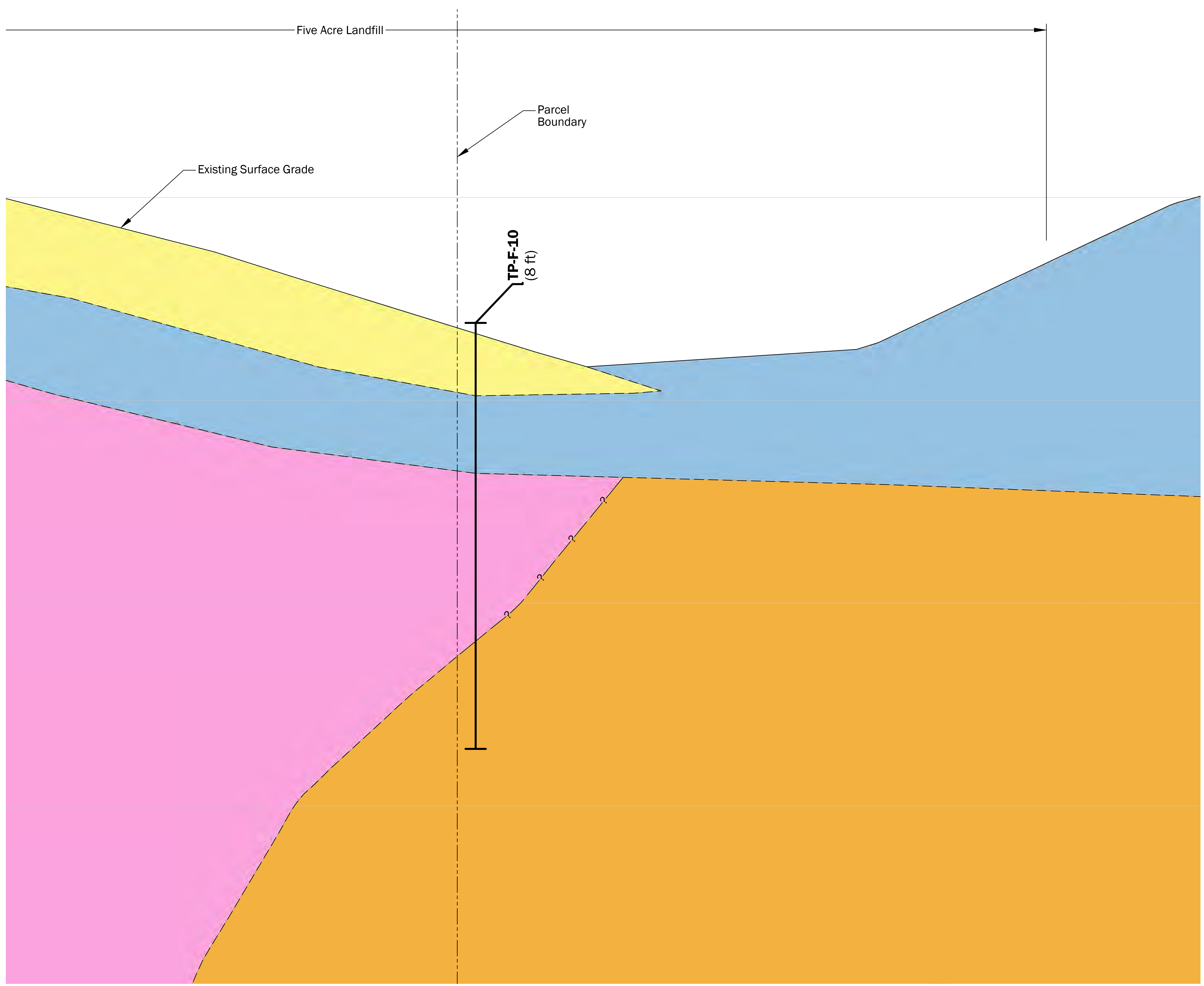
Cross Section Perimeter Boundary at D

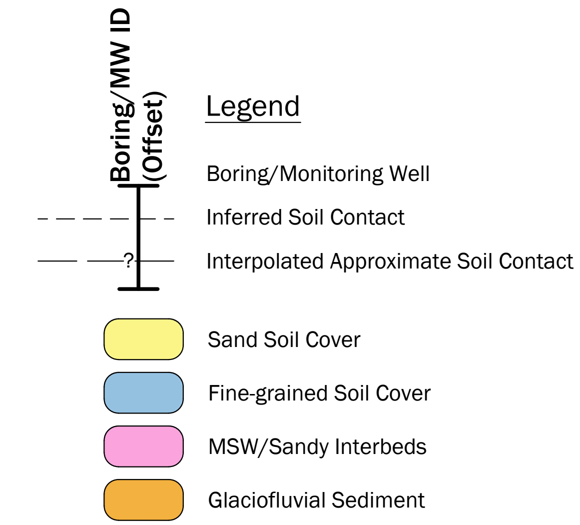
Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 9

C:\Users\syi\appdata\local\temp\AcPublish_19004\0504104O1_F15-F26_Cross Sections AA-II.dwg TAB:F18 Date Exported: 02/24/23 - 13:39 by syi





Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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Datum: NAVD 88, unless otherwise noted.

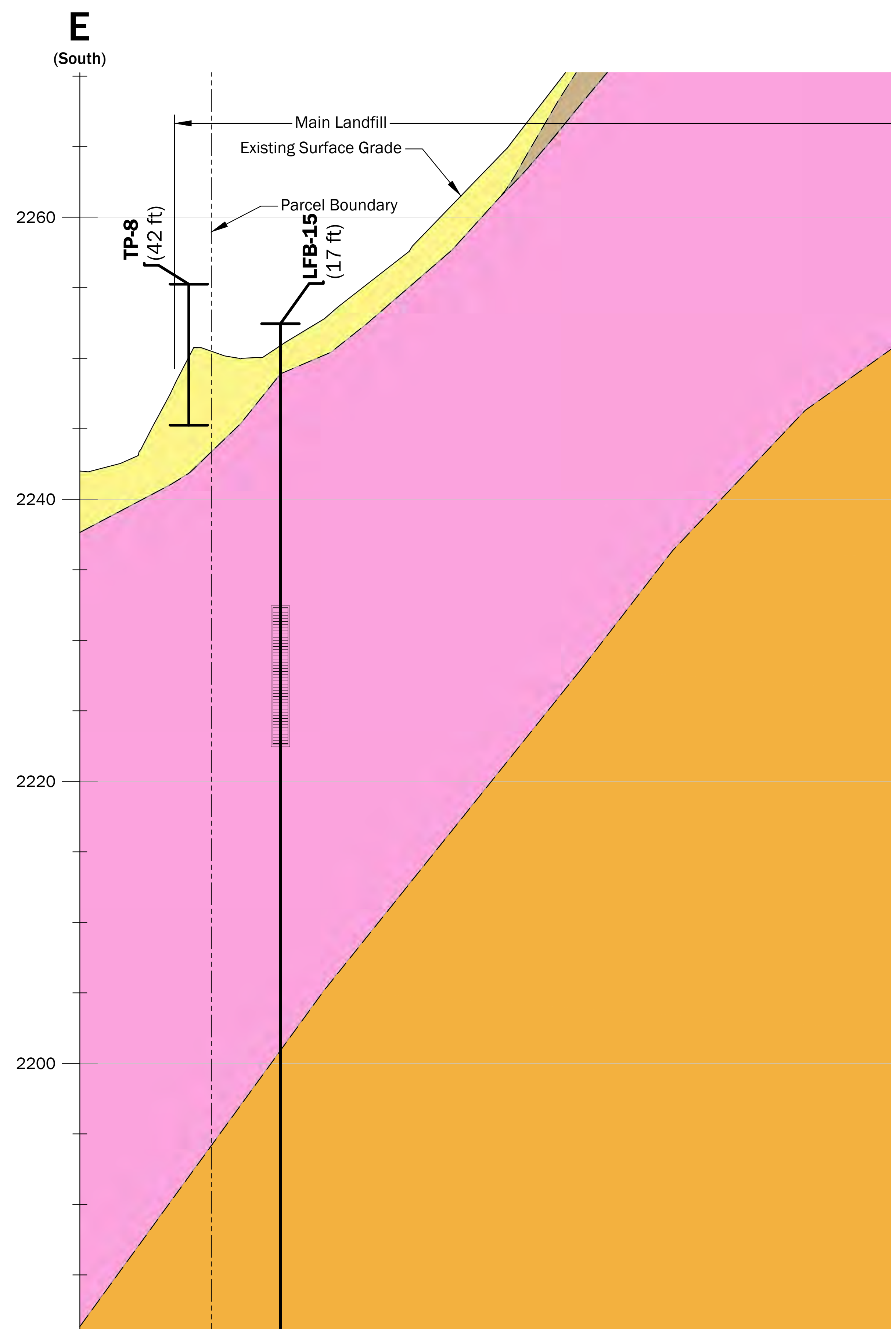
10 0 10
Horizontal Scale in Feet
2.5 0 2.5
Vertical Scale in Feet
Vertical Exaggeration = 4X

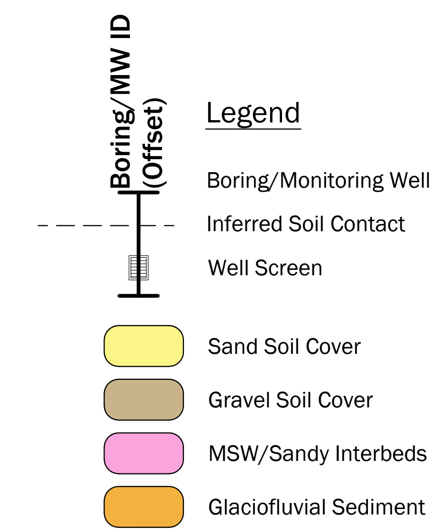
Cross Section Perimeter Boundary at D'

Marshall Landfill
Spokane County, Washington

GEOENGINEERS

Figure 10





Notes:

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4. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

40 0 40
Horizontal Scale in Feet

10 0 10
Vertical Scale in Feet
Vertical Exaggeration = 4X

Cross Section Perimeter Boundary at E

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 11

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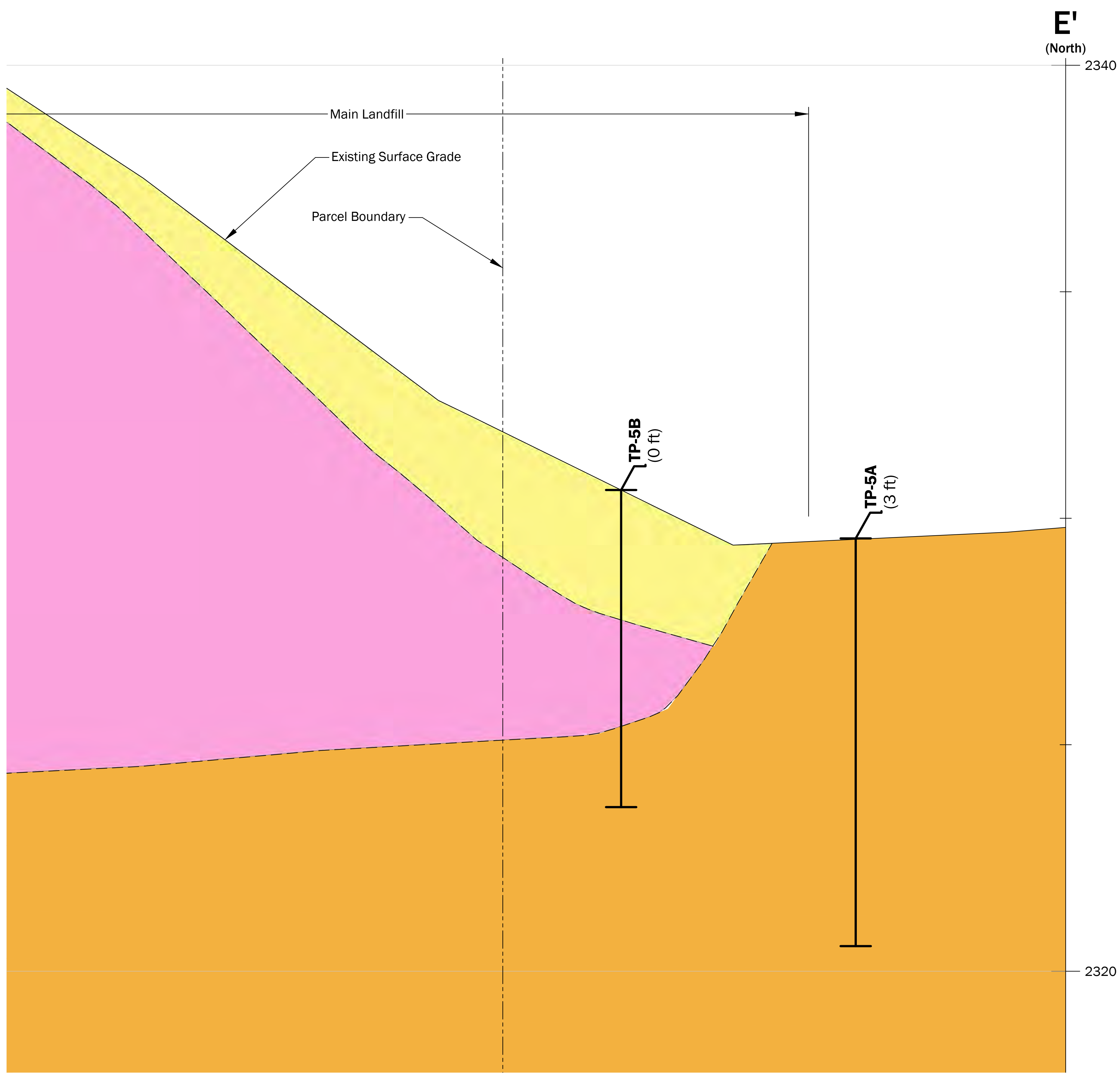

Boring/MW ID
(Offset)

Legend

Boring/Monitoring Well

Inferred Soil Contact

Sand Soil Cover

MSW/Sandy Interbeds

Glaciofluvial Sediment

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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Datum: NAVD 88, unless otherwise noted.

