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PolyMet
Technical Design Evaluation Report
RS55T

Tailings Basin Modifications to Eliminate Water Release via Seepage

Table of Contents

Table of Contents (continued)

List of Tables

List of Figures

Appendices

Executive Summary

Seepage emanates from the toe of slope and several locations further upslope on the exterior dam face of the proposed PolyMet Mining Inc. (PolyMet) tailings basin (formerly the LTVSMC tailings basin; ref. Figure 1). While this seepage on occasion exceeds facility National Pollutant Discharge Elimination System (NPDES) water discharge limits for some parameters (bicarbonates, hardness, conductivity, and iron), allowing this seepage to exit the exterior dam face rather than blocking it improves the overall slope stability of the tailings basin dams. This report presents the evaluation of potential seepage management modifications that can be made to eliminate the seepage while maintaining overall slope stability, and recommends an overall seepage management strategy for implementation. The recommendations were developed by evaluating various approaches to preventing seepage from leaving the basin, by intercepting seepage within the tailings basin and recovering seepage that has left the tailings basin, and developing from the most effective of these a seepage management strategy . The report has been prepared in accordance with the scope requirements for Tailings Basin Modifications Technical Design Evaluation Report (TDER) RS55T.

The recommended seepage management strategy includes the following actions that will be taken upon initiation of tailings basin operation:

- New horizontal drains will be installed in tailings basin embankments to intercept seepage in areas where seeps have previously been observed and monitored. Drains will generally be located near the toe of the embankment, or between the toe and the first bench. Seepage water quality will be monitored and collected seepage will be re-circulated to the tailings basin.
- A seepage barrier and collection system consisting of an earth and clay barrier will be established south of Cell 1E to recover known seepage in this area. Seepage water quality will be monitored and collected seepage will be re-circulated to the tailings basin.

This seepage management strategy is presented in Figure 2. This strategy builds on existing seepage management approaches at the basin using methods that are more passive in nature, flexible in how they can be implemented, and cost effective in addressing impacts to adjacent surface waters and wetlands. The strategy can be expanded if needed, based on future inspection and observation, to include more horizontal drains (closer spacing or implementation in additional seepage areas) or seepage barrier and collection systems if necessary.

This seepage management strategy can be expected to be highly effective because:

- Water will be captured from existing embankment seepage interception systems.
- Water will be captured from existing uncontrolled embankment seeps using additional horizontal drains.
- Water will be captured from existing seeps south of tailings basin Cell 1E.

- Captured water will be routed to collection points in enclosed systems and pumped back to the basin for reuse as process water.
- Scheduled observations will evaluate effectiveness on an on-going basis, and the strategy will be augmented to capture any additional seepage observed.

In aggregate, the seepage management strategy will effectively eliminate the occurrence and outflow of seeps from the tailings basin embankments. This is flow that would otherwise discharge directly to wetlands and standing waters directly adjacent to the basin.

1.0 Introduction

PolyMet Mining Inc. (PolyMet) plans to use the existing Cliffs Erie LLC (CE) (formerly LTV Steel Mining Company (LTVSMC)) tailings basins for disposal of tailings that will be generated from the proposed processing of low-grade polymetallic disseminated magmatic sulfide NorthMet deposit ore. The anticipated quantity of tailings produced by period is summarized in the Tailings Basin Geotechnical and Design report (RS39/40T). The existing tailings basin was operated by LTVSMC for taconite tailings deposition from 1957 to January 2001. PolyMet took ownership of the tailings basin in November 2005. The general layout of the tailings basin in its current configuration is shown in Figure 1.

For the purposes of this report, the term “seepage” refers to water that has contacted tailings and has infiltrated into the subsurface. A portion of this seepage emerges as surface flow on the downstream face of the tailings basin embankments, at or near the embankment toe. In the remainder of this report the term “seep” refers to surface flow emerging at a specific location on the downstream face of the tailings basin embankment, whereas the term “seepage” is used in general reference to those flows to aid readability and in reference to an accumulation of a number of individual seeps. However, this report focuses primarily on the surface flows or “seeps” and preventing seepage from flowing into the wetlands adjacent the tailings basin.

Because of water discharge limit exceedences at existing tailing basin seeps, it will be necessary to collect seepage from historical tailings basin operations and return it to the tailings basin.

As described in the Scope of Work for RS55T (see Appendix A), the evaluation of tailings basin modifications to eliminate seepage release to surface waters is divided in two phases:

- Phase 1 of the evaluation, presented in Section 5, describes concepts for eliminating seepage, including seepage interception approaches, seepage recovery approaches, and a summary of seepage prevention (or liner) approaches. Evaluation of seepage prevention approaches is developed in detail in the report on Hydrometallurgical Residue and PolyMet Flotation Tailings Cell Design and Location (RS28T). A summary of the Phase 1 evaluation outcomes is presented in Table 1.

- Phase 2 of the evaluation, presented in Section 6, describes a seepage management strategy for eliminating surface water release from the tailings basin, developed from the most effective approaches identified in Phase 1 of the evaluation.

The proposed strategy for eliminating seepage at the tailings basin includes supplementing existing drains and seepage collection systems with additional horizontal drains and seepage collection systems in the tailings basin embankments and with placement of a barrier and collection system at the south end of Cell 1E to recover seepage in that area. This strategy builds on existing approaches in place at the basin using approaches that are generally more passive in nature and flexible in how they can be implemented, and cost effective in reducing impacts to adjacent surface waters or wetlands. The proposed seepage management strategy is presented in Figure 2. Details of the strategy and options considered are presented in subsequent sections of this report.

This Technical Design Evaluation Report (TDER) RS55T is not reliant on but does reference other reports. While it is not necessary to review or have reviewed the referenced reports to understand the concepts and plans presented herein, it may be helpful to some readers to have the following documents available in the event that review of RS55T raises detailed questions not addressed within RS55T:

- RS13 – Process Design – Tailings Basin Water Balance
- RS28T – Hydrometallurgical-Residue and Flotation-Tailings Cell Design and Location
- RS39/40T – Process Design – Tailings Basin Design and Geotechnical
- RS46 – Wastewater Modeling – Tailings
- RS64 – Existing Tailings Basin Water Quality Information

2.0 Statement of Goals and Objectives

The goal of the evaluation described herein is to identify an effective strategy for eliminating seepage at the tailings basin to minimize potential adverse environmental effects caused by historical and future seepage leaving the basin. This goal has been accomplished by evaluating various approaches to preventing, intercepting, and recovering seepage, and developing an overall seepage management strategy by combining the most effective approaches to address site-specific conditions.

This report was prepared as a Technical Design Evaluation Report in support of the Environmental Impact Statement effort for the NorthMet Mine and Ore Processing Facilities project. The report contains the essential components described in the Final Scoping Decision for the project for RS55T (see Appendix A). The following aspects of the Scope of Work should be noted:

- Seepage prevention approaches are evaluated and developed in greater detail in Hydrometallurgical Residue and PolyMet Flotation Tailings Cell Design and Location (RS28T). This evaluation is referenced and summarized in this report, but is not repeated in detail.
- The Scope of Work does not include evaluation and screening of alternatives in Phase 1 of the evaluation. However, preliminary screening was determined to be appropriate at this phase; narrowing the approaches before more detailed strategy development in Phase 2.
- Phase 2 of the report focuses on specific seepage prevention, interception, and recovery measures for implementation. The Scope of Work indicates that Phase 2 will evaluate effectiveness, implementability, and cost. These evaluations are now included in Phase 1. Phase 2 includes the development of combinations of Phase 1 options and presents greater detail on the planned seepage management strategy.
- The Scope of Work indicates that “Wherever possible, quantitative measures (i.e., gals/minute or mgd for seepage) of effectiveness will be provided.” This level of detail is generally not included at this time, but will be developed as part of detailed design. The recommended seepage management strategy is designed to effectively eliminate seepage from the tailings basin for beneficial recovery/reuse as flotation process water. Thus, implementation of this strategy will eliminate direct discharge of seepage to adjacent surface waters.

3.0 Description of Existing Tailings Basin

The existing tailings basin (shown in Figures 1 and 2) is an unlined basin constructed in stages beginning in 1953. The tailings basin is configured as a combination of three adjacent cells, identified as Cell 1E, Cell 2E, and Cell 2W. Figures 3, 4, and 5 show representative cross sections through the perimeter embankments of the basin. During previous operation there was standing water in all three of the tailings basin cells (2W, 1E, and 2E) (Barr Engineering 2000b). Water from precipitation and from basin operation infiltrated through the tailings materials and left the basin as seepage. The basins have been idle since January 2001 and water levels in the basins have declined since then.

3.1 Project Setting

Native unconsolidated surficial deposits in the area of the tailings basin generally consist of dense silty sand and clay Rainy lobe till (Jennings and Reynolds, 2005). In places, the till is overlain by up to 10 feet of organic peat. Cobbles and boulders have been noted in this till at other nearby project sites. No soil boring information is available to definitively determine the vertical extent of the till, the depth to bedrock in the basin area, nor the on-site presence of cobbles and boulders. The Minnesota Geological Survey has developed a regional Depth to Bedrock Map that indicates depth to bedrock in the tailings basin area is generally between 0 and 50 feet, with bedrock located at the surface in some locations (Jirsa et. al, 2005). Up to 20 feet of till has been observed in basin borings (see RS39/40T). Based on available information, the till at the site is likely less than 50 feet thick.

Regionally, groundwater is believed to flow from the upland areas in the south and bordering the basin, to the Embarrass River in the north (Siegel and Ericson, 1980). Groundwater is typically found under unconfined conditions. The amount and nature of the interactions between the unconsolidated surficial deposits and the underlying bedrock and area wetlands are unknown.

Documented seeps are present along the basin embankments at a number of locations (Northeast Technical Services 2006). Figure 6 presents seeps currently being monitored as part of the tailings basin NPDES permit. Available seep monitoring data is summarized in Table 2.

3.2 Historic Development of Existing Tailings Basin

The existing tailings basin was developed by constructing perimeter embankments and placing tailings from the iron ore processing operations directly onto native material (Barr Engineering, 2000). Perimeter embankments were constructed from coarse tailings using an upstream method of construction. Tailings were deposited in the basin on the inside crests of the cell perimeter embankments using a network of piping. Tailings were discharged to alternate portions of the tailings basin by means of portable spigotting systems. This method of tailings placement resulted in the deposition of coarse tailings near the points of discharge around the periphery of the basin. These coarse materials were periodically pushed up on the embankment crest to progressively raise the perimeter embankments. Fine tailings settled out at greater distances from the point of discharge and are generally located near the center of the cells and on portions of the perimeter where spigot discharge did not occur for extended periods of time.

More detailed information on grain size distribution of LTVSMC tailings and relationship between grain size and distance from the tailings discharge point can be found in RS39/40T.

Coarse tailings have a higher internal friction angle and drain more readily than fine tailings. This makes coarse tailings a more desirable material for embankment construction than fine tailings because the coarse tailings provide more stable slopes for similar slope geometry. The characteristics of the tailings are presented in RS39/40T.

Because the basin is unlined and the perimeter embankments do not have a clay core or cutoff, water is free to drain from the basin surface and leave the basin as seepage, eventually discharging to the surrounding wetlands or groundwater aquifers.

3.3 Description of Existing Tailings Basin Features and Conditions

The LTVSMC tailings disposal operation was discontinued in January 2001. The tailings basin has been inactive except for reclamation, maintenance and inspection activities since that time. Piezometers and weirs were established in and around the basin area during operation to monitor piezometric head and seeps throughout the basin. Most of this instrumentation remains, and is used for annual dam safety inspections and evaluations. The weirs are located in seepage collection trenches located around the basin perimeter and are monitored for flow rate and sampled for water quality. Individual seeps are also monitored for flow rate and water quality. Existing tailings basin water monitoring information is presented in RS64 and the locations of basin instrumentation and available data from piezometers and weirs are summarized in RS39/40T. The location of seeps that are part of the basin monitoring program and the NPDES permit for the basin are shown in Figure 6. Seep flow data is summarized in Table 2.

In general all of the piezometers indicate a drop in piezometric head within the embankments and the basin area since the basin closure in 2001. In general, seepage rates at weir and seep monitoring locations have also declined. Observations from annual dam safety inspections (Barr Engineering 2005a) indicate diminished rate and extent of seeps since basin operations ceased.

3.3.1 Cell 2W

Cell 2W is the largest and highest of the three cells, covering approximately 1,450 acres in surface area with an average fill height of 200 feet. Cell 2W includes approximately 25,900 linear feet of perimeter dam, including the west, north, and south sides of the cell. A splitter or interior dike on the east edge of Cell 2W separates Cell 2W from Cells 1E and 2E. Cross sections A, B, E, and H (shown on Figure 1) are located along the perimeter embankment of Cell 2W.

Following the cessation of basin operation in 2001, the remaining surface water in Cell 2W drained to Cells 1E and 2E and infiltrated into tailings. Cell 2W has been re-vegetated by seeding and mulching (Barr Engineering 2005a).

Data from piezometers located in Cell 2W (this data is presented in RS39/40T) indicate a continual, gradual decrease in piezometric head within the embankments and basin area since 2001. This includes piezometers associated with the following cross sections:

- Cross section A (A-1, A-3, and A-9)

- Cross section B (P1B, P1B1-99, and B-2)
- Cross section E (E-1, E-5, DH96-10, and DH96-11)
- Cross section H (P2HA-99, P2HB-99, P1H-99, P3H1-99, P3H1-99, P2H1-99, P1H1-99, P3H-99, DH96-28A, DH96-28, DH96-30[1], DH96-32A, and DH96-32)

  [1] *DH96-30 does not demonstrate this same trend*

The data from seeps and weirs near Cell 2W generally shows a decline in seepage. Annual inspection observations (Barr Engineering 2005a) also suggest that seeps are less prevalent on the downstream embankment and that less standing water is present along the perimeter embankment toe than was observed in 2000 and prior years. Ponded water along the toe of the west embankment directly adjacent to wetland areas near Cross Section A is reported to have receded since 2000, and water levels in the adjacent wetland appear to have dropped several feet (Barr Engineering 2005a).

Seepage monitoring data for seeps around Cell 2W from May 2002 to October 2006 is presented in Table 2 and active and historic seep locations are provided in Figure 6. This data indicates that total seepage has declined and total seepage flow from active seeps remaining in October 2006 (Seeps 20, 24, and 25) had decreased to less than 30 gpm.

3.3.2 Cell 1E

Cell 1E is located east of Cell 2W and south of Cell 2E. Cell 1E covers approximately 980 acres in surface area with an average fill height of 60 feet. Cell 1E includes 22,450 linear feet of perimeter dam, including portions of the south and east sides of the cell. Undisturbed natural high ground forms a portion of the perimeter on the southeast corner. The west edge is formed by a splitter dike between Cell 2W and Cell 1E. The north edge is formed by a splitter dike between Cell 2E and Cell 1E. Cross section D (shown on Figure 1) is located along the splitter dike between Cells 1E and 2E. No other cross sections are available in Cell 1E.

Cell 1E still impounds water, but at lower levels than during active LTVSMC basin operations. Process water has drained into Cell 2E and infiltrated into tailings. Seeps are present near the toe of the embankment along the south end of Cell 1E. Seeding and mulching operations and re-grading of eroded areas have been performed throughout the cell (Barr Engineering, 2005 a).

The only piezometer data available for Cell 1E is associated with cross section D. This includes piezometers D-1 and D-4. Data from these piezometers (included in RS39/40T) indicate an increase in basin piezometric head following basin shutdown in 2001, followed by a continual, gradual decrease in piezometric head since 2001.

Seepage monitoring data for seeps at the south end of Cell 1E from May 2002 to October 2006 is presented in Table 2 and active and historic seep locations are provided in Figure 6. This data indicates that total seepage peaked during or after October 2004 at 449 gallons per minute (gpm) and total seepage flow in October 2006 had decreased to 199 gpm.

3.3.3 Cell 2E

Cell 2E is located east of Cell 2W and north of Cell 1E. Cell 2E is the lowest of the three cells and covers approximately 620 acres in surface area. Average fill height is 60 feet. Cell 2E includes 17,750 linear feet of perimeter dam, including the north and part of the east edges. Undisturbed natural high ground forms a portion of the east edge. The west edge is formed by a splitter dike separating Cell 2E from Cell 2W. The south edge is formed by a splitter dike separating Cell 2E from Cell 1E.

Cell 2E still impounds water, but at lower levels than during active LTVSMC operations.

Data presented in RS39/40T for piezometers located in Cell 2E includes piezometers associated with the following cross sections:

- Cross section D (D-1 and D-4)
- Cross sections F and J (F-2, DH96-37A, DH96-37, DH96-39, DH96-40/PN1J-99, AND PN1F-99)
- Cross section G (G-2 AND G-3)

Data graphs indicate either continual, gradual decrease in piezometric head since 2001 (as in the case of DH96-37A and DH96-37), or a short-term increase in water levels following basin shutdown, followed by a continual, gradual decrease in piezometric head since 2001.

Seeding and mulching operations and re-grading of eroded areas have been performed throughout the cell (Barr Engineering, 2005 a). Logging operations have been undertaken along the eastern portion of Cell 2E in the undisturbed high ground area.

Seepage monitoring data for Cell 1E seeps from May 2002 to October 2006 is presented in Table 2 and active and historic seep locations are presented in Figure 6. This data indicates seep flow at Seep 31 discontinued between October 2005 and October 2006. In contrast, seep flow at Seep 30 continues and was estimated at 127 gpm in October 2006.

4.0 Future Tailings Basin Development

PolyMet plans to continue development of the existing tailings basin for tailings disposal from the processing of NorthMet deposit ore. Consideration of future tailings management includes evaluation of the characteristics of future tailings, evaluation of the existing conditions of the existing tailings basin, and the impacts that continued development of the tailings basin will have on seepage. Impacts on seepage are addressed herein, while other items such as slope stability and closure are addressed in other documents.

4.1 Flotation Tailings Material Physical Characterization

Samples of PolyMet tailings were collected from the flotation processing tailings discharge point at the SGS Lakefield pilot plant facility located in Lakefield Ontario, Canada (Barr Engineering, 2005c). The samples were taken from a point in the pilot plant process equivalent to the full-scale process point where tailings will enter the tailings basin. The pilot scale tailings are considered representative of full scale tailings. Laboratory testing was performed on these samples to provide physical characteristics for use in planning, design, and evaluation of the PolyMet tailings basin. Laboratory testing of physical characteristics has also been performed for LTVSMC tailings. Available laboratory testing information for PolyMet and LTVSMC tailings materials are presented in the RS39/40T report.

4.2 Expected Effects of Future Tailings Basin Operations

During PolyMet operations, seepage rates and the presence and extent of seeps on perimeter embankments adjacent areas of flotation tailings deposition are likely to increase relative to existing conditions due to the increasing water levels in the cells as the cells are built up over time.

Seepage from the basin has the potential to affect wetlands adjacent to the basin in two ways. First, as seepage leaves the basin and eventually enters the adjacent wetlands, the seepage may negatively affect the quality (or water quality) of the wetland. Water quality predictions for basin seepage are presented in another report/study (RS46 Wastewater Modeling – Tailings) and methods to maintain tailings basin water quality to appropriate standards are presented in the Detailed Project Description (both of these reports will be completed subsequent to the preparation this document). Secondly, reducing the quantity of seepage that leaves the basin area will affect the hydrology of adjacent wetlands. Depending on the magnitude of the reduction in seepage, this could alter the character of vegetation and habitat of the wetland.

5.0 Preliminary Screening of Approaches to Eliminate Seepage Release

The first step in assessing approaches for eliminating seepage release at the tailings basin site was to identify the range of potential management approaches and develop a preliminary (Phase 1) evaluation and screening of these approaches to identify those with the greatest potential for implementation at this site. Phase 2, addressed in Section 6 of this report, involved the development of a seepage management strategy based on a combination of the most effective approaches identified in Phase 1. While the scope of work for this report (Appendix A) did not include evaluation and screening in the Phase 1 evaluation, preliminary screening was determined to be appropriate at this phase; narrowing the approaches before strategy development in Phase 2.

Phase 1 evaluation and screening of approaches were completed by developing a list of seepage control technologies with reasonable technical viability for implementation at the tailings basin. Each approach evaluated includes a description of the technology along with a synopsis of constructability and suitability, effectiveness, relative cost, and comments on other important considerations. The estimates of relative costs are based on published sources or documented contractor quotes. Appendix B provides a summary of assumptions and cost information used to develop the cost estimates included in this section.

Approaches to eliminate seepage release from the tailings basin were grouped under the following categories:

- Seepage prevention approaches that utilize tailings basin liners.

  For seepage prevention approaches, the Hydrometallurgical Residue Cell and PolyMet Flotation Tailings Basin Design and Location report (RS28T) provides a detailed evaluation of liner alternatives along with recommendations for liner technology implementation. This information is summarized here, but is not presented in detail. It should be noted here that evaluation of liner systems for flotation tailings basin seepage prevention was included to comply with RS55T scope requirements. However, testing performed by SRK since the scoping of RS55T has confirmed that the flotation tailings will be non-reactive. Lined basins are not proposed for flotation tailings.

- Seepage interception approaches that intercept seepage before it leaves the basin boundary and collect the seepage water for monitoring and return to the basin.

- Seepage recovery approaches that collect seepage outside of the basin for monitoring and return to the basin.

Seepage collection rates could range widely across the basin; from less than 1 gpm to over 500 gpm (ref. Table 2). Future seepage collection rates could be higher as the basins are returned to service. For the purposes of this preliminary study, it was assumed that each collection system (collection point) has a pumping capacity of 500 gpm and cost estimates reflect this assumption.

5.1 Screening Criteria

Screening for basin seepage control alternatives or approaches consisted of evaluating the benefits and drawbacks of each of the approaches to eliminate technologies deemed to have the least potential for successful implementation. The following unfavorable characteristics were considered when eliminating approaches in the initial review:

- Unreliable, undeveloped, or uncertain performance
- Uncertainties in constructability
- Significantly higher construction costs compared to other approaches with similar effectiveness
- High operation and maintenance efforts, particularly if they would extend into the post closure period of the project, as MDNR rules favor low maintenance approaches (Minnesota Rules Chapter 6132).

Any approach with two or more of these unfavorable characteristics was dropped from further consideration unless there was a unique feature or other compelling reason to carry an approach forward for future consideration.

5.2 Seepage Prevention Approaches

Seepage prevention approaches ("liner" approaches) include technologies that minimize the quantity of water passing through PolyMet flotation tailings and leaving the basin as seepage. Seepage prevention approaches include a perimeter liner on only the more porous perimeter of the basin, fully lined cells within the existing basin, and augmenting taconite tailings with soil admixtures to reduce hydraulic conductivity.

