Tailings Basin Geotechnical Instrumentation and Monitoring Plan

Cell 2E

Prepared for
Poly Met Mining, Inc.

Version 3

May 15, 2017

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Tailings Basin Geotechnical Instrumentation and Monitoring Plan
Cell 2E

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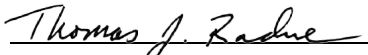
Certifications

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.



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1.0 Introduction

This Tailings Basin Geotechnical Instrumentation and Monitoring Plan (Plan) describes the plan for geotechnical instrumentation and monitoring of Cell 2E, the first cell of the Tailings Basin that will be reactivated for disposal of Flotation Tailings for Poly Met Mining, Inc.'s (PolyMet's) NorthMet Project (Project). In this document, the Flotation Tailings Basin (FTB) refers to the proposed NorthMet Flotation Tailings impoundment placed atop Cells 1E and 2E of the former LTV Steel Mining Company (LTVSMC) tailings basin, and the Tailings Basin is the combined LTVSMC tailings basin and the FTB. The purpose of this Plan is to guide monitoring of the Cell 2E dams to maintain safe operation of the Tailings Basin. Cell 2E is located in the northeast portion of the Tailings Basin as shown on Large Figure 1. The design and operation of the FTB dams are described in this Flotation Tailings Management Plan.

Stability monitoring will be required throughout construction, operations, and after closure to verify that FTB dam design constraints are met. Stability monitoring will include existing and proposed piezometers to monitor the piezometric surface in the FTB dams, and inclinometers and survey monuments to monitor dam movement. The instrumentation will be located within the perimeter dams of Cell 2E (the north dam of Cell 2E, the dam between Cell 2E and 1E, the dam between Cell 2E and 2W), and in a section of the north face of the dam connecting Cell 2E and 2W. The monitoring system will be expanded as tailings deposition transitions from Cell 2E to Cell 1E/2E, and data will periodically be gathered and analyzed from other existing monitoring points as necessary to confirm overall Tailings Basin dam stability. Large Figure 2 shows the locations of existing instruments.

This Plan for Cell 2E includes:

- Stability monitoring plans, including instrument locations, instrument descriptions, and data collection and analysis plans
- Planned monitoring activities that provide information related to dam stability, including construction monitoring, pond level monitoring, and tailings deposition monitoring
- Reporting
- Exhibit A – Technical Specifications – Fully Grouted Vibrating Wire Piezometers
- Exhibit B – Technical Specifications – Standpipe Piezometers
- Exhibit C – Technical Specifications – Inclinometer Installations

This Plan provides detail on Cell 2E instrumentation upgrades and monitoring to be performed prior to development of the FTB. This Plan will be updated once construction and tailings deposition begins. The Plan will also be reviewed on a periodic basis and updated as needed due to dam raises, when the FTB expands from Cell 2E to combined Cells 1E/2E, as instrumentation becomes worn or obsolete, and as otherwise needed to maintain sufficient geotechnical instrumentation and monitoring of the Tailings Basin dams.

This Plan focuses on Cell 2E, the only cell that will receive tailings for deposition through Mine Year 7, with dam raises occurring to maintain required tailings capacity and freeboard. Concurrent with the specified Cell 2E monitoring, monitoring instrumentation planned to remain in dam sections for Cells 1E and 2W will continue to be monitored and periodically improved or replaced as needed. Prior the point in time where Cells 2E and 1E merge and dam raises on the combined Cell 1E/2E begin, a comprehensive update of this Plan will occur to identify instrumentation upgrades and additions required to monitor the combined cells.

2.0 Stability Monitoring

Stability monitoring of Cell 2E will be carried out during all phases of the Project: construction, operations, and closure. Prior to and during construction, piezometers will be installed to monitor pore water pressures within the dam and foundation, and inclinometers and survey monuments will be installed to monitor for deformation of the dams. This instrumentation and data will add to that already in place. A comprehensive monitoring database will be developed to save and track piezometer, inclinometer, and survey data for the dam throughout the 20-year period of construction and operation. Monitoring of the dam will continue upon Tailings Basin closure until the Minnesota Department of Natural Resources allows reduction or discontinuance.

Selection of locations to be monitored is based on a variety of factors:

- To monitor dam performance at dam cross-section locations believed to be more susceptible to movement than other cross-section locations, due to factors such as cross-section specific foundation conditions, tailings layering and strength characteristics, and/or seepage conditions
- To provide piezometric and inclinometer data along dam cross-sections to facilitate seepage and stability analysis
- To monitor dam cross-sections that may be irregular in geometry or subject to unique loading conditions
- To compare current and future dam performance to historic performance when historic data exists

Stability monitoring, in conjunction with future geotechnical explorations, will provide data for Dam Safety Inspections (Section 5 this Flotation Tailings Management Plan). It will also be used to validate and refine the slope stability models (Appendix B of this Dam Safety Permit). As described in this plan new instrumentation will be installed prior to restarting the Tailings Basin. Additional geotechnical data and baseline instrument readings will be gathered concurrent with and following the instrument installations. Following the second year of operation, a geotechnical exploration will be performed to verify that the Flotation Tailings have been deposited in accordance with the initial slope seepage and stability modeling. Similar explorations and modeling analyses will be performed on a periodic basis throughout the construction of the FTB dams to allow for immediate corrections to the design, if needed, to maintain stability.

Instrumentation and monitoring for Cell 2E dams will consist of:

- **Vibrating Wire and Standpipe Piezometers** – to monitor the piezometric surface in the dams and foundations and the increases in pore water pressure resulting from the dam construction and tailings deposition
- **Inclinometers** – to monitor dam movement during and after construction of the dam

- **Survey Monuments** – to monitor dam movement
- **Construction Monitoring** – to monitor material type and compaction and target grade elevations
- **Pond Level Monitoring** – to monitor pond elevation, pond size, and beach length
- **Tailings Deposition Monitoring** – to monitor pond setbacks, tailings deposition profile, and material strength

Personnel who will be responsible for Cell 2E dam management are:

- *PolyMet Operations Contact* – Beneficiation Division Manager or designee – Responsible for overall Cell 2E design, planning, operations, maintenance, and monitoring.
- *Design Engineer* (a Minnesota-registered professional engineer retained as an independent consultant specifically for dam safety expertise) – Responsible for geotechnical explorations and data gathering, performance monitoring data review and interpretation, dam safety inspection and reporting assistance, tailings dam planning and design assistance, and permitting assistance.

2.1 Instrumentation System

The stability monitoring program for Cell 2E will use a combination of existing and new instruments to monitor the piezometric surface in the dams, increases in pore water pressure, and dam movement. Instruments in the monitoring network will be evaluated for maintenance and/or replacement as part of reporting procedures discussed in Section 4.0. Instruments may be added to or removed from this network as necessary in conjunction with changes to the Project. Not all existing instruments will be part of the ongoing monitoring plan: some will be decommissioned. Large Figure 2 identifies the existing instruments. Table 1 and Table 2 describe the current condition of the instrumentation (based on review in 2016), and recommend instrumentation for continued use or for decommissioning. Large Figure 3 shows existing and proposed instruments to be used in the Cell 2E monitoring network.

2.1.1 Instruments Condition Review

An instrumentation conditions review is completed annually in conjunction with instrumentation data review. As described in the following sections a number of instruments are recommended for decommissioning, and in some cases for replacement. This includes a number of inclinometers as identified in Table 1, all pneumatic piezometers, and one pneumatic piezometer/inclinometer. The inclinometers are being decommissioned because valid data cannot be collected due to inclinometer casing abnormalities. Pneumatic piezometers will be reviewed concurrent with new instrument installations and if those that require maintenance (Table 2) cannot be returned to full functionality, they may also be replaced at that time. Decommissioning of these instruments will occur concurrent with or in advance of Cell 2E construction activities.

2.1.1.1 Inclinometers

The basin has been inactive since January of 2001. Monitoring of inclinometers has continued since then, but the inclinometers have not been routinely maintained or replaced because their usefulness tends to diminish with time (the risk of dam movement at the inactive Tailings Basin and the relative value of the inclinometer data diminishes with time). Prior to reactivation of the basin new inclinometers will be installed as described later in this plan. Of the existing inclinometers, four are fully functional, four are suspect, and three are recommended for decommissioning, as listed in Table 1. The inclinometers are being decommissioned because valid data cannot be collected. Decommissioning of these instruments will occur concurrent with or in advance of Cell 2E construction activities.

Table 1 Inclinometer Condition Review

Instrument	Cross-Section Location	Status	Comments
DH96-10	E	Functional	Continue to collect and review data
DH96-12	E	Suspect – collect to evaluate for changing conditions, but flag for replacement	Apparent settlement-based casing errors (DPE) which may worsen with time
DH96-18	A	Functional	Continue to collect and review data
DH96-19	A	Decommission – replace prior to basin restart	Probe cannot reach the bottom of the casing, data are not meaningful
DH96-28	H	Functional	Continue to collect and review data
DH96-32	H	Decommission – replace prior to basin restart	Casing abnormalities, data are not meaningful
DH96-37	J	Suspect – collect to evaluate for changing conditions for now, but consider for replacement	Apparent settlement-based casing errors (DPE) which may worsen with time
DH96-46	F	Suspect – collect to evaluate for changing conditions, but flag for replacement	Casing abnormalities, lack of confidence in data
DH96-47	F	Decommission – replace prior to basin restart	Casing abnormalities, data are not meaningful
DH99-1	H	Suspect – collect to evaluate for changing conditions, but flag for replacement	Casing abnormalities, lack of confidence in data
2E_2016_INC_K2	K	Functional	New installation, continue to collect and review data

2.1.1.2 Piezometers

Multiple types of piezometers exist at the site, including standpipe piezometers, vibrating wire (VW) piezometers, and pneumatic piezometers. Due to age and lack of maintenance and issues with failing or stuck diaphragms, all pneumatic piezometers are recommended for decommissioning. New vibrating wire piezometers in the existing Cell 1E/2E splitter dam at Cross-Section K are collecting baseline data and have no apparent issues. The condition of standpipe piezometers are described in Table 2. These instruments will be decommissioned concurrent with or in advance of Cell 2E construction activities.

Table 2 Piezometer Condition Review

Instrument	Cross-Section Location	Status	Comments
A-1	A	Functional	Continue to collect and review data
A-3	A	Functional	Continue to collect and review data
A-9	A	Functional	Continue to collect and review data
B-2	B	Functional	Continue to collect and review data
P1B1-99	B	Functional	Continue to collect and review data
P1B-99	B	Functional	Appears to be dry now, continue to collect and review data
D-1	D	Functional, but recommend maintenance	Continue to collect and review data; redevelop and slug test piezometer to assess quality of data and condition of piezometer
D-4	D	Functional, but recommend maintenance	Continue to collect and review data; redevelop and slug test piezometer to assess quality of data and condition of piezometer
E-5	E	Requires maintenance	Blockage at 20 feet – recommend flushing and using downhole camera to review
F-2	F	Functional, but recommend maintenance	Continue to collect and review data; redevelop and slug test piezometer to assess quality of data and condition of piezometer
G-2	G	Functional, but recommend maintenance	Continue to collect and review data; redevelop and slug test piezometer to assess quality of data and condition of piezometer
P2HA-99	H	Functional, but recommend maintenance	Continue to collect and review data; redevelop and slug test piezometer to assess quality of data and condition of piezometer
P2HB-99	H	Functional	Continue to collect and review data
P1H-99	H	Functional	Continue to collect and review data
P3H1-99	H	Functional	Appears to be dry now, continue to collect and review data
P2H1-99	H	Functional	Appears to be dry now, continue to collect and review data

Instrument	Cross-Section Location	Status	Comments
P1H1-99	H	Functional	Continue to collect and review data
P3H-99	H	Functional	Appears to be dry now, continue to collect and review data
K-1	K	Functional	Continue to collect and review data
K-2	K	Functional	Continue to collect and review data
K-3	K	Functional	Continue to collect and review data

2.1.2 Existing Instruments to Be Used

Table 1 and Table 2 list the existing instruments, their current level of functionality, and their intended use in the future. Existing instruments to be used in the Cell 2E monitoring network include standpipe piezometers, and vibrating wire piezometers as identified on Large Figure 3 and shown in detail on Large Figure 4 through Large Figure 10.

2.1.3 New Instruments to be Installed

Proposed new instruments consist of 72 nested vibrating wire (VW) piezometers and 12 inclinometers as identified on Large Figure 3 and shown in detail on Large Figure 4 through Large Figure 10. The new instruments will be located in the Cell 2E perimeter dams that correspond to six cross-section locations (H, J, F, G, D and I) shown on Large Figure 3. Installation will occur prior to FTB dam construction and deposition of Flotation Tailings in Cell 2E.

Future instrument installations will occur with alternating lifts of dam construction and will be evaluated as part of future stability monitoring plan updates. The overall philosophy for instrumentation placement and objectives for monitoring is summarized in Section 0 and described further in Section 3.0.

2.2 Instrument Details

The following sections provide instrumentation details for the Cell 2E monitoring network. Monitoring locations will be reviewed annually and modified as needed throughout the life of Cell 2E. Monitoring points that become non-functional or that no longer warrant monitoring based on the annual evaluation will be properly decommissioned. However, it will be preferable to consistently monitor the same points throughout the life of the FTB; supplemented with additional instrument installations as dam height increases.

2.2.1 Piezometers

Nested VW piezometers will be installed along the typical cross-sections modeled as a part of the dam design process and at other nearby locations as necessary for ongoing performance monitoring of the dams. The piezometers will be placed to allow for monitoring of pore water pressures within the dam profile. Each piezometer nest will include three piezometers. The bottom piezometer at each location will be installed in the native till below the dam (referred to as piezometer "c" in the nest) to understand pore

water pressure within the relatively permeable foundation. The middle piezometer will generally be placed at an elevation of 10 feet above the native material and tailings interface to monitor conditions along typical modeled slope failure surfaces (referred to as piezometer "b" in the nest). The top piezometer will generally be placed in the existing slimes and fine tailings below the existing LTVSMC coarse tailings (referred to as piezometer "a" in the nest), where pressures are often elevated due to the fine nature of those existing slimes and fine tailings. Having nested piezometers allows for an understanding of whether upward or downward flow (or both) are occurring at given location.

For Cross-Sections H, J, F, and G on Large Figure 3, the piezometer nests will be installed at four locations along the dam profile, as shown on Large Figure 4 through Large Figure 7. For Cross-Sections D and I on Large Figure 3, the piezometer nests will be installed at the crest of the existing dams as shown on Large Figure 8 and Large Figure 9. Piezometers at Cross-Section K shown on Large Figure 10 have been installed at the crest, mid-slope of the north-facing slope, and at the north toe of the dam. Monitoring zones for these piezometers are preliminary and will be confirmed in the field at the time of installation.