10 0 10
Horizontal Scale in Feet

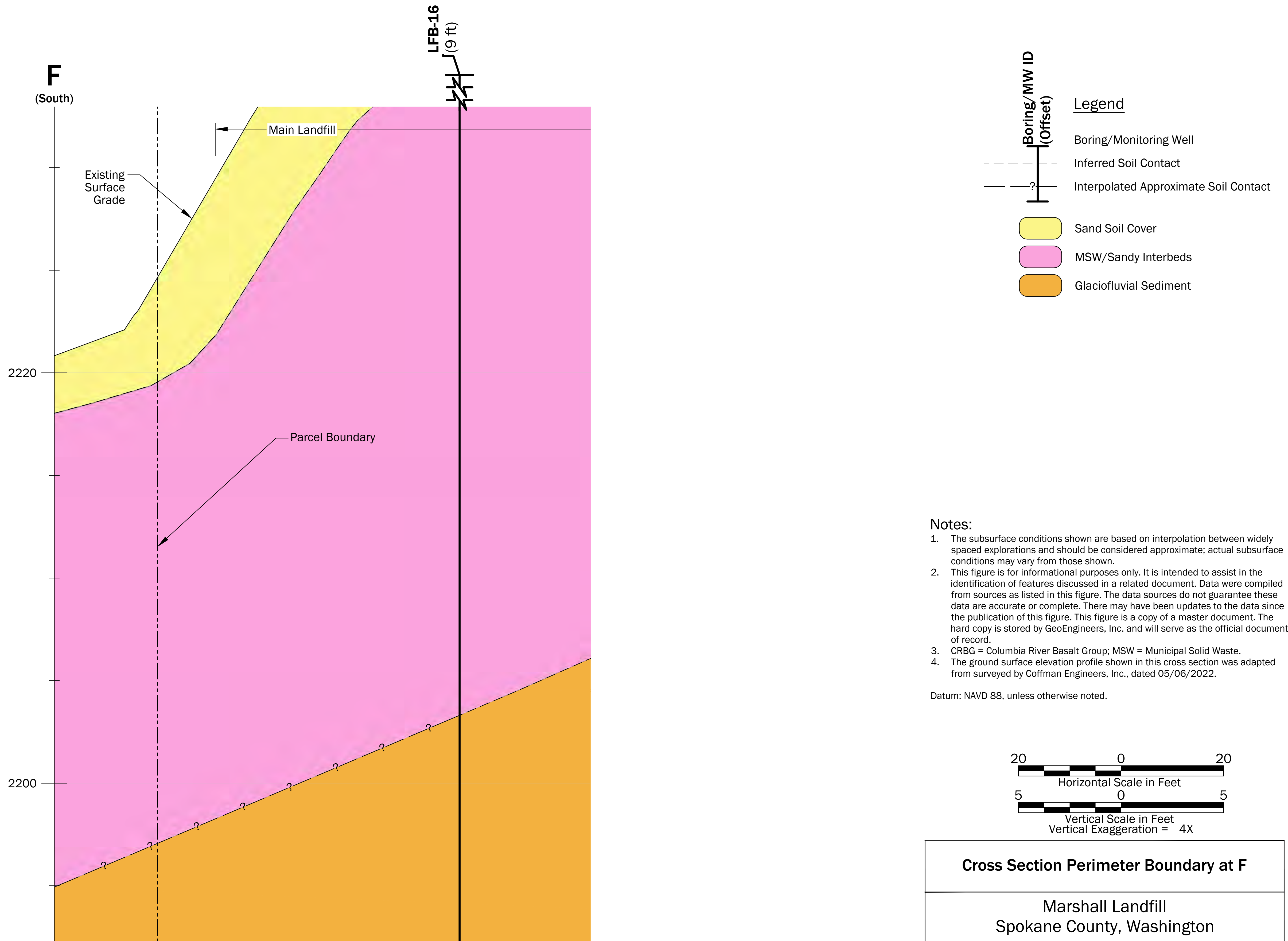
2.5 0 2.5
Vertical Scale in Feet
Vertical Exaggeration = 4X

Cross Section Perimeter Boundary at E'

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 12



Notes:

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4. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

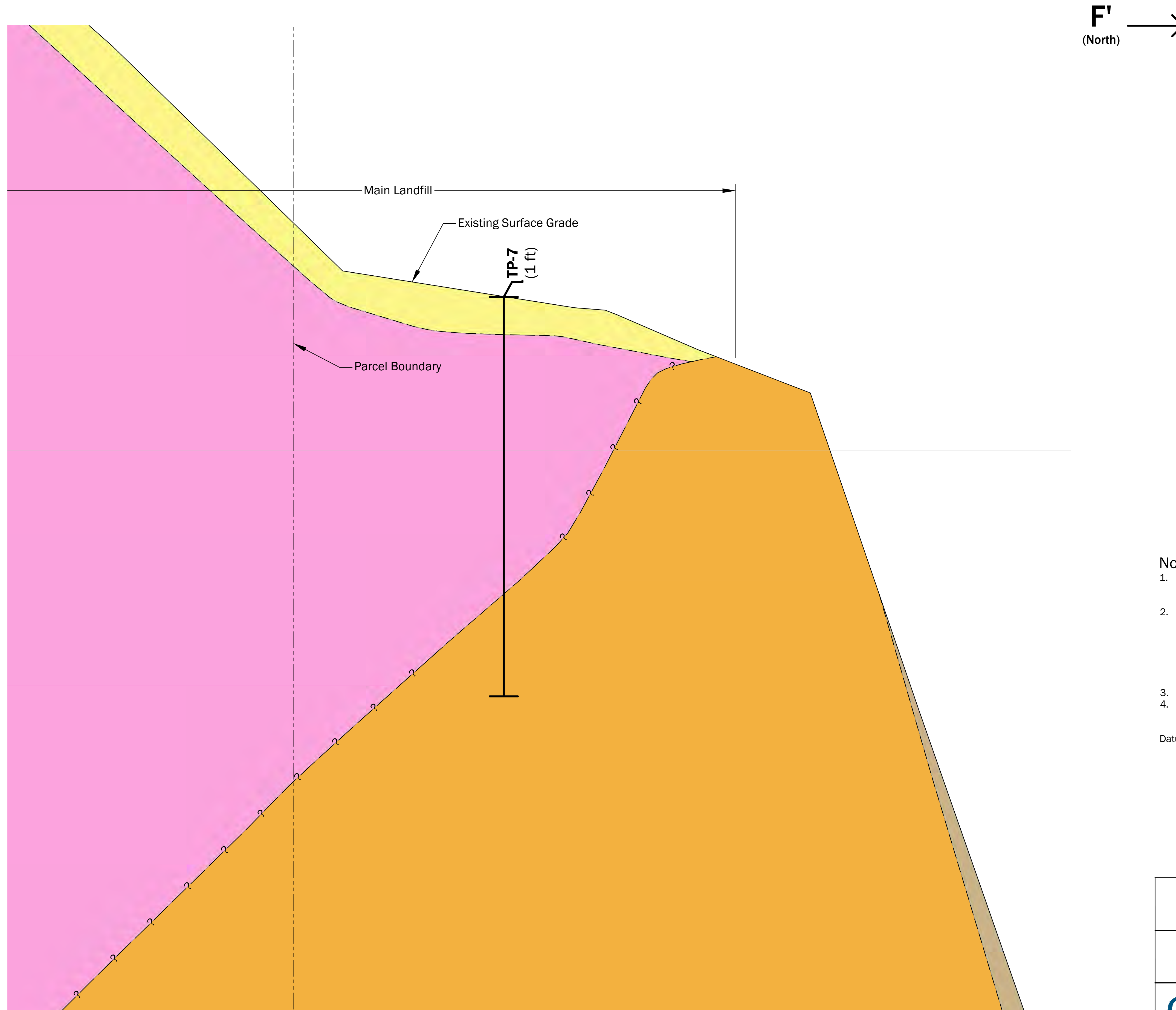
Datum: NAVD 88, unless otherwise noted.

Cross Section Perimeter Boundary at F

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 13



Legend

Boring/MW ID (Offset)

- Boring/Monitoring Well
- Inferred Soil Contact
- Interpolated Approximate Soil Contact
- Sand Soil Cover
- Gravel Soil Cover
- MSW/Sandy Interbeds
- Glaciofluvial Sediment

Notes:

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Datum: NAVD 88, unless otherwise noted.

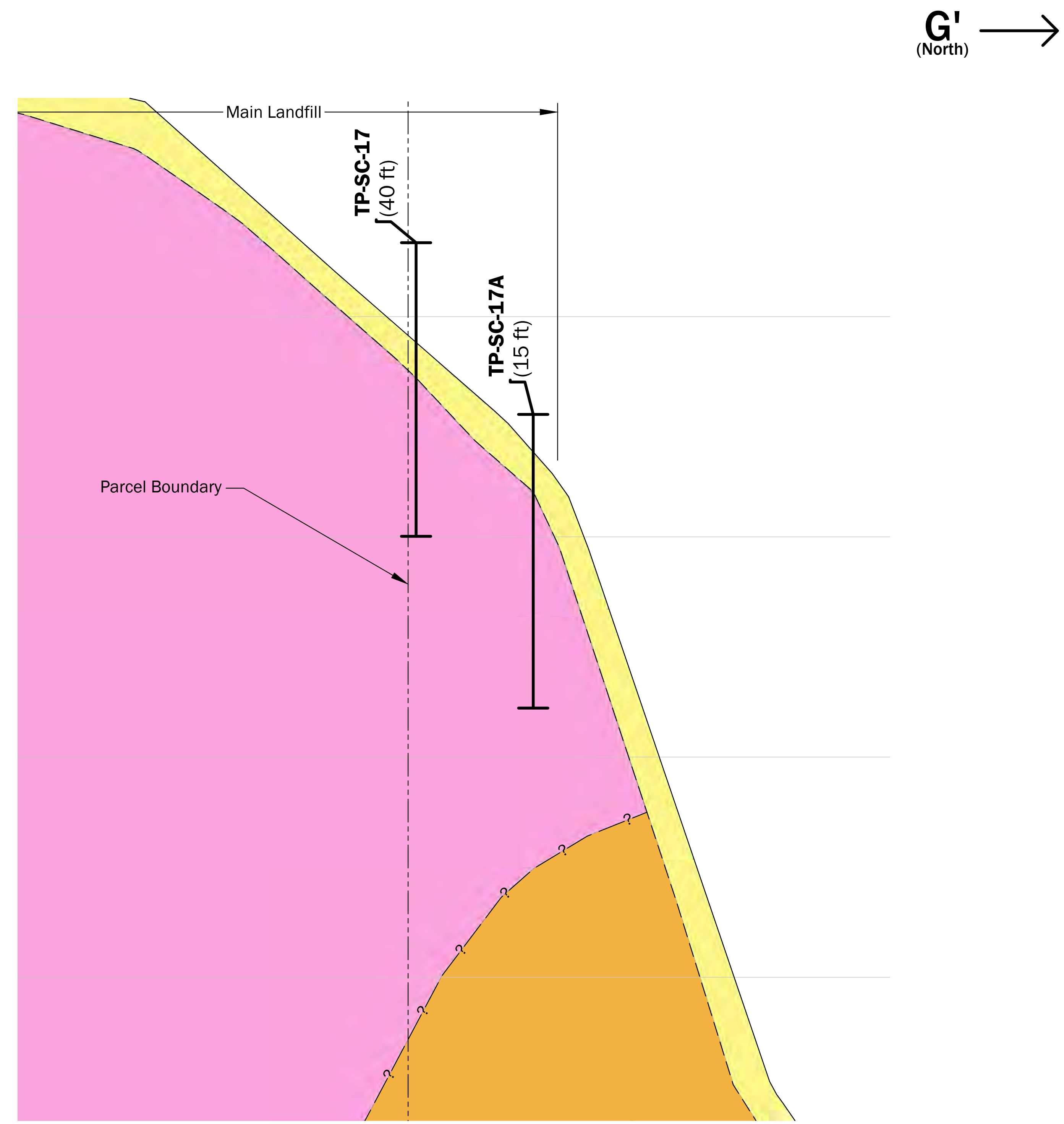
10 0 10
Horizontal Scale in Feet
2.5 0 2.5
Vertical Scale in Feet
Vertical Exaggeration = 4X

Cross Section Perimeter Boundary at F'

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure 14



Boring/MW ID
(Offset)

Legend

Boring/Monitoring Well
Inferred Soil Contact
Interpolated Approximate Soil Contact

Sand Soil Cover
MSW/Sandy Interbeds
Glaciofluvial Sediment

Notes:

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Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet
5 0 5
Vertical Scale in Feet
Vertical Exaggeration = 4X

Cross Section Perimeter Boundary at G'

Marshall Landfill
Spokane County, Washington

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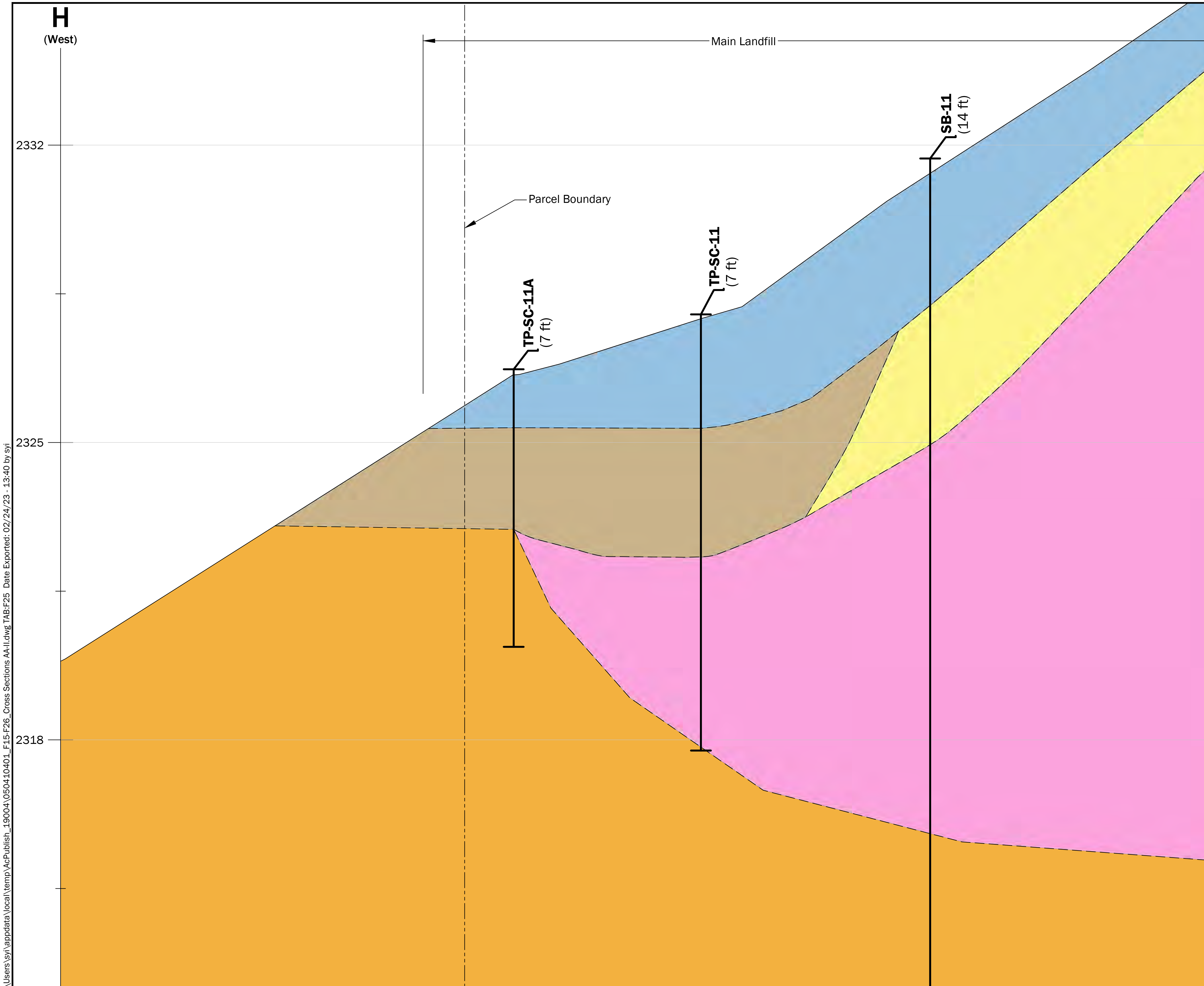
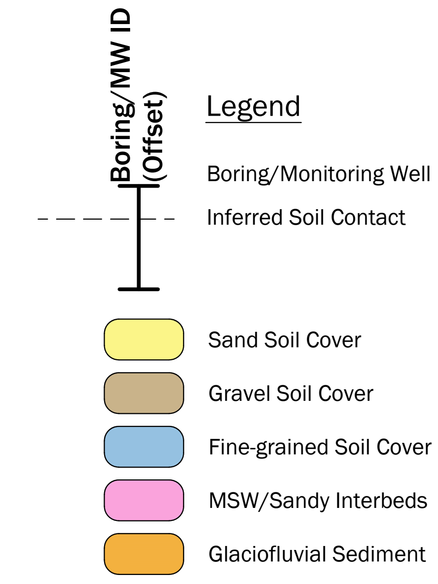
Figure 15





Notes:

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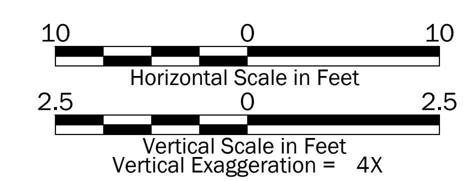
Datum: NAVD 88, unless otherwise noted.