5.2.1 Perimeter Liner

The perimeter liner (and fine tailings liner) approach makes use of the fact that fine tailings and slimes currently in the center of the basin have significantly lower hydraulic conductivity than the coarse tailings (RS39/40T) and therefore reduce infiltration and seepage leaving the center of the basin. Coarser taconite tailings are present around the perimeter of the cells. These coarser tailings have higher hydraulic conductivities than fine tailings and slimes, and could be lined to reduce the overall hydraulic conductivity and seepage from the basin.

A liner system (using one of the approaches recommended in the Fully Lined Basin approach in Section 5.2.2) could be constructed over the more permeable coarse tailings around the perimeter of the basin. This perimeter liner could be constructed from fine tailings or slimes, clay, or synthetic material. PolyMet tailings could be deposited in a manner to leave fine tailings and tailings slimes in the central unlined portion of the basin to continue to reduce seepage in this portion of the basin. A sketch of this approach is presented in Figure 7.

The perimeter liner approach would reduce the overall rate of seepage from the basin, and because of the significant reduction in lined area, offers significant cost reduction in comparison to a fully lined approach. However, a perimeter liner approach is not recommended for further consideration because the fine tailings still allow relatively high rates of seepage in comparison to other fully lined alternatives.

5.2.2 Fully Lined Basin

A variety of fully lined basin approaches were evaluated in detail in RS28T, including single liner, composite liner, and double liner systems. The evaluation in RS28T was developed to assess cost and performance, including consideration of the following factors:

- Per Acre Cost
- Chemical Compatibility
- Availability of Material
- Tolerance of Differential Settlement
- Freeze-Thaw Resistance
- Ease of Installation
- Construction Season Limitations
- Ease of Permitting
- Containment Ability
- Ability to Accommodate Vertical Expansion

The evaluation in RS28T concludes that the most effective alternatives for lining the flotation tailings basin are:

- Composite liner systems using a geomembrane liner above a geosynthetic clay liner.
- A composite liner system or a single layer geomembrane liner system over fine tailings.

The cost of these liner systems ranges from $280 million to $320 million or more for Cells 1E and 2E. More detailed descriptions of these liner systems and the process for liner evaluation is presented in RS28T. As previously noted, the scope of RS55T required evaluation of liner systems for flotation tailings basins. Since the flotation tailings have been found to be non-reactive, and since other methods will be utilized to eliminate seepage, liner systems for the flotation tailings basins are not proposed.

5.2.3 Tailings Augmentation Liner

Augmentation of tailings is a specific technology subset of the fully lined basin approaches. This approach was listed in the scope of work for RS55T, and so is presented as its own approach. This approach consists of mixing some combination of clay, bentonite, or cement materials with existing taconite tailings on the basin surface to a depth of 10 to 20 feet using specialized equipment to establish a liner of low hydraulic conductivity. While it is possible to accomplish tailings augmentation using a barge and working over water for inundated areas, the increased expense and uncertainty in quality assurance ruled out an over-water work approach to tailings augmentation. Therefore, implementing a tailings augmentation approach would require dewatering of open-water areas to provide a stable area for equipment and materials placement on top of existing unconsolidated fine tailings and slime materials. A sketch of this approach is presented in Figure 8.

The estimated range of implementation costs for tailings augmentation is $250,000 to $500,000 per acre (Cornforth, 2005) or $400 million to $800 million for Cells 1E and 2E. Augmenting tailings is not considered a preferred alternative for a variety of reasons, including high cost, difficulty of ensuring quality of installation, possibility of poor chemical compatibility with tailings, and potential difficulty of permitting based on uncertainties in construction and performance.

In general, seepage prevention approaches are very costly (per acre costs of $175,000 or more for a single liner and $200,000 or more for a composite liner; $280 million to $320 million or more for Cells 1E and 2E) and are not significantly more effective at eliminating seeps on the downstream face of tailings basin embankments than the combination of interception and recovery approaches.

Furthermore, because liner systems are assumed to have some leakage for the purposes of determining environmental impact, and in practical application usually do, a well designed seepage interception/recovery system coupled with plant processing strategies that minimize the content of sulfide minerals in tailings is expected to have a surface water environmental impact on a par with a liner system.

5.3 Seepage Interception Approaches

Seepage interception approaches include technologies that intercept seepage before this water leaves the basin perimeter and collects the water for return to the tailings basin. Seepage interception approaches could be implemented as the primary basin modification for managing seepage at the tailings basin. These approaches can be targeted and implemented to address specific areas where seeps are present. Thus effective use of these approaches does not require continuous implementation around the entire perimeter of the basin. Existing shallow collection ditches along the basin perimeter that currently serve to collect and route seep flows would be replaced with enclosed pipe systems to prevent loss of seepage, and to route this water to a collection point for pump-back. A summary of the Phase 1 screening evaluation of nine different seepage interception approaches is provided in Table 1. The approaches are discussed on a case-by-case basis in the following sections, and include:

- Horizontal Drains
- Seepage Collection Trenches
- Vertical Extraction Wells

For any of the seepage interception approaches, a system will be necessary to manage the captured water. This will include a method to collect and route water for monitoring and return to the basin. In this sense, all of the approaches are active in nature. The estimated construction costs associated with such a collection and pump-back system, estimates for which are provided in Appendix B, are about $54,000 per sump/pump location, in addition to the costs of the seepage interception system, which are described in the subsequent sections. While specific seepage interception approaches involve varying degrees of ongoing operation and maintenance, all of them will require ongoing operation and maintenance for monitoring and return to the basin, for as long as the system is operating (including post closure). As noted in Appendix B, estimated annual costs for operation and maintenance associated with a single sump/pump location with pumping capacity of around 500 gpm would be around $45,000.

5.3.1 Horizontal Drains

Horizontal drains consist of slotted or perforated PVC or HDPE pipe extended into the embankment from the downstream face to intercept and collect seepage from within the embankment (Cornforth, 2005). Horizontal drains are typically installed with at least a slight gradient so that they drain by gravity to the downstream face of the embankment. Horizontal drains would likely extend up to 500 feet into the embankment in areas where seepage control is required to eliminate seeps and enhance slope stability. Drain length would be less in areas where slope stability enhancement is not required. A sketch of a horizontal drain system is presented in Figure 9.

Drains would be installed near the toe of the embankment, or between the toe and the first bench. Horizontal drains are installed using horizontal or angled drilling equipment mounted on rubber tired or tracked drill rigs. This equipment would access the work area using existing access roads along the toe or on benches. Horizontal drains are already in place in several locations on the north and west perimeters of the tailings basin. These existing drains could be refurbished, modified, or supplemented to increase their effectiveness.

Seepage would be collected at the embankment face and diverted from the horizontal drains to a sump where water would be pumped for return to the basin.

This approach can capture a significant portion of seepage when the phreatic surface is above the toe of the embankment. Reduction of the phreatic surface in the embankment provides an additional benefit by increasing the stability of the embankment.

Unit cost for horizontal drain installation is about $20 per lineal foot of drain (Cornforth, 2005). Additional cost will be required for mobilization and access, and development of a collection header, collection sump, and pump-back system. An order-of-magnitude estimate for implementing a horizontal drain system was developed for this report (ref. Appendix B) and is estimated to be about $33,000 per 100-foot section of embankment protection. This assumes 3-inch diameter slotted casings extending 500 feet into the embankment at 50 foot spacing between drains. Smaller diameter casings and shorter drains will likely be used at some locations. It is assumed that a single sump/pump system, would serve each 2,000 to 2,500 foot section of the drain system.

Concerns with this approach include:

- Horizontal drains cannot capture seepage at elevations below the elevation of the drain, allowing lower elevation seepage to leave the basin perimeter (this can be mitigated using vertical wells as subsequently described),
- At some locations site access may be difficult at or near the embankment toe,
- Construction activities could impact wetlands.

Benefits of this approach include:

- Feasible and proven technology that is commonly applied at tailings basins and is already present in several locations at the LTVSMC tailings basin,
- Effectively captures and eliminates seepage at site of installation and has a high probability of capturing any seepage at elevations above the site of installation (e.g., above embankment toe elevation),

- Passive technology for seepage interception and routing to seepage recovery locations (pump-back system is not passive),
- Secondary benefit in improving embankment stability,
- Relatively easy to install and low cost in comparison to other drain technologies (such as seepage trench or vertical extraction wells),
- Some deep seepage would continue to flow into adjacent wetlands areas, reducing potential impacts to the hydrology and vegetation of adjacent areas.

Because of the relatively low cost, proven technology, and potential to capture seepage in the embankment and improve embankment stability, this approach is recommended for further evaluation.

5.3.2 Seepage Collection Trench

A seepage collection trench consists of a slotted or perforated pipe laid in a sand or gravel-filled trench located at or near the downstream toe of the embankment to collect seepage (Cornforth, 2005). The trench would extend into the till just beyond the toe of the embankment, and be backfilled with granular, free-draining material. Trench depths would likely be between 10 and 15 feet, based on a likely balance between constructability and effectiveness. Trench widths would likely be 3 to 4 feet. The trench would intercept seepage, collect the seepage in the pipe at the base of the trench, and divert seepage by gravity drainage to a sump where water would be pumped back to the basin. A sketch of a seepage collection trench is presented in Figure 10.

A seepage interception trench will collect water from both sides, including tailings basin seepage as well as water from adjacent wetlands or open water areas outside the basin. A complimentary approach to reduce potential impacts on adjacent wetlands would be to combine a seepage interception trench with a barrier placed between the trench and the wetland or open water areas.

An order-of-magnitude estimate for implementing a seepage interception trench is about $7,000 per 100 foot of protection. This assumes a 12-foot deep, 3-foot wide trench with an 8-inch diameter slotted or perforated plastic drain pipe. In considering the cost for implementing this approach, it should be noted that a seepage interception trench would require intermediate sump and pump collection points and likely also require a barrier approach to minimize the collection of water from adjacent wetland or open water areas. It is assumed that a single collection point could service on the order of 2,000 to 2,500 feet of embankment protection. Seepage barrier options and associated costs are described in Section 5.4.

Concerns with this approach include:

- Potential impacts to adjacent wetlands if trench collects water from the wetlands areas,
- Potential reduction of tailings dam embankment stability during construction while trench is open near the toe of the embankment,
- Site access may be difficult at or near embankment toe,
- Construction activities could impact wetlands,

- Significant changes in existing ground surface elevation could complicate design and construction.

Benefits to this approach include:

- Likely to be effective at capturing significant portion of seepage above base of trench,
- Passive technology for seepage interception and routing to seepage recovery locations (pump-back system is not passive),
- Likely to reduce phreatic surfaces in embankment, improving embankment stability.

Because of the likely effectiveness, passive nature, potential to capture a significant portion of seepage, and potential to improve embankment stability, this approach is recommended for further evaluation.

5.3.3 Vertical Extraction Well Points

Vertical extraction well points consist of a line of vertical (or angled) slotted or perforated pipes placed in the ground to intercept seepage and pump seepage from the wells, drawing down the phreatic surface (Cornforth, 2005). Well pumps draw water from the well points and pump the water to a central collection point for return to the basin. This approach is well suited for most soil conditions. A sketch of vertical extraction wells is presented in Figure 11. A variation to this that is not treated as a stand-alone approach is to use vacuum extraction well points in-place of or in addition to well points with dedicated pumps in each well. The vacuum well point approach offers the advantage of ease and economics of installation and operation, but includes the drawback of significant limitations on operating head. Therefore, such a system would likely be used in small isolated areas near the toe of the basin dams to recover seepage that is not recovered by other primary seep collection systems.

Extraction wells could be placed near the centerline of the embankment dam, along the downstream slope, or near the toe of the embankment. The location of the well points will impact the drawdown of the groundwater system outside the basin. Placement near the toe will likely have some affect on wetlands adjacent to the basin.

Vertical extraction wells are a more complex and costly approach than horizontal drains or a seepage collection trench. In addition to installation efforts, this approach would require ongoing operation and maintenance to keep the wells operating.

An order-of-magnitude estimate for implementing a vertical extraction well system is about $37,000 per 100 feet of protection. This assumes 6-inch-diameter wells, 300 feet deep, spaced at 50-foot intervals and placed near the crest of the embankment for increased benefit to slope stability. However, well depth can be less if wells are placed closer to the toe or first bench of the embankment. Water from each extraction pump system would be pumped directly to the basin.

Concerns with this approach include:

- Expensive system that relies on ongoing operation and maintenance to remain effective (not passive in any sense),

- Potential impacts from significant reduction in seepage water quantity to wetland hydrology outside of basin, though this can be minimized based on well depth and location.

Benefits to this approach include:

- Likely to be effective at capturing a significant portion of the seepage,
- Flexibility to install wells at various alignments along the embankment to balance effectiveness of seepage interception with impacts to adjacent wetlands,
- Flexibility to vary depths of wells to intercept seepage at various elevations,
- Likely to reduce phreatic surfaces in embankment, improving embankment stability.

Despite the high cost and ongoing active operation and maintenance associated with this approach, vertical extraction wells are recommended for further evaluation because of their potential effectiveness, especially for implementation in circumstances where other approaches might not be constructible or effective.

5.4 Seepage Recovery Approaches

Seepage recovery approaches include technologies to establish barriers that impede seepage from leaving the basin limits, which are then augmented with a seepage collection trench to recover the flow that is blocked by the barrier.

Seepage barriers are most effective when tied into a low permeability layer, such as clay or bedrock. No information is available to determine the extent and characterization of foundation soils or the depth to and nature of bedrock in the basin area. Available borings in the basin demonstrate that the till is at least 20 feet thick in places. The uncertainty of soil conditions will affect the feasibility and cost of seepage barrier approaches. Therefore, approaches with greater flexibility for application in varying soil conditions, or greater certainty in cost for implementation in varying soil conditions are preferred.

Seepage barriers are generally located at or upstream of the centerline of the crest of the dam or embankment. Constructing a barrier along the downstream slope or near the toe of the embankment has the potential to raise the phreatic surface within the embankment dam and negatively impact embankment stability (BuRec, 1987). As such, ground surface modifications such as shallow ditches or a collection trench system will be necessary to manage the build up of elevated water levels and surface water runoff that can be expected to develop on the basin side of the barrier. Captured water will then need to be routed to a sump and pump-back system for return to the basin.

It should be noted that the depth of protection assumed for the cost estimate differs for each of the barrier approaches to reflect the most likely application for each approach. It should also be noted that seepage barriers will reduce the volume of seepage leaving the basin, potentially affecting the hydrology of adjacent wetlands and standing water in these areas.

The seepage recovery approaches that were considered in this evaluation, which are more fully described in the following sections of this report, included:

- Steel Sheetpile Cutoff
- Compacted Soil Barrier
- Grout Curtain
- Mixed-In-Place Overlapping Piles
- Deep Soil Mix Barrier
- Slurry Trench Barrier

5.4.1 Steel Sheetpile Cutoff

A steel sheetpile cutoff consists of a row of vertical interlocking steel sheets driven into the ground near the toe of the embankment to impede seepage. Steel sheetpile cutoffs are especially well suited for stratified soils with high horizontal and lower vertical permeability. Steel sheetpile is not well suited for site conditions with boulders and cobbles (Corps of Engineers EM 1110-2-1901). Practical limitations of steel sheet pile cutoff are reached around 50 feet deep. A sketch of a steel sheetpile cutoff is presented in Figure 12.

Steel sheetpile cutoff is a relatively simple, proven approach that would require no special equipment or skills that are not likely to be available from regional contractors. For this site the sheetpile cutoff would be combined with a shallow seepage collection trench to recover seepage on the tailings basin side of the cutoff.

An order-of-magnitude estimate for implementing a steel sheet pile cutoff with seepage collection trench is about $87,000 per 100 foot of protection. This assumes a 30-foot deep cutoff, and does not factor in any site-specific circumstances, such as access or difficult soil conditions.

Concerns with this approach include:

- Variability in ground surface elevation on the embankment perimeter could complicate design and construction,
- Steel sheetpile is not well suited for site conditions with boulders and cobbles, such as may exist at this site,
- Depth to competent bedrock or other low permeability layer may require sheet pile lengths that make this approach very expensive or un-feasible.

Benefits to this approach include:

- Likely to be effective at impeding seepage, preventing a significant portion from leaving the basin area,
- Conventional technology with very little specialty construction equipment or skills necessary.

Because of the high cost (in comparison to other recovery approaches) and concerns with suitability of this approach with soil conditions around the basin, this approach is not recommended for further evaluation.

5.4.2 Compacted Barrier of Impervious Material

A compacted barrier is constructed by excavating a trench near the toe of the embankment and backfilling the trench with compacted clay material. A compacted barrier is well suited for most soil conditions. This approach uses simple, conventional construction technology, and for a shallow barrier is likely the lowest cost barrier approach. Care would need to be taken to assure the open trench does not jeopardize tailings dam embankment stability during construction. Practical limitations of a compacted barrier are reached around 10 to 15 feet deep. A sketch of a compacted barrier is presented in Figure 13. As with other seepage recovery approaches, the compacted barrier would be combined with a shallow seepage collection trench to recover seepage on the tailings basin side of the cutoff.

An order-of-magnitude estimate for implementing a compacted clay barrier with seepage collection trench is about $33,000 per 100 foot of protection. This assumes a 12-foot deep by 9-foot wide clay barrier, and does not factor in any site-specific circumstances, such as access, availability of clay material, difficult foundation conditions, and water management during construction.

Concerns with this approach include:

- Availability of adequate materials within reasonable proximity will affect the cost,
- Variability in ground surface elevation on the embankment perimeter could complicate design and construction,
- Open trench during construction could affect embankment stability,
- Because of depth limitations, may be less effective in capturing seepage than deeper barrier or drain approaches.

Benefits to this approach include:

- Simple, conventional construction technology,
- Low cost (in comparison to other barrier approaches),
- Likely to be effective at impeding seepage, preventing a significant portion from leaving the basin area.

Because of the relatively low cost (in comparison to other recovery approaches) and reasonable potential for impeding seepage, this approach is recommended for further evaluation.

5.4.3 Grout Curtain

A grout curtain consists of a row or overlapping rows of vertical holes drilled and grouted into the ground near the toe of the embankment. The pattern of the holes forms overlapping grout pillars and densifies the soils to impede seepage (Cornforth, 2005). Grout curtains can be constructed up to depths of 100 feet below ground surface. Grout curtains are not well suited for site conditions with boulders and cobbles. A sketch of a grout curtain is presented in Figure 14.

A grout curtain would represent a significant effort (and associated high cost) to prepare the ground along the alignment and complete the grouting process. A grout curtain is most practical where depth or character of foundation materials make a sheet pile wall or a cutoff trench impractical. A grout curtain would be combined with a shallow collection trench to recover seepage on the tailings basin side of the cutoff.

An order-of-magnitude estimate for implementing a grout curtain barrier and seepage collection trench is about $184,000 per 100 foot of protection. This assumes two rows of 20-foot deep grout holes spaced 5 feet apart, and does not factor in any site-specific circumstances, such as access, availability of clay material, difficult foundation conditions, and water management during construction.

Concerns with this approach include:

- High cost (in comparison to other recovery approaches),
- Variability in ground surface elevation on the embankment perimeter could complicate design and construction,
- Grout curtain would only be an effective solution in sandy or porous media (not suitable for clay, sandy clay, silty clay, dense silt materials, or soils with cobbles and boulders).

Benefits to this approach include:

- Likely to be effective at impeding seepage, preventing a significant portion from leaving the basin area,
- Scalable approach that can extend to greater depths than other barrier approaches.

Because of the high cost (in comparison to other recovery approaches) and concerns with suitability of this approach with soil conditions around the basin, this approach is not recommended for further evaluation.

5.4.4 Mixed-in-place Overlapping Piles

Mixed-in-place piles are constructed using hollow-shaft, mixing-head augers rotated into the soil while cementitous grout is pumped through the shaft. Piles are placed in an overlapping plan at or near the embankment toe to impede seepage. Mixed-in-place piles are suitable for most soil conditions unless there is significant presence of boulders or cobbles. A sketch of mixed-in-place overlapping piles is presented in Figure 15. Overlapping piles would be combined with a shallow collection trench to recover seepage on the tailings basin side of the cutoff.

An order-of-magnitude estimate for implementing mixed-in-place overlapping piles with seepage collection trench is about $207,000 per 100 foot of protection. This assumes two rows of 20-foot deep in-place piles spaced 6 feet apart, and does not factor in any site-specific circumstances, such as access, difficult foundation conditions, and water management during construction.

Concerns with this approach include:

- High cost (in comparison to other recovery approaches),
- Specialized construction method, unlikely to be available from local contractors,
- Variability in ground surface elevation on the embankment perimeter could complicate design and construction,
- Not suitable if boulders or cobbles are present.

Benefits to this approach include:

- Could be effective at impeding seepage, preventing a significant portion from leaving the basin area,
- Scalable approach that can extend to greater depths than other barrier approaches.

Because of the high cost (in comparison to other recovery approaches) and concerns with suitability of this approach with soil conditions around the basin, this approach is not recommended for further evaluation.

5.4.5 Deep Soil Mix Barrier

A deep soil mix barrier uses special equipment to churn and mix soil and inject a bentonite or cementitous grout into the soil. The equipment is suspended from a crane, and the equipment head is moved up and down as the crane moves along the barrier alignment at the ground surface, creating a barrier roughly 3 feet wide, and up to 50 feet or more deep, depending on project need and soil conditions (Cornforth, 2005). Deep soil mixing is suitable for most soil conditions, except for soils containing boulders and cobbles. Deep soil mixing would be combined with a shallow collection trench to recover seepage on the tailings basin side of the barrier. A sketch of a deep soil mix barrier is presented in Figure 16.

An order-of-magnitude estimate for implementing a deep soil mix barrier and seepage collection trench is about $188,000 per 100 foot of protection. This assumes a 30-foot deep barrier, and does not factor in any site-specific circumstances, such as access or difficult subgrade soil conditions. It should be noted that the depth of protection assumed for the cost estimate differs for each of the recovery approaches to reflect most likely application for each approach.

Concerns with this approach include:

- High cost (in comparison to other recovery approaches),
- Specialized construction method, not available from local contractors,
- Variability in ground surface elevation on the embankment perimeter could complicate design and construction,
- Not well suited for site conditions with cobbles and boulders, such as may exist at this site.

Benefits to this approach include:

- Could be effective at impeding seepage, preventing a significant portion from leaving the basin area,
- Scalable approach that can extend to greater depths than other barrier approaches,

Because of the high cost (in comparison to other recovery approaches) and the potential to encounter cobbles and boulders, this approach is not recommended for further evaluation.