VW piezometers will be installed per requirements of the Technical Specifications (Exhibit A) and Installation Diagram (Large Figure 11). If standpipe piezometers are installed at a future date, installation will generally follow the configurations shown on Large Figure 11 and follow specifications in Exhibit B.

2.2.2 Inclinometers

Standard inclinometers were previously installed along a number of alignments in all Tailings Basin cells. However, according to recent dam safety inspections (Reference (1)) those inclinometers have been compromised and will be decommissioned. New inclinometers will be installed at Cross-Sections H, J, F, G, D, and I to monitor for deformation. The inclinometers will be positioned such that they intersect the anticipated surface of greatest deflection; the model-estimated surface yielding the lowest slope stability safety factor. An inclinometer is already installed at Cross-Section K. Inclinometers may be combined with select proposed piezometer boreholes if deemed appropriate during geotechnical installations. Typical installation details are included on Large Figure 11 and technical specifications are provided in Exhibit C.

2.2.3 Survey

A full topographic survey of Cell 2E will be performed at least annually; with localized topographic surveys performed more frequently during dam construction activities, generally on the order of monthly or quarterly. At least once during the year, survey measurements will be taken of 21 survey monuments along Cross-Sections H, J, F, G, D, I, and K, checking for any sign of horizontal or vertical movement. The survey monuments are identified on Large Figure 3 and shown in detail on Large Figure 4 through 10. A reference datum will be selected such that benchmarks are on solid ground well beyond the footprint of the dam. Survey frequency will decrease in the future after Cell 2E closure.

2.3 Data Collection & Analysis

Piezometer, inclinometer, and survey readings will be taken quarterly, at a minimum, to detect any potential instability. Readings will be collected more frequently during construction activities to guide any real-time adjustment of the construction rate needed to maintain stability. Frequency will be dependent

on the rate of construction and will be determined at the time the construction schedule is determined. A Project data network will collect data continuously from VW piezometers (and VW inclinometers if subsequently installed). The continuous readings will be recorded using a datalogger and are recommended to be downloaded monthly or at an increased frequency if the need arises.

Preconstruction data analysis will generally be performed annually with the dam safety review, or more frequently if conditions are observed to be changing (i.e., high pond levels, etc.). Further evaluations of data will be performed on a monthly to quarterly basis during the first stage of construction. These analyses will include field measurements of standpipe piezometers and inclinometers to verify readings obtained by the monitoring system. The frequency of ongoing analyses will be re-evaluated as construction and operation progress.

Ongoing monitoring will be performed by the Design Engineer or authorized representative to allow for real-time modification of construction, monitoring, and operation means and methods as required to maintain dam safety.

Each dam raise will require data collection and analysis. The piezometric surface of water flowing through the Tailings Basin and FTB dams must be controlled to maintain the phreatic surface at or below the surface determined in SEEP/W modeling (Appendix B of this Dam Safety Permit). Prior to each FTB dam raise, the allowable water level elevations in piezometers and the movements predicted to occur in inclinometers will be established. Elevation data consisting of the dam surface elevation, instrument depth, allowable water level, and measured water level will be collected, and observed elevations will be compared to allowable elevations. Threshold values will be established as described in Section 3.2. Variation between observed piezometric water levels and allowable piezometric water levels (toward or beyond threshold values) will require review and consultation with the Design Engineer to determine what actions, if any, are required to reduce water levels. Threshold vertical and lateral movement for inclinometers and survey markers will be established for each monitoring location.

2.4 Related Monitoring Activities

Ongoing monitoring and periodic updates to data utilized in seepage and stability modeling will be part of the overall stability monitoring activities. Additional detail on these related monitoring activities can be found in other facility documents including this Flotation Tailings Management Plan. Results of these monitoring activities will be included in the annual reporting and the dam safety inspections.

2.4.1 Construction Monitoring and Quality Control

Construction activity associated with Cell 2E includes construction of buttressing for the north dam, and upstream dam construction of eight individual lifts, the first starting during the first year of operation. Construction monitoring and construction quality control requirements are outlined in the construction specifications and therefore are not repeated herein. Further, construction quality control testing and monitoring requirements will be outlined in detail prior to each construction event as a means by which the personnel assigned by PolyMet to be responsible for tailings basin construction can readily track and

confirm that the necessary construction monitoring and quality control is being implemented. Construction monitoring and quality control activities will fall into three broad categories:

- *Quality Control Surveying* – to collect data on elevations, grades, slopes, and material thickness. Survey data includes finished elevations and dam features. Specific locations for survey points include the dams, bentonite-amended cover, buttresses, and tailings discharge and return water pipelines as described in the construction specifications (Attachment G of Flotation Tailings Management Plan).

- *Soil & Material Testing* – to include in-field and in-laboratory material testing by an independent geotechnical exploration contractor and soils testing laboratory. Field and laboratory tests are outlined in the construction specifications and include sieve analysis, soil compaction tests, and other tests that may be required (Attachment G of Flotation Tailings Management Plan), in addition to construction event specific geotechnical explorations that may be specified. Testing of materials used for dam construction will occur for each phase of construction to identify trends in variability of the construction materials.

- *Instrumentation Monitoring* – to include non-routine instrument-specific (i.e., inclinometers, piezometers, survey markers) monitoring and reporting through the course of specific construction events.

Information collected as part of construction will be included in annual reporting.

2.4.2 Pond Level Monitoring

Pond water levels will be routinely monitored and managed to maintain sufficient freeboard between the pond water level and the top of the Cell 2E dams. Pond water levels will be recorded daily (manually or via automated systems.) A data trend toward insufficient freeboard will immediately be brought to the attention of the *Operations Contact*. Pond water level records will be included in annual reporting.

2.4.3 Tailings Deposition Monitoring

Tailings deposition in Cell 2E will be monitored through a variety of activities including:

- *Setback Observations* – observations of the beach width to maintain the specified setback between the inside crest of the dam and the edge of the pond provides an indicator of adequate freeboard to manage the pond during severe precipitation events. Observations will occur daily and become more frequent with prolonged and/or intense rainfall events (Section 5.3.3 of this Flotation Tailings Management Plan).

- *Bathymetric Survey* – a bathymetric survey of the dams and Flotation Tailings will monitor the deposition profile of tailings and allow for updates to deposition practices as necessary. The survey will occur during the first year of operations and then once every other year (Section 5.3.3 of this Flotation Tailings Management Plan).

- *Material Strength Investigations* – cone penetration test (CPT) soundings, vane shear tests (VST) and/or standard penetration test (SPT) borings will confirm the strength of deposited Flotation Tailings in Cell 2E. The investigation will occur within the first year of operations and then at least once every other year (Section 5.3.3 of this Flotation Tailings Management Plan).

3.0 Observational Method

The observational method employs sequences of data gathering, detailed calculations and performance predictions, additional data gathering and observations, and design modifications as needed to maintain required operating conditions at the Tailings Basin. First, the engineer uses available information to prepare an initial concept and design that will predict the behavior of the basin. As the stages of construction progress, the engineer monitors and tests the site to obtain more detailed information. Information from this instrumentation and monitoring program is an example of this stage in the Observational Method. The predicted behavior is now compared with the measured behavior, enabling the engineer to revise the original predictions. Repeating this process leads to successive refinements in tailings basin dam design and construction. Tailing basin dams are typically built in stages, thus the observational method to design is well suited for minimizing risk.

3.1 Data Updates

Part of the Observational Method entails additional data gathering, followed by data interpretation and then design review and adjustment as needed in response to the new data. Data types that will typically be updated through the course of Tailings Basin development include:

- Geotechnical Data – from future instrumentation installation activities, geotechnical explorations and in-laboratory material testing
- Instrumentation Data – piezometric data and deformation data from inclinometers and survey monuments
- Observations and Monitoring Data – from pond level data, from construction observations, from topographic surveys, and from systematic and periodic site review

The gathered data will, when appropriate and necessary, be used to adjust material strength, basin geometry, and/or basin operating criteria.

3.2 Instrumentation Thresholds

A threshold value for instrumentation is a reading that indicates a significant departure from the expected range of readings based on design modeling and prompts an action such as increased surveillance or an emergency action. A threshold value is set in consideration of the values used in the analysis or design, and is influenced by the historical data and predictions of future performance. Threshold values must be established based on the specific circumstances of the site. They may be used to identify unusual readings, readings outside the limits of the instrument's historic range, and/or readings that, in the judgement of the responsible engineer, need evaluation. Both magnitude and rate of change in values may need to be established. Threshold values for various instruments (e.g., piezometers, inclinometers, and survey monuments) will be established following completion of instrumentation installation and baseline monitoring (prior to initiating operations at the Tailings Basin) and revised throughout the project life, based on the following list of factors.

- Historical data: Historic data, considering seasonal fluctuations, variations due to historical construction activities and considering magnitude and rate of changes.

- Sensitivity analysis: For selected critical sections, sensitivity analysis will be performed to identify threshold values such as pore pressures, stresses and deformation that trigger a failure in the model (limit equilibrium method). Combinations of selected instruments (e.g., piezometers or inclinometers) will be utilized in sensitivity analyses to trigger a failure in the model. Advanced numerical analysis (e.g., FLAC) will be considered, if warranted, to set threshold criteria related to deformation, considering progressive failures and excessive deformations that the limit equilibrium method is unable to accommodate.

- Trend analysis: The established threshold values may be modified and updated based on overall trends. Data will follow trends, such as decreasing or increasing with time or depth, seasonal fluctuation, direct variation with basin water level, direct variation with temperature, or a combination of such trends. Data inconsistent with established trends will be investigated and verified.

- Failure mode: The threshold values will be associated with potential failure mode, such as piezometer readings associated with stress increase and strength decrease sufficient to induce slope instability. Inclinometers or survey monuments will be associated with displacement or deformation of the dam that may or may not be directly associated with eminent failure. The threshold values will be established based on the potential failure modes.

- Visual monitoring: The instrumentation threshold values will be established along with the visual monitoring program.

- Revision: The established threshold values (magnitude and rate of changes) will be regularly calibrated in response to ongoing data acquisition and review.

Table 3 is an example of the expected and threshold data values that will be established for each inclinometer and each piezometer as a means to compare predicted data values with measured values. The table will be fully populated once the new instrumentation is installed, baseline data is established, and corresponding geotechnical models updated to produce the table data.

Table 3 Instrumentation Summary and Thresholds (Sample Table)

Monitoring Device	Purpose	Name and Location	Monitoring Frequency	Normal Data Range
Vibrating Wire Piezometers	Measurement of Pore Water Pressure (Hydraulic Head)	XX-XX-X1	Continuous	Pore water pressure between XX and YY
		XX-XX-X2		Pore water pressure between XX and YY
		XX-XX-X3		Pore water pressure between XX and YY
ShapeAccelArray (SAA) Inclinometers	Measure Horizontal Slope Movement	YY-YY-Y1	Continuous	Distance vs Time (TBD)
		YY-YY-Y2		Distance vs Time (TBD)
		YY-YY-Y3		Distance vs Time (TBD)
Survey Monuments (Alignment Hubs)	Measure Horizontal and Vertical Slope Movement	AA-AA-A1	As Specified During Construction Events Monthly During Routine Operations	Distance vs Time (TBD)
		AA-AA-A2		Distance vs Time (TBD)
		AA-AA-A3		Distance vs Time (TBD)

3.3 Response to Instrumentation Threshold Incursion

Once an instrument reading falls above or below the established threshold value, an action is required. The range of action levels will depend on degree of departure of the data, number of instruments that show similar indications, severity of the situation and potential failure modes. Examples of situations that may require action include:

- A minor departure from the historical record (possibly in order to simply receive an alert from the person reading the instrument thus verifying that measurements are being monitored)
- A major departure from the historical record (possibly indication of a developing failure mode)
- A departure from historical reaction to changes in other instruments
- Levels indicating the approach of potential instability or other forms of failure such as piping

Once threshold values are established following instrument installation and baseline monitoring, this Instrumentation and Monitoring Plan will be updated to document instrumentation names, locations, and monitoring frequencies.

Recommended response actions to instrumentation threshold incursion are summarized in Large Table 1 and Large Table 2.

4.0 Reporting and Plan Updates

Annual reports will present a compilation and evaluation of the information collected from instrumentation and monitoring described in this Plan, and may include the following:

- Evaluation of survey data
- Evaluation of monthly data downloaded from VW piezometers (and SAA or automated inclinometers if subsequently installed)
- Evaluation of the adequacy of the existing instrumentation and determination of the need for any changes (new installations, maintenance, or instrument decommissioning)
- Updates to cross-sections documenting construction activities associated with dam lifts
- QAQC of the monitoring data to identify potential errors and trends that may warrant instrument maintenance and/or replacement

In cases where updates to seepage and slope stability models are warranted based on data from instrumentation and monitoring varying from what is expected, any resulting recommendations for modifications to dam design and/or Tailings Basin operations or monitoring will be included in the annual report.

This Plan will be updated periodically based on changes to facility operations, instrumentation, and construction activity. These updates are expected to occur:

- Prior to initial construction
- Prior to each subsequent dam raise

Revision History

Date	Version	Description
December 7, 2012	1	Initial release as Attachment D to Version 2 of the Flotation Tailings Management Plan
April 12, 2013	1	Attachment D to Version 3 of the Flotation Tailings Management Plan
November 21, 2014	1	Attachment D to Version 4 of the Flotation Tailings Management Plan
March 3, 2015	1	Attachment D to Version 5 of the Flotation Tailings Management Plan
July 11, 2016	2	Attachment D to Version 6 of the Flotation Tailings Management Plan
May 15, 2017	3	Attachment D to Version 7 of the Flotation Tailings Management Plan

References

1. **Barr Engineering Co.** 2013-2014 Tailings Basin Dam Safety Inspection Report. Prepared for Cliffs Erie, LLC. February 2015.