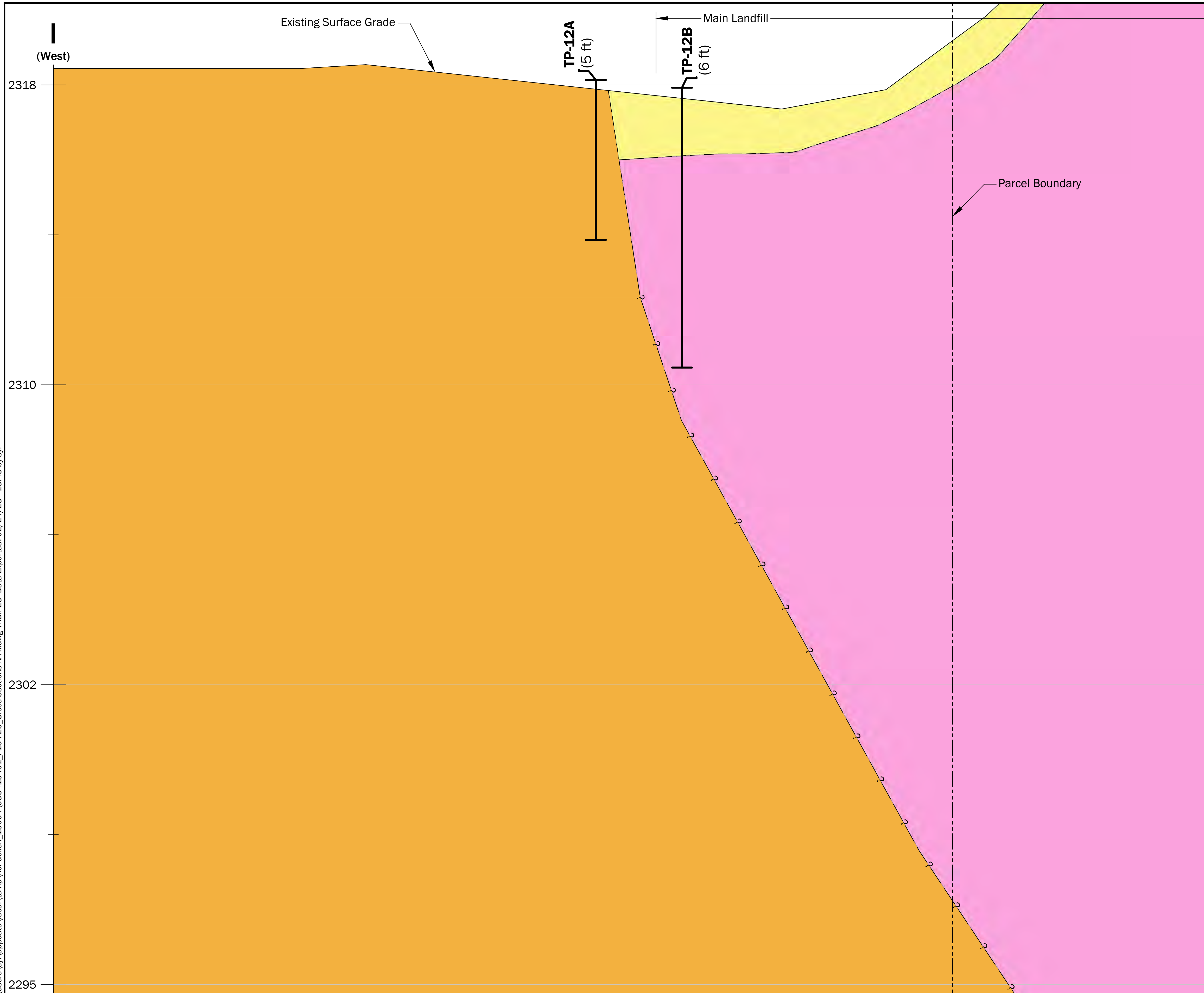


Cross Section Perimeter Boundary at H

Marshall Landfill
Spokane County, Washington

GEOENGINEERS

Figure 16



Legend

Boring/MW ID (Offset)

Boring/Monitoring Well

Inferred Soil Contact

Interpolated Approximate Soil Contact

Sand Soil Cover

MSW/Sandy Interbeds

Glaciofluvial Sediment

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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Datum: NAVD 88, unless otherwise noted.

10 0 10
Horizontal Scale in Feet

2.5 0 2.5
Vertical Scale in Feet
Vertical Exaggeration = 4X

Cross Section Perimeter Boundary at I

Marshall Landfill
Spokane County, Washington

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Figure 17

APPENDIX B

Hydraulic Conductivity Estimates

Appendix B. Grain-Size-Based Hydraulic Conductivity Estimates.

Marshall Landfill Project, Spokane County, Washington

Boring	Depth	Soil Type	10 Percent Passing	60 Percent Passing	90 Percent Passing	Fraction Fines	Equation 1 [1] Saturated Hydraulic Conductivity [2]			Equation 2 [1] Saturated Hydraulic Conductivity [2]			Equation 3 [1] Saturated Hydraulic Conductivity [2]		
			d_{10}	d_{60}	d_{90}	f_{fines}	K			K			K		
	ft bgs		*mm*	*mm*	*mm*		*cm/sec*	*in/hr*	*ft/d*	*cm/sec*	*in/hr*	*ft/d*	*cm/sec*	*in/hr*	*ft/d*
Main Landfill															
TP-SC-1	4-5	GP	0.6	8.00	80.00	0.03	3.9E-02	55.87	111.74	**2.5E-01**	**360**	**721**	6.9E-01	979.88	1959.77
TP-SC-7	0.5-1	SP	0.47	3.30	26.00	0.03	9.4E-02	132.91	265.83	**1.8E-01**	**249**	**498**	5.2E-01	732.03	1464.06
									Main Landfill Average	**2.1E-01**	**305**	**609**			
Five-Acre Landfill															
TP-SC-24[4]	1-2	SP-SM	0.06	3.80	36.00	0.11	8.0E-03	11.37	22.74	5.2E-02	73.05	146.10	**4.5E-04**	**0.64**	**1.29**
TP-SC-25[3]	0.5-1.5	SM	0	5.30	51.00	0.17	NA	NA	NA	NA	NA	NA	NA	NA	NA
TP-SC-26	0.5-1.5	SP-SM	0.47	2.50	32.00	0.05	6.9E-02	98.17	196.34	**1.7E-01**	**245**	**489**	2.1E+00	2944.21	5888.42
TP-SC-30[4]	0.5-1	SP-SM	0.06	3.00	40.00	0.11	6.9E-03	9.81	19.62	5.2E-02	73.05	146.10	**1.6E-03**	**2.24**	**4.48**
TP-SC-31	0.5-1	SP-SM	0.47	9.50	65.00	0.05	3.3E-02	46.56	93.11	**1.7E-01**	**245**	**489**	4.2E-03	5.89	11.78
TP-SC-33[3]	0-1	SM	0	1.70	27.00	0.13	NA	NA	NA	NA	NA	NA	NA	NA	NA
									Five-Acre Landfill Average	**8.7E-02**	**123**	**246**			

Equations:

Equation 1 (Standard Equation): $\log_{10}(K_{sat}) = -1.57 + 1.90 * d_{10} + 0.015 * d_{60} - 0.013 * d_{90} - 2.08 * f_{fines}$

Equation 2 (Coarse-Grained Soils): $\log_{10}(K_{sat}) = -1.32 + 1.225 * d_{10} - 0.376 * f_{fines}$

Equation 3 (Fine-Grained Soils): $\log_{10}(K_{sat}) = -2.89 + 7.57 * d_{10} - 0.527 * d_{60} + 0.030 * d_{90} + 0.142 * f_{fines}$

Reference:

Washington Department of Ecology (WADOE), 2019. Stormwater Management Manual for Eastern Washington. Pub No. 18-10-044, Chapter 6, P. 744-746

Notes:

1. Equations 1 through 3 are adapted from the WADOE 2019 Stormwater Management Manual for Eastern Washington (SMMEW).
2. Bold values refer to the most appropriate analysis for a given grain-size distribution based on guidance provided by SMMEW.
3. The 10 percent passing value was not quantified and, therefore, Equations 1 through 3 are not applicable.
4. d_{10} value projected based upon grain-size distribution curve.

ft = feet; bgs = below ground surface; mm = millimeter; cm = centimeter; sec = second; in = inch; hr = hour; d = day; NA = not applicable

APPENDIX C

Soil Cap Mix Design

Bryce Hanson, GIT
GeoEngineers, Inc.
523 E Second Ave
Spokane, WA 99202

April 18, 2023

Project Number L23156

PROJECT: **Soil Cap Mix Design**

SUBJECT: **Results of Laboratory Testing**
Report #1

At your request, we provided laboratory testing services for the subject project. Services were limited to the performance of specific laboratory tests, selected at your discretion.

For this period, our involvement was limited to laboratory testing of three samples delivered to our laboratory on February 21, 2023. Laboratory tests were performed in general accordance with methods listed in the attached *Laboratory Summary* sheet.

If you have questions regarding this report, please call.

Respectfully Submitted,
Budinger & Associates, Inc.

Terri Ballard
Laboratory Manager

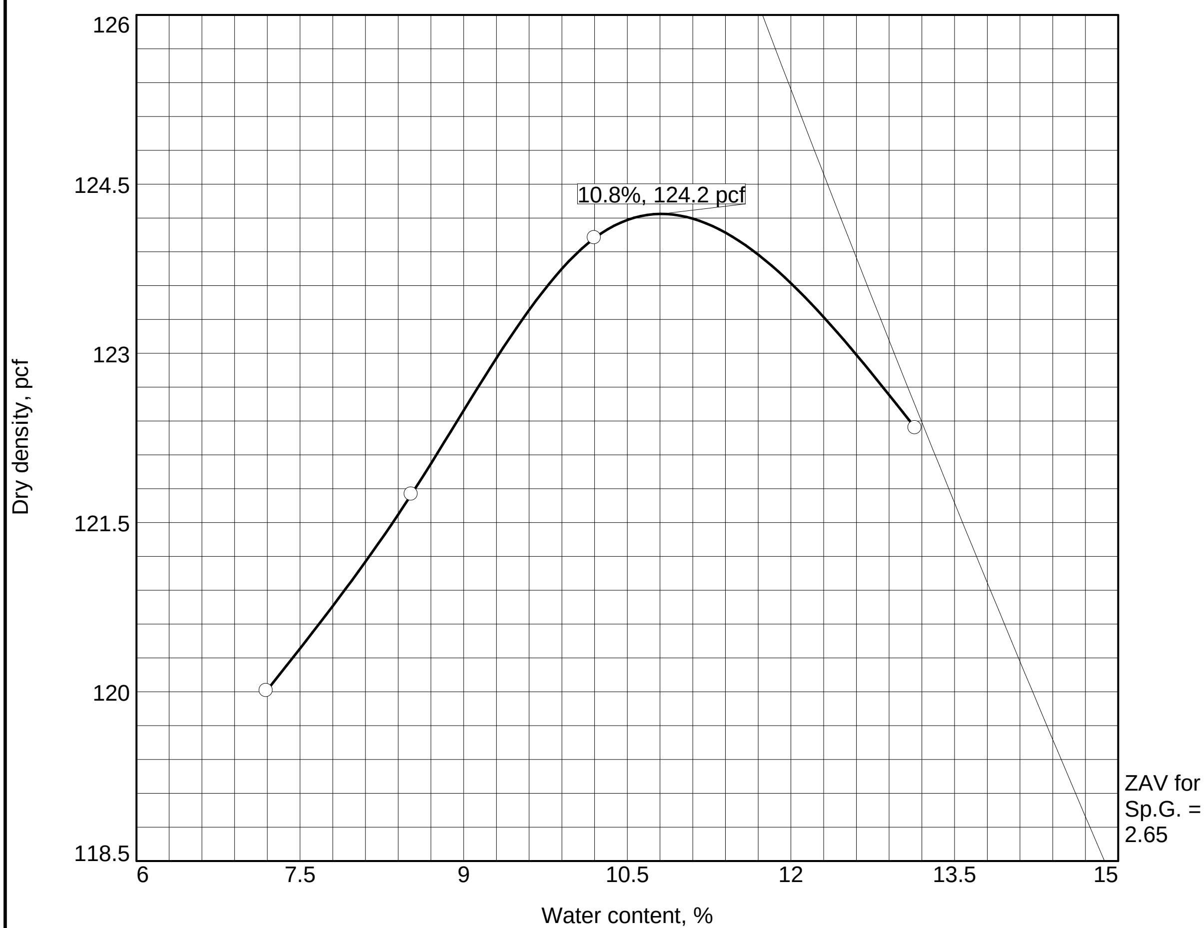
TJB/lat/Addressee –
Bryce Hanson – bhanson@geoengineers.com
Scott Lathen – slathen@geoengineers.com

Attachments:
Soils Laboratory Summary – 1 page
Moisture-Unit Weight Relationship Report – 3 pages
Hydraulic Conductivity Using a Flexible Wall Permeameter Report – 5 pages

SOILS
LABORATORY SUMMARY

	UNITS	TEST METHOD			
LABORATORY NUMBER			23-0163	23-0164	23-0165
SAMPLED BY			Client	Client	Client
SAMPLE TYPE			Bulk	Bulk	Bulk
DATE RECEIVED			2/21/23	2/21/23	2/21/23
SAMPLE SOURCE			Action Materials	TP-23 S1 (0-0.5-1.5)	TP-27 S1 (0-0.5-1.0)
PROCTOR		ASTM D698			
Maximum Unit Weight	pcf		124.2	131.9	133.4
Optimum Moisture	%		10.8	10.3	9.3
Sample Moisture	%		5.6	5.9	4.5
Bulk Specific Gravity (+3/4")		ASTM C127		2.525	2.408
Maximum Unit Weight, Corrected	pcf			137.4	136.0
Optimum Moisture, Corrected	%			8.6	8.6
PERMEABILITY		ASTM D5084			
Flexible Wall (12% Bentonite)	cm/sec		2.45×10^{-8}	–	–
Flexible Wall (9% Bentonite)	cm/sec		7.60×10^{-6}	8.24×10^{-6}	–
Flexible Wall (6% Bentonite)	cm/sec		–	1.62×10^{-5}	3.02×10^{-6}

Moisture-Unit Weight Relationship



Test specification: ASTM D 1557-12 Method B Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
			5.6				0.0	

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 124.2 pcf Optimum moisture = 10.8 %	Sand trace silt +12% Bentonite by dry weight (Tailings Borrow)

Project No. L23156 **Client:** GeoEngineers

Project: Soil Cap Mix Design

○**Source of Sample:** Action Materials **Sample Number:** 23-0163

BUDINGER & ASSOCIATES, INC.