5.4.6 Slurry Trench

A slurry trench is constructed by excavating a vertical-sided trench at or near the toe of the embankment and backfilling the trench with a low-permeability bentonite or cement slurry to impede seepage (Cornforth, 2005). Slurry trenches are well suited for most soil conditions, but would not be well suited where cobbles or boulders are present. Practical limitations of slurry trench depth are likely about 20 to 30 feet. Greater depths can be attained by dropping interlocking concrete panels into the trench. However, the cost for such a panel system is significantly higher than a shallow trench system. A slurry trench would be combined with a shallow collection trench to recover seepage on the tailings basin side of the trench. A sketch of a slurry trench is presented in Figure 17.

An order-of-magnitude estimate for implementing a slurry trench and seepage collection trench is about $139,000 per 100 foot of protection. This assumes a 15 foot deep, 3 foot wide slurry trench, and does not factor in any site-specific circumstances, such as access, availability of clay material, difficult foundation conditions, and water management during construction.

Concerns with this approach include:

- Variability in ground surface elevation on the embankment perimeter could complicate design and construction,
- Open trench during construction could affect embankment stability,
- Low strength of slurry material could affect long-term embankment stability,
- Not suitable if boulders or cobbles are present.

Benefits to this approach include:

- Likely to be effective at impeding seepage, preventing a significant portion from leaving the basin area.

Because of the high cost (in comparison to other recovery approaches) and potential to encounter cobbles and boulders, this approach is not recommended for further evaluation.

5.5 Most Effective Approaches

To identify the most effective seepage prevention, interception, and recovery approaches, a qualitative ranking of the approaches was performed. Factors considered in the ranking include:

- Constructability and adaptability of the approach to varying site conditions.
- Effectiveness/reliability of the approach.
- Construction, operation and maintenance costs for each approach.
- Potential for adverse impacts on tailings basin dam stability.
- Issues associated with access for construction.
- Impacts on adjacent wetlands.
- Implementation cost on a per-100 foot of tailings dam basis.

The results of the relative ranking of the approaches are presented in Table 1. This screening of the seepage prevention, interception, and recovery approaches resulted in determination of the following most effective approaches:

Two seepage prevention (liner) approaches are recommended for further evaluation, including:

- Composite liner systems utilizing a geomembrane liner above a geosynthetic clay liner,
- Geosynthetic clay single liner.

Three interception approaches are recommended for further evaluation, including:

- Horizontal Drains,
- Seepage Collection Trench,
- Vertical Extraction Well Points.

While recovery approaches are limited in their application, or may have limited effectiveness unless combined with seepage interception (barrier) approaches, they can be important elements in seepage management for specific conditions. Therefore, the compacted clay barrier approach is also recommended for further evaluation.

Some of the benefits or weaknesses of one seepage prevention, interception or recovery approach relative to another are not fully captured in Table 1. For example; the horizontal drains offer significant benefits in terms of improved tailings basin dam slope stability relative to the seepage collection trench. This is the result of the degree to which the drains can push the phreatic surface within the basin farther away from the face of the dams, whereas lesser benefits in this regard will be achieved with seepage collection trenches. Likewise, compacted soil barriers may be better suited to site conditions that include cobbles and boulders than would a steel sheetpile cutoff, deep soil mix barrier, or slurry trench barrier. Although these other recovery approaches have been dropped from further consideration due to cost and the potential to encounter cobbles and boulders during installation, these other recovery approaches do offer the advantage of allowing barrier installation to greater depths, provided soil conditions are suitable.

Selection of seepage management approaches requires balancing of many considerations. Judgment and professional experience and expertise must be combined with consideration of relative pros and cons of the various alternatives, all in light of site specific conditions (which will be further characterized during final design), to arrive at recommendations for seepage prevention, interception, and recovery systems that are carried forward for further consideration, and implementation. In light of this, it is known that:

- Cobbles and boulders may be encountered in natural subgrade soils at the site,
- Seepage will increase as tailings basins are returned to service and dams are raised, thereby decreasing slope stability safety factors,
- Existing dams adjoin or nearly adjoin existing wetlands, limiting toe-of-slope access for construction.

Therefore, for general area seepage that is emanating from the existing tailings basin dams and/or can be expected to begin once the basins are returned to service, the horizontal drains appear to offer the greatest benefit including:

- Effectively capturing and eliminating seepage at site of installation with a high probability of capturing any seepage at elevations above the site of installation (e.g., above embankment toe elevation),
- Forcing the phreatic surface away from the exterior face of the dams, thereby improving slope stability,
- Accommodating incremental installation as needed to resolve location-specific seepage and/or slope stability issues.

For locations where seepage is occurring at a high rate from an isolated area, a recovery system in combination with a sump and pump system is likely most appropriate. In this regard and again given site-specific conditions, it seems appropriate to begin with a recovery system approach that is reasonably easy to construct and would seem to have a high probability for success. The compacted soil barrier offers the advantage of accommodating some cobble and boulder conditions that may exist at this site and, in the event that it is ultimately not as effective as desired, possibly facilitating access by the larger equipment and materials needed for construction of another recovery system approach in the future.

The seepage prevention, interception, and recovery approaches recommended from this initial evaluation (Phase 1) were subsequently carried forward for use in development of a seepage management strategy. This strategy (Phase 2) is presented in Section 6 of this report.

6.0 Seepage Management Strategy

Phase 2 of this evaluation consists of the development of a seepage management strategy to address known seepage conditions that exist or that have historically existed at the existing tailings basin, and conditions that are likely to be encountered as part of PolyMet's proposed development of the tailings basin. In addition to eliminating seepage from future tailings, it will be necessary to collect seepage from historic tailings basin operations because of existing water discharge limit exceedences. In order to complete the final design and implementation of the strategy, it will be necessary to complete additional monitoring and investigations in subsequent phases of this project.

Because of the high cost of liner systems, their limited potential to significantly reduce seepage related environmental impact from historical seeps compared to a well designed seepage interception/recovery system, and the constructability issues associated with lining Cells 1E and 2E of the existing basin, the use of liners to contain flotation tailings was dropped from further consideration.

6.1 Seepage Management Strategy

The seepage management strategy is summarized in this Section 6.1 and described in greater detail in Section 6.2. The strategy employs the most effective approaches identified in the Phase 1 screening evaluation. The strategy will be implemented prior to or in conjunction with (whichever is most appropriate) initiation of tailings basin operation and includes:

- Installation of new horizontal drains that will capture and eliminate seepage in tailings basin dams in areas where seeps have previously been observed, monitored, and remain active. Horizontal drains are assumed to consist of small diameter drains at 50 foot spacing and extending up to 500 feet into the embankment. Drains will generally be located near the toe of the embankment, or between the toe and the first bench. Final diameter, length, spacing, extent, and elevation of drains will be determined as part of final design. Drains will be installed at the following locations (see Figure 2):

    - In the Cell 2W north embankment in the vicinity of Seep 20, Seep 24, and Seep 25. This drain system is expected to be approximately 2,000 feet in length.

    - In the Cell 2E north embankment in the vicinity of Seep 30. This drain system is expected to be approximately 1,000 feet in length.

  Additional horizontal drains will be placed along perimeter embankments to intercept and collect any identified but previously un-managed seeps that continue to flow. Drain lengths will be varied as needed to manage location-specific seepage conditions. The extent of the horizontal drain system implementation will be determined based on historic seep conditions as well as seep conditions observed at the time of detailed design development and field installation.

  Horizontal drains will also be designed and constructed as needed for the purpose of embankment stabilization. Embankment stabilization requirements are addressed in RS39/40T. Drains needed for embankment stabilization, if any, will be designed and implemented at the same time and in coordination with the seepage management strategy, resulting in implementation of a horizontal drain system that accomplishes both seep management and dam stability improvement objectives.

The horizontal drain systems will include components to intercept and collect seepage. Water will be returned to the tailings basin. Seeps from drains that are implemented solely for embankment stability will be collected and managed using the same program as seep management drains.

- A seepage recovery system will be established in the area south of Cell 1E to collect known seepage in this area (which forms the headwaters of Second Creek or Knox Creek). This system is expected to consist of a compacted clay barrier that blocks flow and diverts it to a seepage collection trench and sump and pump system. Water will be returned to the tailings basin.

Two other areas of the tailings basin show significant flow rates, and will be addressed as follows:

- The flow from the Emergency Basin Outflow culvert ranges from about 500 gpm to 1,000 gpm. This basin has historically collected flows from surface water runoff and seepage from the tailings basin, as well as likely contribution from groundwater in the vicinity of the basin. Because PolyMet will not direct process water to the Emergency Basin, and because the most recent seep monitoring data shows cessation of flows from seeps in the vicinity of the Emergency Basin, the Emergency Basin and its outflow will become a stormwater system. Therefore, no further modifications are recommended for the Emergency Basin.

- The culvert or culverts at the north east corner of Cell 1E flow into the basin from adjacent upland areas. Flow data is limited, but indicate flows on the order of 40 to 50 gpm. These upland area flows have not been in contact with tailings materials. The culverts will be plugged, removed, or reconstructed to re-direct this water away from the basin.

This basic seepage management strategy is presented in Figure 2. This strategy builds on existing approaches in place at the basin, and approaches that are more passive in nature, flexible in how they can be implemented, and cost effective in reducing impacts to adjacent surface waters. It can be expanded based on inspection and observation to include more horizontal drains (closer spacing, expanded coverage to adjacent areas, or implementation in additional seep areas) or seepage barrier and collection systems if necessary and it also can provide for improvements in tailings embankment stability if necessary.

6.2 Conceptual Design

To further detail the seepage management strategy, conceptual designs for the seepage interception and recovery systems have been prepared. The conceptual designs specifically apply to seepage emanating from the perimeter dams of the existing Cell 1E, 2E, and 2W tailings basins, including collection of general toe-of-slope seepage, and collection of the location-specific seepage that discharges from the southern side of Cell 1E into Second Creek. The objective for each of these seepage interception/recovery systems are summarized below, followed by a description of the design concepts for each system supplemented by the attached figures.

6.2.1 Seepage Interception – At Toe-of-Slope of Tailings Basin Dams

As noted previously and as shown on Figure 6, the existing tailings basin dams have exhibited seepage at multiple locations in the past and continue to exhibit seepage at several locations along the toe of slope. At active seep locations seepage generally exits the slope and is visible on the ground surface at or near the toe of slope, but is occasionally evident on the side slope of the dams at elevations somewhat higher than the toe elevation. The seepage does not occur consistently across the entire exterior face of the lower portion of the dam. Rather, the seepage tends to occur in a random pattern in both vertical and horizontal dimensions along the toe and face of the lower portions of the dam. This seepage is evidence of a phreatic surface within the tailings basin near the seep location that extends above the elevation of the natural ground surface surrounding the basins.

An elevated phreatic surface that is not planned for and/or properly controlled can have a detrimental affect on dam slope stability and, to the extent that seepage exits the exterior slope of the tailings basin dams, represents an uncontrolled discharge to nearby wetland areas. Historical monitoring data indicates that some of the tailings basin seeps have exceeded discharge limits for bicarbonates, hardness, specific conductance, and iron. The elevated phreatic surface is well understood and, while the seepage does reduce the overall slope stability safety factor, the seepage is not currently of a magnitude sufficient to produce slope instability. As the tailings basins are returned to service and the phreatic surface begins to rise, slope stability safety factors may be further reduced and discharges to nearby wetlands increased, warranting the ongoing monitoring, evaluation, and control of seepage in the tailings basin dams that is planned as a routine part of tailings basin operations.

Strategic placement of lateral drains is planned near the toe of slope at active seep locations to systematically intercept and collect seepage within the perimeter dam. The drains will reduce the elevation of the phreatic surface and improve the overall slope stability (increasing the slope stability safety factor) while simultaneously eliminating the uncontrolled discharges to nearby wetlands.

The planned approach to toe-of-slope seepage collection consists of horizontal drains discharging to sump and pump systems from which collected seepage is returned to the tailings basin for reuse. The seepage collection system for the tailings basin dams generally consists of:

- Small diameter (typically 1 ½" to 2" dia. but possibly as large as 3" dia.) slotted PVC pipes installed into boreholes drilled horizontally into the perimeter dams of the tailings basin.

  Drain pipes will vary in length but will be installed a distance of up to 500 feet into the dam, with approximately a 0.5 percent slope angle to improve efficiency of drainage from the pipes. Pipe spacing horizontally will typically be 50 feet center-to-center, with spacing and length adjusted (increased or decreased) as needed to address location-specific seepage conditions. Cleanout access points will be provided at the end of each horizontal drain. The horizontal drain system is depicted in Figures 18, 19, and 20.

- Header pipes connecting the horizontal drains; routing collected seepage to intermediate sump locations.

Header pipes will be sloped toward sump locations at minimum slopes of 0.5 percent. A profile of the planned header pipe system is depicted in Figure 19. The system in Figure 19 shows the header system for seepage collection on all of the north and east side of Cell 2E of the tailings basin. However, the system is configured for installation in increments and will be installed in increments on an as needed basis.

- Sump and pump systems for returning collected seepage to the tailings basin.

  Discharge lines from the sump and pump systems will be relatively small diameter such that flow velocities within the pipes are kept high to resist freezing in the winter. Discharge pipes will be insulated and/or buried if needed to further reduce the potential for winter freeze-up. General routing of the sump discharge lines to the tailings basin is depicted in Figure 20.

Some important aspects of the seepage collection system include:

- Horizontal boreholes and seep collection pipes of sufficient length and frequency and with sufficient redundancy such that the phreatic surface within the perimeter tailings basin dams is controlled to the extent required. Adequate control of the phreatic surface will be monitored through use of piezometers.

- Design of the seep collection pipe slot size to minimize clogging. Slot size will generally be selected to preclude intrusion of the coarse and fine tailings into which the drain pipes will be installed. Cleanout access to the drain pipes will facilitate cleaning of the drain pipes in the event that silt or slimes enter or partially clog the horizontal drains.

- Freeze protection of the seep collection system such that system operation/performance in the winter is maintained. Freeze protection will be accomplished by placement of insulation and soil fill as depicted in the figures referenced above.

- Inclusion of pressure relief and/or vacuum breaker valves as needed to limit system operating pressures (positive or negative) within the discharge pipes.

- Provisions for drain-back of the discharge pipes such that the potential for water stagnation and winter freeze-up within the discharge pipes is minimized.

- Construction sequencing so as to avoid reductions in overall slope stability that could result from excavation for seepage collection system installation. Construction will be sequenced such that for any trenching required, open trench length will be restricted to a maximum length of approximately 30 feet. This restriction, in combination with placement of soil fill for pipe cover in lieu of installation in proportionately deeper trenches will minimize construction impacts on slope stability.

6.2.2 Seepage Recovery – At Second Creek

Seepage estimated to flow at rates of hundreds of gallons per minute currently discharges into Second Creek from near the toe of the railroad embankment that forms the southern boundary of tailings basin Cell 1E. The railroad embankment is a massive structure consisting of a mix of small to large diameter rock/overburden. The existing slope angle of the embankment averages approximately 1.4 horizontal to 1.0 vertical. The maximum embankment height, occurring at the seep location, is approximately 160 feet. While the seepage at this location does not currently represent a concern from a slope stability standpoint, the seep is uncontrolled. The discharge from the seep ultimately meanders away from the toe of the embankment and enters a drainage swale located further south.

The planned approach to elimination of this seepage is to create a cutoff structure that blocks the seepage, allowing it time to drain into a seepage collection trench, and then pumps the collected seepage from a sump back into Cell 1E of the existing tailings basin. The seepage collection system for this location, which would be positioned approximately 75 to 100 feet downstream (south) of the seepage face, generally consists of:

- A cutoff berm and trench that creates a barrier to continued downstream flow of the seepage.

  The berm consists of a soil berm with a natural or man-made (soil and bentonite mix) clay cutoff and an upstream seepage collection trench. The trench is gravel-filled and includes a slotted drain pipe to facilitate discharge of collected seepage into a sump. The overall system is depicted in cross-section in Figure 21. A typical detail of the cutoff berm is depicted in Figure 22.

- A seep collection sump located near one end of the seepage cutoff berm.

  The sump consists of a pre-cast concrete manhole of minimum 6-foot diameter, with a float controlled high head pump. The sump system is depicted in Figure 23.

- A discharge pipe extending from the sump, up the side-slope of the railroad embankment, discharging into Cell 1E of the existing tailings basin.

  The discharge pipe diameter will be small (on the order of 4” to 6” dia.) such that flow velocity in the pipeline remains high to resist winter freeze-up. Pump and pipe sizing will be adjusted as appropriate during final design such that the estimated seepage flow rate can be accommodated in a single discharge pipeline. The pipe will not be buried as it rises along the railroad embankment side slope, but will be insulated to further reduce the potential for winter freeze-up. The discharge pipe will be fitted with vacuum breaker and/or pressure relief valves as needed to limit system operating pressures (positive or negative) within the discharge pipe. In addition, the pump system will be designed to allow drain-back of the pipe such that the pipe is empty when pumping is not occurring.

As noted on Figure 22, the anticipated depth of the gravel-filled trench located within the seepage cut-off berm is approximately 5-feet. However, during final design of this cutoff it is anticipated that several soil borings will be performed along the proposed alignment of the berm to gather information for use by the contractor when planning berm construction, and to confirm soil types and depths in the vicinity of the trench and berm. This information will aid in final design of trench depth and configuration and in overall project bidding.

Finally, the sump, pump, and piping system will require sizing to accommodate the entire volume of flow emanating from the seeps. Since the flow rate is likely somewhat variable now and since it may increase as the tailings basin is returned to service, consideration will be given during final design to sizing the sump for higher flow rates that may occur in the future and/or to providing an auxiliary sump that, with subsequent addition of pumps and piping, could be placed into service on an as needed basis if flow rates do increase in the future.

6.3 Effectiveness

Effectiveness of the seepage management strategy will be evaluated based on the elimination of seepage that would otherwise flow into the adjacent surface waters outside the tailings basin. Technical Design Evaluation Report RS13 describes the tailings basin water balance and includes estimation of seepage out of the basin. Existing seep monitoring includes data from 41 locations around the basin. Six of these locations have been identified as areas with measured seepage rates greater than one gallon per minute. These locations are shown in Figure 6 and highlighted in Table 2. Implementation of seepage management will focus on these areas, and can be expected to be highly effective because:

- Existing seep collection measures along Cell 2W and 2E embankments will be augmented to capture seepage in lined or enclosed systems and route seepage to collection points for monitoring and return to the tailings basin.
- Horizontal drains will be constructed in areas where un-controlled seeps are present on Cell 2W and 2E embankments to capture these flows, and route seepage to collection points for monitoring and return to the tailings basin.
- Many of the small historical seeps associated with Cell 2W have already been eliminated as a result of the cessation of tailings disposal in that cell.
- Scheduled site observations will be used to monitor horizontal drain performance. The seepage collection system will be augmented with additional horizontal drains as necessary to mitigate un-controlled seeps.
- A seepage barrier will be established to confine and capture flows south of Cell 1E for monitoring, treatment and/or direct re-circulation to the tailings basin.

In aggregate, these measures will effectively eliminate the occurrence and outflow of seeps from the tailings basin embankments. This is flow that would otherwise contribute directly to surface water in wetlands and standing waters directly adjacent to the basin.

6.4 Implementation

Implementation of the seepage management strategy will include detailed design and construction of the tailings basin modifications. Detailed design will include additional field investigations, monitoring, and studies. Construction will proceed immediately upon development of the tailings basin to incorporate the strategy described above. Additional implementation may be necessary to address other observed, un-controlled seeps along the embankments.

Additional field investigations that will be undertaken as part of detailed design for the tailings basin will include:

- Continued piezometric head monitoring and basin surface water level monitoring to assist ongoing understanding basin seepage and water balance conditions as required by the Dam Safety Permit,
- Continued inventory, mapping, monitoring, and evaluation of seep locations, extents, flow rates, and water quality,
- Completion of geotechnical investigations of soil conditions at the basin perimeter in areas where seepage barriers or seepage collection trenches may be implemented as part of strategy implementation.

Using this information, detailed design will be completed for the seepage management strategy approaches to lay out system feature location, and to develop site specific implementation costs.

6.5 Costs

Estimated costs were developed for implementation of the basic seepage management strategy described above. The costs presented in this report represent an opinion of probable construction cost. Most of the unit-cost data was obtained from R.S. Means Heavy Construction Cost Data. The estimated cost for the basic seepage management strategy is presented in Table 3. Cost information for this estimate was derived from the estimates for seepage management technologies included in Appendix B and described in Section 5 of this report.

The opinion of probable cost (construction cost, maintenance cost, etc.) presented in this report is made on the basis of Barr's experience and qualifications in northern Minnesota and represents Barr's best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project. The opinion of cost will change as further design is completed. In addition, since there is no control over the cost of labor, materials, equipment, or services furnished by others, or over the contractor's methods of determining prices, or over competitive bidding or market conditions, Barr cannot and does not guarantee that proposals, bids, or actual costs will not vary from the opinion of probable cost prepared by Barr. If greater assurance as to probable cost is required, services of an independent cost estimator may be used. Estimates can be updated after further information is available and complete designs are prepared.

7.0 Conclusions

This report has addressed the objectives and scope requirements described in the October 24, 2005 Tailings Basin Modifications Technical Design Evaluation Report scoping for RS55T (RS55T scope description included in Appendix A).

Phase 1 of the evaluation, described in Section 5, presents concepts for minimizing and/or eliminating water release via seepage, including a summary of the results of seepage prevention (or liner) strategies evaluated in RS28T, and a description of the evaluation of seepage interception and seepage recovery technologies. While the original scope did not include screening of alternatives in Phase 1, preliminary screening was determined to be appropriate at this phase, including assessment of constructability, suitability, effectiveness, and relative cost. Secondary considerations of the screening process included consideration of drawdown of adjacent wetlands, impacts on embankment stability, and ability to accommodate heavy equipment access for construction (trafficability). A summary of the Phase 1 evaluation is presented in Table 1. Phase 1 screening resulted in the recommendation of six most effective approaches, including two seepage prevention, three seepage interception, and one seepage recovery technology.

- Seepage prevention included approaches for lining the existing LTVSMC taconite tailings basins, and resulted in two "most effective" liner technologies.
- Seepage interception included approaches for collecting water from existing controlled or un-controlled seeps on the embankment slopes. Three approaches were considered to be most effective, including horizontal drains, seepage collection/interception trench, and vertical extraction well points. These technologies provide a range of solutions that could be adapted to handle a wide range of site specific circumstances.
- A third category (seepage recovery) of seepage management technologies was also developed to supplement the seepage interception approaches. Barriers would impede seepage and route the seepage water to collection points, recovering seepage water that has left the basin; at the same time preventing water from being drained away from the adjacent wetlands. One seepage recovery approach was considered most effective among the options identified. This consisted of a compacted clay barrier and associated seepage collection trench.