Large Tables

Large Table 1 Visual Warning Signs

Visual Warning Sign and Typical Location	Corresponding Change in Instrumentation Values (depending on location of movement relative to instrumentation)	Potential/Actual Consequences and Notification Procedures	Required Action
Signs of slowly forming erosion at toe and/or exterior face of slope.	No change in instrumentation values expected.	Potential dam instability and/or eventual dam failure if erosion continues. **Level 1 and Level 2 (see Table Notes)**	1) Discuss findings with the Design Engineer. 2) Be prepared to carry out one or more responses such as: a. Resolve source of erosion. b. Repair erosion area. c. Re-establish vegetation (modify design if recommended by Design Engineer). d. Re-inspect area on weekly basis until area is fully restored.
Soft toe condition or increased seepage at downstream slope or dam toe.	Potential increase in piezometric levels.	Internal erosion or slope slumping and eventual dam failure. **Level 1 and Level 2**	1) Discuss the findings with the Design Engineer. 2) Commission a field investigation program if so recommended. 3) Be prepared to carry out one or more responses including: Modification of basin pond operating procedures. Placement of graded overburden/buttress. Installation of drain system. Other design modifications if recommended by Design Engineer.
Cracks developing at dam crest or in slope.	Potential increase in piezometric levels. Potential slope deformation at inclinometers. Potential deflection in alignment monuments.	Deformation of dam structure that may lead to eventual dam failure. **Level 2; potential Level 3**	1) Increase frequency of dam walk-overs to daily until the problem is understood and addressed. 2) Seek advice from the Design Engineer. 3) Monitor crack development for increase in size, spacing, etc. 4) Commission a field investigation if so recommended. 5) Be prepared to carry out one or more responses including: a. Modification of pond and/or basin operating procedures. b. Placement of graded overburden/buttress. c. Temporary cessation of operations. d. Reduction in pond elevation (planned or emergency).
High turbidity in dam seepage flow.	Potential increase in piezometric levels.	Internal erosion and eventual dam failure. **Level 2; potential Level 3**	1) Increase frequency of dam walk-overs to daily until the problem is understood and addressed. 2) Seek advice from the Design Engineer. 3) Take water samples for suspended solids determination if recommended by Design Engineer. 4) Commission a field investigation if so recommended. 5) Be prepared to carry out one or more responses including: a. Modification of pond operating procedures. b. Placement of graded overburden/buttress. c. Installation of drain system. d. Reduction in pond elevation (pumping and/or cessation of tailing discharge).
Pond level close to or approaching overflow level; loss of freeboard.	Potential increase in piezometric levels.	Pond water discharge to environment via emergency overflow. **Level 1**	1) Confirm functionality of emergency overflow channel. 2) Immediately undertake actions to reduce the pond level (increased pumping to WWTP as necessary). 3) Temporarily discontinue seepage recovery. 4) Temporarily terminate tailings discharge to pond. 5) Consult with Design Engineer to identify other actions as needed.

Visual Warning Sign and Typical Location	Corresponding Change in Instrumentation Values (depending on location of movement relative to instrumentation)	Potential/Actual Consequences and Notification Procedures	Required Action
Any other change in seepage conditions.	Potential increase in piezometric levels.	Dam stability safety margin affected. **Level 2; potential Level 3**	1) Seek advice from the Design Engineer. 2) Initiate other responses as may be required (temporarily discontinue seepage recovery). 3) Reduction in pond elevation (pumping and/or cessation of tailing discharge).
Slumping, sliding or bulging of a dam slope or adjacent ground.	Potential increase in piezometric levels. Potential slope deformation at inclinometers. Potential deflection in alignment monuments.	Catastrophic dam breach resulting in release of water or water and liquefied tailings. **Level 2; potential Level 3**	As above (blue shaded box) and: 1) Construct stabilizing berm per direction of the Design Engineer. 2) Initiate geotechnical evaluation per direction of the Design Engineer.
Boils observed downstream of dam.	Potential increase in piezometric levels.	An internal erosion failure possible, with potential breach of the dam. **Level 2; potential Level 3**	As above (blue shaded box) and: 1) Place granular filter buttress over the boils, if approved by the Design Engineer. 2) Initiate geotechnical evaluation per direction of the Design Engineer.
Water vortex within the pool.	No change in instrumentation values expected.	An internal erosion failure in progress, with potential breach of the dam. **Level 2; potential Level 3**	As above (blue shaded box) and: 1) Check downstream of the dam area for increased and/or turbid seepage discharge. 2) Place granular filter buttress against any such areas, if approved by the Design Engineer. 3) Initiate geotechnical evaluation per direction of the design engineer.
Severe flood/intense rainstorm or rapid snowmelt resulting in extreme pond level.	Potential increase in piezometric levels.	Overtopping of dam and resulting erosion and over-steepening of the downstream slope, leading to dam failure. **Level 3**	1) Initiate chain of communications and ensure safety of people. 2) Confirm functionality of emergency overflow channel. 3) Stop discharge into the pond. 4) Lower pond by any practical means approved by the Design Engineer.

Notes for Notification Procedures:

Level 1 – Condition that does not warrant emergency response but requires prompt investigation and resolution.

Level 2 – Potential emergency if condition is sustained or allowed to progress; requires response plan.

Level 3 – Imminent or actual failure requiring partial or complete evacuation, emergency communications and response actions.

Large Table 2 Instrumentation Warning Signs

Instrument Type and Typical Location	Instrumentation Warning Sign	Corresponding Visual Changes (dependent on magnitude of movement)	Potential/Actual Consequences and Notification Procedures	Required Action
Piezometer (single or nested) – Located on Perimeter Dams/Slopes and on Cell Splitter Dams/Slope (ref. Instrumentation and Monitoring Plan for Piezometer Names and Locations)	Gradual or Sudden Increase in Water Level in One or More Piezometers, Above Threshold Action Levels (ref. Instrumentation and Monitoring Plan for Piezometer Reading Values – Predicted and Threshold)	1) Soft toe condition or increased seepage at downstream slope or dam toe. 2) Elevated pond level in basin. 3) Increased turbidity in seepage flows. 4) Boils observed downstream of dam.	1) Excessive seepage through dam and potential for dam breach. 2) An internal erosion failure possible, with potential breach of the dam. 3) Catastrophic dam breach resulting in release of water or water and liquefied tailings. **Level 1, 2 or 3 (situation dependent)**	1) Check the reading again; confirm instrumentation functionality. 2) Intensify reading frequency to daily. 3) Seek advice from the Design Engineer. 4) Commission a field investigation if so recommended. 5) Be prepared to carry out one or more responses including: a. Check downstream of the dam area for increased and/or turbid seepage discharge. b. Place granular filter buttress against any such areas, if approved by the Design Engineer. c. Initiate geotechnical evaluation per direction of the design engineer. d. Modify pond and/or basin operating procedures. e. Temporary cease operations/stop discharge into the pond. f. Lower pond by any practical means approved by the Design Engineer.
Inclinometer – Located on Perimeter Dams/Slopes and on Cell Splitter Dams/Slopes (ref. Instrumentation and Monitoring Plan for Inclinometer Names and Locations)	Gradual or Sudden Movement in Horizontal Direction in One or More Inclinometers (ref. Instrumentation and Monitoring Plan for Inclinometer Reading Values – Predicted and Threshold	1) Cracks developing at dam crest or in slope. 2) Slumping, sliding or bulging of a dam slope or adjacent ground.	1) Deformation of dam structure that may lead to eventual dam failure. 2) Catastrophic dam breach resulting in release of water or water and liquefied tailings. **Level 1, 2 or 3 (situation dependent)**	As above (blue shaded box).
Survey Monument – Located on Crest of Perimeter Dams and on Crest of Cell Splitter Dams	Gradual or Sudden Movement in Horizontal and/or Vertical Direction in One or More Survey Monuments	1) Cracks developing at dam crest or in slope. 2) Slumping, sliding or bulging of a dam slope or adjacent ground.	1) Deformation of dam structure that may lead to eventual dam failure. 2) Catastrophic dam breach resulting in release of water or water and liquefied tailings. **Level 1, 2 or 3 (situation dependent)**	As above (blue shaded box).

Notes for Notification Procedures:

Level 1 – Condition that does not warrant emergency response but requires prompt investigation and resolution.

Level 2 – Potential emergency if condition is sustained or allowed to progress; requires response plan.

Level 3 – Imminent or actual failure requiring partial or complete evacuation, emergency communications and response actions.

Large Figures

Project Areas
Tailings Ponds
Public Waters Inventory (PWI) Watercourses[1]
National Hydrography Dataset (NHD) Rivers & Streams[2]
Existing Private Railroad

[1]These are provisional representations of PWI watercourses found on the current paper regulatory maps.
[2]The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD features are created from MnDNR 24K Streams and 1:24,000 USGS quadrangle maps.
Note: Due to previous disturbance, both data sources may show watercourses that no longer exist.

0 750 1,500 3,000
Feet

BARR

CELL 2E LOCATION
MAP NorthMet Project
Poly Met Mining Inc.

Large Figure 1
Tailings Basin Geotechnical
Instrumentation and Monitoring Plan

Barr Footer: ArcGIS 10.3, 2015-07-21 13:11 File: I:\Client\PolyMet_Mining\Work_Orders\Permitting\Dam_SafetyMaps\FTB\Plan\Large Figure 1 Location Map of Cell 2E.mxd User: arm2

VW Piezometer	Inclinometers	Standpipe Piezometer	Pneumatic Piezometers
2E_2016_PZ_K1top	DH96-10	A-1	DH96-10
2E_2016_PZ_K1bottom	DH96-12	A-3	DH96-11
2E_2016_PZ_K2top	DH96-18	A-9	DH96-28A
2E_2016_PZ_K2middle	DH96-19	B-2	DH96-28
2E_2016_PZ_K2bottom	DH96-28	D-1	DH96-30
2E_2016_PZ_K2bedrock	DH96-32	D-4	DH96-32A
2E_2016_PZ_K3middle	DH96-37	E-5	DH96-37A
2E_2016_PZ_K3bottom	DH96-46	F-2	DH96-37A
	DH96-47	P2HA-99	PN1J-99
	DH99-1	P2HB-99	PH1F-99
		P1H-99	
		P3H1-99	
		P2H1-99	
		P1H1-99	
		P3H-99	
		P1B199	
		P1B99	
		G-2	

- Inclinometers
- Pneumatic Piezometers and Inclinometers
- Pneumatic Piezometers
- Standpipe Piezometers
- Vibrating Wire Piezometers

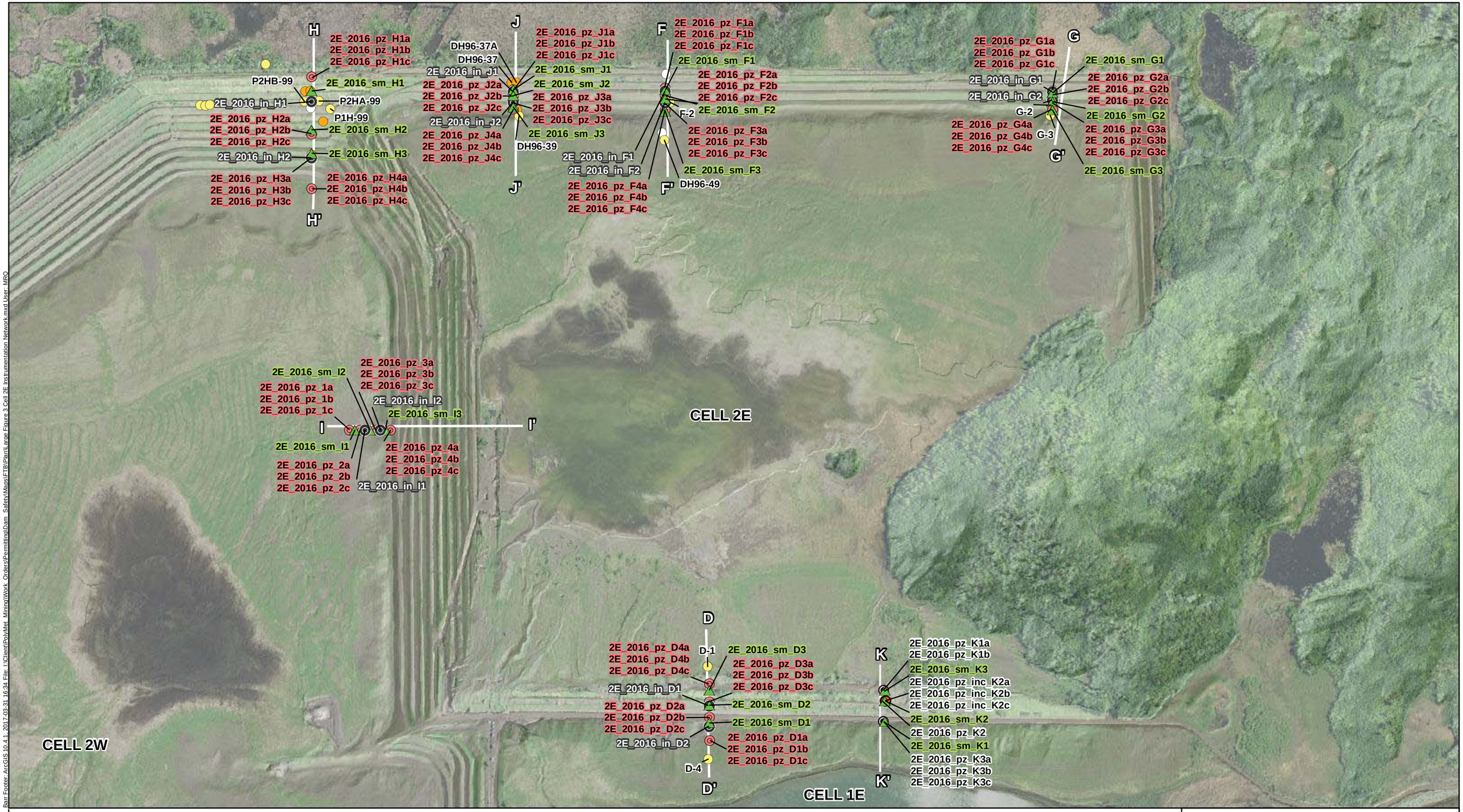
0 1,500 3,000
Feet

BARR

INSTRUMENTATION LOCATIONS
NorthMet Project
Poly Met Mining Inc.

Large Figure 2
Tailings Basin Geotechnical
Instrumentation and Monitoring Plan

Barr Footer: ArcGIS 10.4.1, 2017-03-10,15:12 File: I:\Client\PolyMet_Mining\Work_Orders\Mine_Engineering_Assistance\Maps\Reports\Dam_Safety_Inspections\2016\Large_Figure 2 Instrumentation Locations.mxd User: MRO



Barr Footer: ArcGIS 10.4.1, 2017-03-31, 16:34, File: I:\Client\PolyMet_Mining\Work_Orders\PermittingDam_Safety\Maps\EIS\Plan\Large Figure 3 Cell 2E Instrumentation Network.mxd User: MRO

Cross Section Locations

Proposed Locations
- Survey Monument
- VW Inclinometer
- Nested VW Piezometer

Existing Locations
- Inclinometer
- Inclinometer with Nested VW Piezometer
- Nested VW Piezometer

- Pneumatic Piezometer
- Pneumatic Piezometer & Inclinometer
- Standpipe Piezometer
- VW Piezometer

N

0 750 1,500

Feet

BARR

CELL 2E INSTRUMENTATION NETWORK NorthMet Project Poly Met Mining Inc.