Remarks:

Sampled By Client

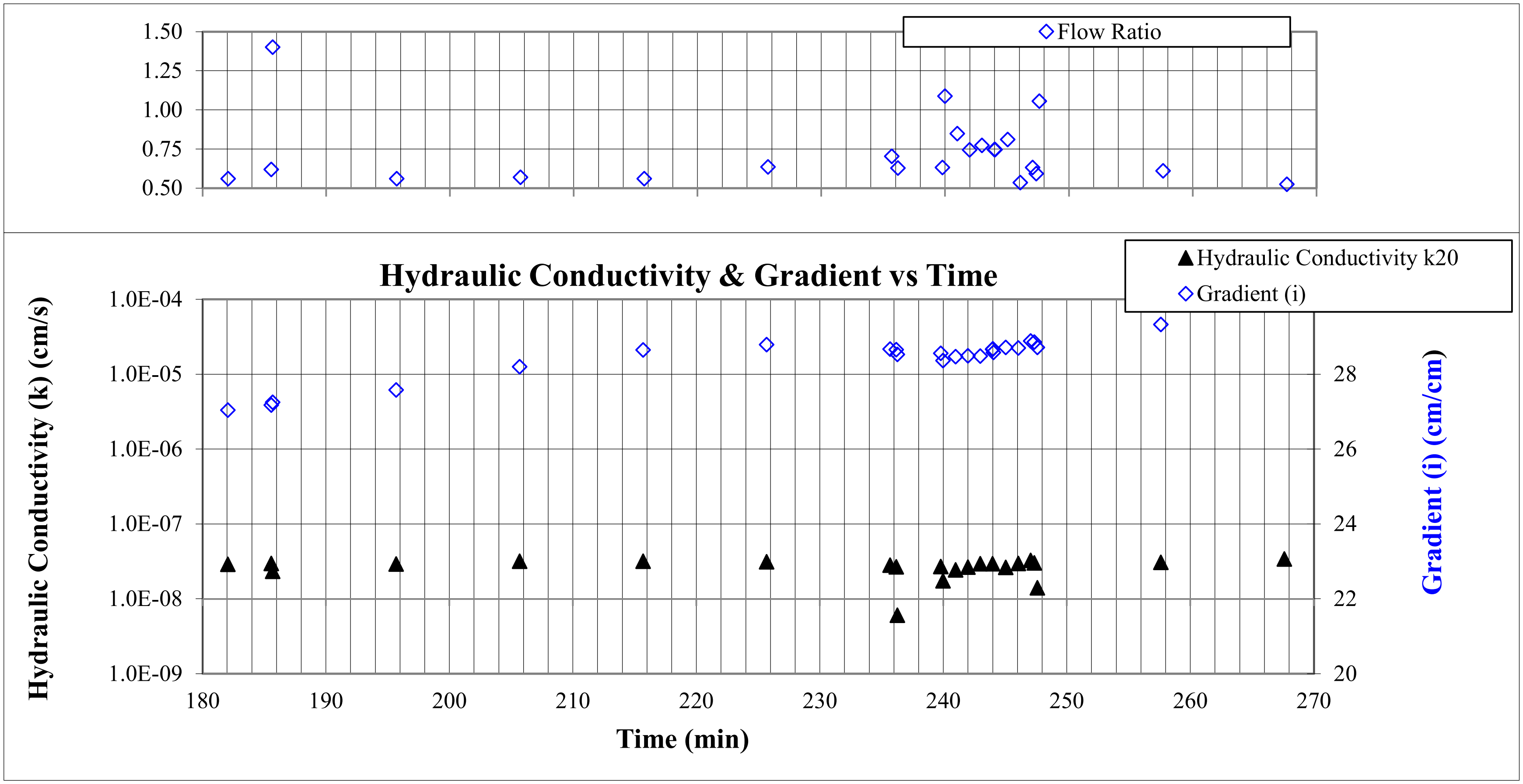
Date: 2/24/23

Tested By: KC **Checked By:** TB

Hydraulic Conductivity using a Flexible Wall Permeameter
ASTM D5084

Project Name:	Soil Cap Mix Design	Sample Description:	Sand Trace Silt +12% Bentonite by dry weight
Project No.:	L23156	Initial/Final Dry Density (pcf):	111.9 / 128.9
Sample ID:	Tailings Burrow +12% Bentonite	Initial/Final Moisture Content:	10.3% / 21.9%
Tested by:	WH	Date Tested:	3/3/2023
Sampled By:	Client	Initial/Final Saturation:	46% / 95%
Sample No.:	23-0163	Consolidation Stress (psi):	5

				Undisturbed:		Remolded:	X
Height:	3.22 in	Height:	8.18 cm	Initial Mass:	641.9 g	Assumed SG:	2.7
Diameter:	2.79 in	Diameter:	7.10 cm	Final Mass:	695 g	Liquid type:	Water
Volume:	19.76 in^3	Volume:	127.49 cm^3			Temperature (deg. C):	21.2



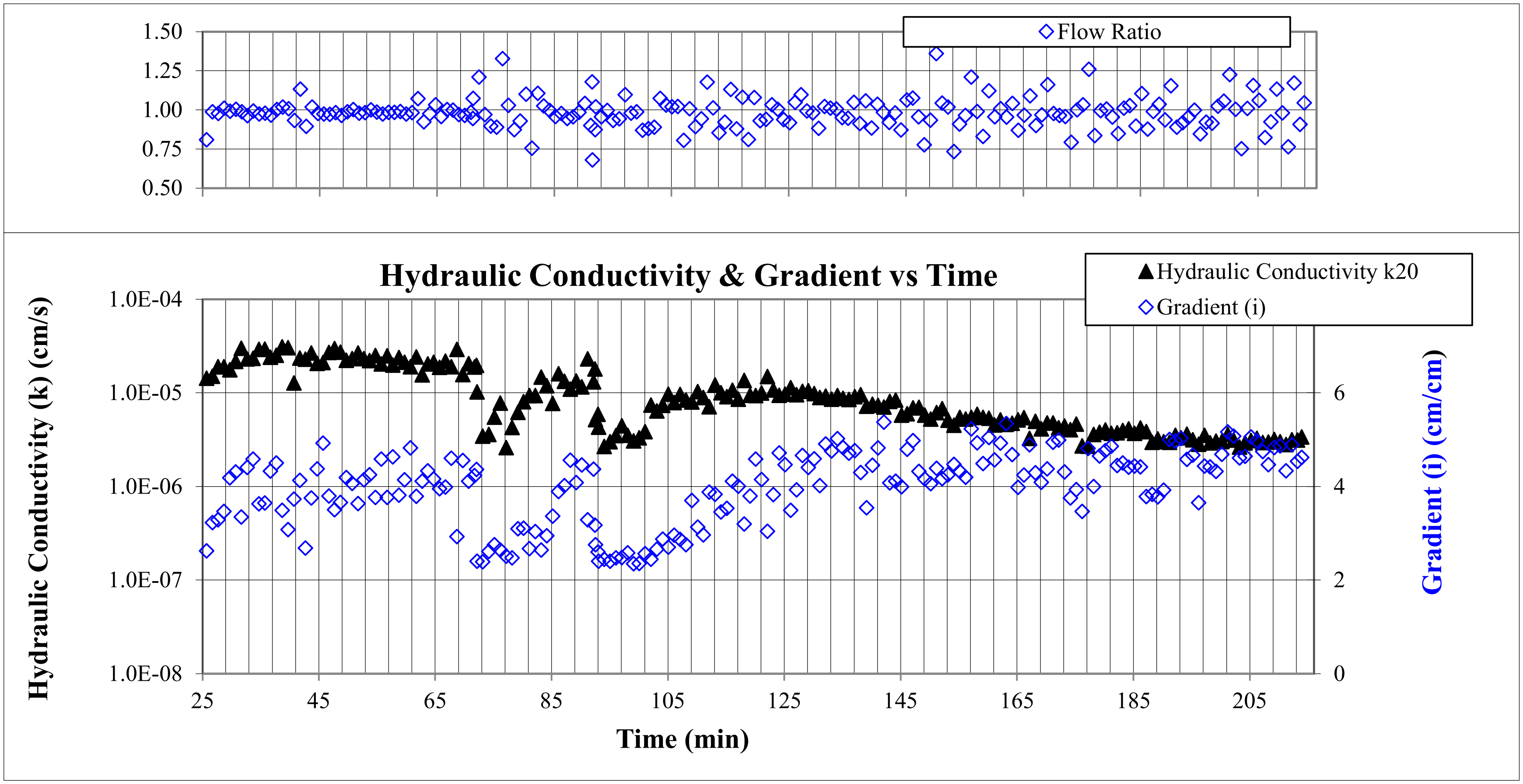
Hydraulic Conductivity k_{20}= 2.45E-08 cm/sec

Budinger & Associates, Inc.
Geotechnical & Environmental Engineers
Construction Materials Testing & Special Inspection

Hydraulic Conductivity using a Flexible Wall Permeameter
ASTM D5084

Project Name:	Soil Cap Mix Design	Sample Description:	Sand trace silt +9% Bentonite by dry weight
Project No.:	L23156	Initial/Final Dry Density (pcf):	111.2 / 106.3
Sample ID:	Tailings Burrow +9% Bentonite	Initial/Final Moisture Content:	11.2% / 23.2%
Tested by:	WH	Date Tested:	4/7/2023
Sampled By:	Client	Initial/Final Saturation:	9% / 95%
Sample No.:	23-0163	Consolidation Stress (psi):	5

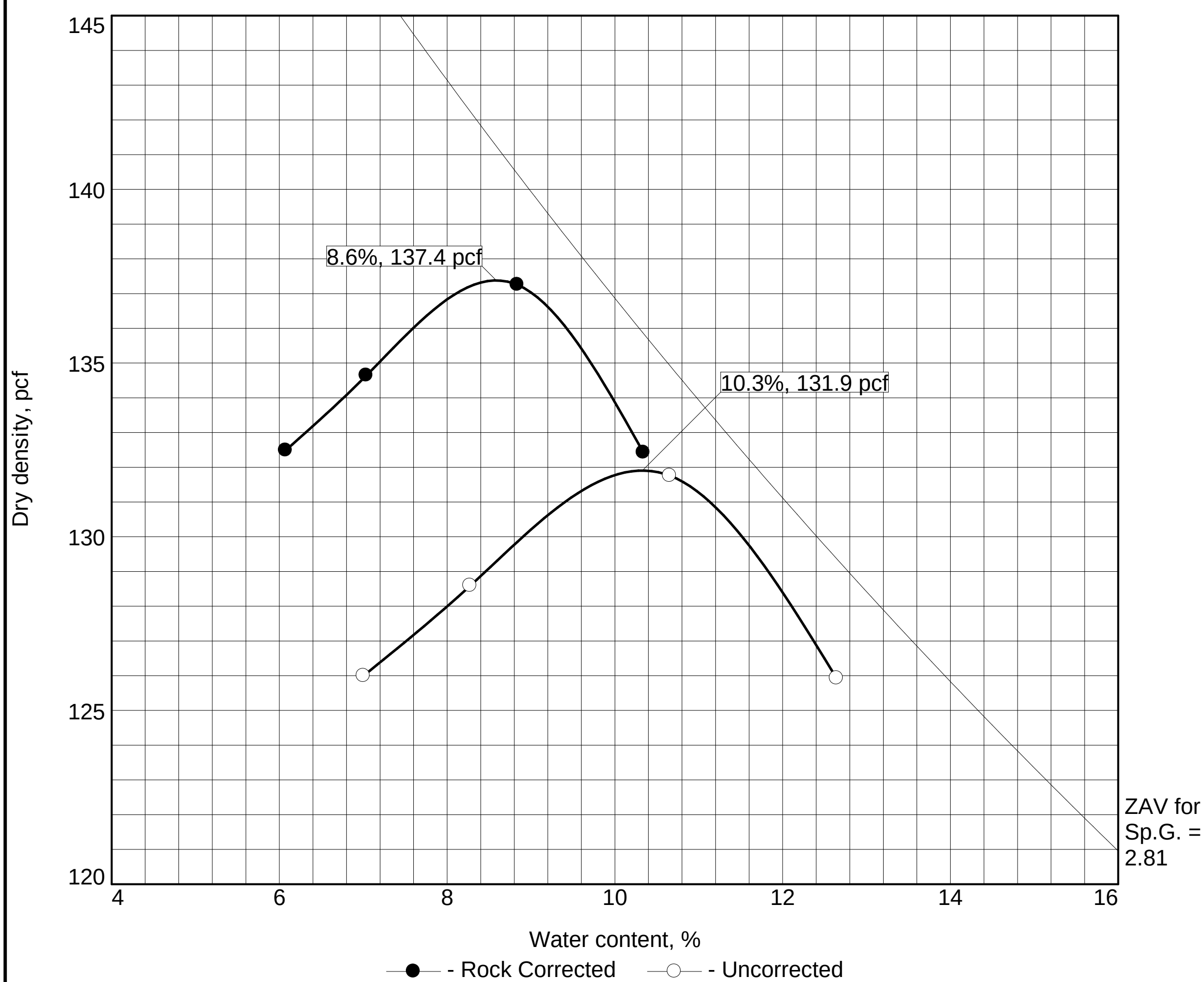
				Undisturbed:		Remolded:	X
Height:	3.25 in	Height:	8.26 cm	Initial Mass:	642.4 g	Assumed SG:	2.7
Diameter:	2.78 in	Diameter:	7.07 cm	Final Mass:	680.5 g	Liquid type:	Water
Volume:	19.80 in^3	Volume:	127.73 cm^3			Temperature (deg. C):	21.2



Hydraulic Conductivity k_{20}= 7.60E-06 cm/sec

Budinger & Associates, Inc.
Geotechnical & Environmental Engineers
Construction Materials Testing & Special Inspection

Moisture-Unit Weight Relationship



Test specification: ASTM D 1557-12 Method B Modified
ASTM D4718-15 Oversize Corr. Applied to Each Test Point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
			5.9	+3/8"= 2.525			24.4	

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 137.4 pcf	131.9 pcf	Silty sand with gravel +6% Bentonite by dry weight
Optimum moisture = 8.6 %	10.3 %	

Project No. L23156 **Client:** GeoEngineers
Project: Soil Cap Mix Design

○**Source of Sample:** On-site **Sample Number:** 23-0164

Remarks:
Sampled By Client
Sampled At TP-23 S-1 (0-0.5-1.5)

BUDINGER & ASSOCIATES, INC.