In Phase 2 of the evaluation, development of a seepage management strategy for implementation yielded a plan to address the known seeps at the tailings basin site, with expansion capabilities as needed to also address potential future seeps. The seepage management strategy was developed from a combination of effective approaches considering the nature of seepage, embankment conditions, and foundation conditions. Available information on basin geotechnical characteristics, piezometric head, and seepage rates were considered in the development of the strategy.

Because of the high cost of prevention approaches and their limited potential to significantly reduce seepage related environmental impact from historical seeps compared to a well designed seepage interception/recovery system, and the constructability issues related to applying liners systems to basins already in operation, the prevention approaches were not carried forward.

The result is a seepage management strategy that addresses existing and anticipated seepage conditions. Implementation of the seepage management plan can be expected to be highly effective because:

- Water will be captured from existing embankment seep collection systems in lined or enclosed systems that route seepage to collection points for pump-back to the basin,
- Water will be captured from existing uncontrolled embankment seeps by additional horizontal drains,
- A barrier will be placed to capture flow from seeps and seepage south of Cell 1E,
- Captured water will be routed to collection points in lined or enclosed systems and be pumped back to the basin,
- Scheduled observations will be used to monitor effectiveness on an on-going basis,
- The strategy will be augmented to capture any additional uncontrolled seepage observed on the embankments.

In aggregate, the seepage management strategy will effectively eliminate the occurrence and outflow of seeps from the tailings basin embankments. This is flow that would otherwise discharge directly to wetlands and standing waters directly adjacent to the basin.

8.0 References

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Tables

Seepage Management Approach		Relative Ranking by Primary Screening Criteria: Constructability, Adaptability	Effectiveness, Reliability	O&M Effort	Implementation Cost (per 100-foot of alignment) See Note	Relative Ranking by Secondary Screening Criteria: Potential Beneficial Impacts to Embankment Stability	Potential Adverse Impacts to Embankment Stability	Trafficability / Access for Construction	Impact on Adjacent Wetlands and Open Water Hydrology	Final Ranking	Disposition of Approach
Seepage Prevention (Liner) Approaches			***see RS 28T for evaluation of liner alternatives***								
Seepage Interception/Collection Approaches											
	Horizontal Drains	med	high	med	$33,000	high	high	med	med	High	Carry Forward
	Seepage Collection Trench	med	med	med	$7,000	low	med	med	med	Medium	Carry Forward
	Vertical Extraction Wells	high	med	low	$37,000	med	high	high	med	High	Carry Forward
Seepage Interception (Barrier) Approaches											
	Steel Sheetpile Cutoff	med	med	med	$87,000	low	med	med	med	Low	Drop
	Compacted Barrier	med	high	med	$33,000	low	med	med	med	Medium	Carry Forward
	Grout Curtain	med	med	med	$184,000	low	med	med	med	Low	Drop
	Mixed in Place Overlapping Pile Barrier	low	med	med	$207,000	low	med	med	med	Low	Drop
	Deep Soil Mix Barrier	med	med	med	$188,000	low	med	med	med	Low	Drop
	Slurry Trench Barrier	med	high	med	$139,000	low	med	med	med	Low	Drop

Key:
high Favorable evaluation
med Neutral evaluation
low Un-favorable evaluation

Note: Implementation cost excludes sump/pump systems and system operation and maintenance, which are common to all approaches.

Table 1
Summary of Phase 1 Screening Evaluation

E S T I M A T E D F L O W S (G P M)

	Seep ID	Description	May 2002	December 2002	November 2003	October 2004	October 2005	October 2006
	Seep 1	Emergency Basin area seep	1	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	No Flow
	Seep 2	Emergency Basin area seep	Not Measurable	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	No Flow
*	Seep 3	Emergency Basin area seep	6	12	No Data Recorded	No Data Recorded	Not Measurable	No Flow
*	Seep 4	Emergency Basin area seep	25 - 30	42	11	No Data Recorded	Not Measurable	No Flow
*	Culvert (WS-011)	Combined flow of seeps in area of and including seeps 1, 2, 3, & 4 near emergency basin.	Not Measurable	Not Measurable	No Data Recorded	21.8	7.2	No Flow
	Seep 5	Emergency Basin area seep	0.8	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	Not Measureable
	Seep 6	Emergency Basin area seep	1.6	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	Not Measureable
	Seep 7	Emergency Basin area seep	1.6	0.9	No Data Recorded	No Data Recorded	Not Measurable	Not Measureable
*	Seep 8	Emergency Basin area approx. 4 seeps in one small area.	3.5	35	33	No Data Recorded	Not Measurable	Not Measureable
	Seep 9	Emergency Basin area seep	Not Measurable	Not Measurable	No Data Recorded	No Data Recorded	Not Measurable	Not Measureable
*	Weir (WS-012)	NPDES Permit station	94	25	25	35	0.2	No Flow
*	EB Outflow	Emergency Basin outflow	1051	568	797	928	896	554
	Seep 10	West side of TB	Not Measurable	>50	No Data Recorded	No Data Recorded	Not Measurable	No Flow
	Seep 11	West side of TB	Not Measurable	0.5	No Data Recorded	No Data Recorded	Not Measurable	No Flow
	Seep 12	West side of TB	Not Measurable	0.5	No Data Recorded	No Data Recorded	Not Measurable	No Flow
	Seep 13	West side of TB	1 - 1.5	0.5	No Data Recorded	No Data Recorded	Not Measurable	No Flow
	Seep 14	West side of TB	0.8	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	0.47 (Seeps 14-17 Combined)
	Seep 15	West side of TB	Not Measurable	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	0.47 (Seeps 14-17 Combined)
	Seep 16	West side of TB	Not Measurable	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	0.47 (Seeps 14-17 Combined)
	Seep 17	West side of TB	Not Measurable	No Flow / Could Not Locate	No Data Recorded	No Data Recorded	Not Measurable	0.47 (Seeps 14-17 Combined)
*	Weir (West Side Seep)	West side of TB	24	25	9	3	No Flow	No Flow
*	SD-006	NPDES Permit station	1387	247	359	406	509	356
	Seep 18	West side of TB road	Not Measurable	2.0	No Data Recorded	No Data Recorded	No Flow	No Flow
*	Seep 19	West side of TB road	Not Measurable	22	No Data Recorded	No Data Recorded	No Flow	No Flow
	Seep 20	Northwest side of TB pipe flow	1.5 - 2.0	5.0	9	No Data Recorded	2.1	1.59
	Seep 21	Northwest side of TB	0.5	1.5	No Data Recorded	No Data Recorded	No Flow	No Flow
	Seep 22	Northwest side of TB	1.0 - 1.5	7.0	5	5	5	1.35
	Seep 23	No pipe present	Not Measurable	6.0	No Data Recorded	No Data Recorded	No Flow	No Flow
*	Seep 24 (North Side Seep)	Flow from pipe	1.0 - 1.5	20	21	3	2.7	1.08
*	Seep 25	Flow from pipe	2.5 - 3.0	15	29	5	15.5	21.54
	Seep 26	North side of TB	1.0	Frozen	No Data Recorded	No Data Recorded	No Flow	No Flow
	Seep 27	Flow from pipe	0.25	Frozen	<1	No Data Recorded	No Flow	No Flow
	Seep 28	Flow from pipe	0.25	Frozen	No Data Recorded	No Data Recorded	No Flow	No Flow
*	Seep 29	Flow from pipe	25-30	12	5	0.7	No Flow	No Flow
*	Seep 30	Three seeps in one small area, no pipe present.	1.5 - 2.0	12	99	62	81	127
	Seep 31	Various seeps along northeast side of TB flowing onto the road.	Not Measurable	>60	No Data Recorded	No Data Recorded	Not Measurable	No Flow
*	Seep 32	Knox Creek Headwaters, south of TB	No Data Recorded	No Data Recorded	265	360	409 (Seeps 32-33 Combined)	199 (Seeps 32-33 Combined)
*	Seep 33	Knox Creek Headwaters, south of TB	No Data Recorded	No Data Recorded	114	89	See Seep 32	See Seep 32
*	Knox Creek Headwaters	Seeps 32 and 33 Combined	554	332	See Seep 32 and 33	See Seep 32 and 33	See Seep 32 and 33	See Seep 32 and 33
*	Inflow (culvert)	NE end of TB process water pond	No Data Recorded	No Data Recorded	No Data Recorded	42	67	151

* Indicates "significant" flows (measured flows greater than 10 gpm).

Not Measurable - Moisture observed but could not quantify flow.

No data Recorded - Seepage was not measurable, did not exist, and/or was not recorde

No Flow - No flow observed.

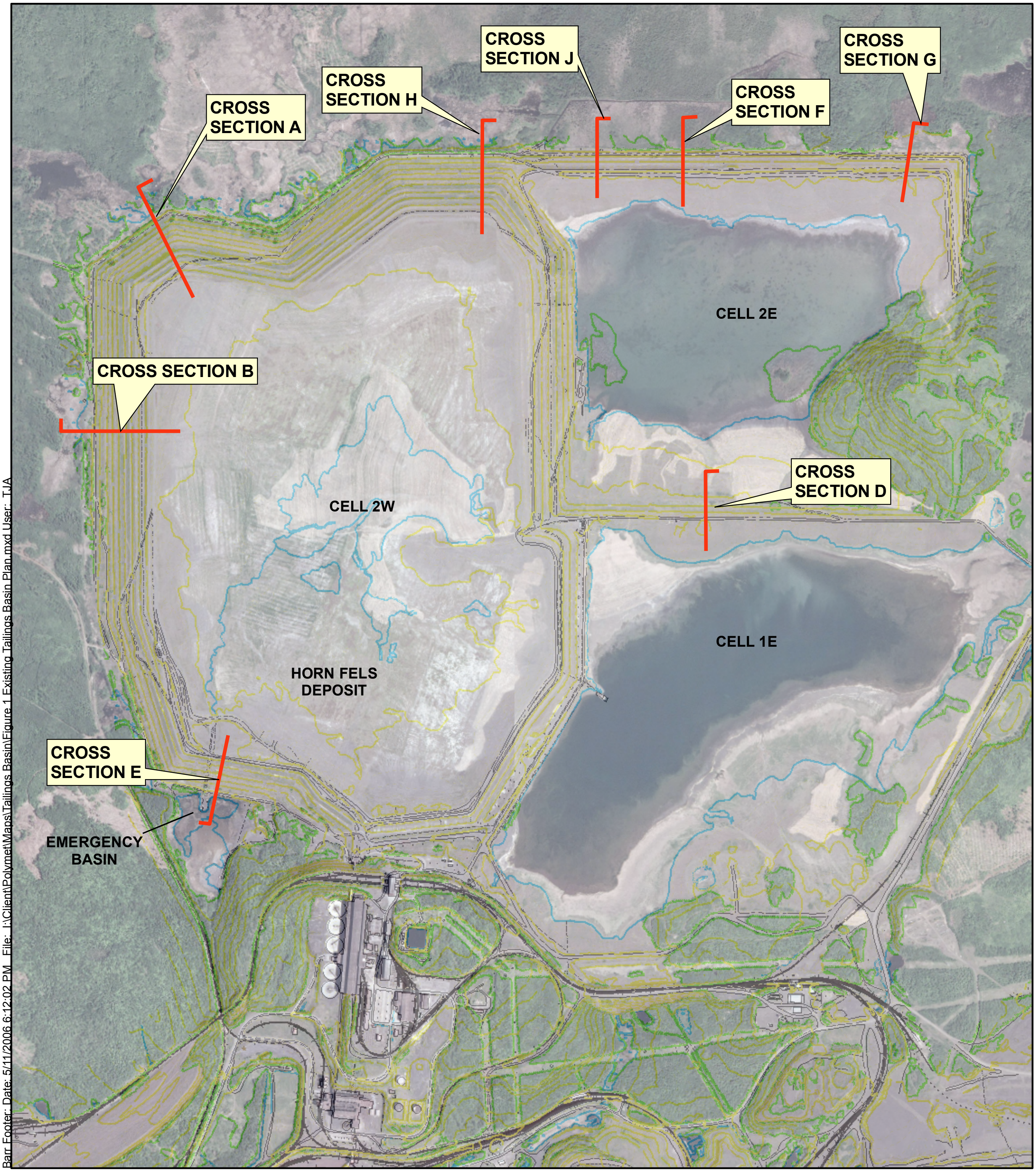
Table 2
Summary of Seep Flow Monitoring

	Units	Quantity	Unit Rate	Extension	Totals
Seep 20 / Seep 24 / Seep 25 Area					
Horizontal Drain System	lf	2000	$290	$580,000	
Collection Sump / Pump-Back System	ls	1	$54,000	$54,000	
				Subtotal:	$634,000
Seep 30 Area					
Horizontal Drain System	lf	1000	$290	$290,000	
Collection Sump / Pump-Back System	ls	1	$54,000	$54,000	
				Subtotal:	$344,000
Seep 32 / Seep 33 Area					
Compacted Barrier and Ditch System	lf	600	$330	$198,000	
Collection Sump / Pump-Back System	ls	1	$54,000	$54,000	
				Subtotal:	$252,000
				Total:	**$1,230,000**

Note: Extensions are rounded to nearest $1,000.
Costs exclude contingency, design, permitting, project management, and administration.

Table 3
Seepage Collection System
Cost Estimate

Figures

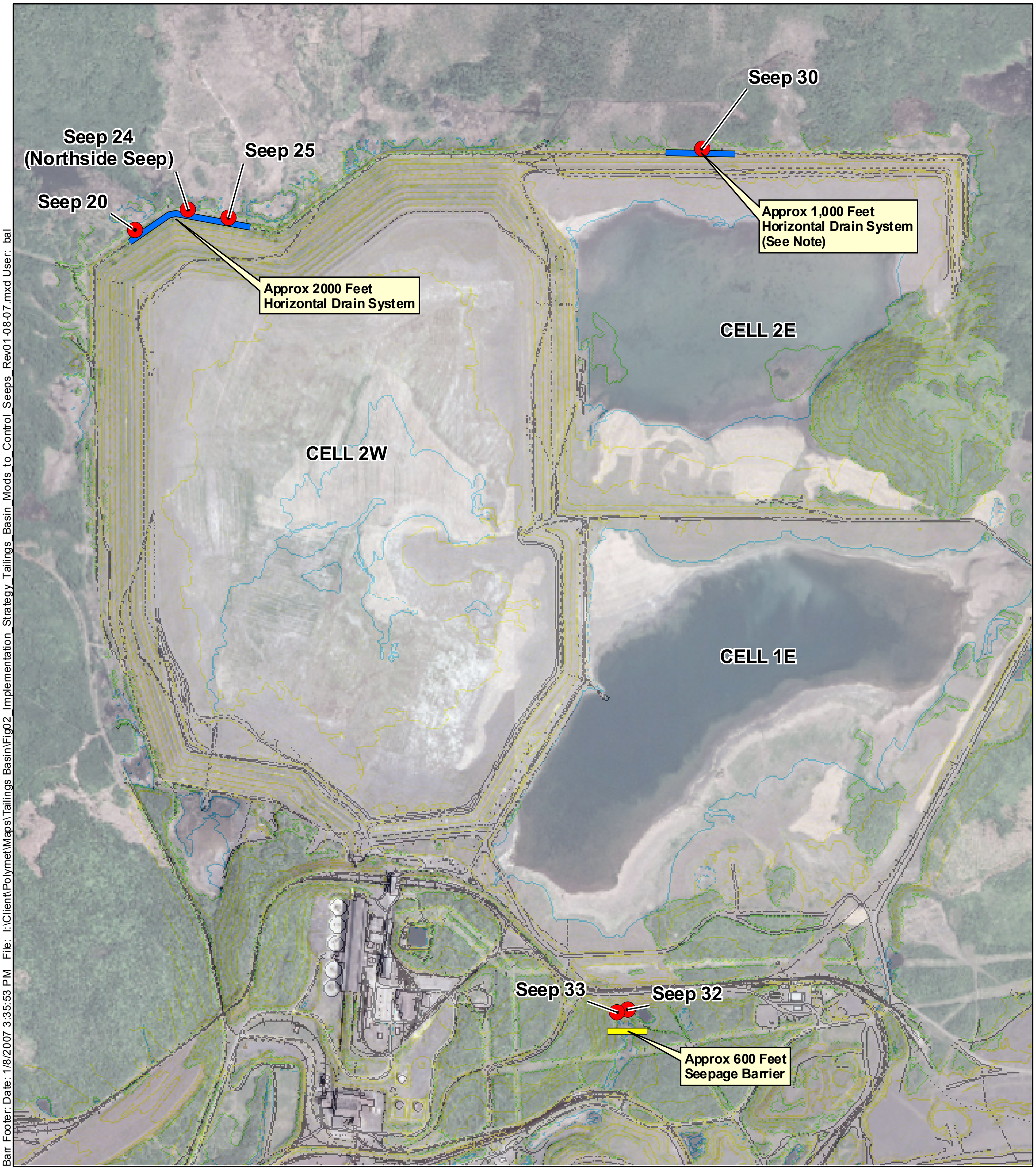


Cross Sections

0 1,000 2,000 4,000

Feet

Figure 1
Existing Tailings Basin Plan



Active Seeps

Implementation Strategy

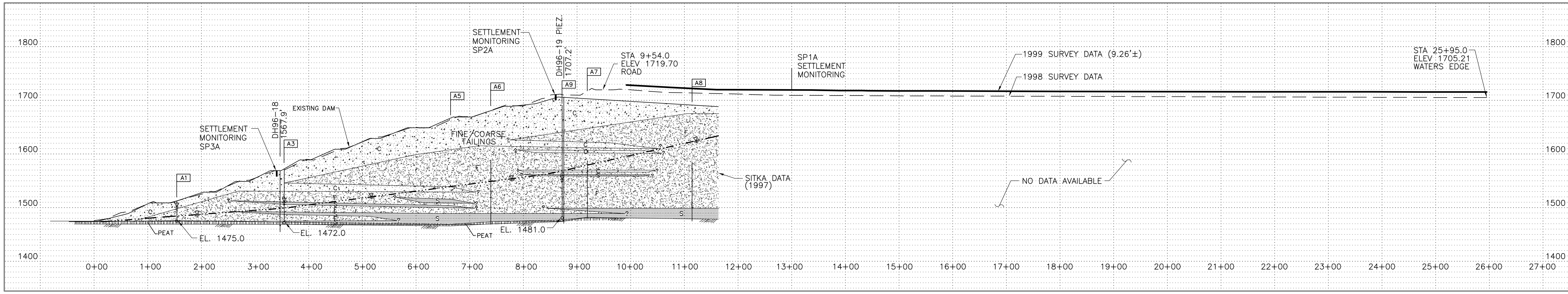
Horizontal Drain System

Seepage Barrier

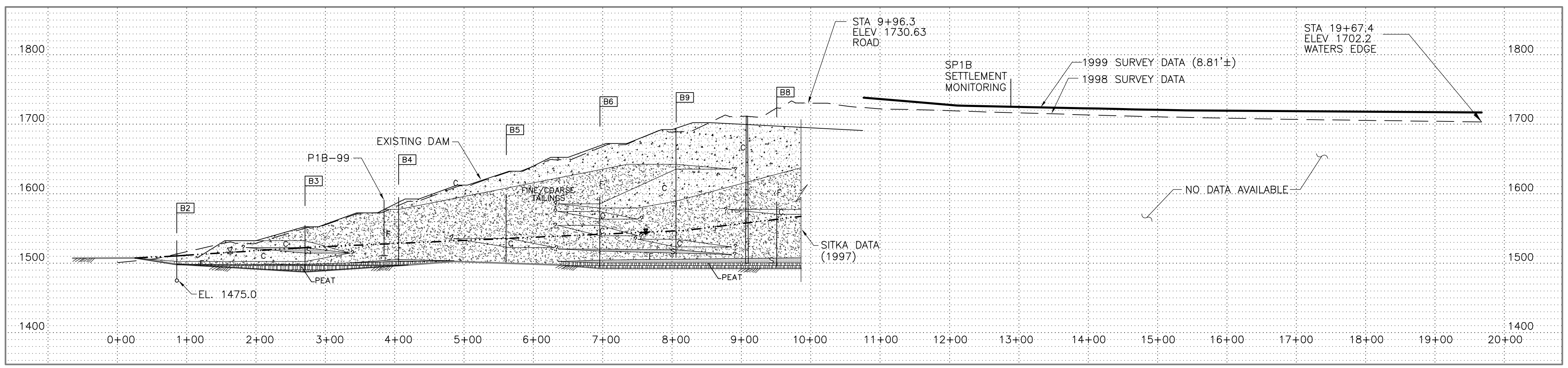
Note: Additional horizontal Drain to be installed along north side of Cell 2E for slope stability not shown (See RS39/4OT)

0 1,000 2,000 4,000
Feet

Figure 2
Implementation Strategy
Tailings Basin Modifications
to Control Seeps



CROSS SECTION A



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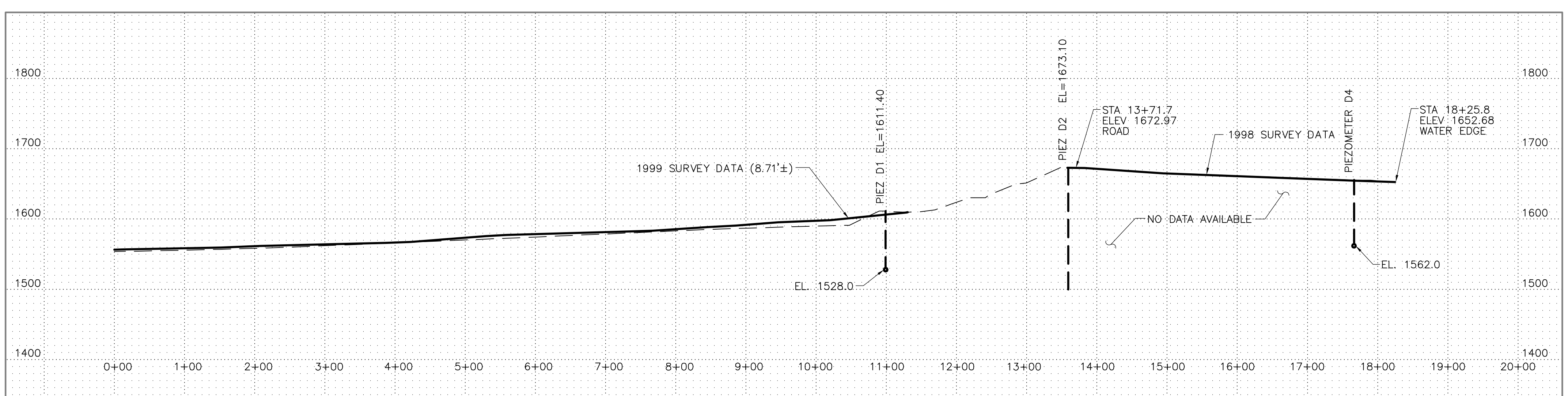
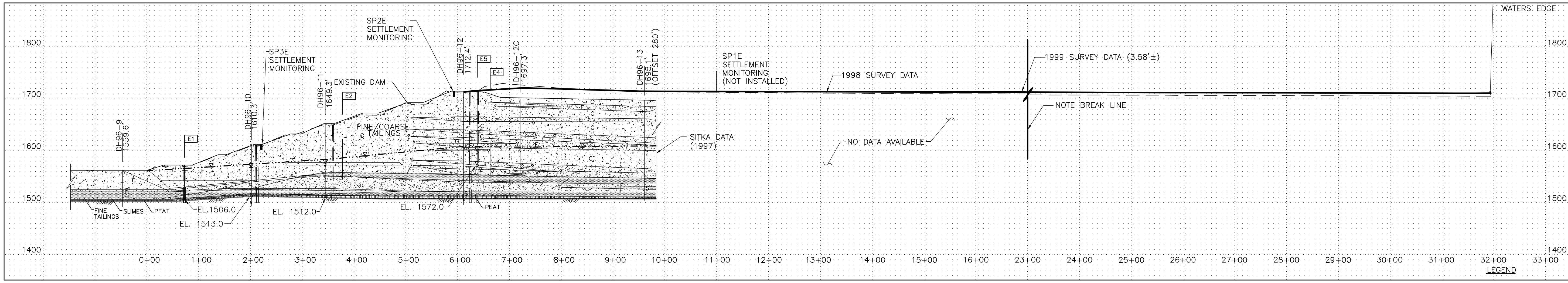