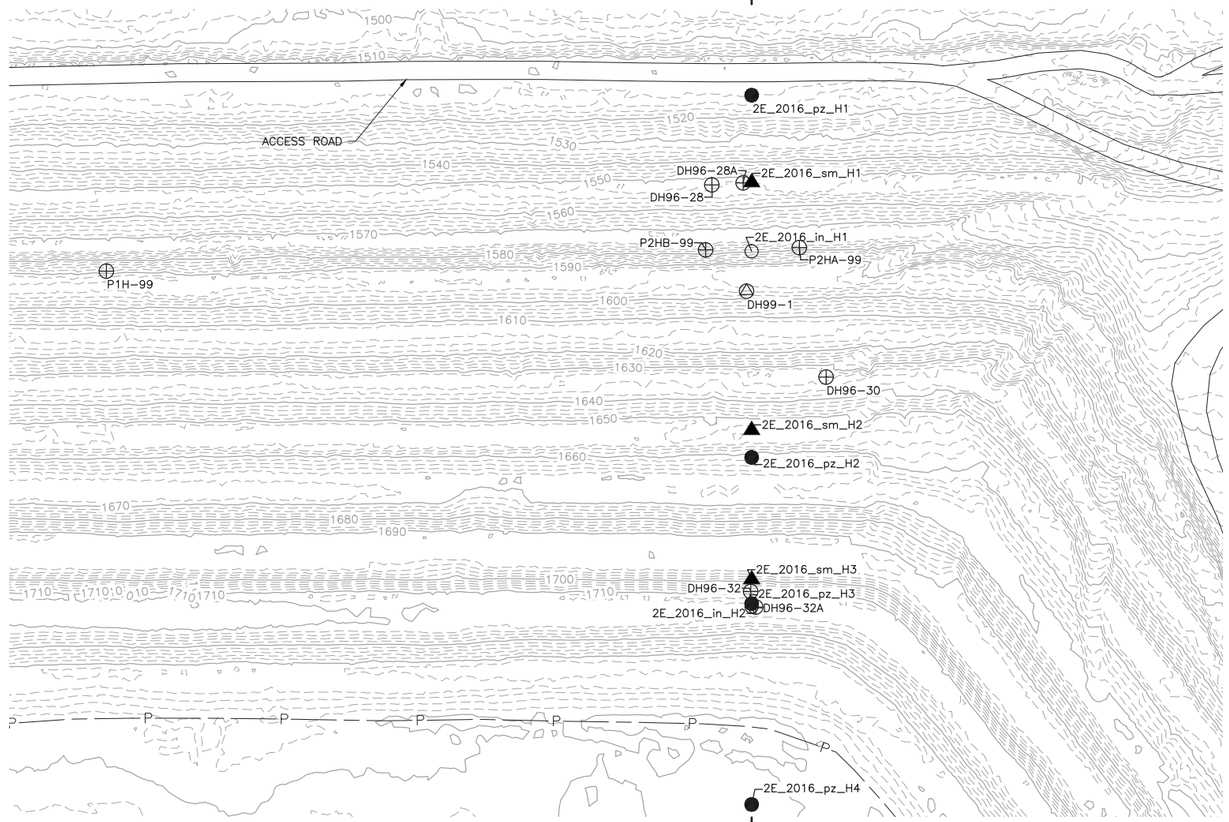
Large Figure 3
Tailings Basin Geotechnical Instrumentation and Monitoring Plan

LEGEND:

- STANDPIPE PIEZOMETER LOCATION
- INCLINOMETER LOCATION
- PROPOSED VW PIEZOMETER
- PROPOSED INCLINOMETER
- PROPOSED SURVEY MONUMENT

NOTE:

INSTRUMENT LOCATIONS ARE APPROXIMATE AND WILL BE CONFIRMED IN THE FIELD.



1 – PLAN: CROSS-SECTION H

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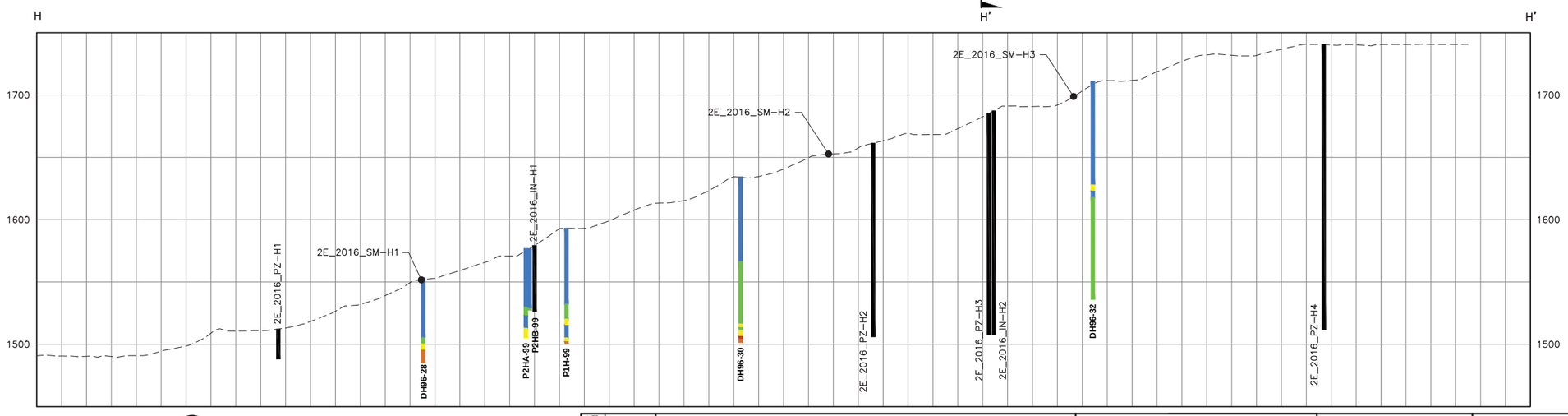

1 – SECTION: CROSS-SECTION H

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SCALE IN FEET

EXISTING INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
P2HB-99	Standpipe Piezometer	Toe	2W
P2HA-99	Standpipe Piezometer	Toe	2W
P1H-99	Standpipe Piezometer	Embankment	2W
DH96-28	Pneumatic Piezometer (D)	Toe	2W
DH96-28A	Pneumatic Piezometer (D)	Toe	2W
DH96-32	Pneumatic Piezometer & Inclinometer (D)	Crest	2W
DH96-30	Pneumatic Piezometer (D)	Embankment	2W
DH96-32A	Pneumatic Piezometer (D)	Crest	2W
DH99-1/I1H-99	Inclinometer (D)	Toe	2W

NOTE:

(D) INDICATES INSTRUMENT THAT WILL BE DECOMMISSIONED

PROPOSED INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_pz_H4c	Nested VW Piezometer	Interior	2W
2E_2016_pz_H4b	Nested VW Piezometer	Interior	2W
2E_2016_pz_H4a	Nested VW Piezometer	Interior	2W
2E_2016_pz_H3c	Nested VW Piezometer	Crest	2W
2E_2016_pz_H3b	Nested VW Piezometer	Crest	2W
2E_2016_pz_H3a	Nested VW Piezometer	Crest	2W
2E_2016_pz_H2c	Nested VW Piezometer	Embankment	2W
2E_2016_pz_H2b	Nested VW Piezometer	Embankment	2W
2E_2016_pz_H2a	Nested VW Piezometer	Embankment	2W
2E_2016_pz_H1c	Nested VW Piezometer	Toe	2W
2E_2016_pz_H1b	Nested VW Piezometer	Toe	2W
2E_2016_pz_H1a	Nested VW Piezometer	Toe	2W
2E_2016_in_H2	Inclinometer	Crest	2W
2E_2016_in_H1	Inclinometer	Embankment	2W
2E_2016_sm_H3	Survey Monument	Interior	2W
2E_2016_sm_H2	Survey Monument	Crest	2W
2E_2016_sm_H1	Survey Monument	Embankment	2W

LEGEND:

- COARSE TAILINGS
- FINE TAILINGS
- SLIMES
- NATIVE TILL
- PEAT

NOTE:

STRAGRAPHY AND INSTRUMENT DEPTH IS APPROXIMATE AND WILL BE UPDATED AS PART OF FUTURE GEOTECHNICAL INSTRUMENT INSTALLATIONS.

VER NO.	DATE	DESCRIPTION
1	7-11-16	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 6 – ATTACHMENT D
2	3-31-17	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 7 – ATTACHMENT D

ISSUE STATUS	VERSION	DATE
FOR PERMITTING	2	3-31-17
FOR CONSTRUCTION	–	–
NOT APPROVED FOR CONSTRUCTION		

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

PRINTED NAME THOMAS J. RADUE

SIGNATURE Thomas J. Radue

DATE 3-31-17 LICENSE# 20951

DRAWN: CMB2

CHECKED: SJW

BARR PROJECT NO.: 23/69-0862

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

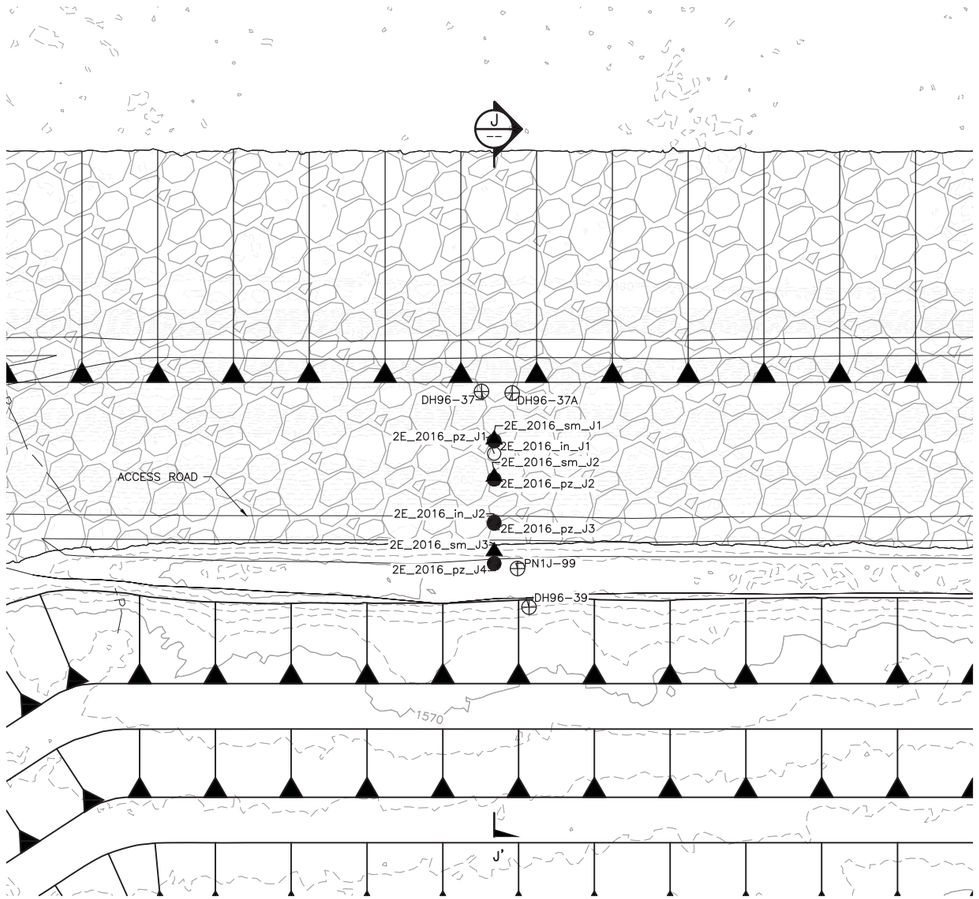
FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION H

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
4700 WEST 77TH STREET
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. LARGE FIGURE 4

REV .



1 PLAN: CROSS-SECTION J

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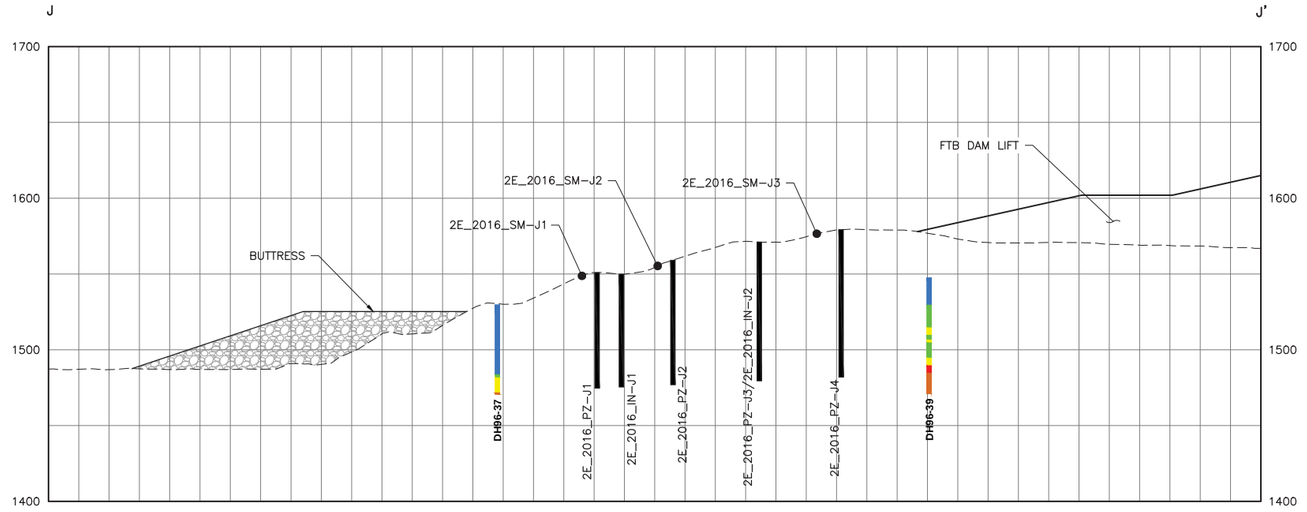

LEGEND:

- COARSE TAILINGS
- FINE TAILINGS
- SLIMES
- NATIVE TILL
- PEAT

1 SECTION: CROSS-SECTION J

0 50 100

SCALE IN FEET

NOTE:

STRAGRAPHY AND INSTRUMENT DEPTH IS APPROXIMATE AND WILL BE UPDATED AS PART OF FUTURE GEOTECHNICAL INSTRUMENT INSTALLATIONS.

LEGEND:

- STANDPIPE PIEZOMETER LOCATION
- INCLINOMETER LOCATION
- PROPOSED VW PIEZOMETER
- PROPOSED INCLINOMETER
- PROPOSED SURVEY MONUMENT

NOTE:

INSTRUMENT LOCATIONS ARE APPROXIMATE AND WILL BE CONFIRMED IN THE FIELD.