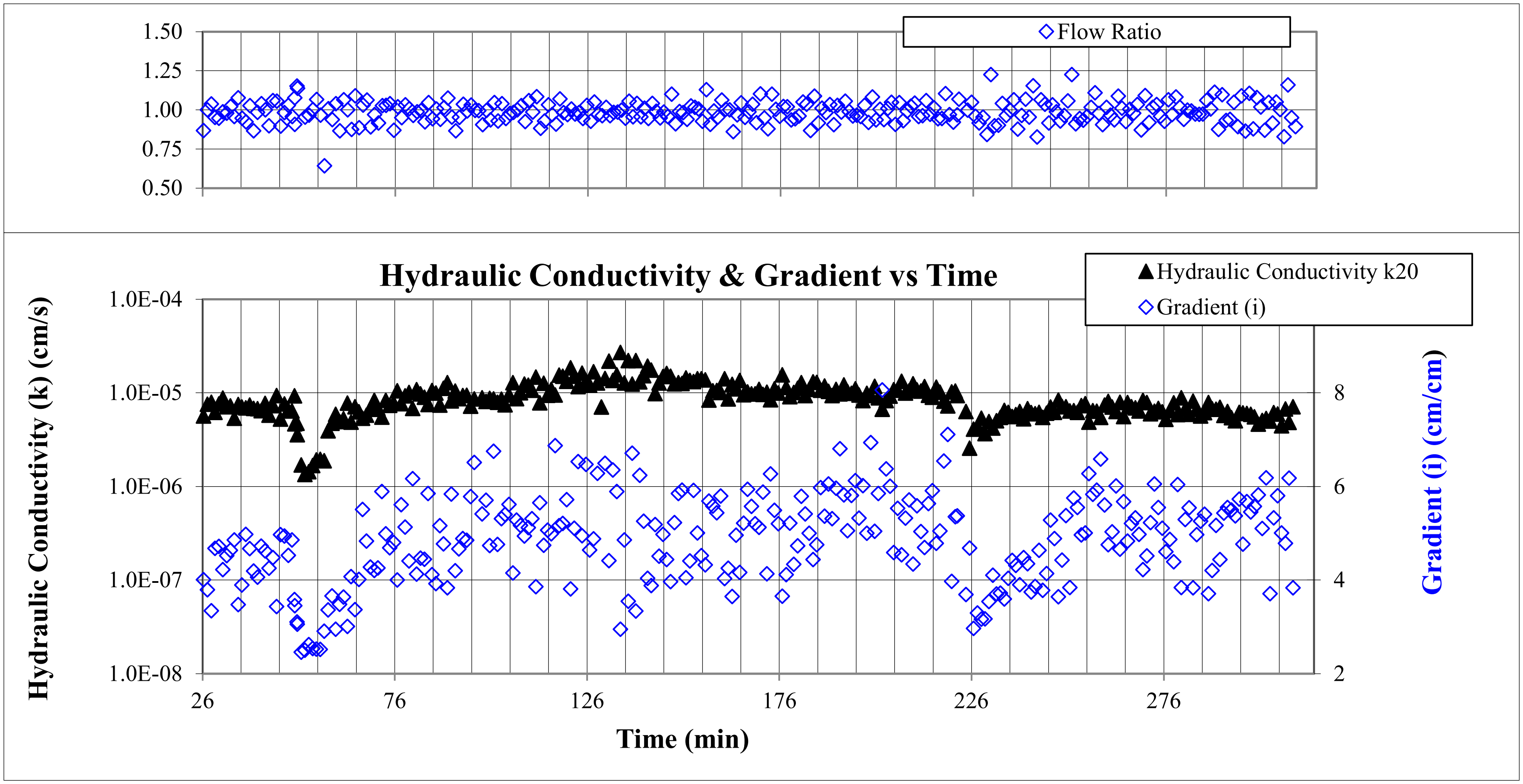
Date: 2/24/23

Tested By: TS **Checked By:** KC

Hydraulic Conductivity using a Flexible Wall Permeameter
ASTM D5084

Project Name:	Soil Cap Mix Design	Sample Description:	Silty sand with Gravel +9% Bentonite by dry weight
Project No.:	L23156	Initial/Final Dry Density (pcf):	118.7 / 114.1
Sample ID:	TP-23 S-1 +9% Bentonite	Initial/Final Moisture Content:	10.0% / 18.6%
Tested by:	WH	Date Tested:	4/3/2023
Sampled By:	Client	Initial/Final Saturation:	11% / 95%
Sample No.:	23-0164	Consolidation Stress (psi):	5

				Undisturbed:		Remolded:	X
Height:	3.05 in	Height:	7.74 cm	Initial Mass:	642.9 g	Assumed SG:	2.7
Diameter:	2.80 in	Diameter:	7.11 cm	Final Mass:	666.2 g	Liquid type:	Water
Volume:	18.76 in^3	Volume:	121.05 cm^3			Temperature (deg. C):	21.2



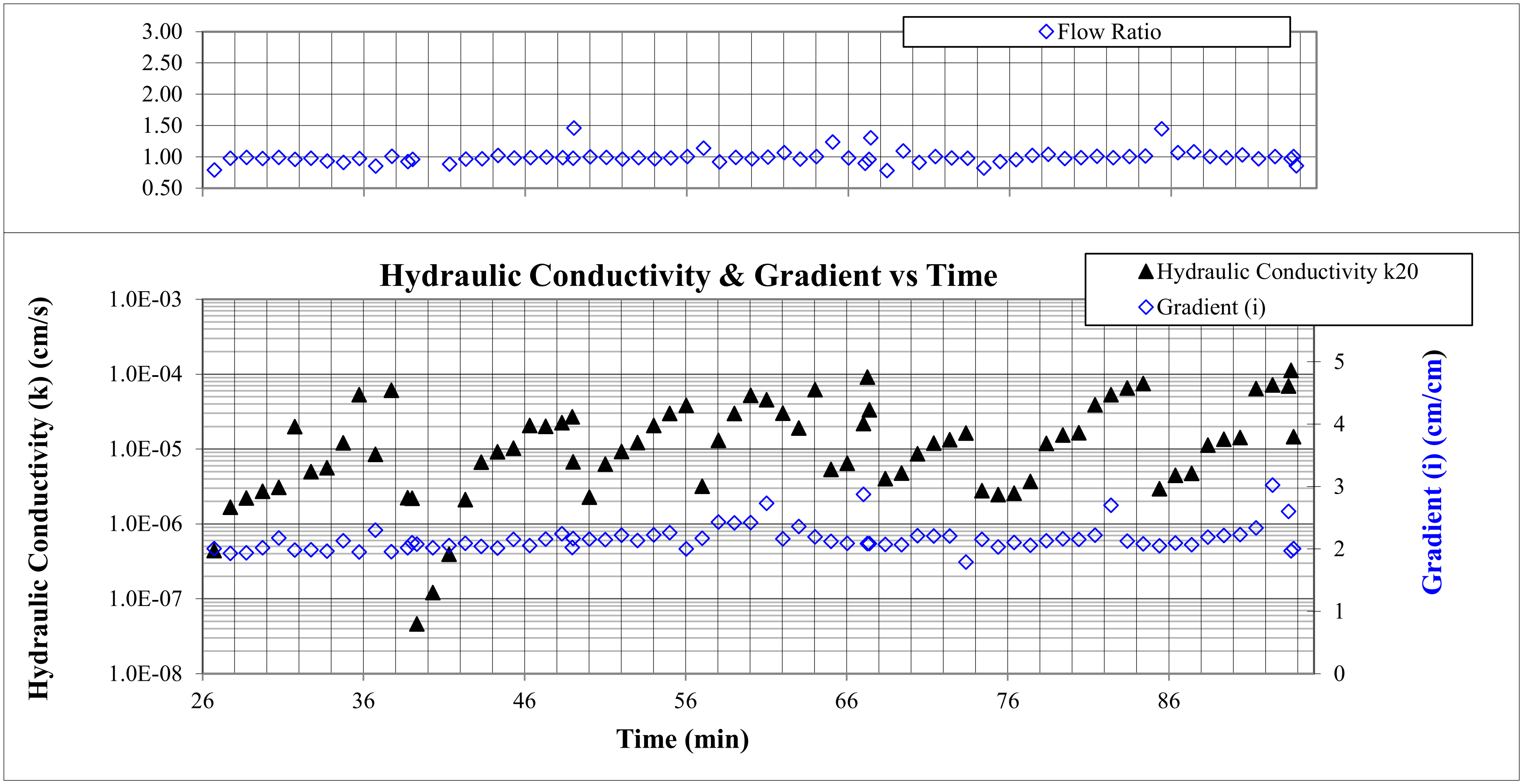
Hydraulic Conductivity k_{20}= 8.24E-06 cm/sec

Budinger & Associates, Inc.
Geotechnical & Environmental Engineers
Construction Materials Testing & Special Inspection

Hydraulic Conductivity using a Flexible Wall Permeameter
ASTM D5084

Project Name:	Soil Cap Mix Design	Sample Description:	Silty sand with Gravel +6% Bentonite by dry weight
Project No.:	L23156	Initial/Final Dry Density (pcf):	118.9 / 118.3
Sample ID:	TP-23 S-1 +6% Bentonite	Initial/Final Moisture Content:	10.0% / 16.1%
Tested by:	WH	Date Tested:	3/9/2023
Sampled By:	Client	Initial/Final Saturation:	17% / 95%
Sample No.:	23-0164	Consolidation Stress (psi):	5

				Undisturbed:		Remolded:	X
Height:	3.23 in	Height:	8.20 cm	Initial Mass:	684.9 g	Assumed SG:	2.7
Diameter:	2.80 in	Diameter:	7.12 cm	Final Mass:	718.6 g	Liquid type:	Water
Volume:	19.93 in^3	Volume:	128.61 cm^3			Temperature (deg. C):	21.2



Hydraulic Conductivity k_{20}= 1.62E-05 cm/sec

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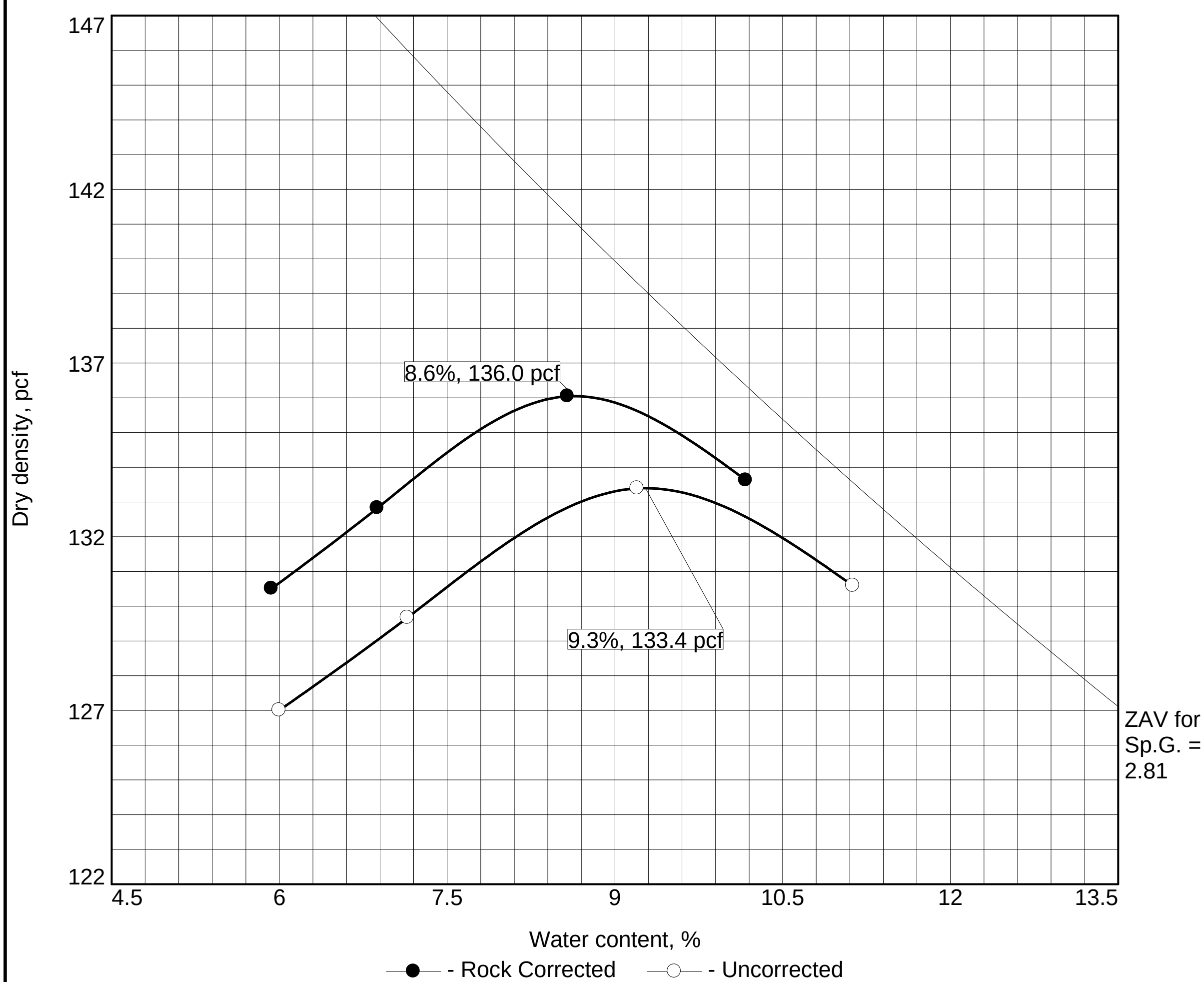
Geotechnical & Environmental Engineers
Construction Materials Testing & Special Inspection

Moisture-Unit Weight Relationship



Test specification: ASTM D 1557-12 Method B Modified
ASTM D4718-15 Oversize Corr. Applied to Each Test Point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
			4.5	+3/8"= 2.408			17.3	

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 136.0 pcf	133.4 pcf	Silty sand with gravel +6% Bentonite by dry weight
Optimum moisture = 8.6 %	9.3 %	

Project No. L23156 **Client:** GeoEngineers
Project: Soil Cap Mix Design

○**Source of Sample:** On-site **Sample Number:** 23-0165

Remarks:
Sampled By Client
Sampled At TP-27-S1 (0-0.5-1.0)

BUDINGER & ASSOCIATES, INC.