CROSS SECTION D

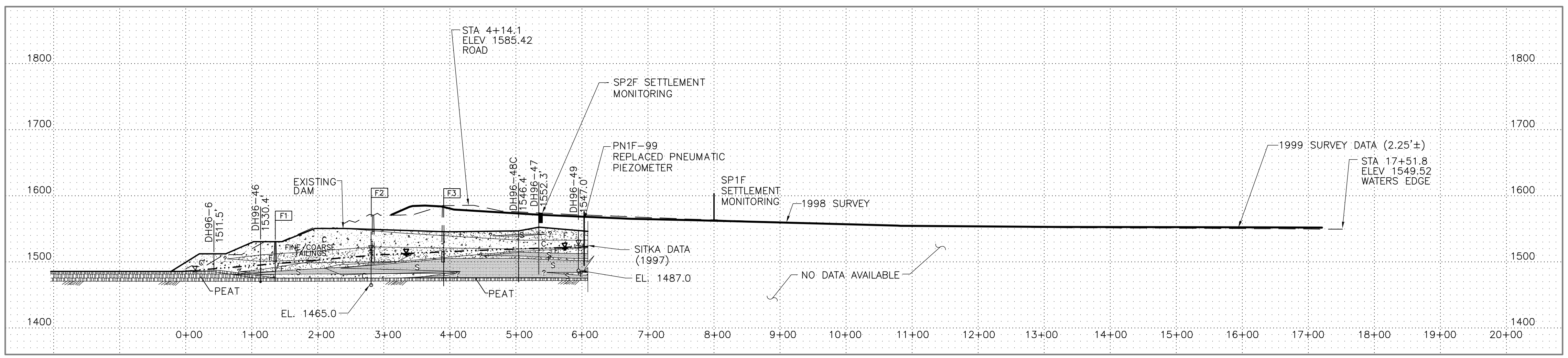
Figure 3

EXISTING TAILINGS BASIN
CROSS SECTIONS A, B, AND D

RLG M:\CAD\2369862\22634_1.DWG Plot at 1 01/19/2006 10:16:20



CROSS SECTION E



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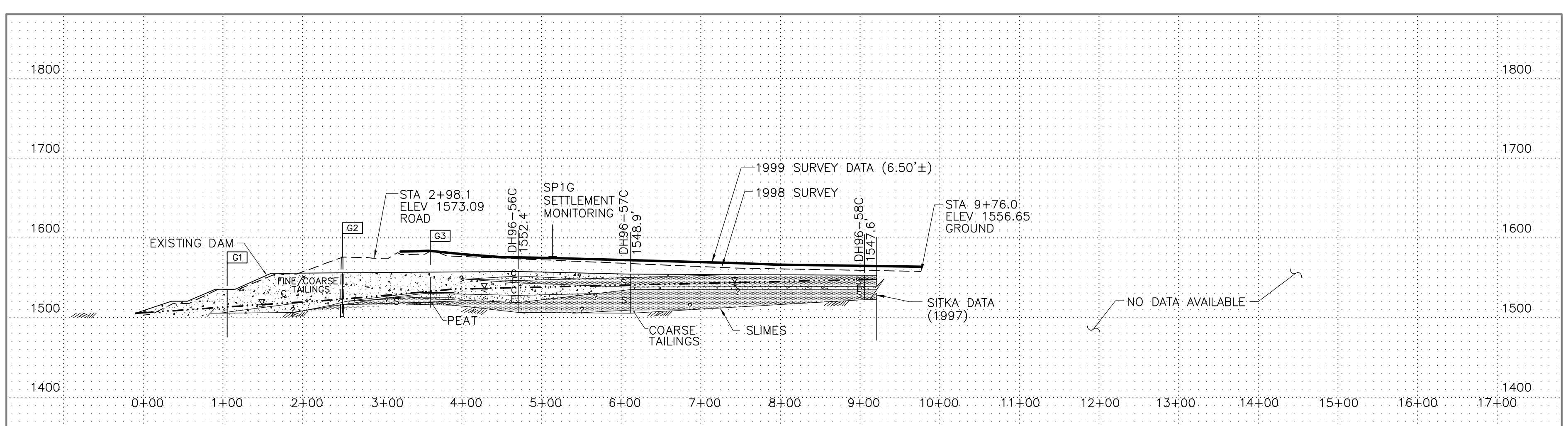
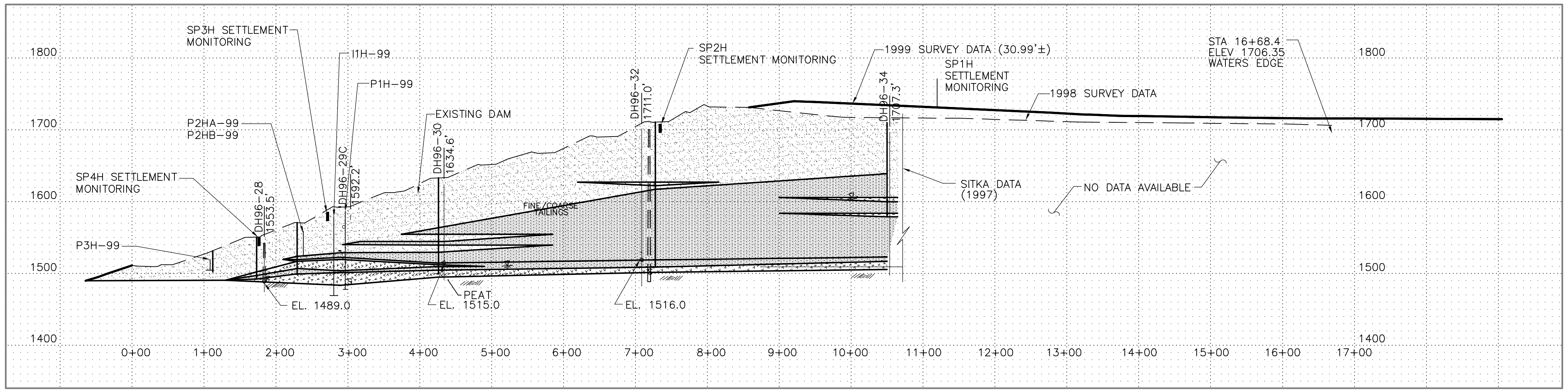


CROSS SECTION G

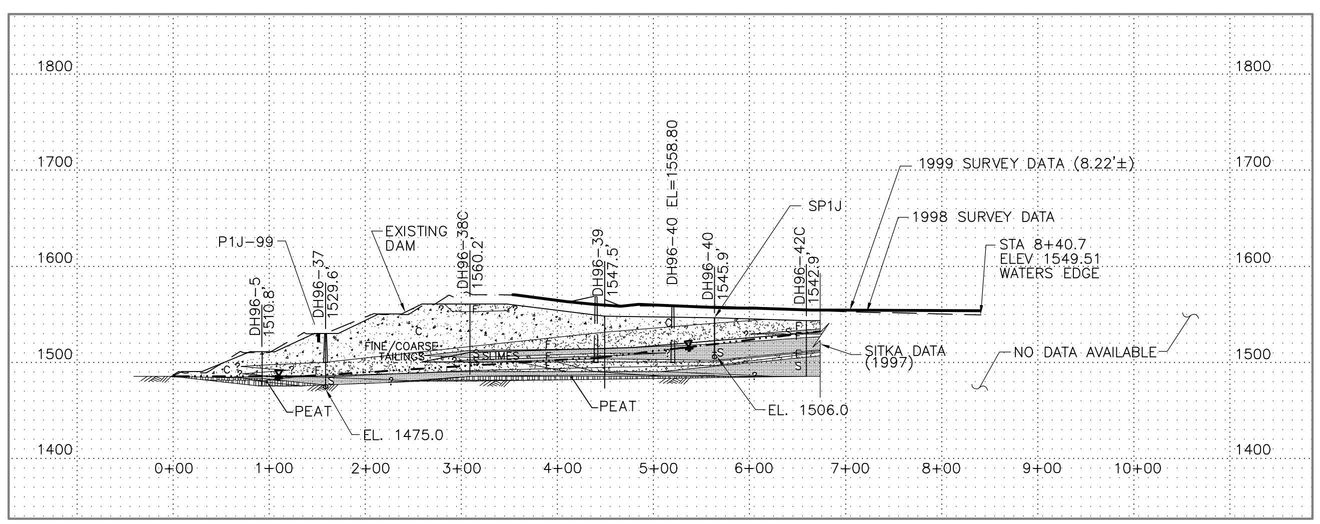
RLG M:\CAD\2369862\22637_1.DWG Plot at 1 01/19/2006 10:18:31

Figure 4

EXISTING TAILINGS BASIN
CROSS SECTIONS E, F, AND G



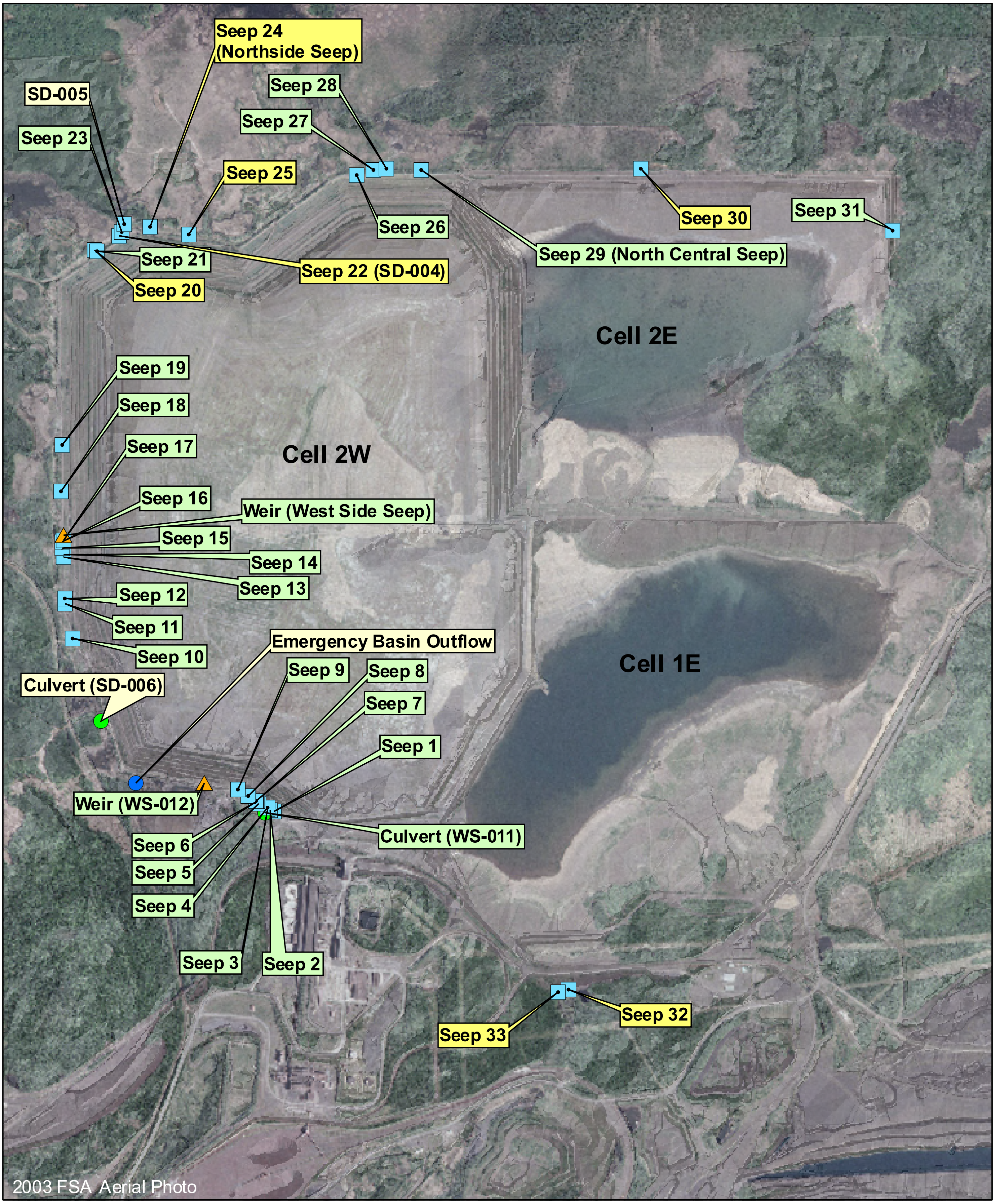
CROSS SECTION H



CROSS SECTION J

Figure 5

EXISTING TAILINGS BASIN
CROSS SECTIONS H AND J



Seeps

- Culvert
- Emergency Basin Outflow
- Seeps
- Weirs

- Surface Discharge
- Flow Not Measurable or No Flow
- Active Seep

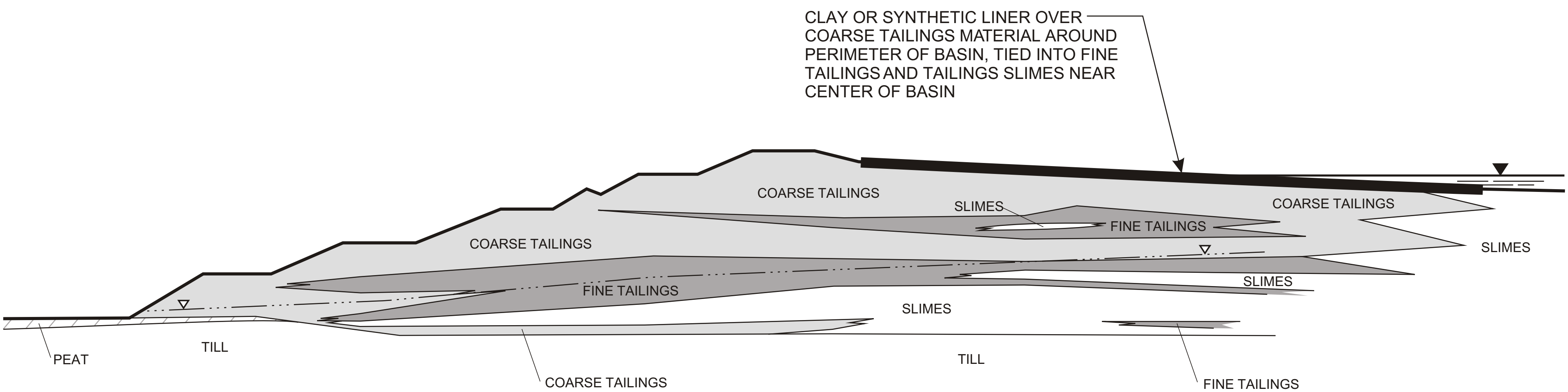
Note: Seep data provided by Northeast Technical Services