EXISTING INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
DH96-39	Pneumatic Piezometer	Tailings/Crest	2E
DH96-37	Pneumatic Piezometer (D)	Embankment	2E
DH96-37A	Pneumatic Piezometer (D)	Embankment	2E
PN1J-99/DH96-40	Pneumatic Piezometer (D)	Tailings/Crest	2E

NOTE:

(D) INDICATES INSTRUMENT THAT WILL BE DECOMMISSIONED

PROPOSED INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_pz_J4c	Nested VW Piezometer	Interior	2E
2E_2016_pz_J4b	Nested VW Piezometer	Interior	2E
2E_2016_pz_J4a	Nested VW Piezometer	Interior	2E
2E_2016_pz_J3c	Nested VW Piezometer	Crest	2E
2E_2016_pz_J3b	Nested VW Piezometer	Crest	2E
2E_2016_pz_J3a	Nested VW Piezometer	Crest	2E
2E_2016_pz_J2c	Nested VW Piezometer	Embankment	2E
2E_2016_pz_J2b	Nested VW Piezometer	Embankment	2E
2E_2016_pz_J2a	Nested VW Piezometer	Embankment	2E
2E_2016_pz_J1c	Nested VW Piezometer	Toe	2E
2E_2016_pz_J1b	Nested VW Piezometer	Toe	2E
2E_2016_pz_J1a	Nested VW Piezometer	Toe	2E
2E_2016_in_J2	Inclinometer	Crest	2E
2E_2016_in_J1	Inclinometer	Embankment	2E
2E_2016_sm_J3	Survey Monument	Interior	2E
2E_2016_sm_J2	Survey Monument	Crest	2E
2E_2016_sm_J1	Survey Monument	Embankment	2E

VER NO	DATE	DESCRIPTION
1	7-11-16	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 6 – ATTACHMENT D
2	3-31-17	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 7 – ATTACHMENT D

ISSUE STATUS		
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PRINTED NAME THOMAS J. RADUE

SIGNATURE Thomas J. Radue

DATE 3-31-17 LICENSE# 20951

DRAWN: CMB2

CHECKED: SJW

BARR PROJECT NO.: 23/69-0862

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

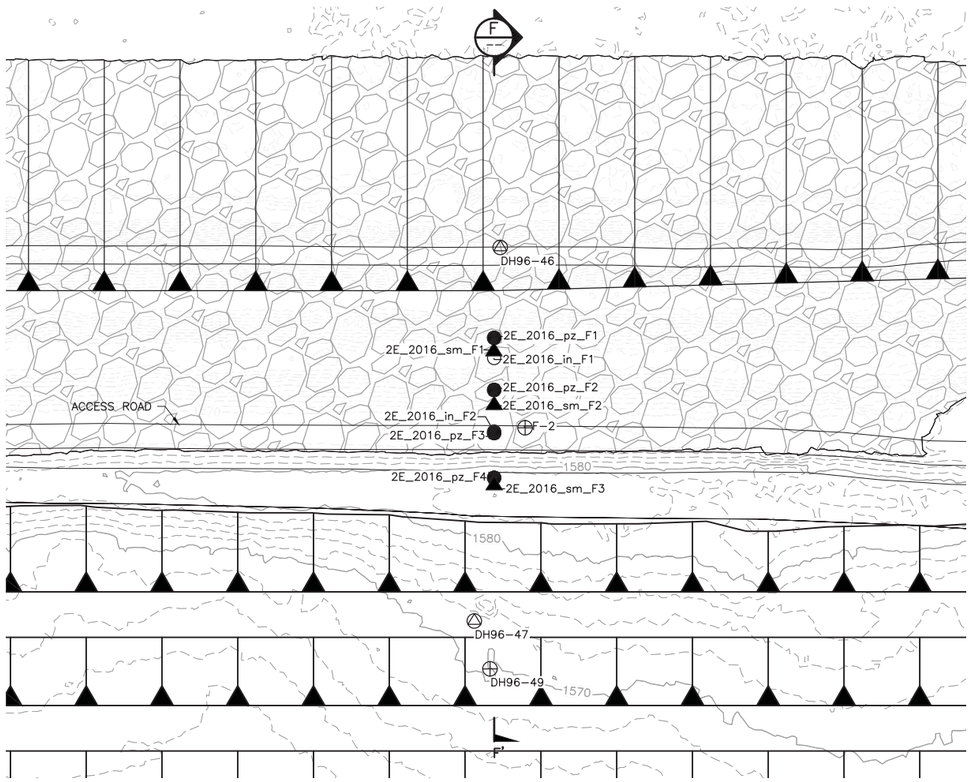
FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION J

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
4700 WEST 77TH STREET
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. LARGE FIGURE 5

REV .



1 PLAN: CROSS-SECTION F

0 100 200

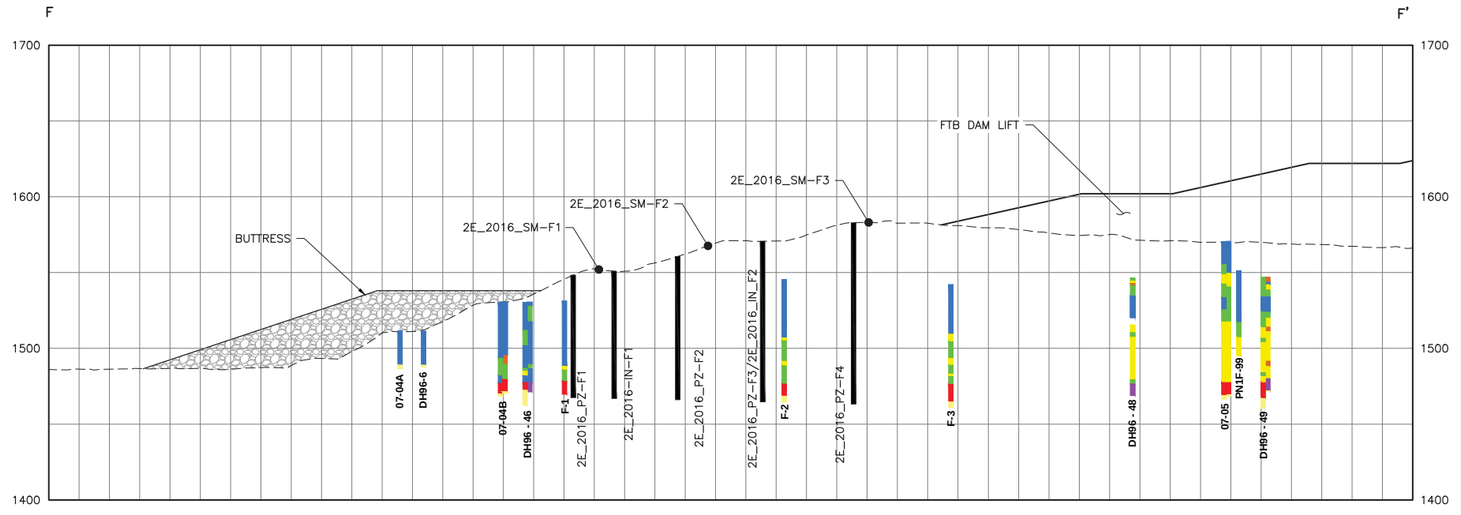
SCALE IN FEET

NOTE:

INSTRUMENT LOCATIONS ARE APPROXIMATE AND WILL BE CONFIRMED IN THE FIELD.

LEGEND:

- ⊕ STANDPIPE PIEZOMETER LOCATION
- △ INCLINOMETER LOCATION
- ● PROPOSED VW PIEZOMETER
- ○ PROPOSED INCLINOMETER
- ▲ PROPOSED SURVEY MONUMENT



LEGEND:

- COARSE TAILINGS
- FINE TAILINGS
- SLIMES
- NATIVE TILL
- PEAT

1 SECTION: CROSS-SECTION F

0 50 100

SCALE IN FEET

NOTE:

STRAGRAPHY AND INSTRUMENT DEPTH IS APPROXIMATE AND WILL BE UPDATED AS PART OF FUTURE GEOTECHNICAL INSTRUMENT INSTALLATIONS.

EXISTING INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
F-2	Standpipe Piezometer	Crest	2E
DH96-49/PN1F-99	Standpipe Piezometer	Tailings	2E
DH96-46	Inclinometer (D)	Embankment	2E
DH96-47	Inclinometer (D)	Tailings	2E

NOTE:

(D) INDICATES INSTRUMENT THAT WILL BE DECOMMISSIONED

PROPOSED INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_pz_F4c	Nested VW Piezometer	Interior	2E
2E_2016_pZ_F4b	Nested VW Piezometer	Interior	2E
2E_2016_pz_F4a	Nested VW Piezometer	Interior	2E
2E_2016_pz_F3c	Nested VW Piezometer	Crest	2E
2E_2016_pz_F3b	Nested VW Piezometer	Crest	2E
2E_2016_pz_F3a	Nested VW Piezometer	Crest	2E
2E_2016_pz_F2c	Nested VW Piezometer	Embankment	2E
2E_2016_pz_F2b	Nested VW Piezometer	Embankment	2E
2E_2016_pz_F2a	Nested VW Piezometer	Embankment	2E
2E_2016_pz_F1c	Nested VW Piezometer	Toe	2E
2E_2016_pz_F1b	Nested VW Piezometer	Toe	2E
2E_2016_pz_F1a	Nested VW Piezometer	Toe	2E
2E_2016_in_F2	Inclinometer	Crest	2E
2E_2016_in_F1	Inclinometer	Embankment	2E
2E_2016_sm_F3	Survey Monument	Interior	2E
2E_2016_sm_F2	Survey Monument	Crest	2E
2E_2016_sm_F1	Survey Monument	Embankment	2E

VER NO.	DATE	DESCRIPTION
1	7-11-16	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 6 – ATTACHMENT D
2	3-31-17	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 7 – ATTACHMENT D

ISSUE STATUS	VERSION	DATE
FOR PERMITTING	2	3-31-17
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SIGNATURE Thomas J. Radue

DATE 3-31-17 LICENSE# 20951

DRAWN: CMB2

CHECKED: SJW

BARR PROJECT NO.: 23/69-0862

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION F

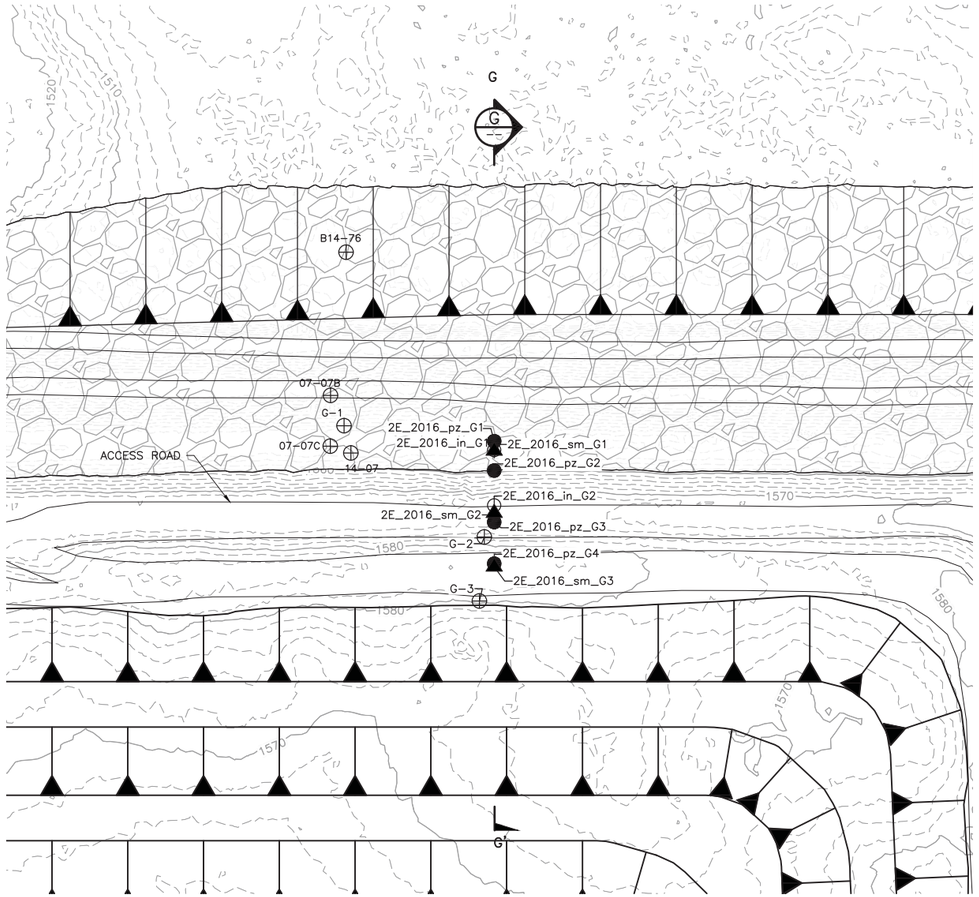
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
4700 WEST 77TH STREET
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. LARGE FIGURE 6

REV .

INCHES 1 2



1 PLAN: CROSS-SECTION G

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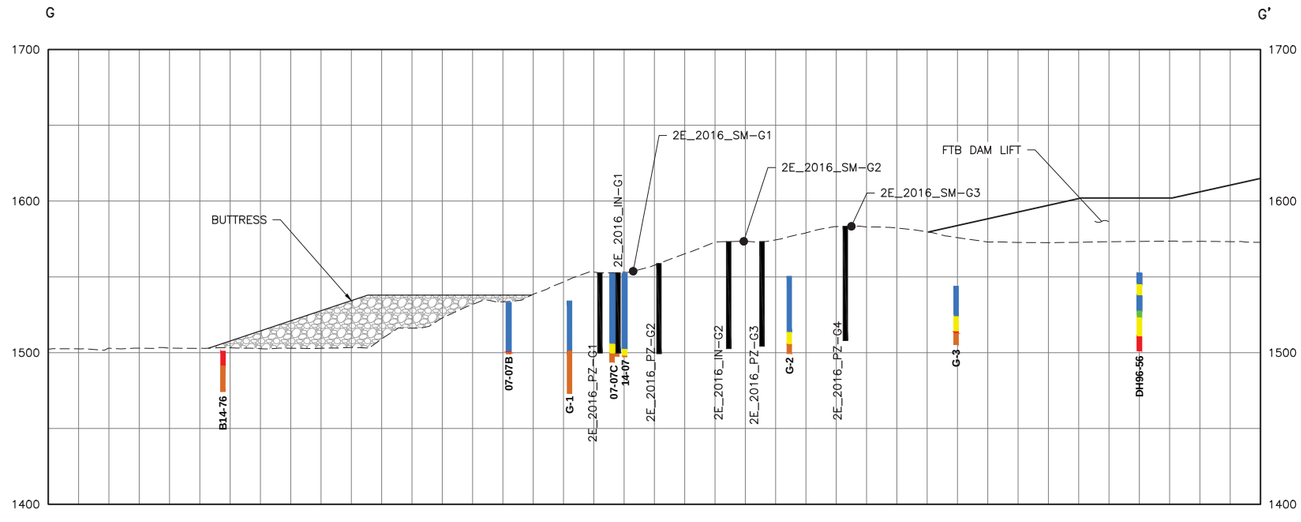

LEGEND:

- COARSE TAILINGS
- FINE TAILINGS
- SLIMES
- NATIVE TILL
- PEAT

1 SECTION: CROSS-SECTION G

0 50 100

SCALE IN FEET

NOTE:

STRAGRAPHY AND INSTRUMENT DEPTH IS APPROXIMATE AND WILL BE UPDATED AS PART OF FUTURE GEOTECHNICAL INSTRUMENT INSTALLATIONS.