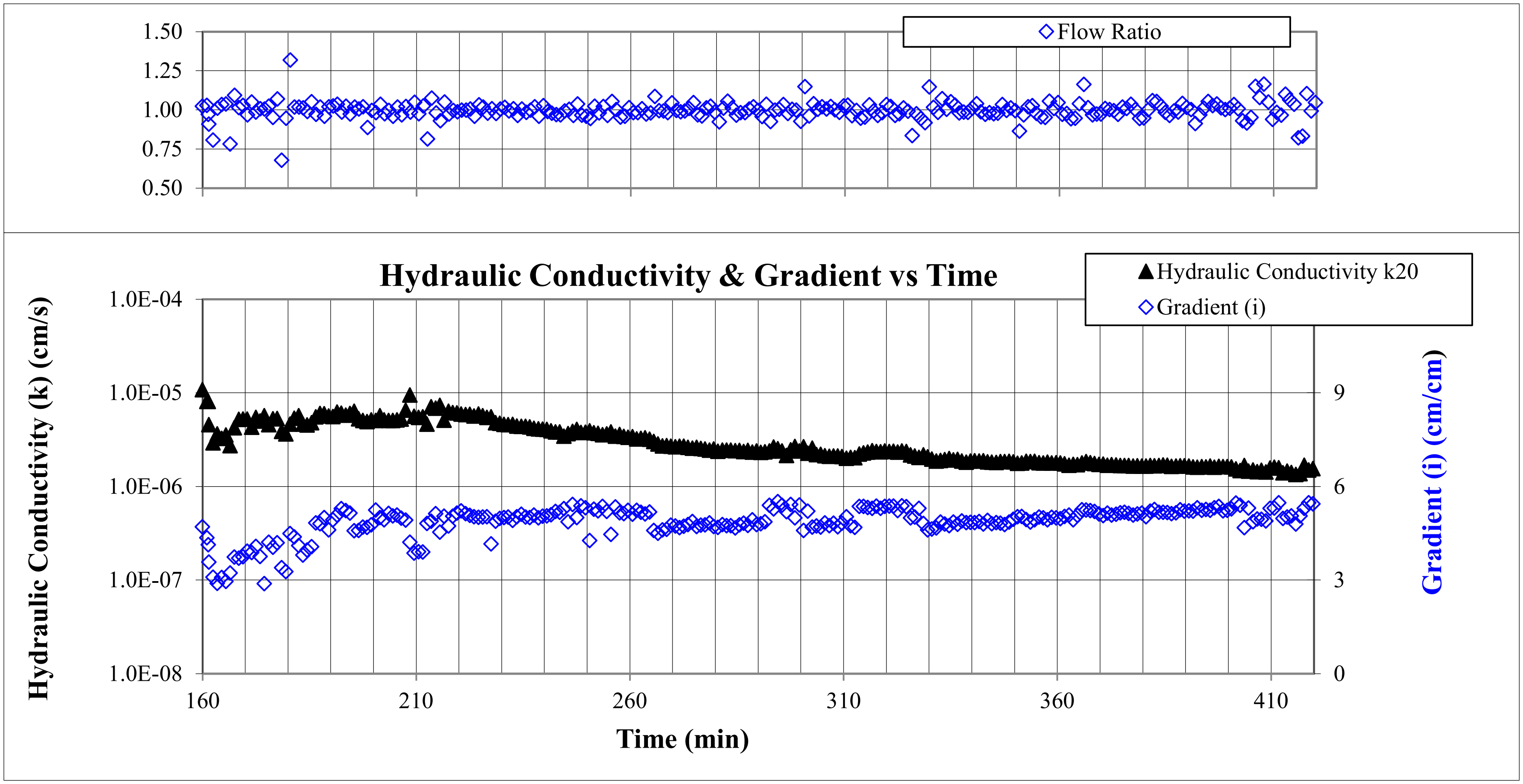
Date: 2/27/23

Tested By: TS **Checked By:** KC

Hydraulic Conductivity using a Flexible Wall Permeameter
ASTM D5084

Project Name:	Soil Cap Mix Design	Sample Description:	Silty Sand with Gravel +6% Bentonite by dry weight
Project No.:	L23156	Initial/Final Dry Density (pcf):	120.7 / 109.1
Sample ID:	TP-27 S-1 +6% Bentonite	Initial/Final Moisture Content:	8.6% / 16.9%
Tested by:	WH	Date Tested:	3/13/2023
Sampled By:	Client	Initial/Final Saturation:	16% / 92%
Sample No.:	23-0165	Consolidation Stress (psi):	5

				Undisturbed:		Remolded:	X
Height:	3.16 in	Height:	8.02 cm	Initial Mass:	672.1 g	Assumed SG:	2.7
Diameter:	2.81 in	Diameter:	7.13 cm	Final Mass:	653.8 g	Liquid type:	Water
Volume:	19.53 in^3	Volume:	125.99 cm^3			Temperature (deg. C):	21.2



Hydraulic Conductivity k_{20}= 3.02E-06 cm/sec

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Construction Materials Testing & Special Inspection

APPENDIX D

High-Level Engineer’s Opinion of Probable Construction Costs for Cover Systems

Marshall Landfill. Summary of Cover and Disposal Options.

Escalation Factor	
A7S5 to Dec 2022	1.17671
PALF to Dec 2022	1.48774
RI/FS to Dec 2022	1.3205

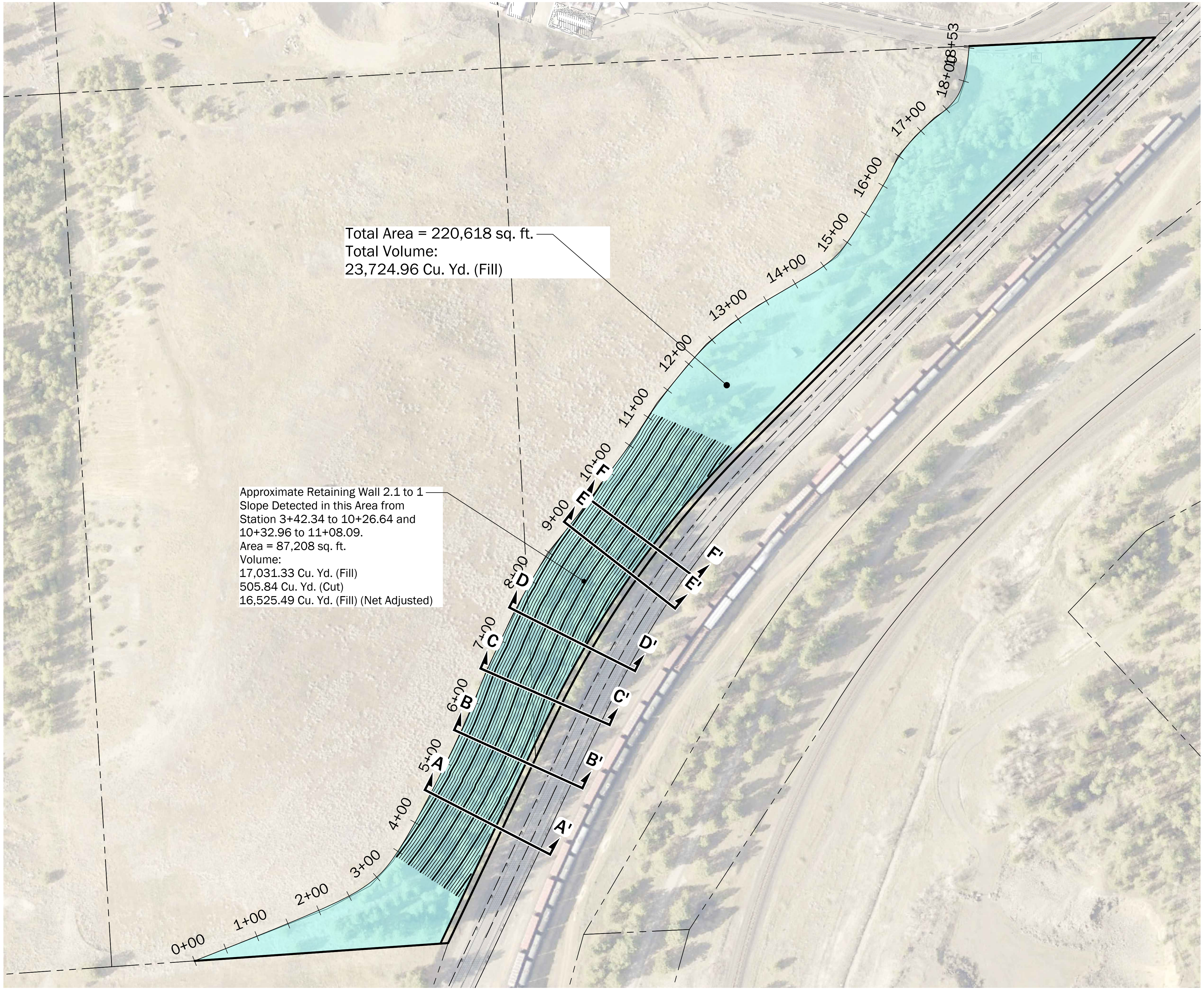
Cost for Prescriptive Cover	Unit	Unit Cost	Cost Per 1 Square Yard	Notes
Hydroseed	SY	$ 1.15	$ 1.15	Avg of A7S5 Bids adjusted to Dec 2022 dollars
6-IN Topsoil	SY	$ 10.00	$ 10.00	Engineer's Estimate (Avg of A7S5 Bids adjusted to Dec 2022 dollars is $6, previous years cost was over $10/SY)
2-FT Borrow Soil (1x10-5 cm/sec)	CY	$ 15.30	$ 10.20	Avg of A7S5 Bids for Screened Embankment adjusted to Dec 2022 dollars
Pug Mill Processing	CY	$ 20.00	$ 13.33	Engineer's Estimate for material hauling to/from pug mill, processing, and hauling to hill.
Bentonite Material	TON	$ 104.14	$ 5.25	PALF - 3% bentonite at $70/ton (WYO-BEN quote), .756 tons/CY. Rounded up for Dec 2022, 10% from testing 2023-04-20
Bentonite Transport	TR	$ 1,833.33	$ 1.97	PALF - $2150/23.5 ton on truck. WYO-Ben Quote. Assume .756 tons/CY
Geonet	SY	$ 20.65	$ 20.65	Avg A7S2 Bids adjusted to Dec 2022 dollars
Geotextile	SY	$ 11.12	$ 11.12	Avg of A7S5 Bids Geotextile Type 2 adjusted to Dec 2022 dollars. Note double layered per RIFS cover.
LLDPE/HDPE Geomembrane	SY	$ 13.50	$ 13.50	Cost of material ($.50/SF) plus cost to install (250X cost of material per vendor)
6" Bedding Sand	SY	$ 15.30	$ 15.30	Avg of A7S5 Bids adjusted to Dec 2022 dollars
			$ 102.46	**COST PER 1 SY COVER SYSTEM**
Cost for Soil Cover				
Hydroseed	SY	$ 1.15	$ 1.15	Avg of A7S5 Bids adjusted to Dec 2022 dollars
6-IN Topsoil	SY	$ 10.00	$ 10.00	Engineer's Estimate (Avg of A7S5 Bids adjusted to Dec 2022 dollars is $6, previous years cost was over $10/SY)
2-FT Borrow Soil (1x10-6 cm/sec)	CY	$ 15.30	$ 10.20	Avg of A7S5 Bids for Screened Embankment adjusted to Dec 2022 dollars
Pug Mill Processing	CY	$ 20.00	$ 13.33	Engineer's Estimate for material hauling to/from pug mill, processing, and hauling to hill.
Bentonite Material	TON	$ 104.14	$ 5.25	PALF - 3% bentonite at $70/ton (WYO-BEN quote), .756 tons/CY. Rounded up for Dec 2022, 10% from testing 2023-04-20
Bentonite Transport	TR	$ 1,833.33	$ 1.97	PALF - $2150/23.5 ton on truck. WYO-Ben Quote. Assume .756 tons/CY
			$ 41.89	**COST PER 1 SY COVER SYSTEM**
Cost for Geo-Structural Wall				
Hydroseed	SY	$ 1.15	$ 1.15	Avg of A7S5 Bids adjusted to Dec 2022 dollars
6-IN Topsoil	SY	$ 15.00	$ 10.00	Engineer's estimate to work soil into Geoweb
6-IN Geoweb	SY	$ 62.50	$ 62.50	Approx. cost from quote for north slope provided in March 2023 ($81,100/30,000 SF for materials + 250% for install)
2-FT Borrow Soil	CY	$ 15.30	$ 10.20	Avg of A7S5 Bids adjusted to Dec 2022 dollars
Pug Mill Processing	CY	$ 20.00	$ 13.33	Engineer's Estimate for material hauling to/from pug mill, processing, and hauling to hill.
Bentonite Material	TON	$ 104.14	$ 5.25	PALF - 3% bentonite at $70/ton (WYO-BEN quote), .756 tons/CY. Rounded up for Dec 2022, 10% from testing 2023-04-20
Bentonite Transport	TR	$ 1,833.33	$ 1.97	PALF - $2150/23.5 ton on truck. WYO-Ben Quote. Assume .756 tons/CY
Composite Drainage Net	SY	$ 21.00	$ 21.00	Avg A7S2 Bids adjusted to Dec 2022.
LLDPE/HDPE Geomembrane	SY	$ 13.50	$ 13.50	Cost of material ($.50/SF) plus cost to install (250X cost of material per vendor)
			$ 138.89	**COST PER 1 SY COVER SYSTEM**

Cost for MSE Wall - 2.1:1 Slope	UNITS	QTY	UNIT COST	SUBTOTAL	
Retaining Wall Area	SF	6500	$ 102.00	$ 663,000.00	Approx area of wall; Avg price from 2020 to 2023 from ITD database for MSE walls
6-IN Topsoil	SY	9700	$ 10.00	$ 97,000.00	Approx area of slope
2-FT Borrow Soil (1x10-6 cm/sec)	CY	6467	$ 15.30	$ 98,922.37	Avg of A7S5 Bids for Screened Embankment adjusted to Dec 2022 dollars
Pug Mill Processing	CY	6467	$ 20.00	$ 129,333.33	Engineer's Estimate for material hauling to/from pug mill, processing, and hauling to hill.
Bentonite Material	TN	841	$ 104.14	$ 87,548.52	Assumed 1.3 TN/CY for sand. Based on lab analysis, 10% per weight. Assume .756 TN/CY for bentonite
Bentonite Transport	TR	36	$ 1,833.33	$ 65,583.92	Assume 23.5 tons per truck
Hydroseed	AC	2	$ 5,548.20	$ 11,119.33	Avg of A7S5 Bids adjusted to Dec 2022 dollars
			TOTAL:	$ 1,152,507.47	

Cost for Max Ex Buttress	UNIT	QTY	UNIT COST	SUBTOTAL	
Remove and Transport Soils and Refuse	CY	15546	$ 20.00	$ 310,925.93	
6-IN Topsoil	SY	9700	$ 10.00	$ 97,000.00	Approx area of slope
2-FT Borrow Soil (1x10-6 cm/sec)	CY	10694	$ 15.30	$ 163,595.84	Avg of A7S5 Bids for Screened Embankment adjusted to Dec 2022 dollars
Pug Mill Processing	CY	10694	$ 20.00	$ 213,888.89	Engineer's Estimate for material hauling to/from pug mill, processing, and hauling to hill.
Bentonite Material	TON	1390	$ 104.14	$ 144,785.99	Assumed 1.3 TN/CY for sand. Based on lab analysis, 10% per weight. Assume .756 TN/CY for bentonite
Bentonite Transport	TR	59	$ 1,833.33	$ 108,461.39	Assume 23.5 tons per truck
Hydroseed	AC	2	$ 5,548.20	$ 11,119.33	Avg of A7S5 Bids adjusted to Dec 2022 dollars
			TOTAL	$ 3,354,792.31	

APPENDIX E

Buttress Retaining Wall



Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Background surveyed by Coffman Engineers, Inc., dated 05/06/2022. Aerial photo provided by ESRI I3 Imagery Aerial.