N

0 1,000 2,000 4,000

Feet

Figure 6
Seep Locations
Tailings Basin

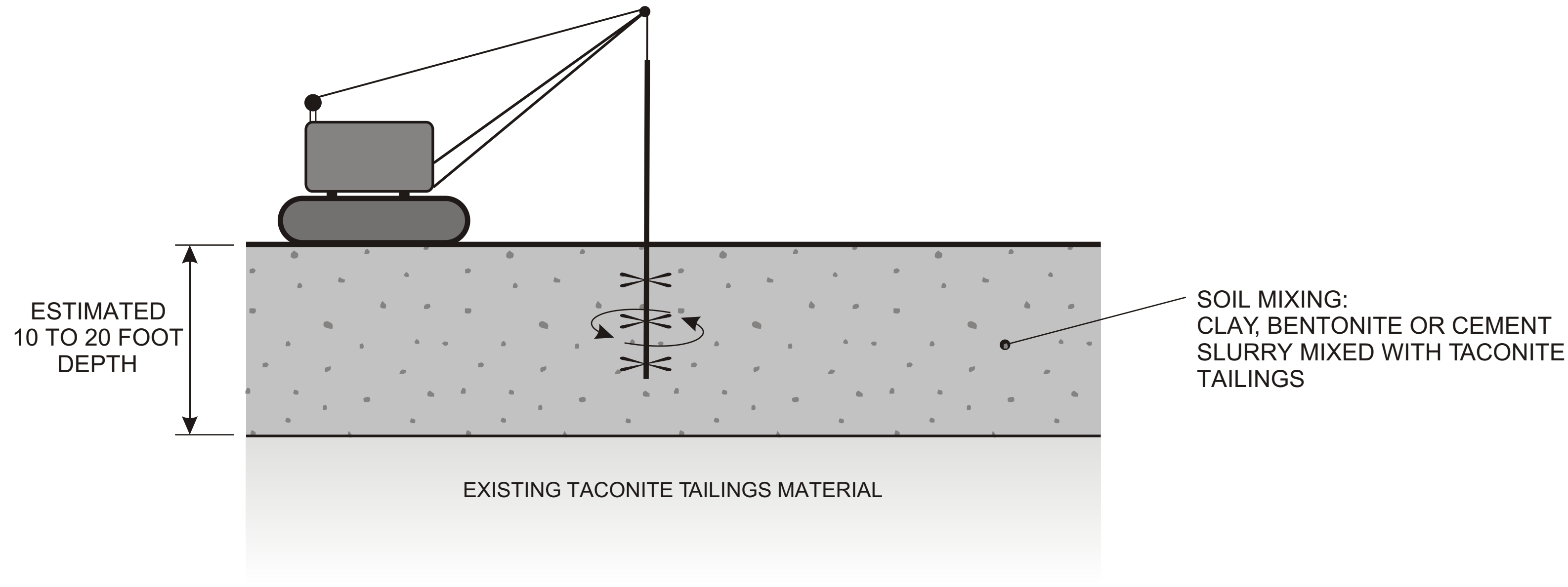


TYPICAL CROSS SECTION

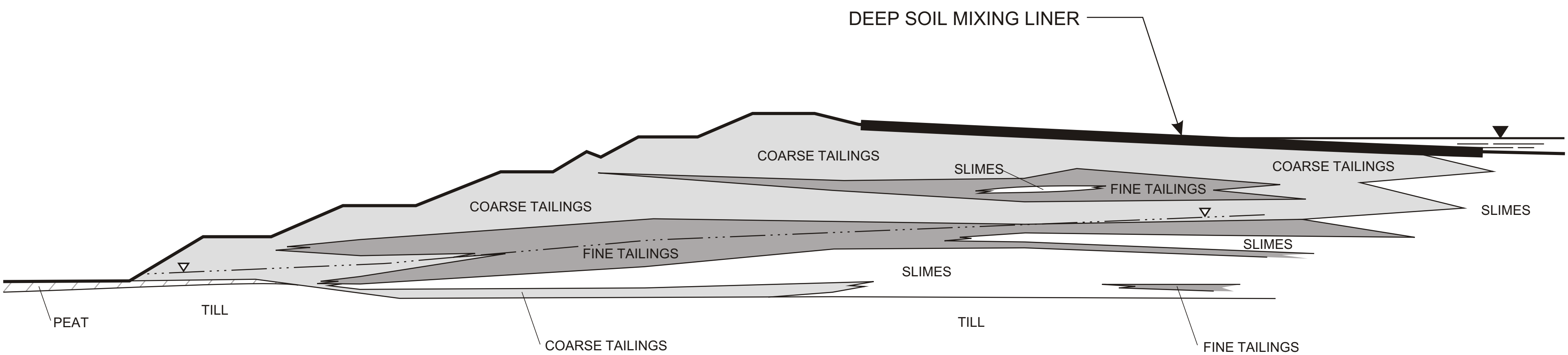
Figure 7

FINE TAILINGS LINER

P:23\69\862\Figures_Graphics\Deep Soil Mixing Liner.CDR RLG 05-15-06



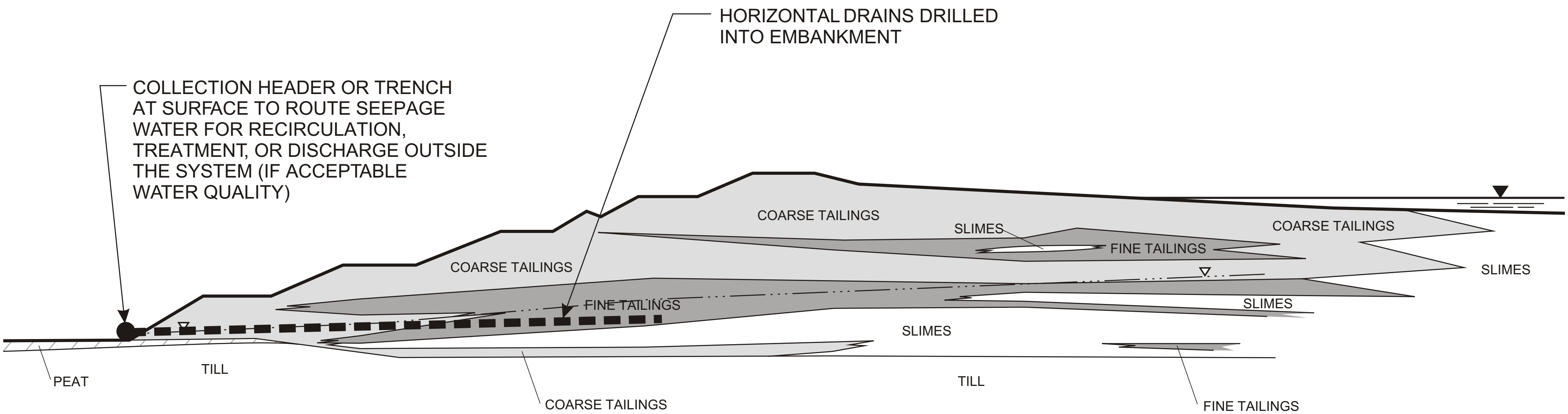
DEEP SOIL MIXING



TYPICAL CROSS SECTION

Figure 8

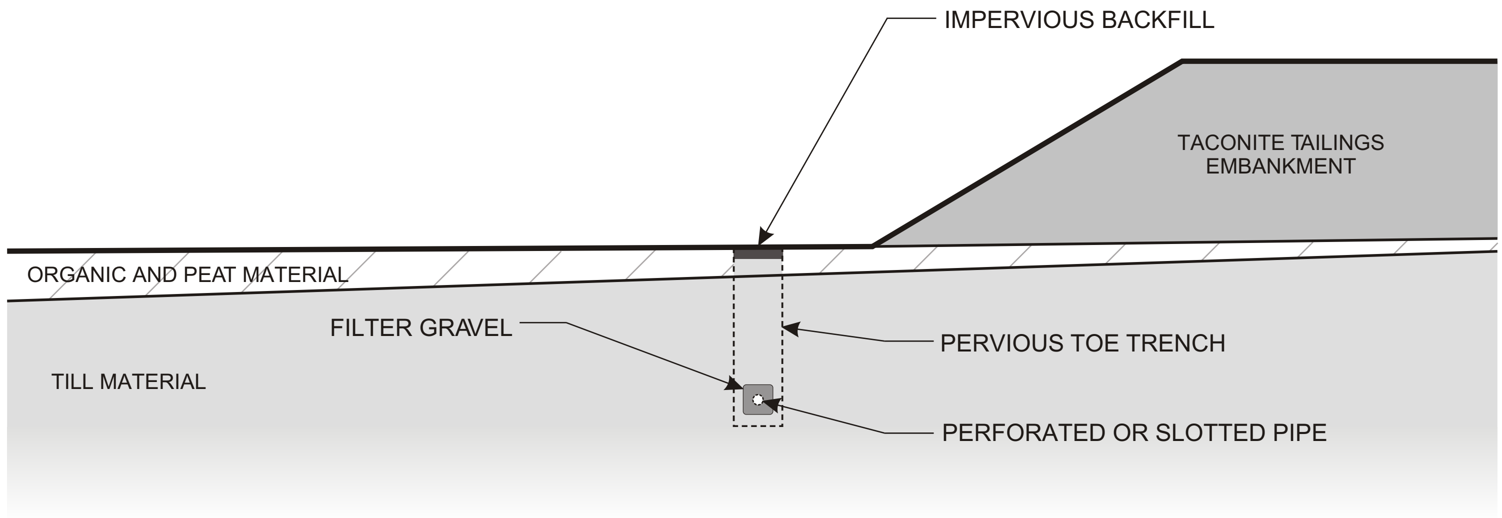
DEEP SOIL MIXING LINER



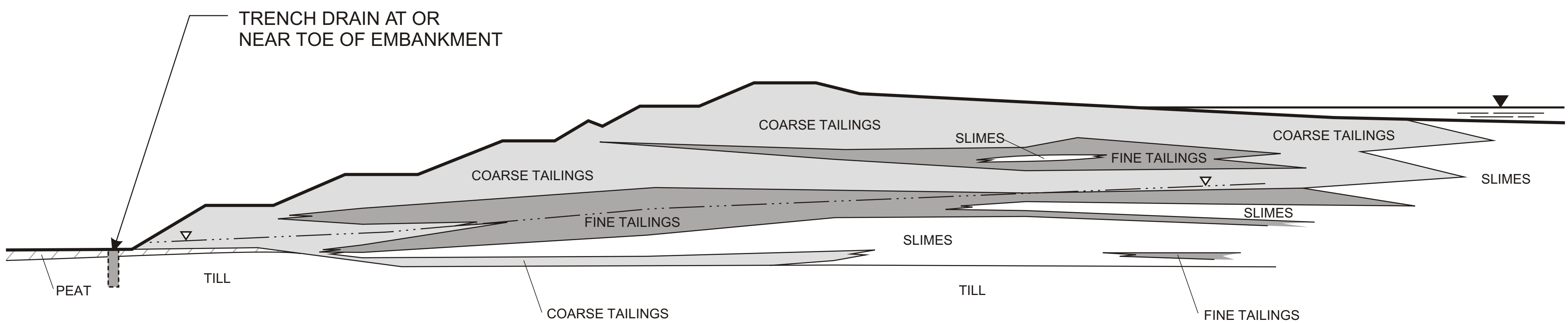
TYPICAL CROSS SECTION

Figure 9

HORIZONTAL DRAIN



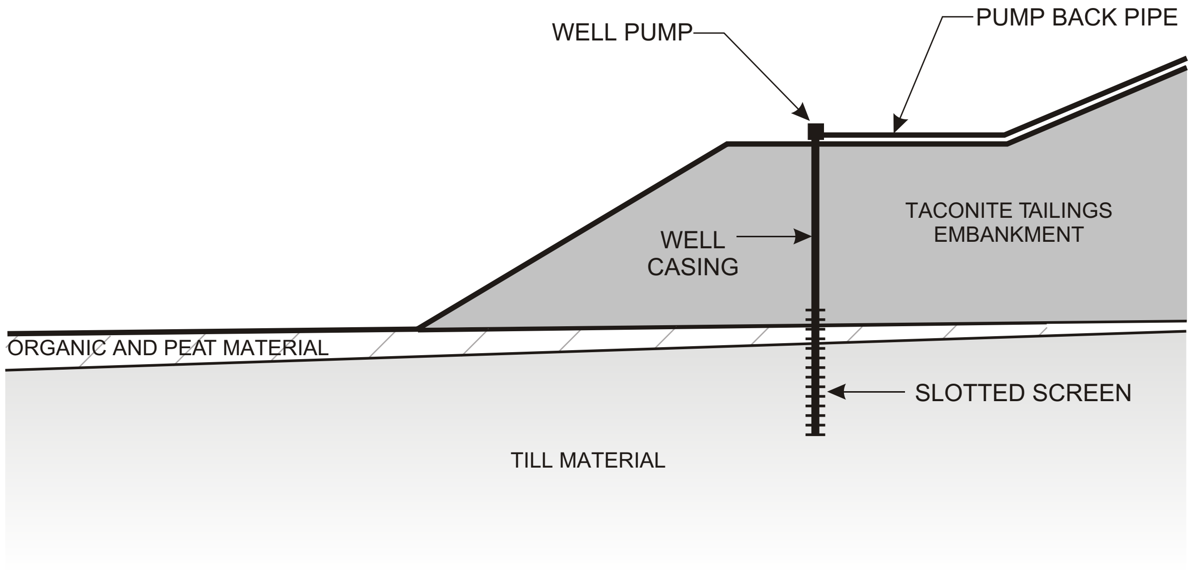
TRENCH DRAIN



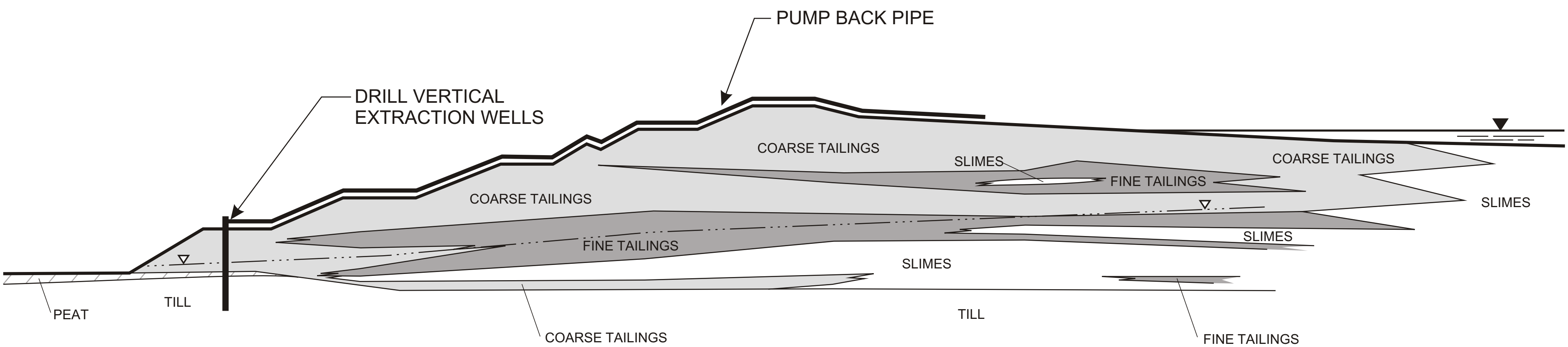
TYPICAL CROSS SECTION

Figure 10

SEEPAGE COLLECTION TRENCH



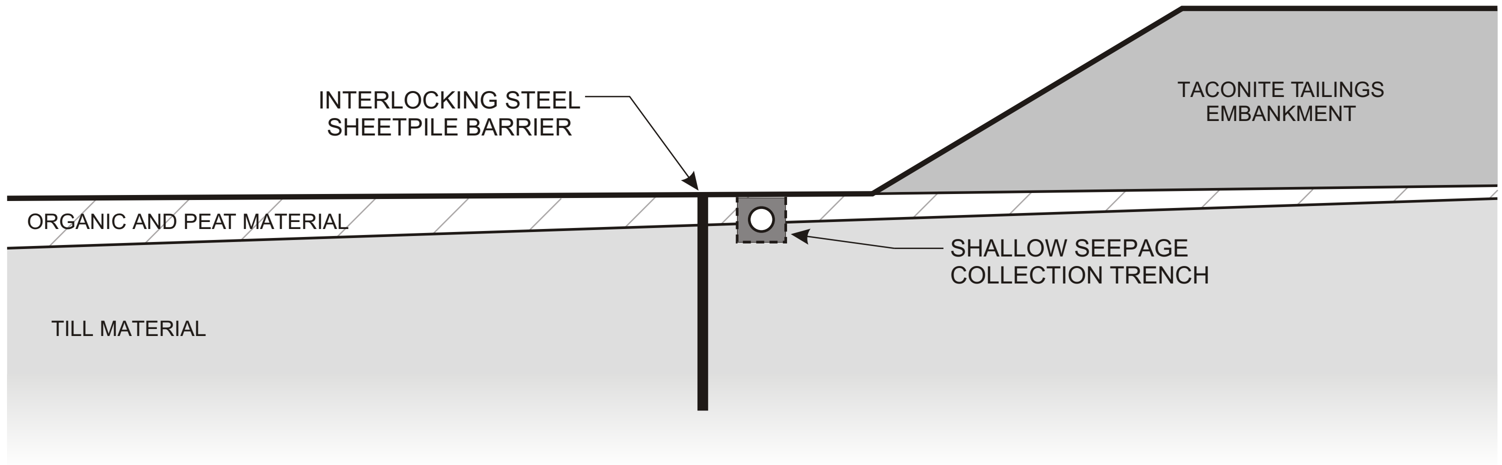
VERTICAL EXTRACTION WELL



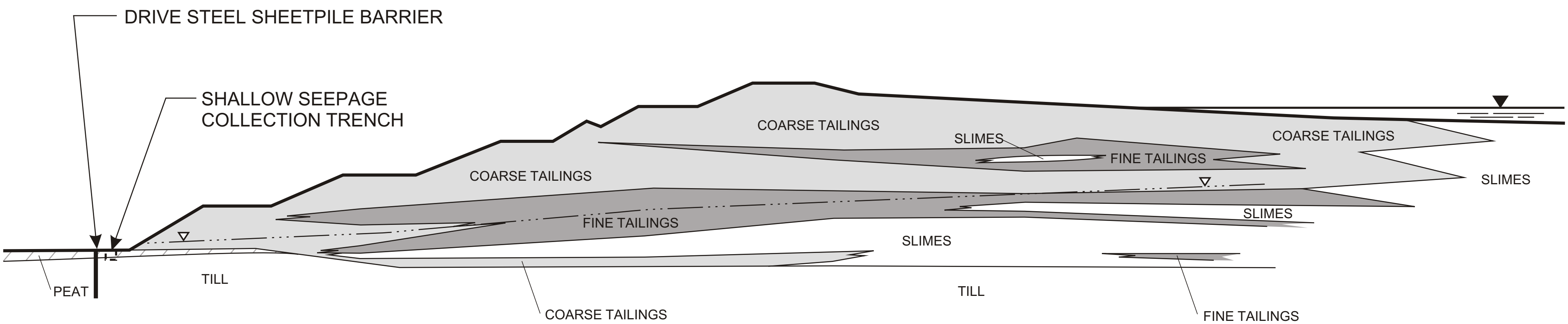
TYPICAL CROSS SECTION

Figure 11

VERTICAL EXTRACTION WELLS



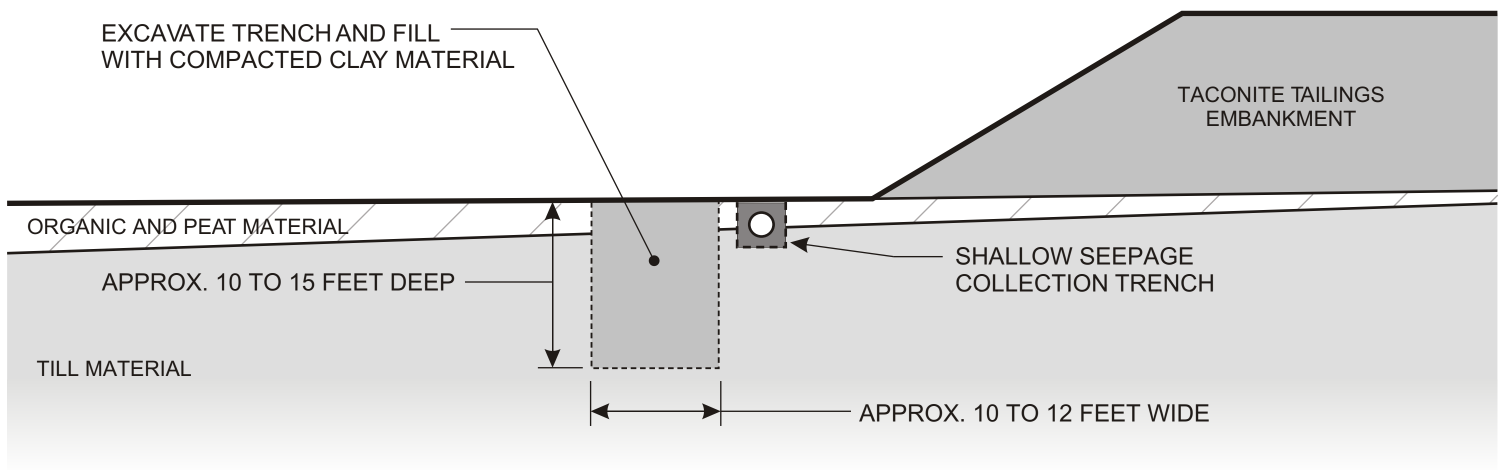
STEEL SHEETPILE CUTOFF



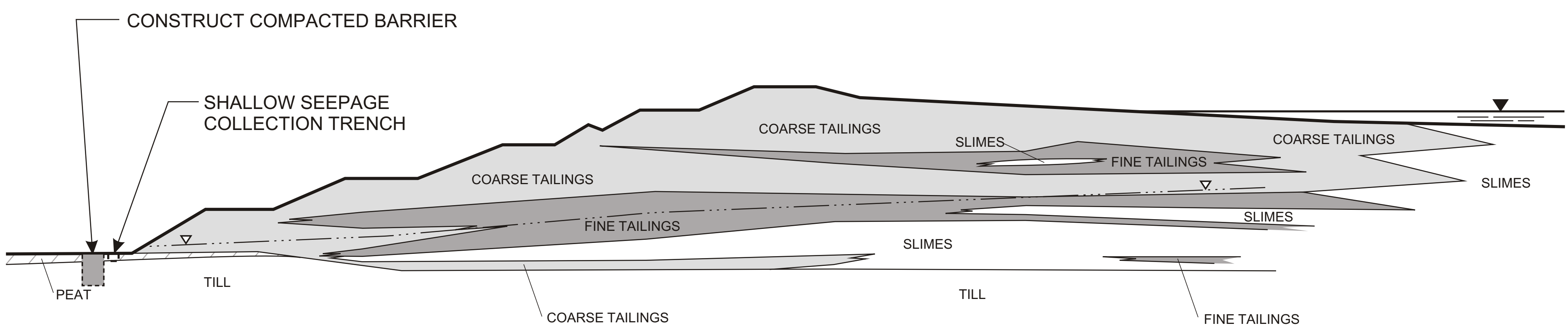
TYPICAL CROSS SECTION

Figure 12

STEEL SHEETPILE CUTOFF



COMPACTED BARRIER

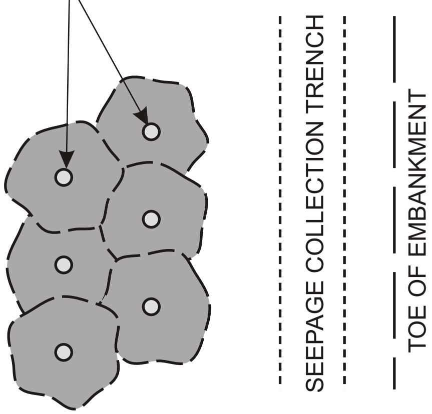


TYPICAL CROSS SECTION

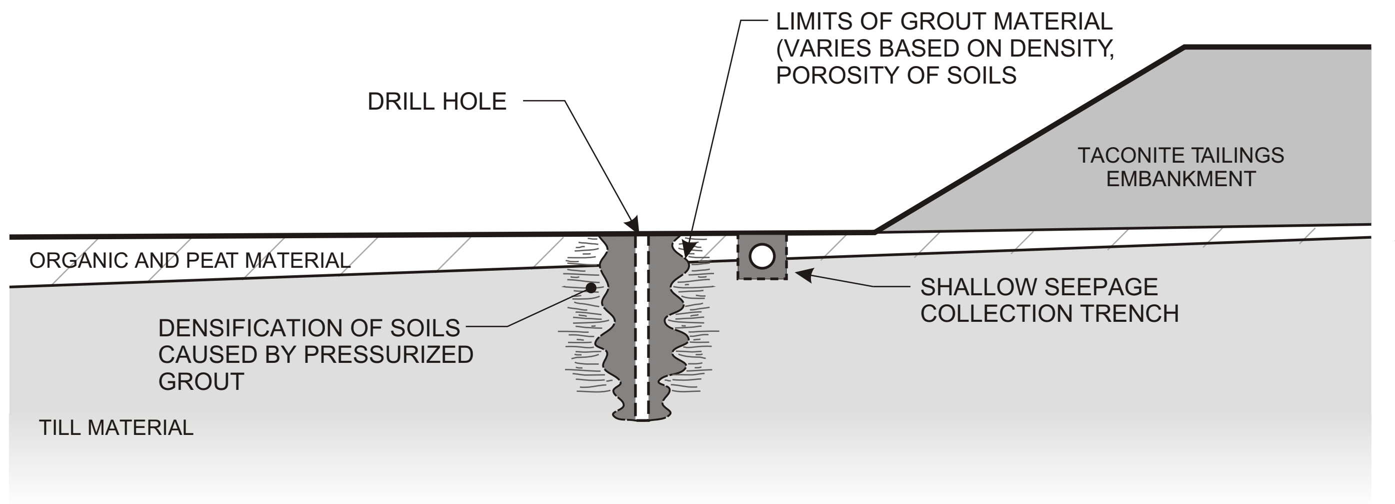
Figure 13

COMPACTED BARRIER

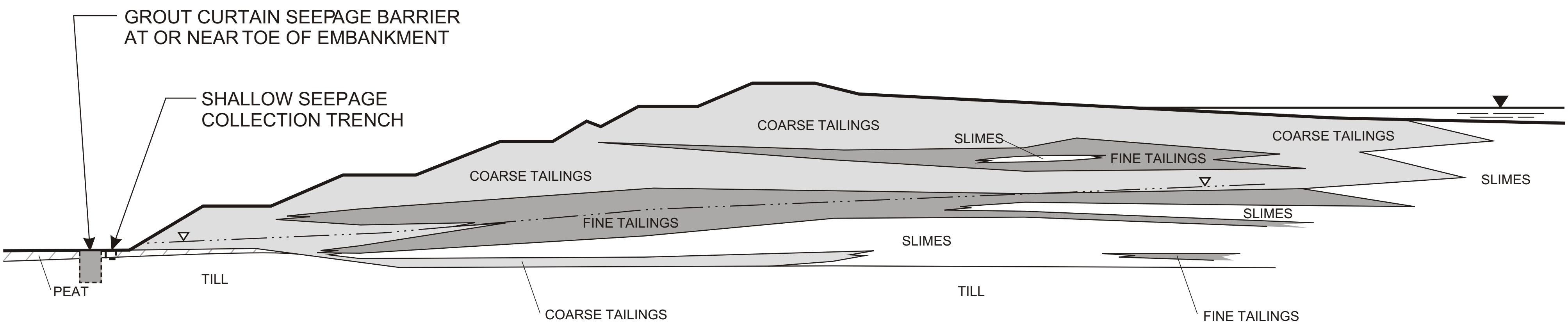
P:23\69\862\Figures_Graphics\Grout Curtain.CDR RLG 5-15-06