NOTE:

INSTRUMENT LOCATIONS ARE APPROXIMATE AND WILL BE CONFIRMED IN THE FIELD.

LEGEND:

- ⊕ STANDPIPE PIEZOMETER LOCATION
- △ INCLINOMETER LOCATION
- ● PROPOSED VW PIEZOMETER
- ○ PROPOSED INCLINOMETER
- ▲ PROPOSED SURVEY MONUMENT

EXISTING INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
G-2	Standpipe Piezometer	Tailings	2E
G-3	Standpipe Piezometer	Crest	2E

NOTE:
LOCATION FOR INSTRUMENTS B14-76, 07-07B, G-1, 07-07C AND 14-07 ARE APPROXIMATE.

PROPOSED INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_pz_G4c	Nested VW Piezometer	Interior	2E
2E_2016_pz_G4b	Nested VW Piezometer	Interior	2E
2E_2016_pz_G4a	Nested VW Piezometer	Interior	2E
2E_2016_pz_G3c	Nested VW Piezometer	Crest	2E
2E_2016_pz_G3b	Nested VW Piezometer	Crest	2E
2E_2016_pz_G3a	Nested VW Piezometer	Crest	2E
2E_2016_pz_G2c	Nested VW Piezometer	Embankment	2E
2E_2016_pz_G2b	Nested VW Piezometer	Embankment	2E
2E_2016_pz_G2a	Nested VW Piezometer	Embankment	2E
2E_2016_pz_G1c	Nested VW Piezometer	Toe	2E
2E_2016_pz_G1b	Nested VW Piezometer	Toe	2E
2E_2016_pz_G1a	Nested VW Piezometer	Toe	2E
2E_2016_in_G2	Inclinometer	Crest	2E
2E_2016_in_G1	Inclinometer	Embankment	2E
2E_2016_sm_G3	Survey Monument	Interior	2E
2E_2016_sm_G2	Survey Monument	Crest	2E
2E_2016_sm_G1	Survey Monument	Embankment	2E

VER NO.	DATE	DESCRIPTION
1	7-11-16	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 6 – ATTACHMENT D
2	3-31-17	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 7 – ATTACHMENT D

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FOR PERMITTING	2	3-31-17
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PRINTED NAME THOMAS J. RADUE

SIGNATURE Thomas J. Radue

DATE 3-31-17 LICENSE# 20951

DRAWN: CMB2

CHECKED: SJW

BARR PROJECT NO.: 23/69-0862

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

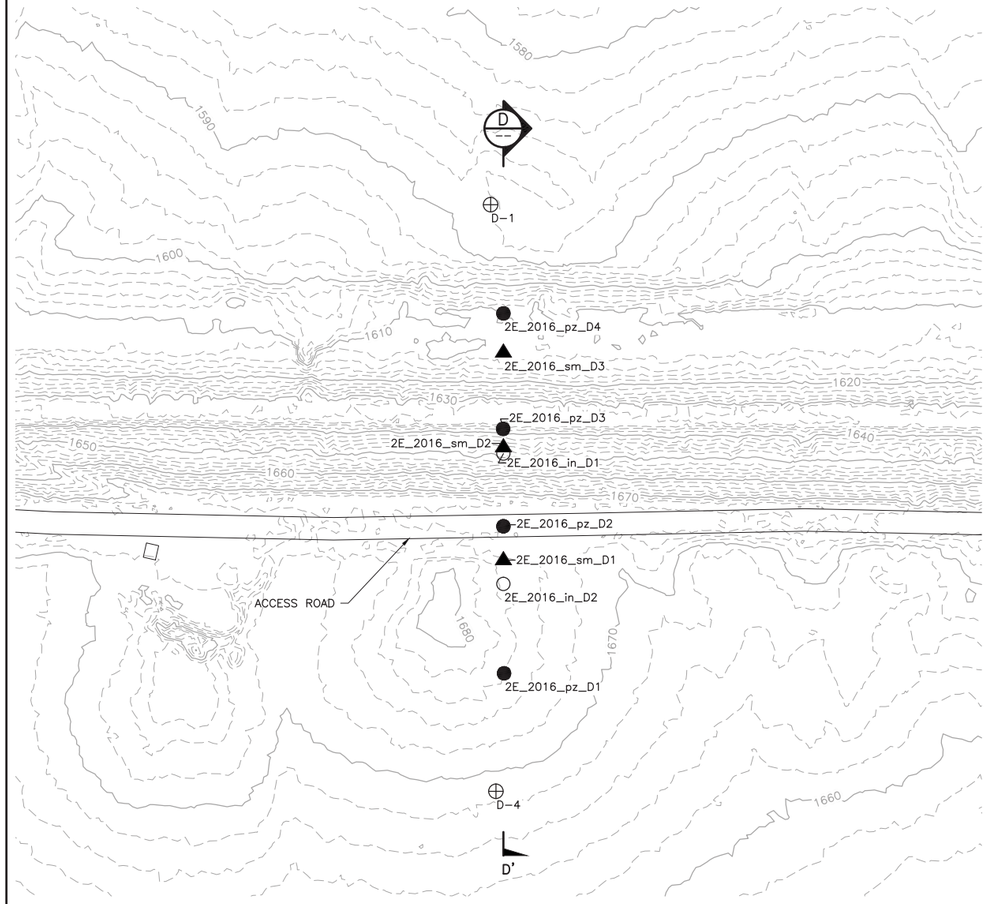
FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION G

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
4700 WEST 77TH STREET
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. LARGE FIGURE 7

REV .



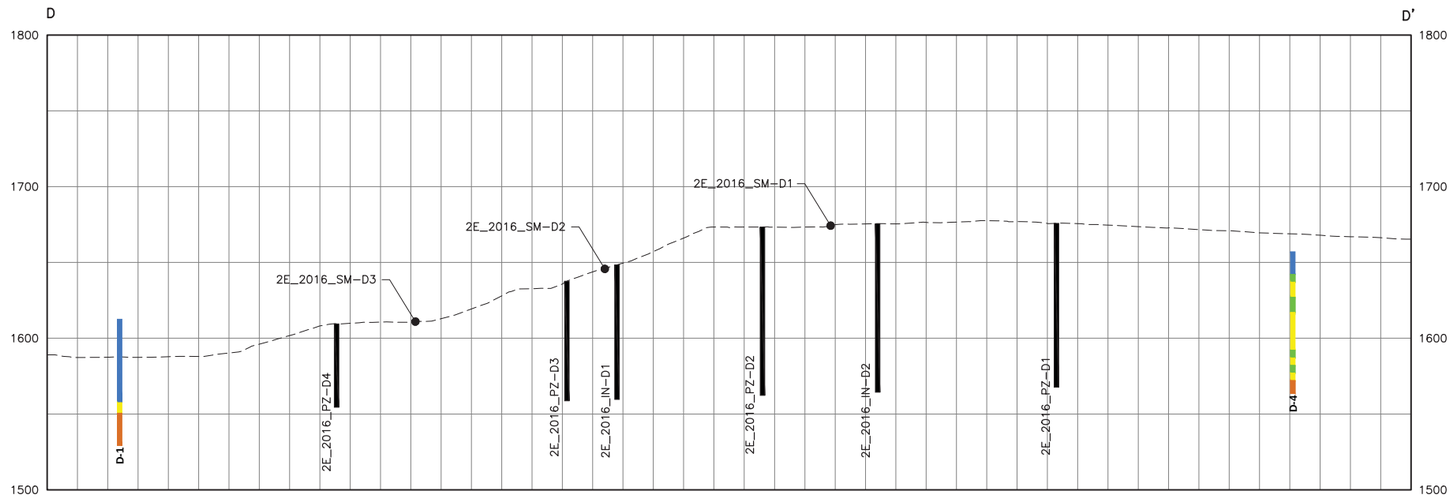
1 PLAN: CROSS-SECTION D

0 100 200

SCALE IN FEET

NOTE:

INSTRUMENT LOCATIONS ARE APPROXIMATE AND WILL BE CONFIRMED IN THE FIELD.



LEGEND:

- COARSE TAILINGS
- FINE TAILINGS
- SLIMES
- NATIVE TILL
- PEAT

1 SECTION: CROSS-SECTION D

0 50 100

SCALE IN FEET

NOTE:

STRAGRAPHY AND INSTRUMENT DEPTH IS APPROXIMATE AND WILL BE UPDATED AS PART OF FUTURE GEOTECHNICAL INSTRUMENT INSTALLATIONS.

LEGEND:

- STANDPIPE PIEZOMETER LOCATION
- INCLINOMETER LOCATION
- PROPOSED VW PIEZOMETER
- PROPOSED INCLINOMETER
- PROPOSED SURVEY MONUMENT

EXISTING INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
D-1	Standpipe Piezometer	Toe of 2E	1E
D-4	Standpipe Piezometer	Tailings	1E

PROPOSED INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_pz_D4c	Nested VW Piezometer	Crest	1E
2E_2016_pz_D4b	Nested VW Piezometer	Crest	1E
2E_2016_pz_D4a	Nested VW Piezometer	Crest	1E
2E_2016_pz_D3c	Nested VW Piezometer	Crest	1E
2E_2016_pz_D3b	Nested VW Piezometer	Crest	1E
2E_2016_pz_D3a	Nested VW Piezometer	Crest	1E
2E_2016_pz_D2c	Nested VW Piezometer	Crest	1E
2E_2016_pz_D2b	Nested VW Piezometer	Crest	1E
2E_2016_pz_D2a	Nested VW Piezometer	Crest	1E
2E_2016_pz_D1c	Nested VW Piezometer	Crest	1E
2E_2016_pz_D1b	Nested VW Piezometer	Crest	1E
2E_2016_pz_D1a	Nested VW Piezometer	Crest	1E
2E_2016_in_D2	Inclinometer	Crest	1E
2E_2016_in_D1	Inclinometer	Embankment	1E
2E_2016_sm_D3	Survey Monument	Interior	1E
2E_2016_sm_D2	Survey Monument	Crest	1E
2E_2016_sm_D1	Survey Monument	Embankment	1E

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2	3-31-17	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 7 – ATTACHMENT D

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SIGNATURE Thomas J. Radue

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CHECKED: SJW

BARR PROJECT NO.: 23/69-0862

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION D

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NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
4700 WEST 77TH STREET
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. LARGE FIGURE 8

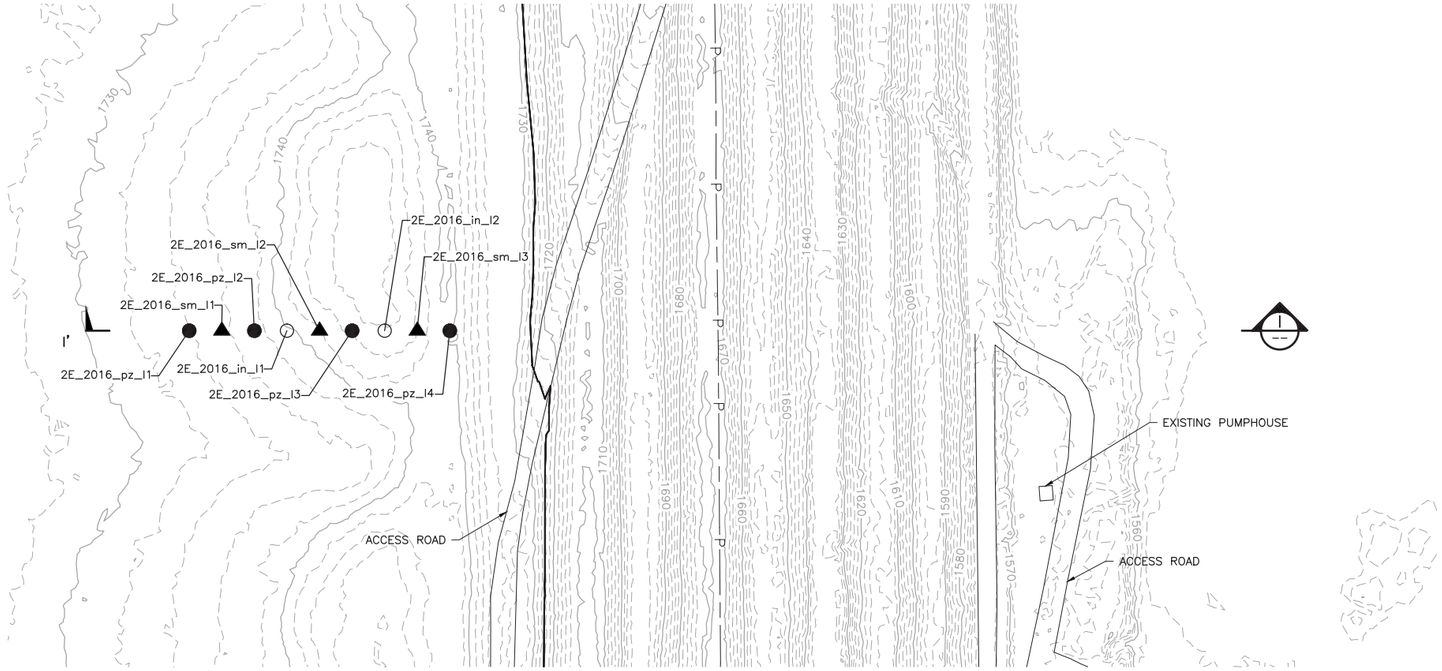
REV .

LEGEND:

- ⊕ STANDPIPE PIEZOMETER LOCATION
- ⏢ INCLINOMETER LOCATION
- ● PROPOSED VW PIEZOMETER
- ○ PROPOSED INCLINOMETER
- ▲ PROPOSED SURVEY MONUMENT

NOTE:

INSTRUMENT LOCATIONS ARE APPROXIMATE AND WILL BE CONFIRMED IN THE FIELD.