Vertical Datum: NAVD 88.

Projection: NAD83 Washington State Planes, North Zone, US Foot.

N
W E
S

150 0 150
Feet

Site Plan

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure X1

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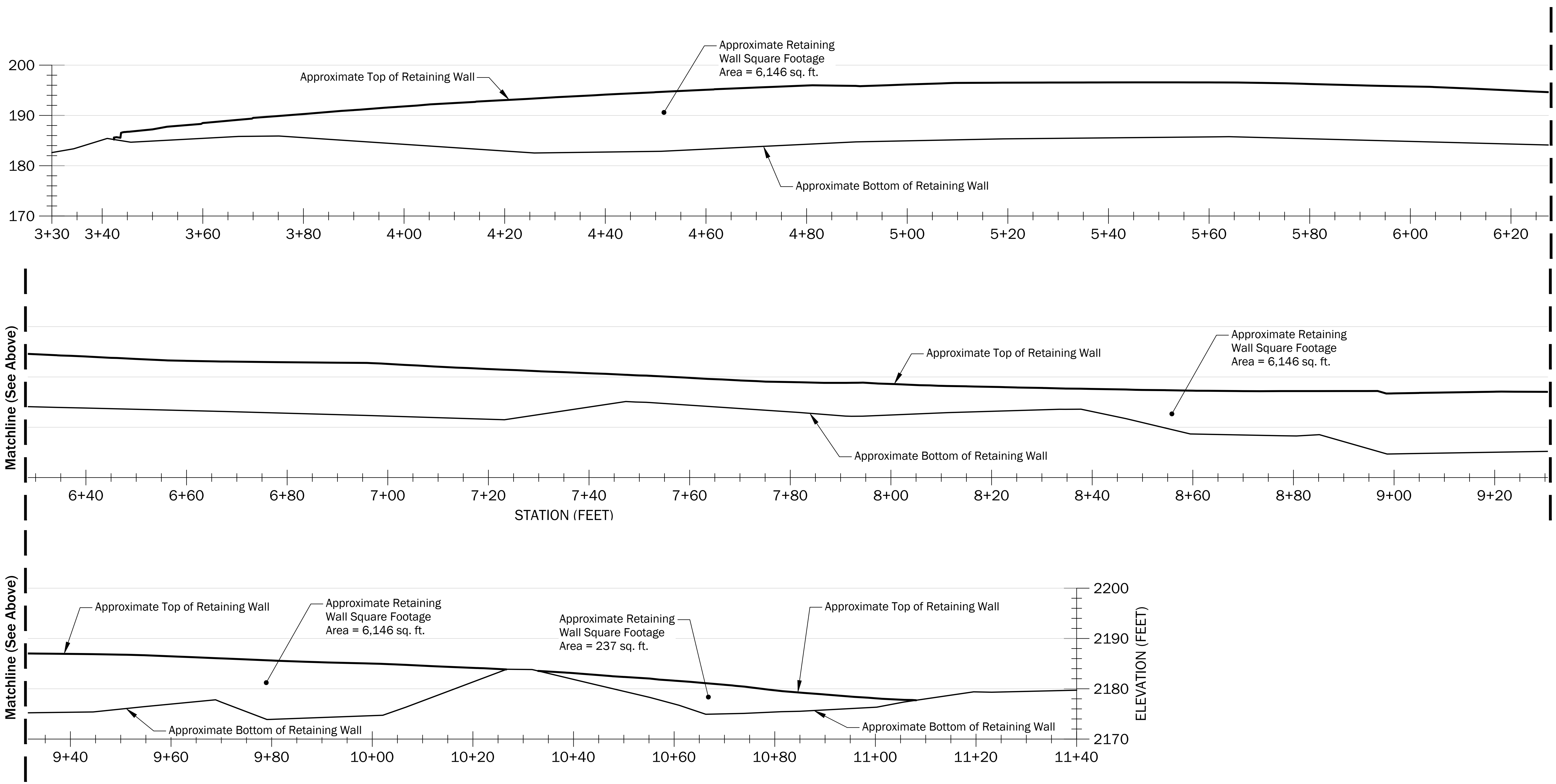

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Profile Retaining Wall

Marshall Landfill
Spokane County, Washington

GEOENGINEERS

Figure X2

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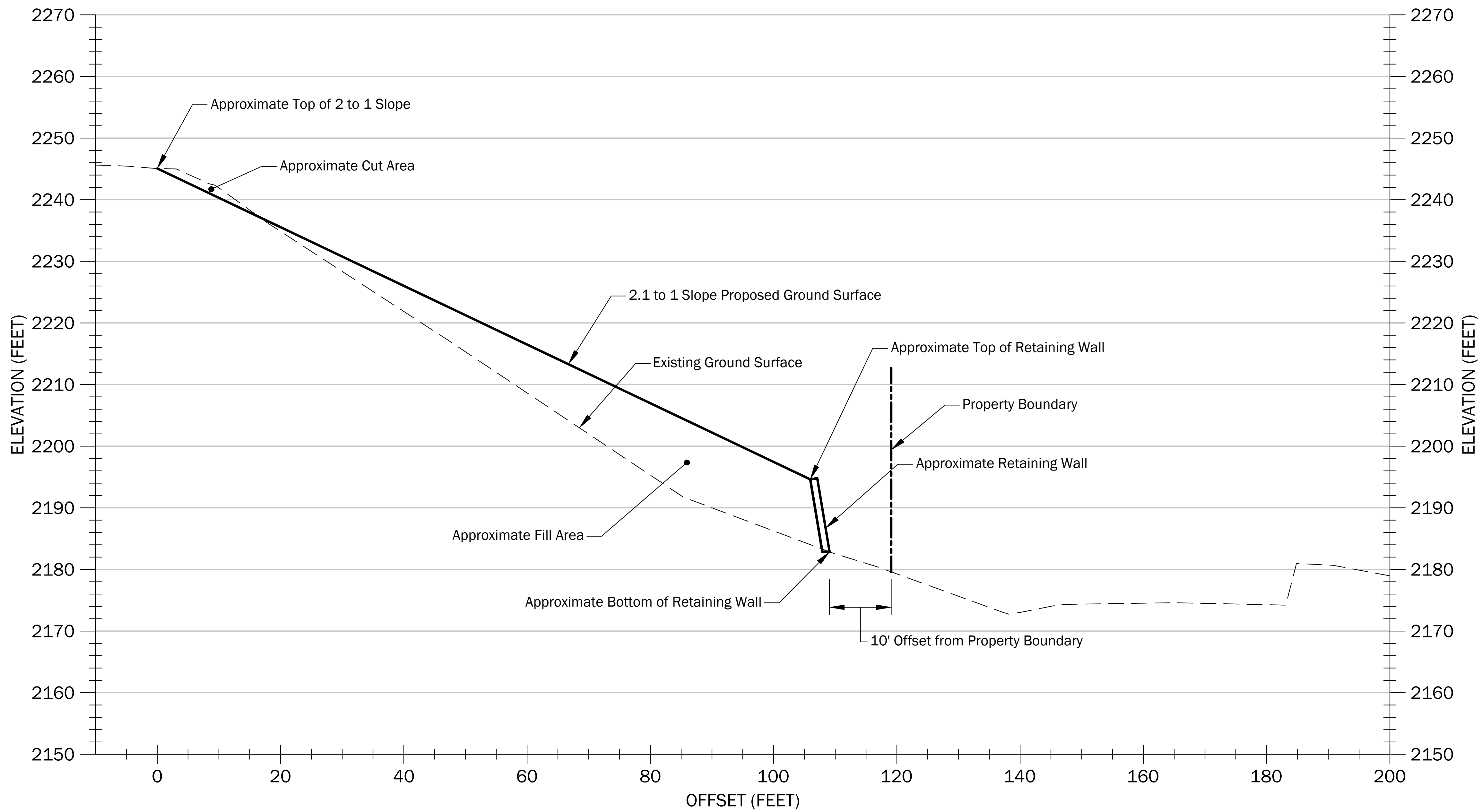

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
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Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section A-A' at Station 4+50

Marshall Landfill
Spokane County, Washington

GeoEngineers

Figure X3

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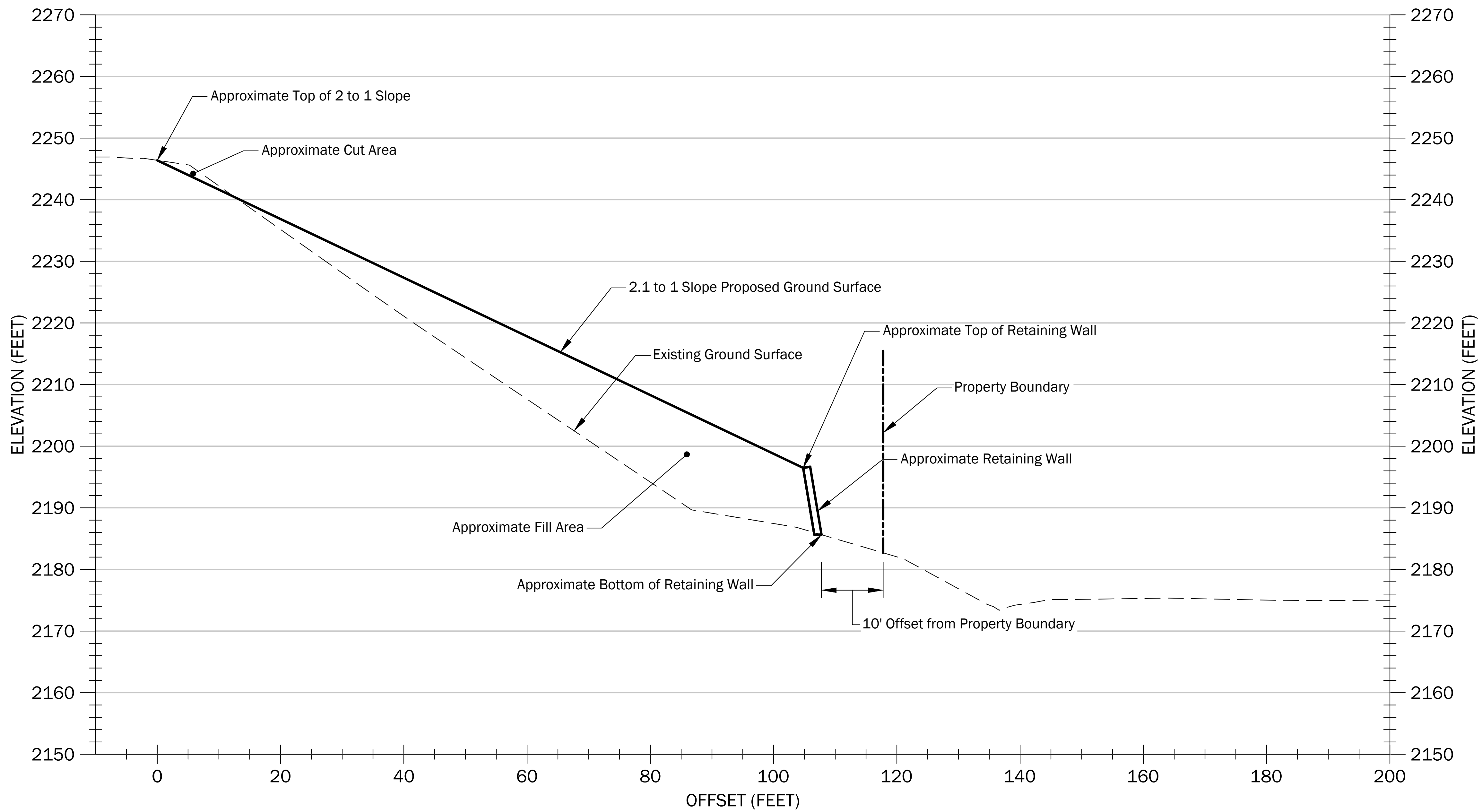

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Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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3. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section B-B' at Station 5+50