GROUT CURTAIN PLAN



GROUT CURTAIN SECTION



TYPICAL CROSS SECTION

Figure 14

GROUT CURTAIN

P:23\69\862\Figures_Graphics\Mixed in Place Overlapping Piles.CDR RLG 5-15-06

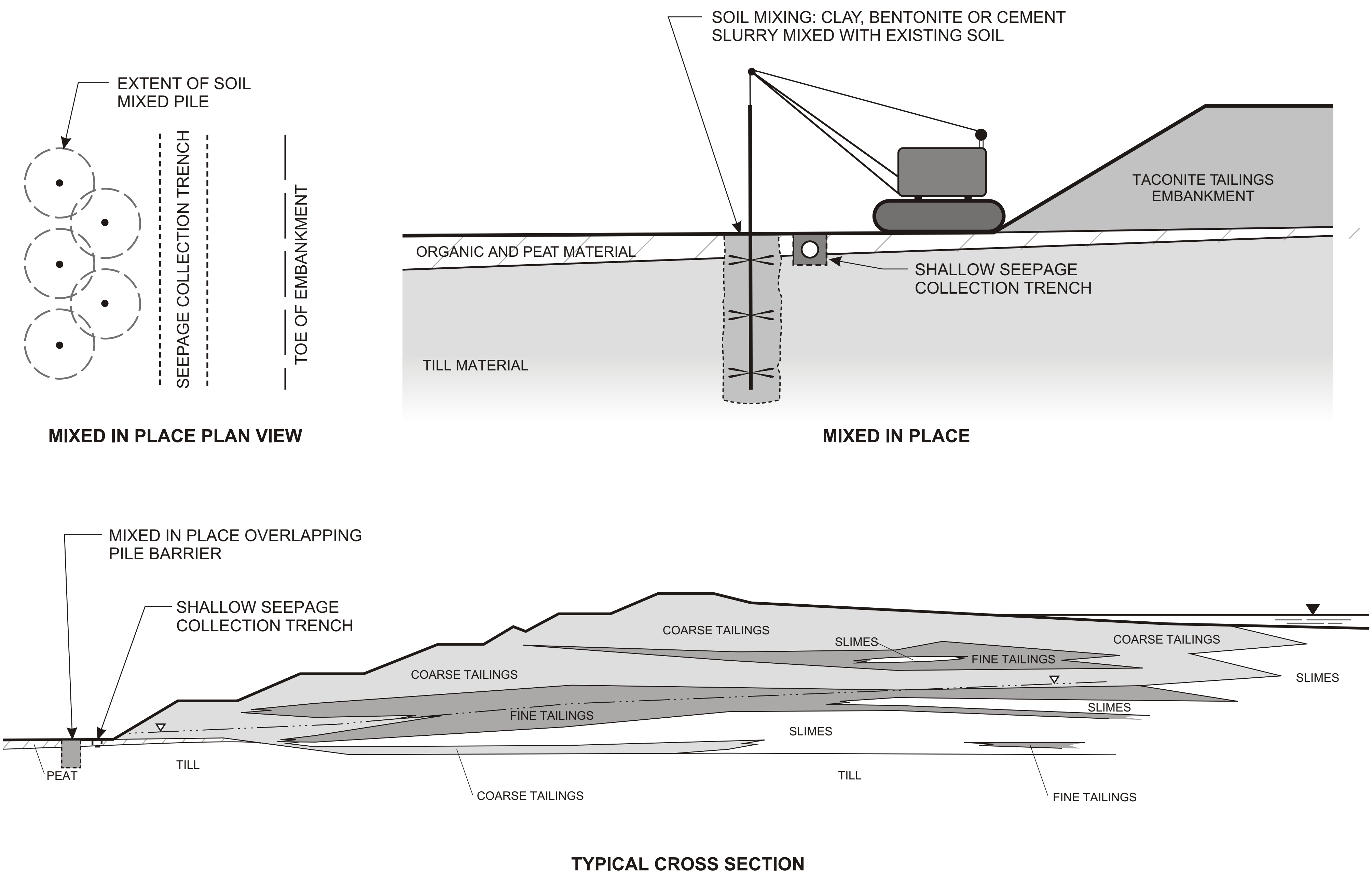
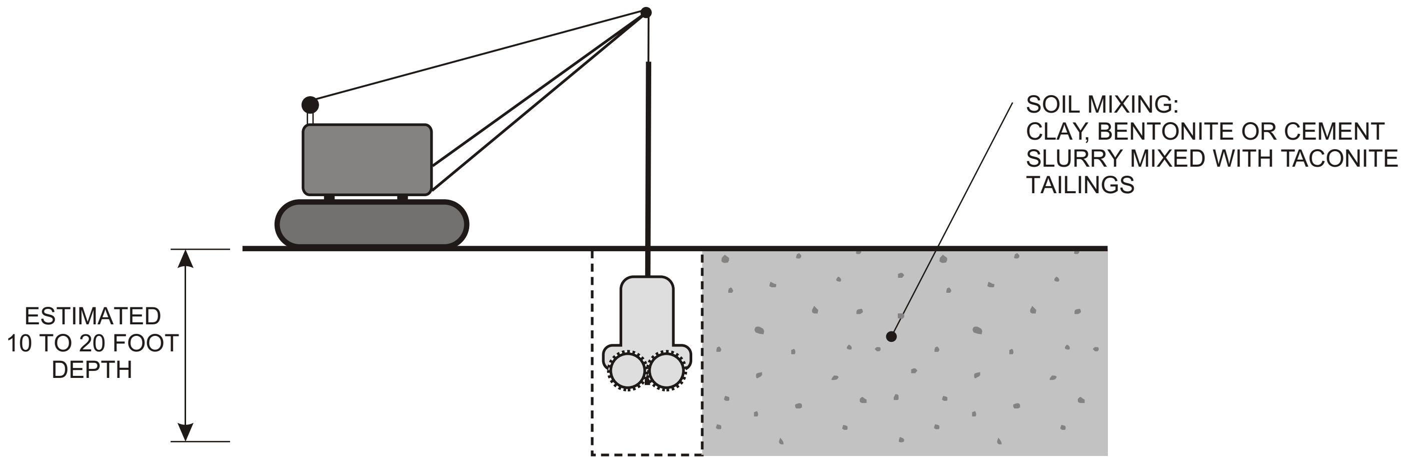


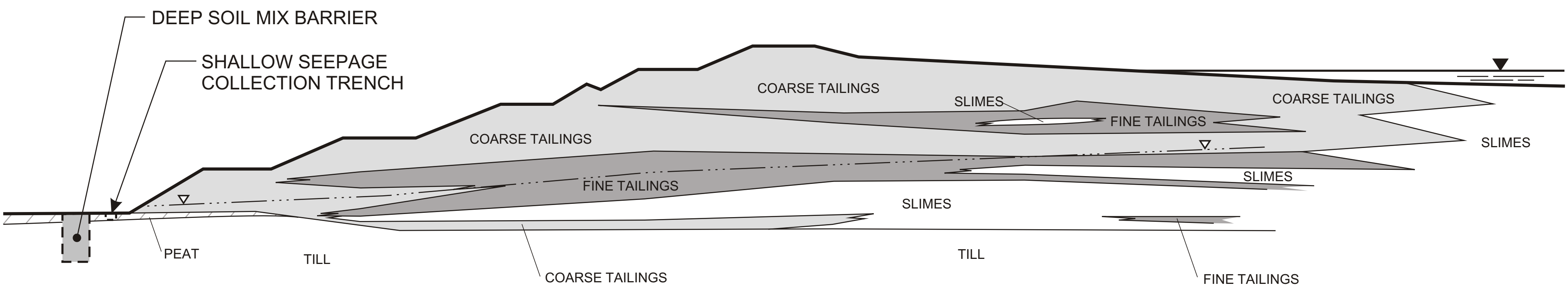
Figure 15

MIXED IN PLACE
OVERLAPPING PILES

P:23\69\862\Figures_Graphics\Deep Soil Mix Barrier.CDR RLG 5-15-06



DEEP SOIL MIX BARRIER

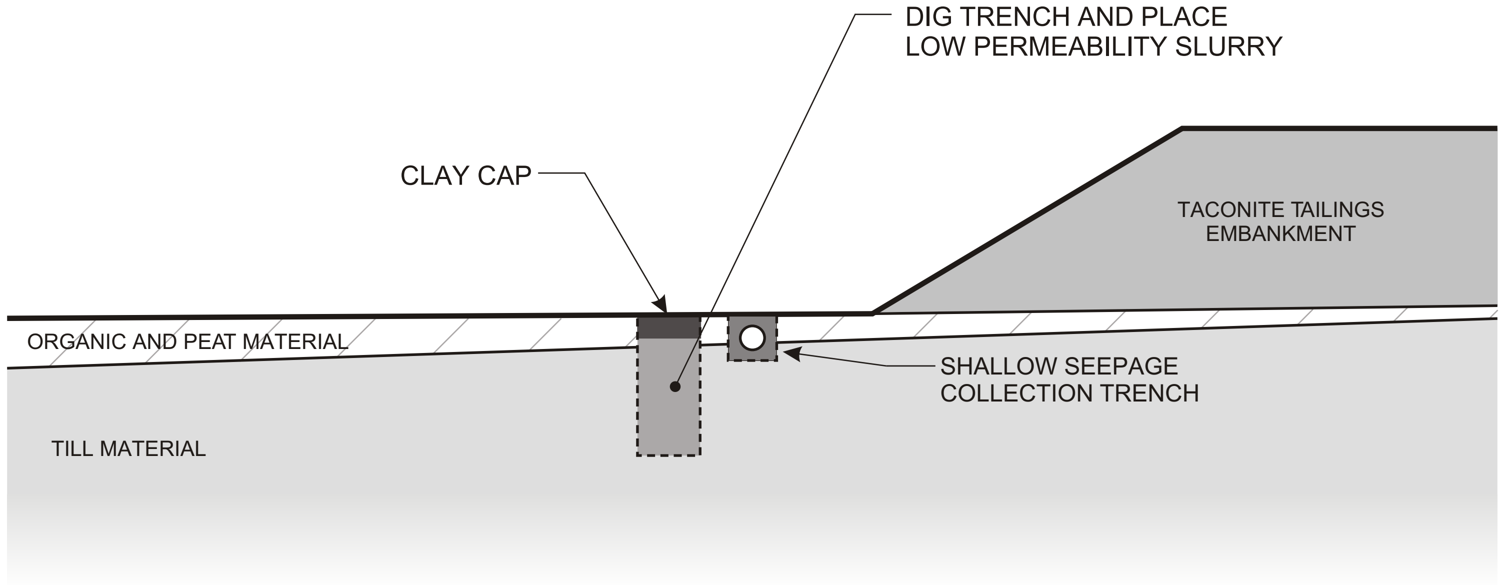


TYPICAL CROSS SECTION

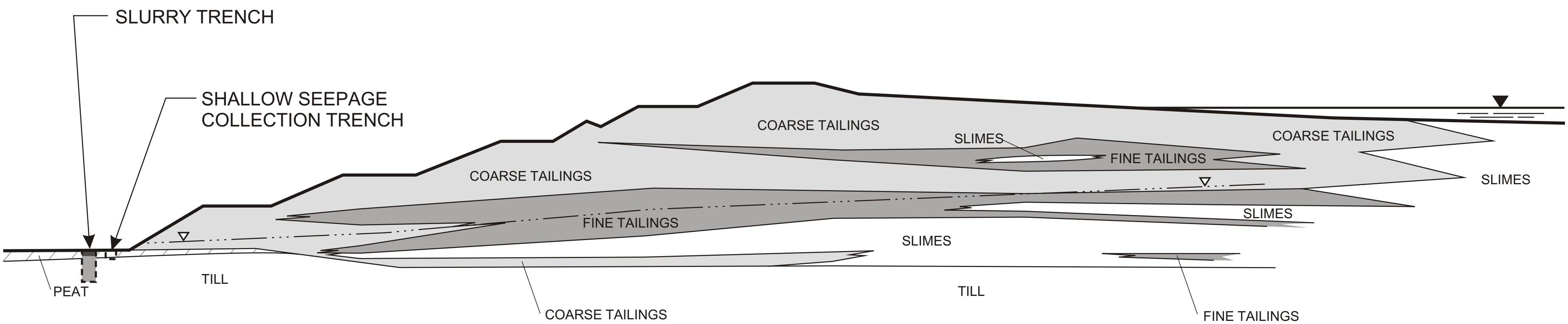
Figure 16

DEEP SOIL MIX BARRIER

P:23\69\862\Figures_Graphics\Slurry Trench.CDR RLG 5-15-06



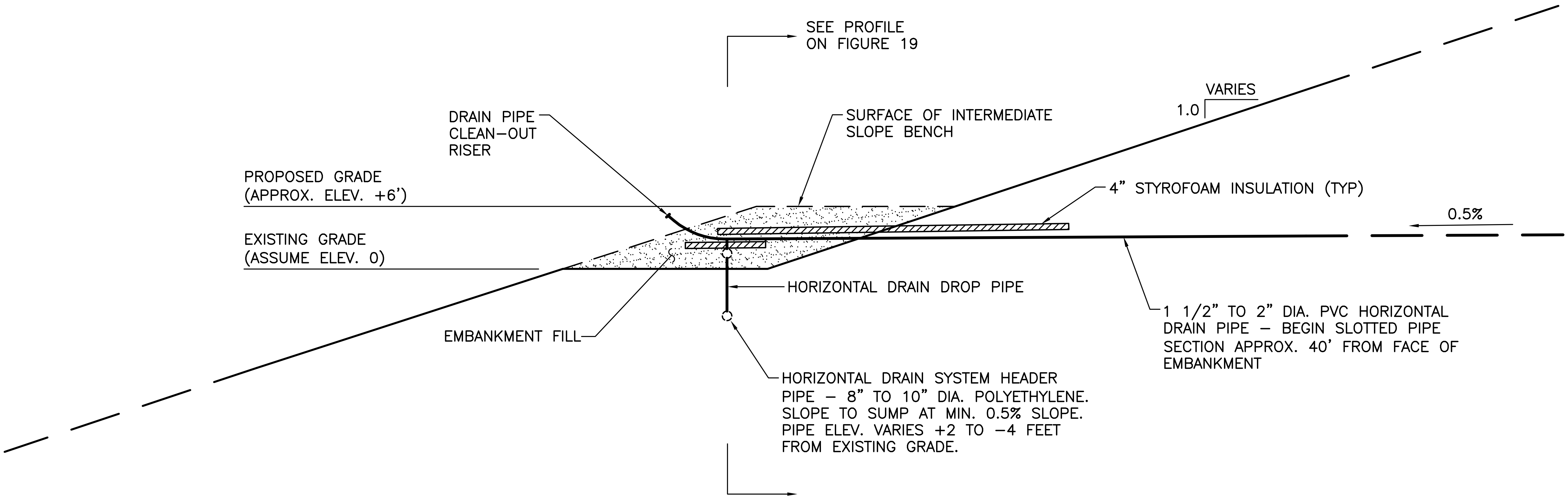
VINYL SHEETPILE CUTOFF



TYPICAL CROSS SECTION

Figure 17

SLURRY TRENCH



NOTES:

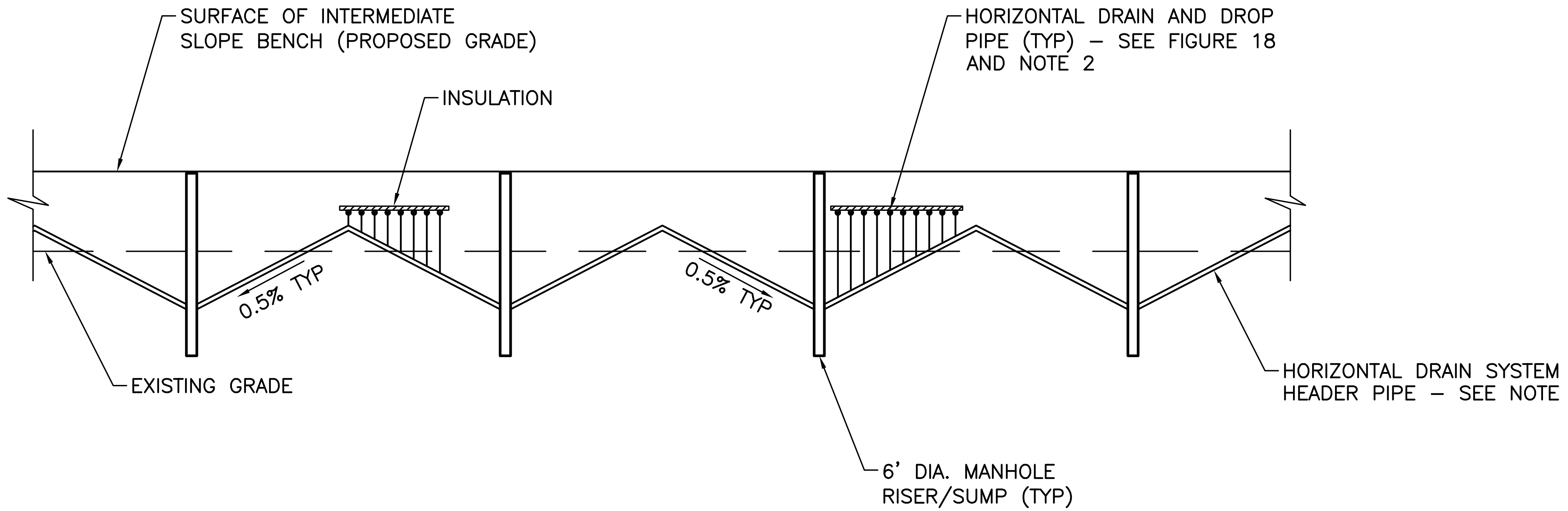
1. GRADE EXISTING ROADWAY TO ACHIEVE CONSTANT, UNIFORM GRADE ON ROADWAY SURFACE PRIOR TO INSTALLATION OF HORIZONTAL DRAINS.

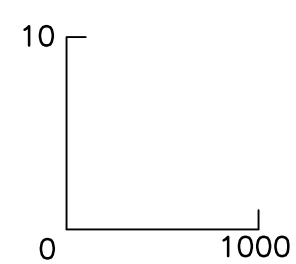
2. DISCHARGE HEADER PIPE TO SUMP. SEE FIGURE 20.

0 10 20
SCALE IN FEET

Figure 18

TYPICAL CROSS SECTION
HORIZONTAL DRAIN
Tailings Basin Seepage Collection System



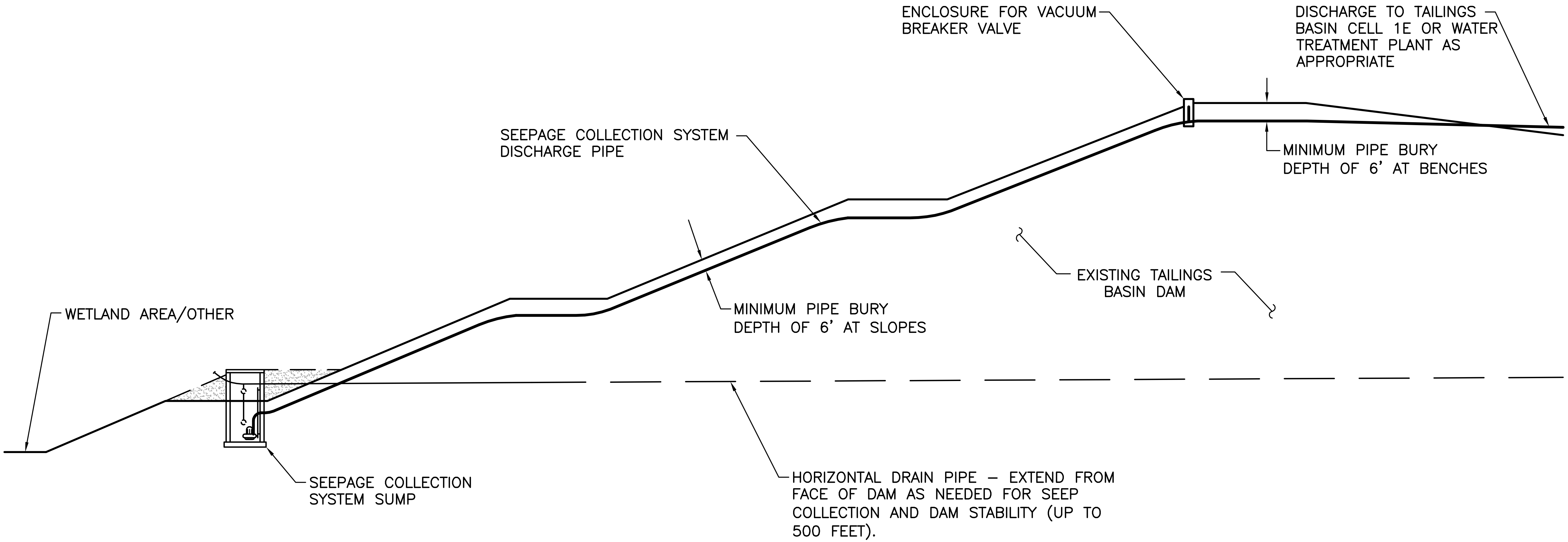


NOTES:

1. THIS FIGURE DEPICTS THE CONCEPT–LEVEL HEADER PIPE AND SUMP PROFILE.
2. SYSTEM TO BE INSATLLED IN INCREMENTS AS NEEDED TO COLLECT SEEPS AND/OR IMPROVE SLOPE STABILITY.

Figure 19

PROFILE
HORIZONTAL DRAIN
Tailings Basin Seepage Collection System



NOTES:

1. SLOPE ANGLES AND BENCH WIDTHS ON TAILINGS BASIN DAMS VARY. SLOPE ANGLE SHOWN IS 2.5H:1V. BENCH WIDTH SHOWN IS 20 FEET.
2. INSULATE DISCHARGE PIPE AS NEEDED TO PREVENT WINTER FREEZE–UP.