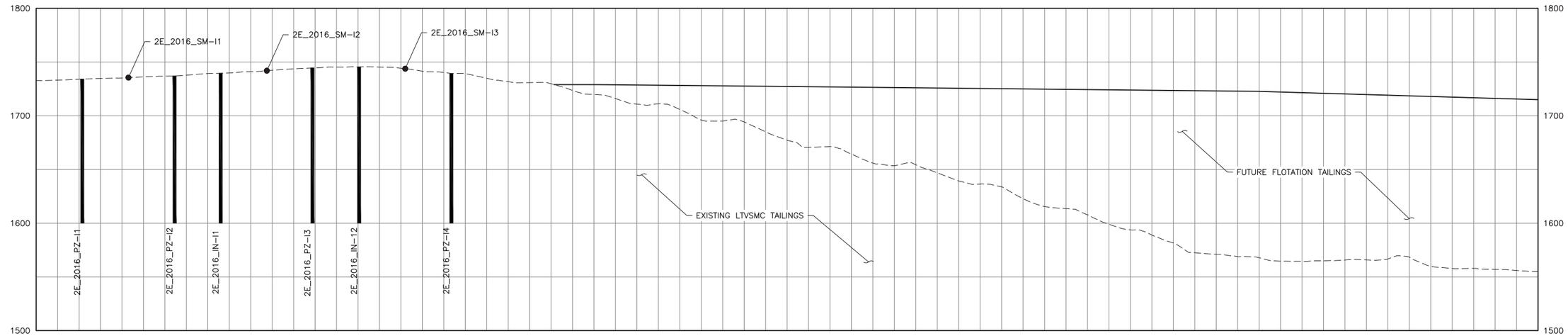
1 PLAN: CROSS–SECTION I

0 100 200
SCALE IN FEET

PROPOSED INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_pz_I4c	Nested VW Piezometer	Crest	2E
2E_2016_pz_I4b	Nested VW Piezometer	Crest	2E
2E_2016_pz_I4a	Nested VW Piezometer	Crest	2E
2E_2016_pz_I3c	Nested VW Piezometer	Crest	2E
2E_2016_pz_I3b	Nested VW Piezometer	Crest	2E
2E_2016_pz_I3a	Nested VW Piezometer	Crest	2E
2E_2016_pz_I2c	Nested VW Piezometer	Crest	2E
2E_2016_pz_I2b	Nested VW Piezometer	Crest	2E
2E_2016_pz_I2a	Nested VW Piezometer	Crest	2E
2E_2016_pz_I1c	Nested VW Piezometer	Crest	2E
2E_2016_pz_I1b	Nested VW Piezometer	Crest	2E
2E_2016_pz_I1a	Nested VW Piezometer	Crest	2E
2E_2016_in_I2	Inclinometer	Crest	2E
2E_2016_in_I1	Inclinometer	Embankment	2E
2E_2016_sm_I3	Survey Monument	Interior	2E
2E_2016_sm_I2	Survey Monument	Crest	2E
2E_2016_sm_I1	Survey Monument	Embankment	2E

I I'



1 SECTION: CROSS–SECTION I

0 50 100
SCALE IN FEET

LEGEND:

- COARSE TAILINGS
- FINE TAILINGS
- SLIMES
- NATIVE TILL
- PEAT

NOTE:

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SIGNATURE Thomas J. Radue

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BARR PROJECT NO.: 23/69–0862

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PLANT DRAWING NUMBER:

FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION I

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BARR ENGINEERING COMPANY
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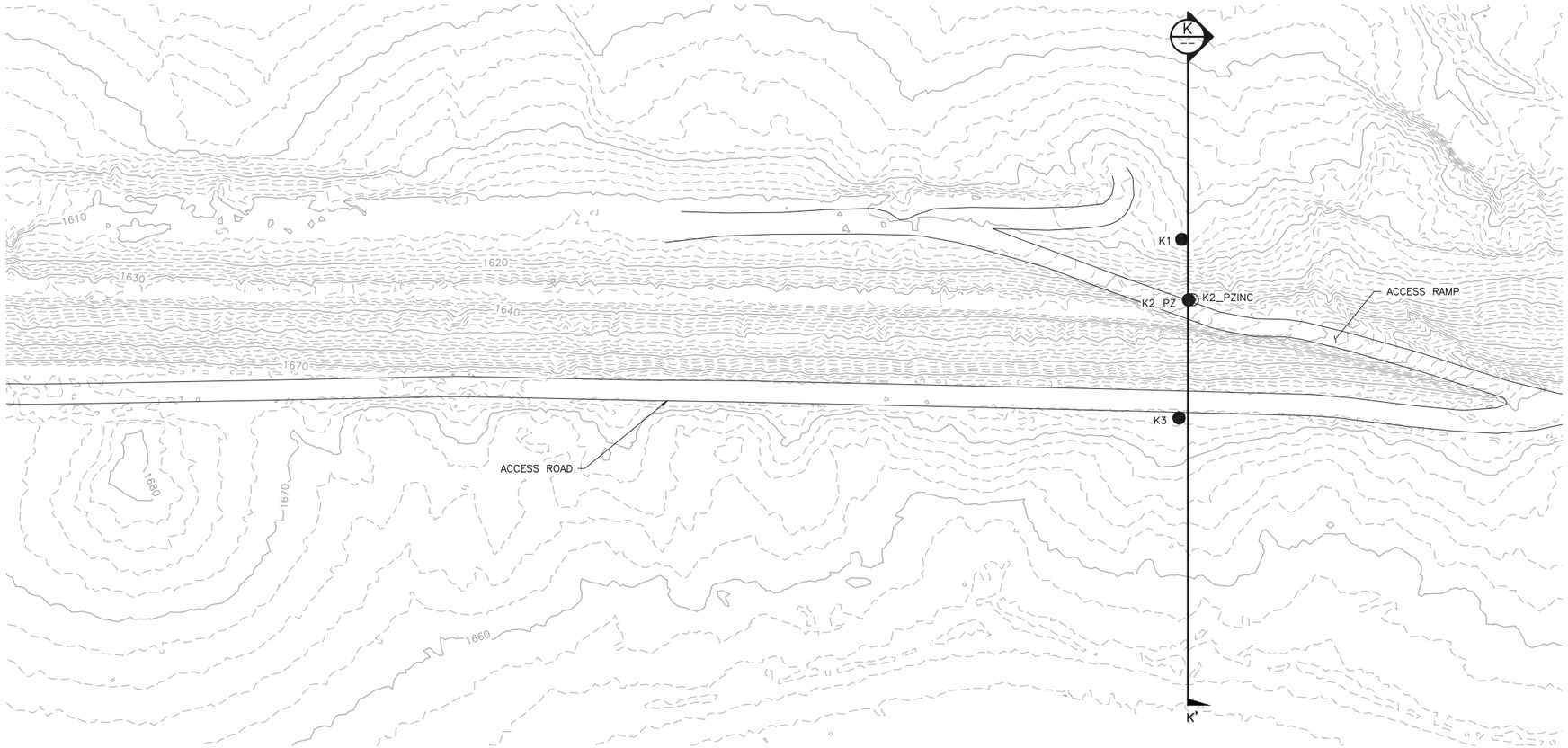
MINNEAPOLIS, MN.
Ph: 1–800–632–2277

DWG. NO. LARGE FIGURE 9

REV .

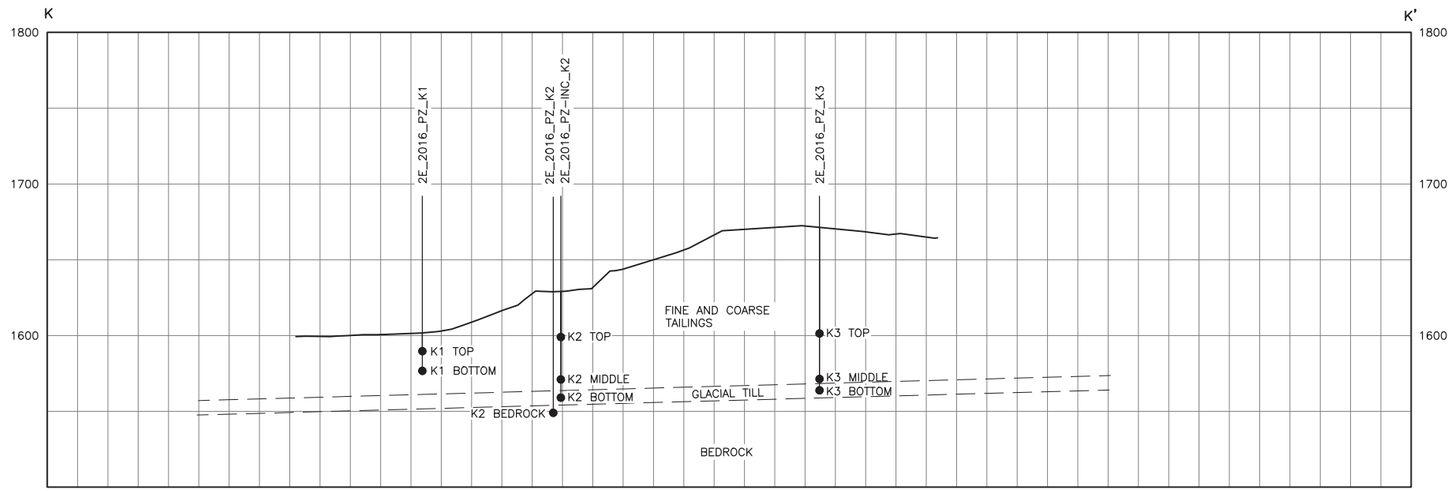


LEGEND:

- VW PIEZOMETER
- INCLINOMETER WITH NESTED VW PIEZOMETER
- SEEP LOCATION

1 PLAN: CROSS-SECTION K

0 100 200
SCALE IN FEET



2 SECTION: CROSS-SECTION K

0 50 100
SCALE IN FEET

EXISTING INSTRUMENTATION

NAME	INSTRUMENTATION	LOCATION	CELL
2E_2016_PZ_K1 top	Nested VW Piezometer	Perimeter Dam Toe	2E
2E_2016_PZ_K1 bottom	Nested VW Piezometer	Perimeter Dam Toe	2E
2E_2016_PZ-INC_K2 top	Inclinometer with Nested VW Piezometer	Mid-Slope	2E
2E_2016_PZ-INC_K2 middle	Inclinometer with Nested VW Piezometer	Mid-Slope	2E
2E_2016_PZ-INC_K2 bottom	Inclinometer with Nested VW Piezometer	Mid-Slope	2E
2E_2016_PZ_K2 bedrock	VW Piezometer	Mid-Slope	2E
2E_2016_PZ_K3 top	Nested VW Piezometer	Crest	2E
2E_2016_PZ_K3 middle	Nested VW Piezometer	Crest	2E
2E_2016_PZ_K3 bottom	Nested VW Piezometer	Crest	2E

NOTES:

1. GROUND SURFACE FROM 2016 SURVEY.
2. STRATIGRAPHY IS APPROXIMATE AND FOR CONCEPTUAL PURPOSES ONLY.

VER NO	DATE	DESCRIPTION
1	7-11-16	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 6 – ATTACHMENT D
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PLANT DRAWING NUMBER:

FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN SECTION K

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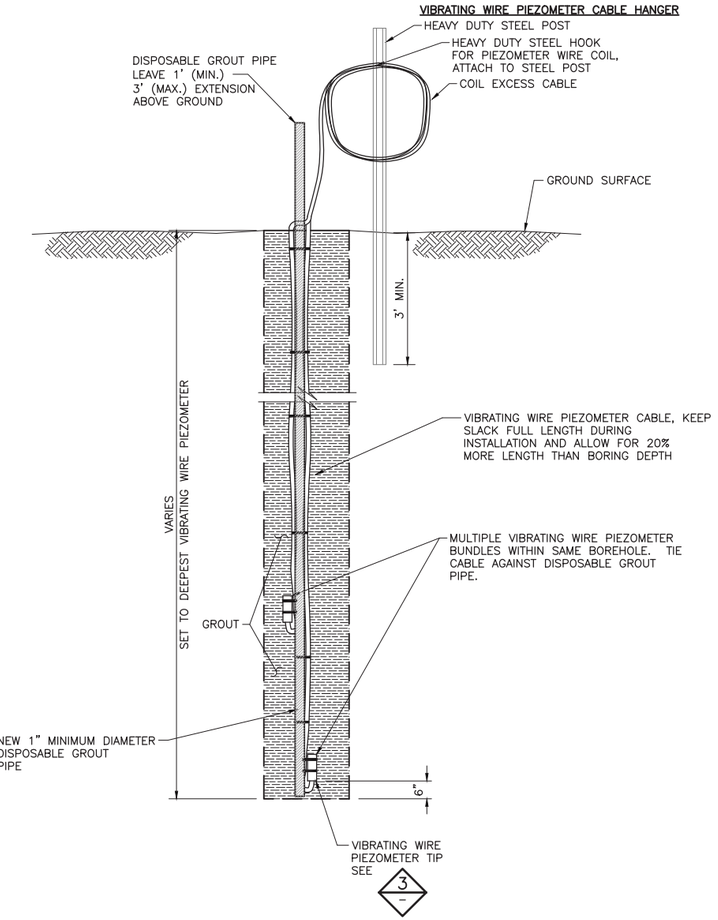
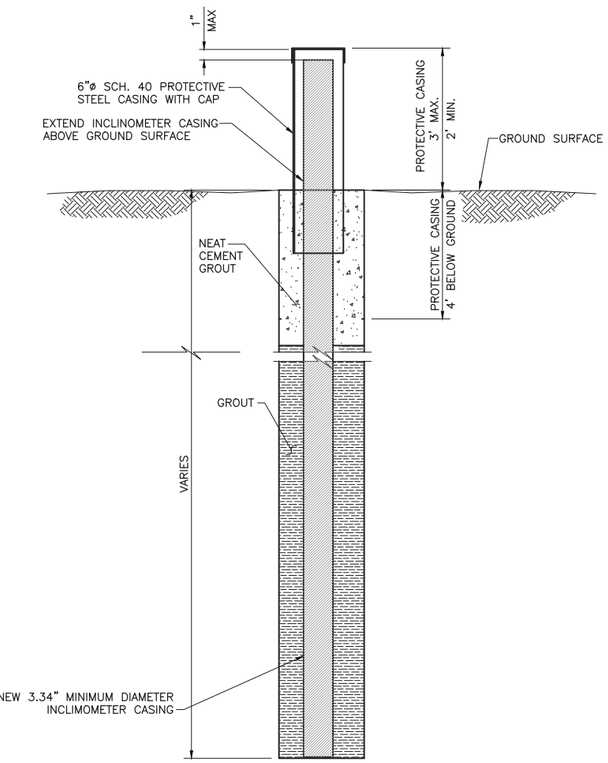
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

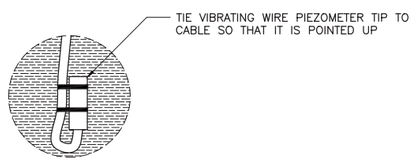
DWG. NO. LARGE FIGURE 10
REV .



1/– DETAIL: TYPICAL (VW) VIBRATING WIRE PIEZOMETER INSTALLATION
N.T.S.