Marshall Landfill
Spokane County, Washington

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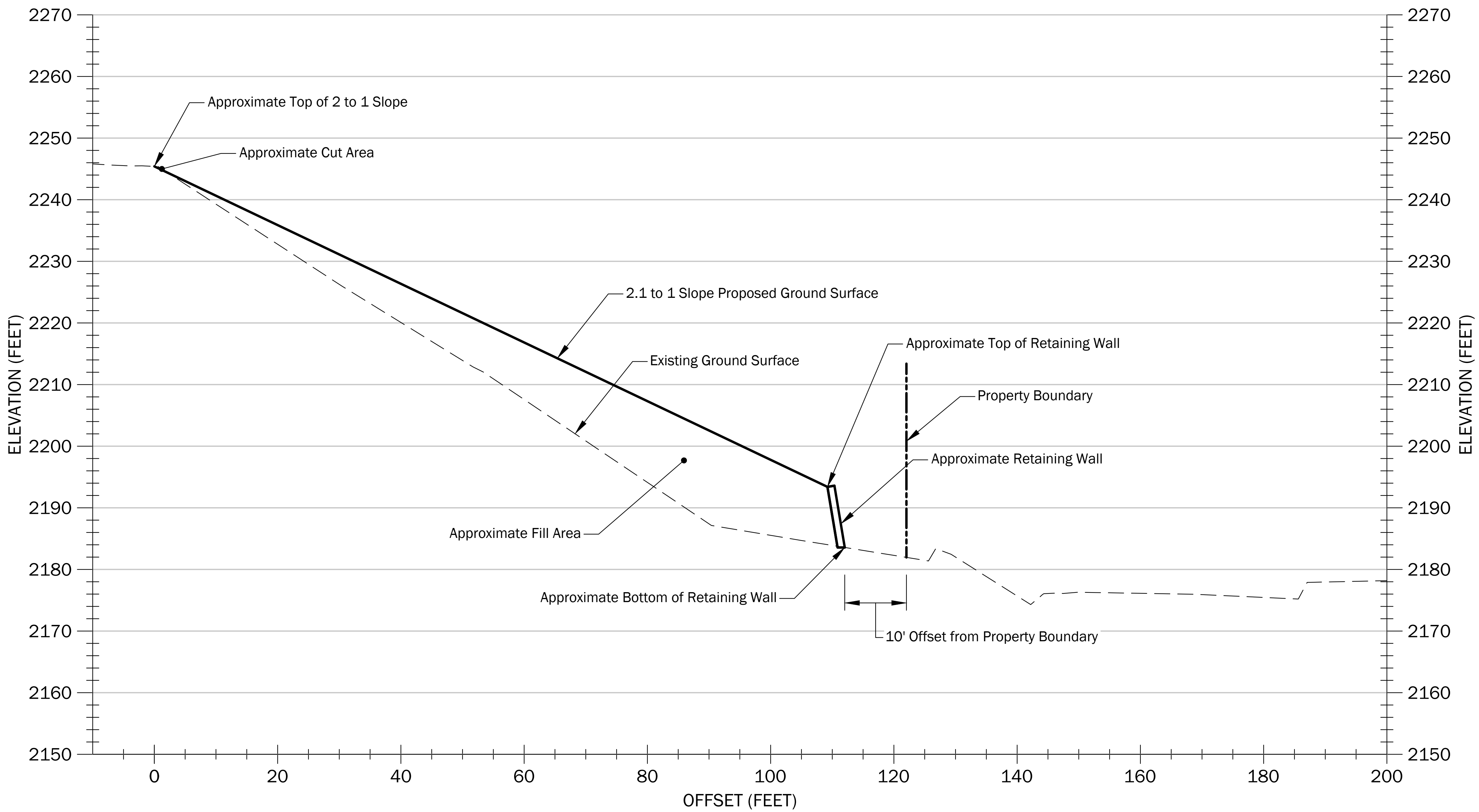
Figure X4



Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section C-C' at Station 6+50

Marshall Landfill
Spokane County, Washington

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Figure X5

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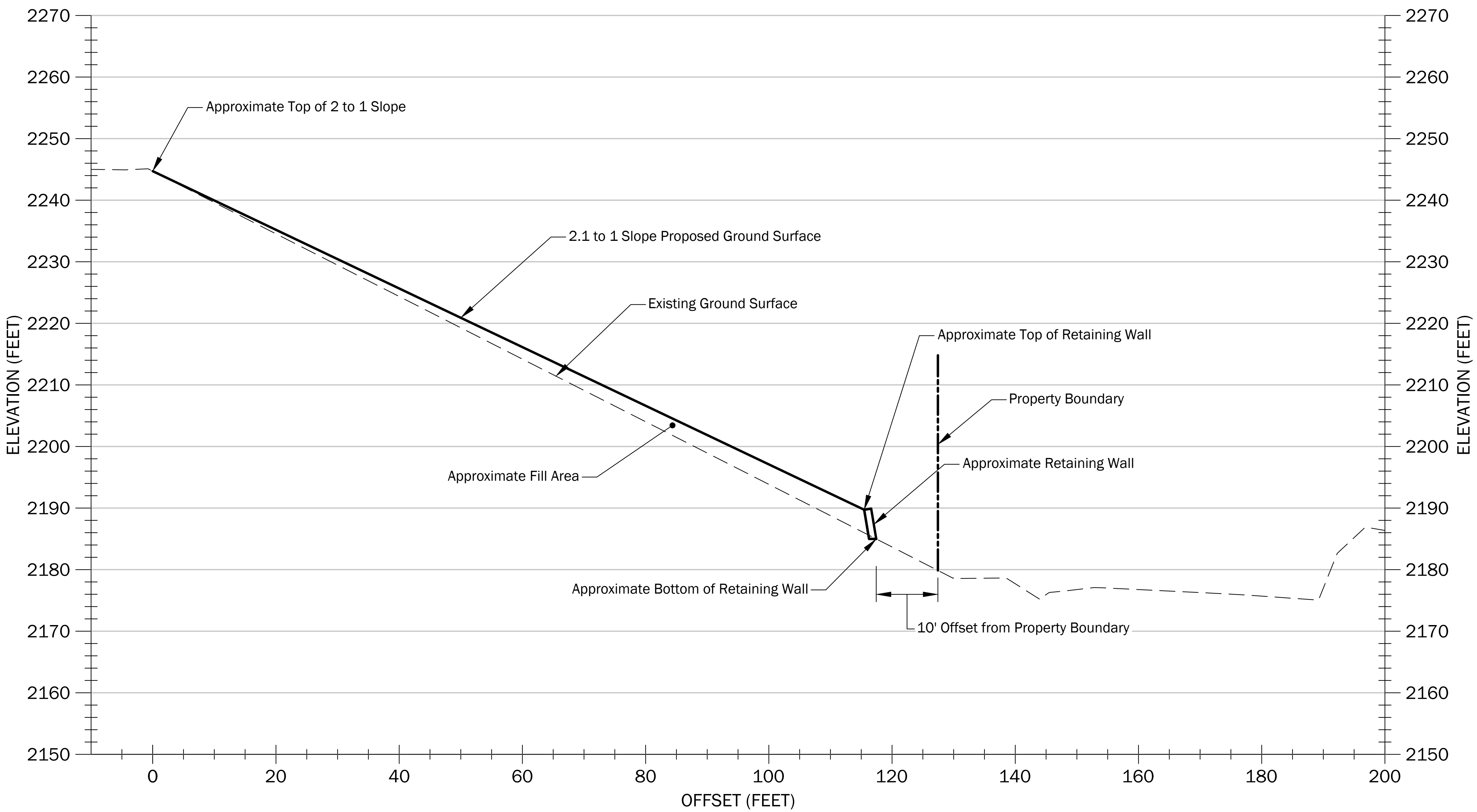

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section D-D' at Station 7+50

Marshall Landfill
Spokane County, Washington

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Figure X6

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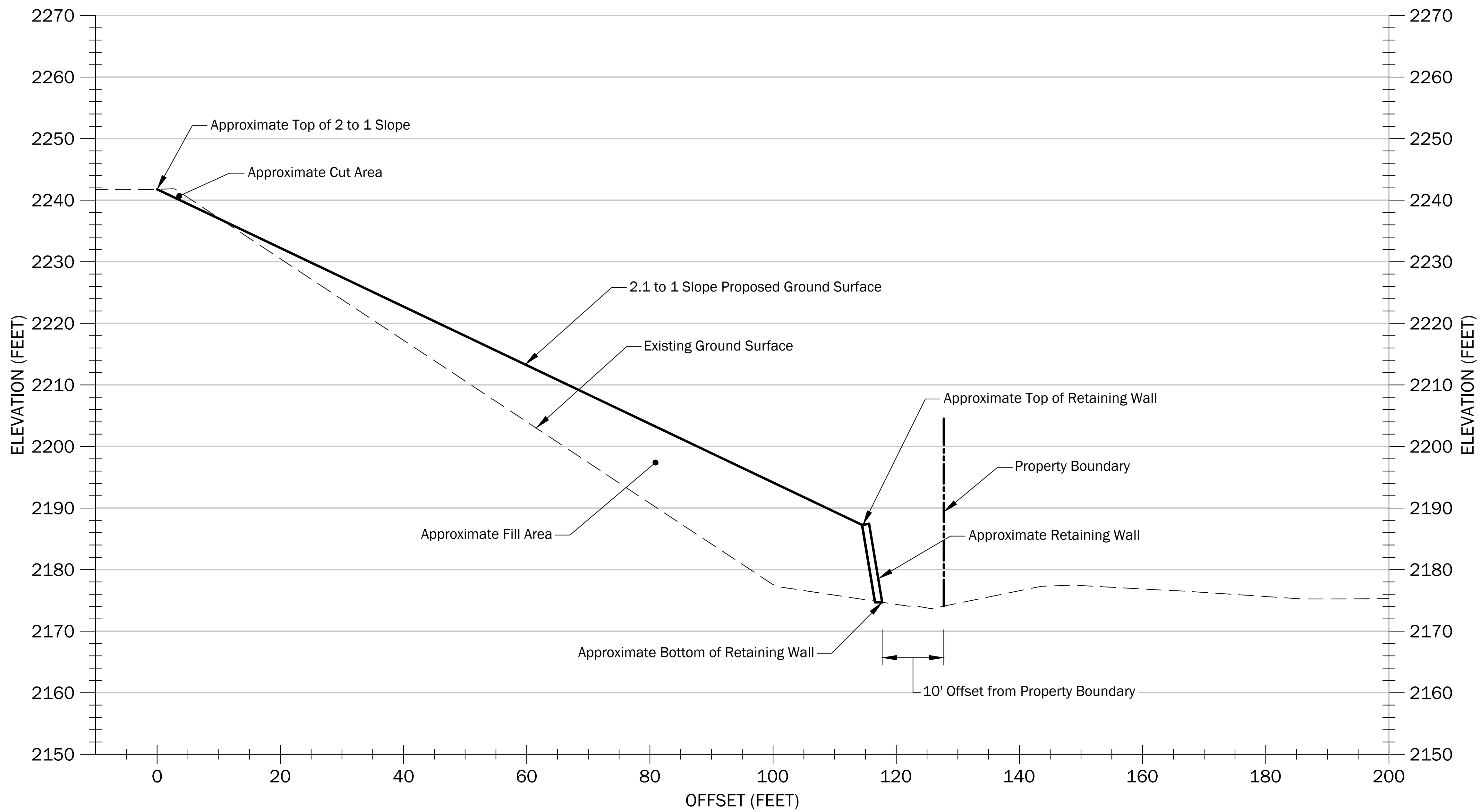

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Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
3. The ground surface elevation profile shown in this cross section was adapted from surveyed by Coffman Engineers, Inc., dated 05/06/2022.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section E-E' at Station 9+00

Marshall Landfill
Spokane County, Washington

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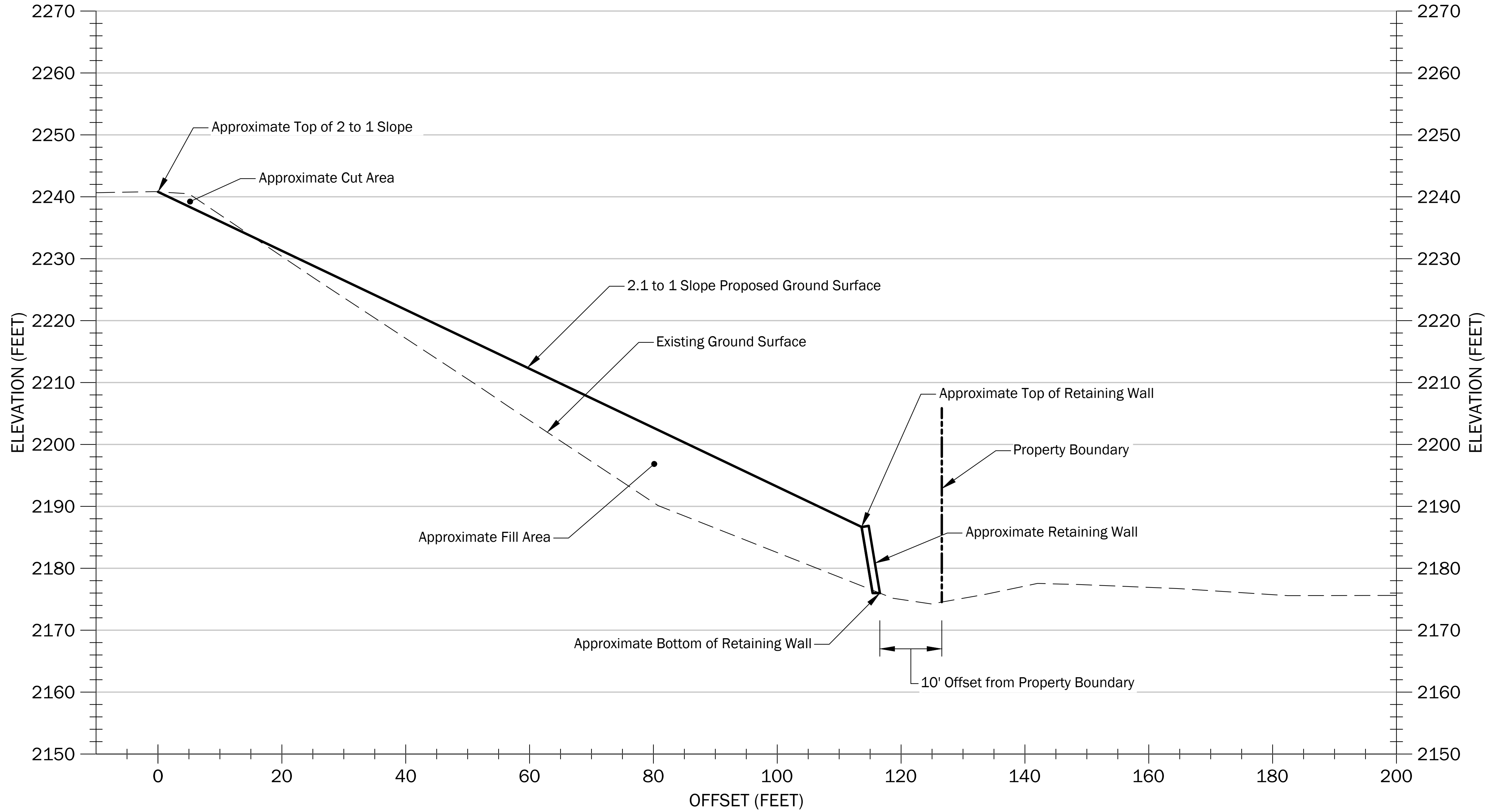
Figure X7



Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.
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Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section F-F' at Station 9+50

Marshall Landfill
Spokane County, Washington

GEOENGINEERS

Figure X8

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