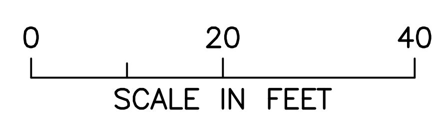
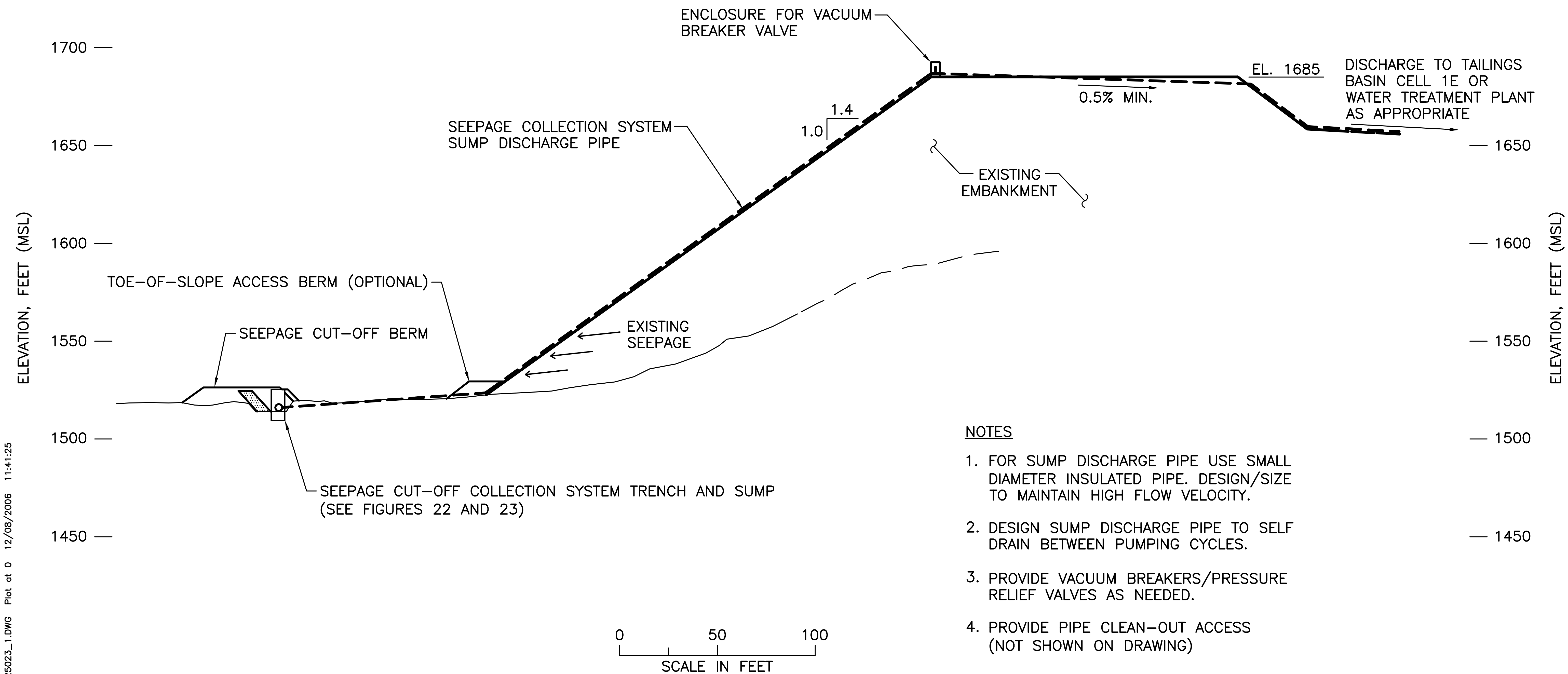


Figure 20

TYPICAL CROSS SECTION
SUMP AND DISCHARGE PIPE
Tailings Basin Seepage Collection System



NOTES

1. FOR SUMP DISCHARGE PIPE USE SMALL DIAMETER INSULATED PIPE. DESIGN/SIZE TO MAINTAIN HIGH FLOW VELOCITY.

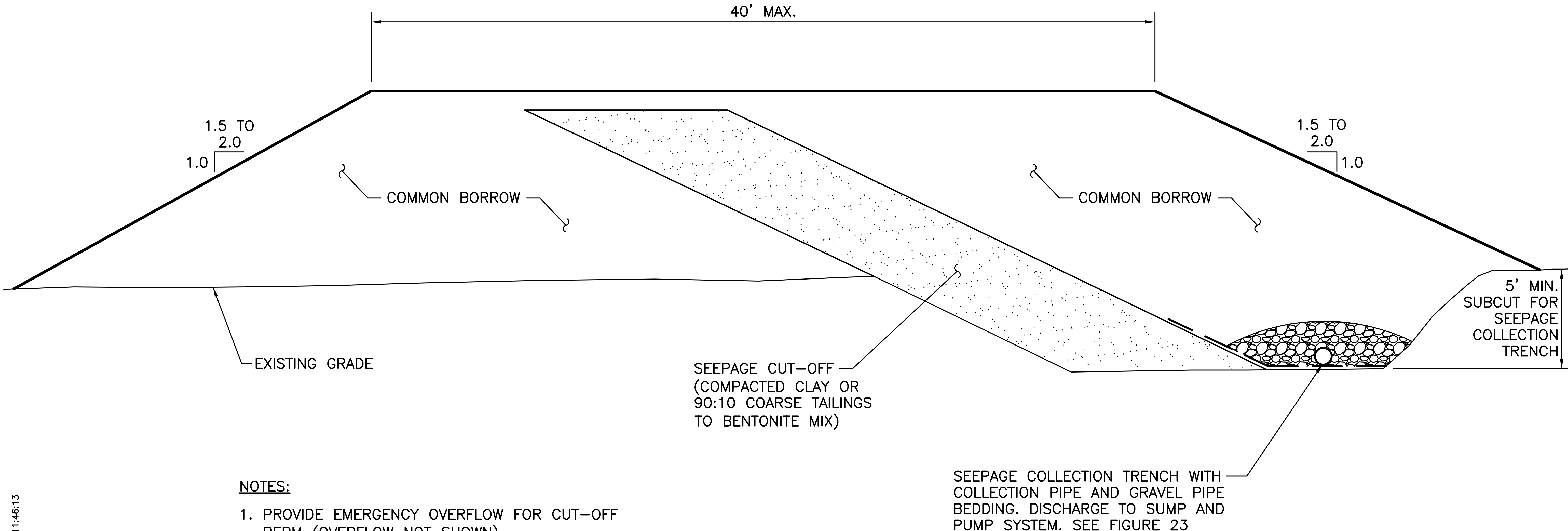
2. DESIGN SUMP DISCHARGE PIPE TO SELF DRAIN BETWEEN PUMPING CYCLES.

3. PROVIDE VACUUM BREAKERS/PRESSURE RELIEF VALVES AS NEEDED.

4. PROVIDE PIPE CLEAN-OUT ACCESS (NOT SHOWN ON DRAWING)

Figure 21

CONCEPT PLAN
SEEPAGE BARRIER AND COLLECTION SYSTEM
Second Creek Seepage Collection System



NOTES:

1. PROVIDE EMERGENCY OVERFLOW FOR CUT–OFF BERM (OVERFLOW NOT SHOWN).
2. SEED, FERTILIZE, AND MULCH SURFACE OF COMPLETED SEEPAGE CUT–OFF BERM.

0 5 10

SCALE IN FEET

Figure 22

TYPICAL SECTION AT
SEEPAGE CUT–OFF BERM
Second Creek Seepage Collection System

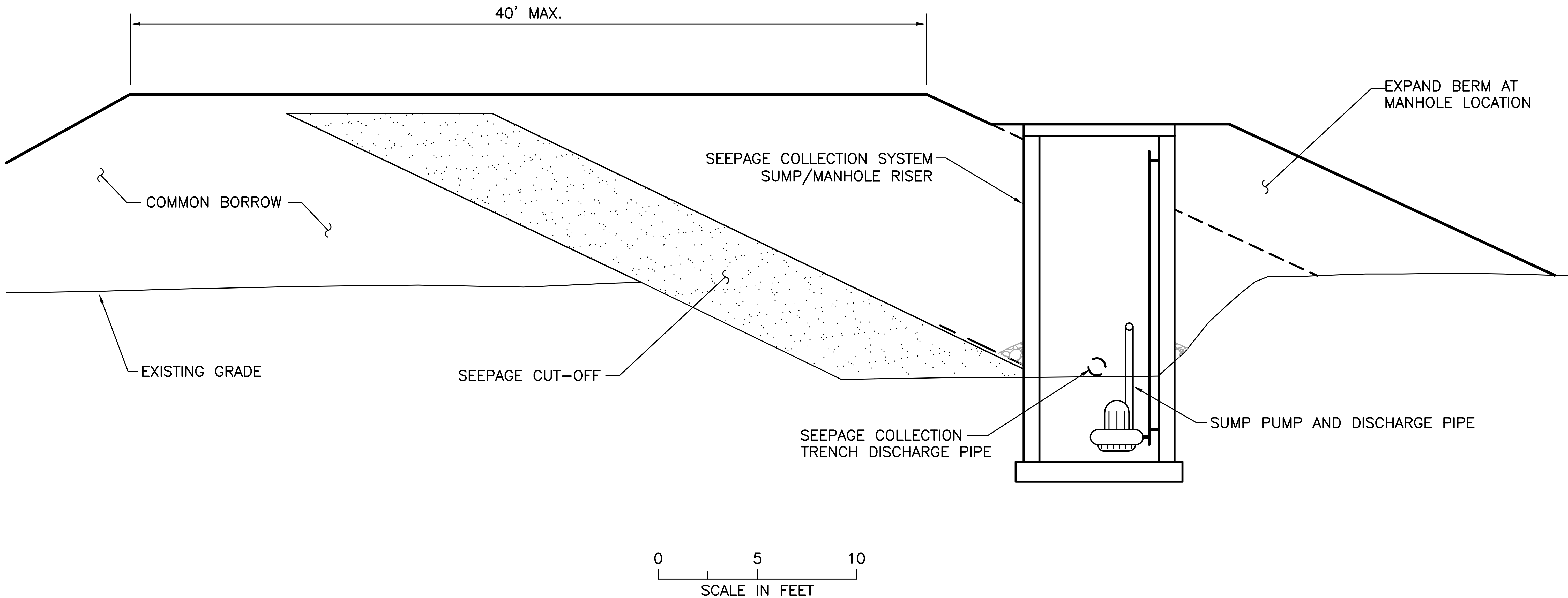


Figure 23

TYPICAL SECTION
SEEPAGE COLLECTION SYSTEM SUMP
Second Creek Seepage Collection System

Appendix A

Scope of Work for RS55T (from Final Scoping Decision)

NorthMet Project – Technical Design Evaluation Report – Scope of Work
October 24, 2005

Name: Tailings Basin Modifications **Due Date:** 3/1/06

Timeline Reference: RS55 **Scoping Decision Reference:** 2.5, 2.7 and 3.3.4

Objective:

Study and report on modifications to the existing tailings basin that would minimize water release via seepage from the tailings basin through seepage collection and recovery, and seepage prevention.

Scope:

Phase 1 of the study will develop conceptual plans for minimizing water release via seepage from the tailings basin. The development of alternatives will be divided into two fundamental approaches: seepage collection and recovery, and seepage prevention. Recommended solutions are likely to represent combinations of these approaches applied in different locations. An important consideration will be preventing or minimizing groundwater drawdown from surrounding wetlands.

Seepage collection will focus on:
1. Collecting water from existing drain pipes (including refurbishment of drain pipes) on the southern and western side of Cell 2W and northern side of Cells 2E and 2W
2. Modifying seepage collection to include additional horizontal or vertical drains
3. Adding a collection system for the uncollected seepage at the south side of Cell 1E
4. Extending the ditching system at the toes of the Cells 2E and 2W dams.
5. Avoidance and minimization of wetland impacts for any seepage collection approach that would draw down wetlands groundwater levels.

Seepage prevention will focus on options for reducing seepage from the basin by adding a liner system. Liner options will include:
1. Lining the more porous perimeter embankments of one or more of the existing cells
2. Entirely lining one or more of the existing cells
3. Adding clay to tailings to reduce permeability

Phase 2 of the study will evaluate the effectiveness, implementability and cost of the options developed in Phase 1, both separately and in combination. Combinations will be developed based on nature of seepage, embankment, and foundation conditions, and are likely to vary along different segments of the perimeter embankments. Trafficability for construction work will be considered based on phreatic surface within the basin, existing elevations and other geotechnical issues being developed as part of the Tailings Basin Geotechnical study. Available information on the tailings basin water level and flow paths as well as hydraulic characteristics of underlining material below the collection ditch or the basin (foundation materials) will be utilized.

Existing/Provided Information:

Details will be provided in the following reports or studies:

1. Process Design – Tailings Basin Water Balance
2. Process Design – Tailings Basin
3. Tailings Basin Geotechnical
4. Map and data for existing seeps
5. East Range Hydrology Study
6. Physical characteristics of existing LTVSMC tailings

Deliverable:

A report summarizing the options for seepage reduction and seepage recovery improvement (study details to be included as an appendix) and ranking them on effectiveness, implementability and cost is required. Highest effectiveness, easiest implementability and lowest cost would be an optimum solution. Wherever possible quantitative measures (ie gals/minute or mgd for seepage) of effectiveness will be provided. Cost will include construction, operation and post closure costs.

Appendix B

Cost Information

PolyMet RS 55 - Tailing Basin Modifications to Minimize Water Release via Seepage

Appendix B - Cost Estimates

	Units	Est Q	Unit Rate	Extension	RS Means Reference	Description of work item
Seepage Collection Approaches						
Seep Collection and Management System						
Header Pipe (graded to drain)	lf	100	$20.50	$2,050	02510.760.0500	12" dia HDPE pipe
Seep Pipe Taps	ea	2	$565.00	$1,130	02510.760.02600	12" tee
			Unit Cost per 100-foot Alignment:		**$3,180**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
		Unit Cost (LS) per Collection Sump / Pump-Back:			**$54,325**	
			Total:	**$57,505**		
Horizontal Drains						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Horizontal Drain Installation	lf	1000	$21.50	$21,500	02445.200.1000	Small diameter boring, 3" sand soil
Horizontal Drain Pipe	lf	1000	$2.76	$2,760	02620.660.0030	3" dia perforated plastic tubing
Header Pipe (graded to drain)	lf	100	$20.50	$2,050	02510.760.0500	12" dia HDPE pipe
Seep Pipe Taps	ea	2	$565.00	$1,130	02510.760.02600	12" tee
			Unit Cost per 100-foot Alignment:		**$27,588**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
		Unit Cost (LS) per Collection Sump / Pump-Back:			**$54,325**	
				$81,913		
Seepage Collection Trench						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Trench excavation	cy	222	$3.24	$720	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	30	$25.50	$756	02620.300.0400	pea stone
Slotted / perforated drain pipe	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
Granular fill material	cy	193	$6.15	$1,184	02315.610.3100	2.25 cy bucket, 200' haul dist
			Unit Cost per 100-foot Alignment:		**$3,084**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
		Unit Cost (LS) per Collection Sump / Pump-Back:			**$54,325**	
				$57,409		
Vertical Extraction Well Points						
Drilling and casing	lf	600	$45.00	$27,000	02520.510.0100	6" well
Well Screens	lf	12	$152.00	$1,824	02520.510.8150	6" well screen
Pump system				$0		
Pump	ea	2	$7,425.00	$14,850	02520.510.3100	30HP, 100 to 300 gpm up to 500' head
Pipe	lf	1600	$9.65	$15,440	02510.760.0200	6" dia HDPE SDR21
			Unit Cost per 100-foot Alignment:		**$59,114**	
				$59,114		
Seepage Barrier Approaches						
Steel Sheetpile Cutoff						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Steel sheetpile installation	sf	3000	$26.50	$79,500	02250.400.1800	25' deep steel sheet pile
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
			Unit Cost per 100-foot Alignment:		**$81,840**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		

PolyMet RS 55 - Tailing Basin Modifications to Minimize Water Release via Seepage

Appendix B - Cost Estimates

	Units	Est Q	Unit Rate	Extension	RS Means Reference	Description of work item
Seepage Collection Approaches						
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
Unit Cost (LS) per Collection Sump / Pump-Back:					**$54,325**	
				$136,165		
Compacted Barrier of Impervious Material						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Trench Excavation	cy	400	$3.24	$1,296	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Clay backfill	cy	400	$23.50	$9,400	RS28 Table J-1	
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
Unit Cost per 100-foot Alignment:					**$13,036**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
Unit Cost (LS) per Collection Sump / Pump-Back:					**$54,325**	
				$67,361		
Grout Curtain						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Grout holes	cy	353.4188	$500.00	$176,709		Staff est (Contreras) 3" dia hole, expanding to 9" dia
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
Unit Cost per 100-foot Alignment:					**$179,049**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
Unit Cost (LS) per Collection Sump / Pump-Back:					**$54,325**	
				$233,374		
Mixed-in-Place Overlapping Piles						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Special equipment mobilization	ls	1	$25,000.00	$25,000	"Landslides in Practice", pg 379	
Grout piles	cy	698.1111	$250.00	$174,528	"Landslides in Practice", pg 379	
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
Unit Cost per 100-foot Alignment:					**$201,868**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
Unit Cost (LS) per Collection Sump / Pump-Back:					**$54,325**	
				$256,193		
Deep Soil Mix Barrier						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Special equipment mobilization	ls	1	$25,000.00	$25,000		"Landslides in Practice", pg 379
Deep soil mix barrier	sf	3000	$52.00	$156,000		"Landslides in Practice", pg 379
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		

PolyMet RS 55 - Tailing Basin Modifications to Minimize Water Release via Seepage

Appendix B - Cost Estimates

	Units	Est Q	Unit Rate	Extension	RS Means Reference	Description of work item
Seepage Collection Approaches						
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
		Unit Cost per 100-foot Alignment:			**$183,340**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
	Unit Cost (LS) per Collection Sump / Pump-Back:				**$54,325**	
				$237,665		
Slurry Trench						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Trench Excavation	cy	4500	$3.24	$14,580	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Slurry fill	cf	3600	$32.50	$117,000	02660.600.0100	concrete slurry
Cap	cy	33	$10.50	$350	02315.210.4010	1.5 cy bucket backhoe
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
		Unit Cost per 100-foot Alignment:			**$134,270**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
	Unit Cost (LS) per Collection Sump / Pump-Back:				**$54,325**	
				$188,595		
Ground Freezing						
Access	acre	0.046	$3,225.00	$148	02230.100.0020	cut and chip light trees to 6"
Trench Excavation	cy	4500	$3.24	$14,580	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Piping installation	lf	600	$4.28	$2,568	02510.740.1160	2" PEP C901
Backfill	cy	4500	$6.15	$27,675	02315.610.3100	2.25 cy bucket, 200' haul dist
Top insulation	sf		$2.14	$0	.07220.700.1966	4" th R20 extruded polystyrene
Surface drain collection system				$0		
Shallow ditch (french drain) system				$0		
Trench excavation	cy	67	$3.24	$216	02315.610.1310	14' to 20' deep, 1.5 cy bucket
Trench base material	cy	67	$25.50	$1,700	02620.300.0400	pea stone
Slotted / perforated drai	lf	100	$2.76	$276	02620.660.0060	6" dia coorugated perforated plastic
		Unit Cost per 100-foot Alignment:			**$47,163**	
Refrigeration plant	ls	1	$500,000.00	$500,000		
		Unit Cost (LS) per Refrigeration Plant:			**$500,000**	
Collection Sump				$0		
Manhole	ea	1	$3,375.00	$3,375	02630.400.1210	6 ft dia, 8 ft deep
Add'l depth risers	vlf	4	$435.00	$1,740	02630.400.1220	add'l cost for increased vert depth
Top slab	ea	1	$630.00	$630	02630.400.1500	6" dia, 8" th
Pump system				$0		
Pump	ea	1	$13,500.00	$13,500	staff estimate	500 gpm
Motor	ea	1	$10,000.00	$10,000	staff estimate	60 to 75 hp motor
Controls	ls	1	$10,000.00	$10,000	staff estimate	
Shafting, piping, valves	ls	1	$3,500.00	$3,500	staff estimate	
Pipe	lf	1200	$9.65	$11,580	02510.760.0200	6" dia HDPE SDR21
	Unit Cost (LS) per Collection Sump / Pump-Back:				**$54,325**	
				$601,488		

Summary of Cost Derivation for Pumps / Pumping

The station will need two manholes. One will be a wet well and only house the suction bell for the pump and the station control floats. It should be about six feet deeper than the invert of the incoming drain. For 500 gpm flow rate go with an 8 foot diameter wet well for now. Detailed design could move it either bigger or smaller depending on flow rate and final pump selection. The dry well manhole will also be at least 8 feet in diameter. Again final design might push it larger but not likely much smaller. We may end up having to lay the motor down on its side in the dry well so it could turn into a box culvert on end or similar.

Pumps will be split case, in line style. The preliminary plan is to lay the pump down on it side so that it can be shaft driven by a totally enclosed fan cooled weather protected motor at the surface on top of the manhole. The motor will be out in the elements. The station will be run by a simplex, float based, pump controller system. This is as simple as it gets. Costs below:

MHs & access hatches – see existing itemized estimate
Pump budget cost: $13,500
Motor budget cost: $10,000 (range was $8,500 to $11,000)
Controls: $10,000
Shafting: $500
Station pipe & valves: $3,000 (suction elbow, straight suction pipe, suction valve discharge elbow, pipe and valve)
SCADA: NONE ASSUMED
Power to station: By others
Drain pipe: By others
Force main: By others

Assume roughly a 50,000 hour pump life for now. If there is a lot of sand or if pumping conditions are far off of bep this will decrease. This equates to just under 6 years of continuous operation. If you expect significantly less than continuous operation then lengthen the life expectancy accordingly. Pump and motor rebuilds are commonly scheduled for every 7 years with municipal wells so that might be a good starting point unless you do expect continuous operation. Note that split case pumps are more robust than submersibles and would likely be rebuilt rather than replaced when they wear. Assume roughly 50% purchase price for a rebuild on the pump.

Draw at 300 gpm is about 38 hp so you would end up with a 40 hp pump. Draw at 500 gpm is about 63 hp so you would end up with a 75 hp motor in that case.

The tables shown below are based on the following assumed pumping conditions:

Static lift: 350 feet
Pipe length: 1,200 feet
Min Flow rate: 300 gpm Table 1
Max Flow rate: 500 gpm Table 2
Pipe material: HDPE
Hazen Williams C: 150
Wire to water efficiency: 72%

Table 1
Minimum pumping rate 300 gpm

Pumping Rate	**300 gpm**	6 inch pipe	40 hp pump	
Item Description	Pumping costs for various electrical rates			
Cost of electricity	$ 0.025	$ 0.035	$ 0.045	$ 0.055
Monthly Demand Charge($10/kW)	$ 281.49	$ 281.49	$ 281.49	$ 281.49
Annual cost for electricity	$ 6,164.61	$ 8,630.45	$11,096.29	$13,562.13
Annual cost with demand charge	$ 9,542.47	$ 12,008.31	$14,474.16	$16,940.00
Cost per day(with demand charge)	$ 26.14	$ 32.90	$ 39.66	$ 46.41
Cost/MG(excludes demand charge)	$ 39.10	$ 54.73	$ 70.37	$ 86.01

Table 2
Maximum pumping rate 500 gpm

Pumping Rate	**500 gpm**	**8** inch pipe	75 hp pump	
Item Description	Pumping costs for various electrical rates			
Cost of electricity	$ 0.025	$ 0.035	$ 0.045	$ 0.055
Monthly Demand Charge($10/kW)	$ 467.69	$ 467.69	$ 467.69	$ 467.69
Annual cost for electricity	$ 10,242.31	$ 14,339.23	$18,436.16	$22,533.08
Annual cost with demand charge	$ 15,854.53	$ 19,951.46	$24,048.38	$28,145.30
Cost per day(with demand charge)	$ 43.44	$ 54.66	$ 65.89	$ 77.11
Cost/MG(excludes demand charge)	$ 38.97	$ 54.56	$ 70.15	$ 85.74

Assume mid-range of 500 gpm pumping rate = $20,000 annual energy cost

Estimated operation and maintenance manpower costs:
Assume 8 hours / week for staff O&M, @ $50/hr (x 52 weeks) = $20,800.

Add $5,000 for annual maintenance or life cycle replacement

Estimated total annual cost = $45,000