2/– DETAIL: TYPICAL INCLINOMETER INSTALLATION
N.T.S.



3/– DETAIL: TYPICAL VIBRATING WIRE PIEZOMETER TIP
N.T.S.

VER NO	DATE	DESCRIPTION
1	7–11–16	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 6 – ATTACHMENT D
2	3–31–17	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 7 – ATTACHMENT D

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DRAWN: CMB2

CHECKED: SJW

BARR PROJECT NO.: 23/69–0862

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

FLOTATION TAILINGS BASIN GEOTECHNICAL INSTRUMENTATION PLAN DETAILS

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
4700 WEST 77TH STREET
MINNEAPOLIS, MN.
Ph: 1–800–632–2277

DWG. NO. LARGE FIGURE 11

REV .

Exhibits

Exhibit A

Technical Specifications – Fully Grouted Vibrating Wire Piezometers

TECHNICAL SPECIFICATIONS
FULLY GROUTED VIBRATING WIRE PIEZOMETERS

1.0 SCOPE

The work covered under this section of the Specifications consists of furnishing all labor, materials, equipment, and performing all operations necessary to construct and install vibrating wire piezometers using the fully grouted method. The piezometer tips will be provided by the OWNER'S REPRESENTATIVE. The proposed piezometer locations are shown on Large Figures 4 through 9 of the Tailings Basin Geotechnical Instrumentation and Monitoring Plan (Plan). Minor adjustments to the proposed locations and elevations may be made in the field by the OWNER'S REPRESENTATIVE.

2.0 RERENCE STANDARDS

2.1 ASTM D-1586 Standard Test Method for Standard Penetration (SPT) and Split-Barrel Sampling of Soils

2.2 ASTM C-150 Specifications for Portland Cement

In case of conflict between these Technical Specifications and the above standards, the Technical Specifications will prevail.

3.0 SUBMITTALS

3.1 Concrete sand product sheet.

3.2 Sand pack gradation product sheet.

3.3 Bentonite product sheet.

3.4 Portland cement product sheet.

3.5 Drilling fluid addition product sheet.

4.0 MATERIALS

4.1 Drilling Fluid

Drilling fluid for boreholes used for vibrating wire piezometers shall be drilling mud, potable water (defined as water which is safe for human consumption in that it is free from impurities in amounts sufficient to cause disease or harmful physiological effects) and bentonite. Other additives may not be added to maintain a stable borehole.

4.2 Portland Cement

Portland Cement (Type I) shall meet the requirements of ASTM C-150.

4.3 Bentonite

Bentonite shall be finely ground, premium-grade bentonite, equal to Quick Gel manufactured by NL Baroid Industries, Inc. of Houston, Texas. The bentonite shall be free from lumps and objectionable material that would prevent easy mixing into a smooth fluid, free from lumps of unmixed bentonite.

4.4 Vibrating Wire Piezometer Tip and Cable

The vibrating wire piezometer shall be a 250 psi tip that meets the specifications of the Slope Indicator Company's Model 52611040 vibrating wire piezometer or approved equal. The cable shall be marked at the factory, at the end where the readout gate is connected, with the following minimum details: length, serial number, and pressure range. These will be supplied by the OWNER'S REPRESENTATIVE.

4.5 Grout for Backfill of Vibrating Wire Piezometers

The grout for backfilling the boreholes of the vibrating wire piezometers shall consist of a mixture of Portland Cement (one bag approximately 94 pounds) to 29 gallons of water to approximately 30 pounds of bentonite as needed. Portland Cement and bentonite shall be weighed and amounts recorded for each batch used for backfill. Water and cement shall be mixed first. The bentonite shall be added slowly under high agitation to make grout creamy, yet pumpable. This yields a cement-water-bentonite ratio by weight of 1:2.5:0.3.

INVESTIGATION CONTRACTOR shall provide a scale to weigh out the proportions of this mix, accurate to the nearest pound. Water proportion shall be measured by 5-gallon bucket that is marked at 1-gallon increments. The OWNER'S REPRESENTATIVE shall approve the grout mix before it is placed in the borehole.

4.6 Concrete Grout for Protective Casing

Concrete grout for piezometer protective casing installation shall consist of 1 part potable water, 2 parts Portland cement, and 2 parts clean sand.

4.7 Protective Casings

Protective casings shall be embedded into the ground surface and extended over the protruding portions of the piezometer casings. The tops of the protective casings shall extend no more than 4 feet above the ground surface and should be embedded a minimum of 2 feet below ground. The protective casings shall consist of Schedule 40 steel with caps and be at least 12 inches in diameter.

4.8 Grout Pipe (Disposable)

The disposable grout pipe shall have a large enough diameter to facilitate grout injection into bottom of borehole while fitting inside hollow-stem auger casing. The disposable grout pipe shall be PVC.

5.0 PERFORMANCE

The INVESTIGATION CONTRACTOR shall practice good piezometer/monitoring well construction procedures that conform with ASTM or other procedures in these specifications. If, in the opinion of OWNER'S CLIENT or OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR'S procedure is inadequate to construct a useable piezometer, the INVESTIGATION CONTRACTOR shall change procedures to meet the requirements of these specifications. The piezometers shall be constructed in the borings specified by OWNER'S REPRESENTATIVE at the time of drilling.

5.1 Piezometer/Monitoring Well Locations

The general locations of the required piezometers are identified on the previously referenced Figures. OWNER'S REPRESENTATIVE will stake the locations of the borings in the field for INVESTIGATION CONTRACTOR.

5.2 Vibrating Wire Piezometer Construction

Each boring shall be advanced to the design depth with a 6¼- inch, minimum inside diameter, hollow-stem auger. Each piezometer shall be assembled and installed so that the tip is at the design depth. The porous piezometer filter tip shall be properly saturated before installation into the borehole and set with the tip up and taped to the disposable grout pipe and/or inclinometer casing as appropriate at each borehole location. Final position of the VW piezometer shall be determined in the field by OWNER'S REPRESENTATIVE.

Once the VW tip has been saturated, the INVESTIGATION CONTRACTOR shall assemble the tip, disposable pipe, and cables in a way to prevent the tip from becoming desaturated. If, due to complications during installation, the tip does become desaturated the tip shall be resaturated.

Each VW piezometer tip shall be calibrated by the OWNER'S REPRESENTATIVE prior to installation.

Grout for backfilling the vibrating wire piezometers shall be placed in the borehole by pumping under pressure through the disposable grout pipe (tremie pipe). The hollow-stem auger shall be withdrawn as necessary during the grouting process. The grout pipe shall permanently remain in the boring.

Grout for backfilling the vibrating wire piezometers shall be mixed to a smooth and thick cream-like consistency, to where it is as heavy as it is feasible to pump. The

INVESTIGATION CONTRACTOR shall be responsible for supplying a pump that is capable of pumping a heavy slurry mix as previously described.

5.3 Piezometer Protection

The protective casing shall be installed to an approximate depth of 2 feet in the borehole. The exact depth shall be adjusted so that the top of the casing is even with the top of the capped riser pipe. The annulus between the protective casing and the borehole wall shall be filled with concrete grout from the ground surface to a depth of 5 feet. The grout surface outside the casing shall be sloped away from the casing. The annulus between the riser pipe and the protective casing shall be filled with grout to a level no more than 12 inches below the top of riser pipe. Well protection shall only be installed at locations designated by OWNER'S REPRESENTATIVE.

5.4 Care and Maintenance of Piezometers

During the course of drilling, the INVESTIGATION CONTRACTOR shall be responsible for the care and maintenance of the piezometers and shall maintain the site in such a condition and protect the piezometers in such a manner that no undesirable materials are spilled, dripped, or introduced into the borehole by any means.

5.5 Borehole Abandonment

If for any reason a borehole or piezometer cannot be completed, the INVESTIGATION CONTRACTOR shall contact OWNER'S REPRESENTATIVE for permission to abandon it. The INVESTIGATION CONTRACTOR shall not abandon any borehole without being directed to do so by the OWNER'S REPRESENTATIVE. Borehole abandonment includes removing all casing, and/or tools from the borehole, sealing the borehole as nearly as possible for its full length with tremied cement grout and restoring the site. If the INVESTIGATION CONTRACTOR abandons a borehole without being directed to do so by OWNER'S REPRESENTATIVE, no payment for work performed on that borehole or piezometer shall be made.

6.0 MEASUREMENT AND PAYMENT

Payment for all materials, equipment, supplies, and labor necessary to perform the work requested under the terms of this Contract will be made according to EXHIBIT D, SCHEDULE OF UNIT PRICES, included with the Contract Documents. All functions not specifically covered by a pay item shall be considered incidental to the work performed. Payment shall be made only for those items ordered or approved by OWNER'S REPRESENTITIVE and meeting the contract requirements.

6.1 Install Vibrating Wire Piezometers

Payment for vibrating wire piezometer installation will be measured per foot of grout placed. Payment will be on a unit price basis and will constitute full compensation for

all labor, equipment, and grout required for vibrating wire piezometer installation, and all other items and operations required for piezometer construction. Borehole advancement for piezometer installation is not included in payment for piezometer installation but will be paid as described under Borehole Advancement by Hollow-stem Auger in the situations where a piezometer is not installed in an SPT boring.

6.2 Furnish and Install Grout Tube

Grout tube payment shall be measured per foot of tube installed. Payment shall be on a unit price and will constitute full compensation for all labor, equipment, and materials required for grout tube installation.

6.3 Backfilling Boreholes – Fully Grouted Boreholes

Grouting fully grouted boreholes used for vibrating wire piezometers will be measured for payment by the foot of borehole grouted. Payment will be by the unit price per foot and will constitute full payment for all materials, labor, and equipment required to seal the borehole, and regrade the area. No payment will be made for work performed to abandon a boring or for an equivalent replacement boring when abandonment is necessary because of some fault of the INVESTIGATION CONTRACTOR'S personnel, equipment, procedure, materials, or for boreholes abandoned without specific direction by OWNER'S REPRESENTATIVE to do so. Work performed and accepted by OWNER'S REPRESENTATIVE prior to abandonment will be counted for payment.

Exhibit B

Technical Specifications – Standpipe Piezometers

TECHNICAL SPECIFICATIONS
STANDPIPE PIEZOMETERS

1.0 SCOPE

The work covered under this section of the Specifications consists of furnishing all labor, materials, equipment, and performing all operations necessary to construct and install all porous stone tip standpipe piezometers and perform well development as required within. The proposed piezometer locations are shown on Large Figures 4 through 9 of the Tailings Basin Geotechnical Instrumentation and Monitoring Plan (Plan). Minor adjustments to the proposed locations and elevations may be made in the field by the OWNER'S REPRESENTATIVE.

2.0 REFERENCE STANDARDS

2.1 ASTM D-5092 Standard Practice for Design and Installation of Ground Water Monitoring Wells

2.2 ASTM C-150 Specifications for Portland Cement

In case of conflict between these Technical Specifications and the above standards, the Technical Specifications will prevail.

3.0 SUBMITTALS

3.1 Concrete sand product sheet.

3.2 Porous stone tip manufacturer's certificates.

3.3 Sand pack gradation product sheet.

3.4 Bentonite product sheet.

3.5 Portland cement product sheet.

3.6 Drilling fluid addition product sheet.

4.0 MATERIALS

4.1 Drilling Fluid

Drilling fluid for boreholes used for porous stone tip standpipe piezometers shall be potable water, which is defined as water which is safe for human consumption in that it is free from impurities in amounts sufficient to cause disease or harmful physiological effects. No additives shall be added to water used for the borings to be used as standpipe piezometers.

Drilling fluid for boreholes used for open pipe piezometers shall use a biodegradable additive such as Revert, an organic polymer manufactured by Johnson Screens of St. Paul, Minnesota or approved equal. Bentonite will not be allowed.

If Revert is used, prior to installation of the piezometer; the INVESTIGATION CONTRACTOR shall flush the borehole with "clean" mud to remove any clay or loose material that has been mixed with the mud while advancing the borehole. The clean mud should be as thin as possible, so that placement of backfill material is not obstructed, but that it does not sacrifice the stability of the borehole. After installation of the piezometer, the piezometer shall be developed to clear any filter cake from the borehole wall alongside the piezometer. To develop, the INVESTIGATION CONTRACTOR shall create inward flow by removing water from the standpipe, allowing formation water to flow inward and break down the filter cake. Piezometer development shall be continued until a sediment-free piezometer is obtained. After the piezometer is developed, ten well volumes of water shall be removed from the piezometer.

4.2 Porous Stone Standpipe Piezometer Tip

The piezometer tip shall consist of a 12-inch porous stone that meets the specifications of the Slope Indicator Company's Standpipe Piezometer Tips, Model 51405102 or approved equal. The piezometer tip shall be joined to the casing by water tight couplings.

4.3 Sand Pack

The sand pack shall consist of a clean, durable, uniformly graded natural sand meeting the specifications of the #30 sand produced by Red Flint Sand and Gravel, Eau Claire, Wisconsin.

4.4 Standpipe Riser Pipe and Fittings

The riser pipe shall be 2-inch inner diameter, schedule 40, PVC pipe. Fittings shall be flush male and female threads and of the same material as the riser pipe as well as water tight. A vented end cap shall be supplied for the top of the riser pipe.

4.5 Standpipe Tip to Riser Coupler

The open pipe piezometer porous tip shall be joined to the riser pipe by a coupler that meets the specifications of the Slope Indicator Company's Pipe Adaptors or approved equal. The piezometer tip shall be joined to the casing by water tight couplings.

4.6 Portland Cement

Portland Cement (Type I) shall meet the requirements of ASTM C-150.

4.7 Neat Cement Grout

The neat cement grout shall consist of a mixture of one bag (94 pounds) Portland cement (Type I) to not more than 6 gallons of potable water. Bentonite up to 5 percent by weight of cement may be added. No other admixtures shall be allowed.

4.8 Bentonite Pellets

Bentonite pellets shall be organic-free, high-swelling, 100 percent pure bentonite compressed into 3/8-inch-diameter pellets equal to NL Baroid Industries of Houston. The pellets shall be kept dry and transported to the site in such a way as to minimize abrasion. The pellets should be coated so as to minimize bridging during placement.

4.9 Concrete Grout for Protective Casing

The concrete grout shall consist of 1 part potable water, 2 parts Portland cement, and 2 parts clean sand.

4.10 Stick-up Protective Casings

Protective steel casings shall be embedded into the ground surface and extended over the protruding portions of the piezometer casings. The tops of the protective casings shall extend no more than 3 feet above the ground surface and should be embedded a minimum of 4 feet below ground. The protective casings shall consist of Schedule 40 steel and be at least 12 inches in diameter. The protective casings shall have a locking cover. The exposed portion of the casing shall be painted with a compatible metal corrosion-resistant primer and a red finish coat prior to delivery on-site. The protective casing cap shall be a painted overlapping steel cap of the same quality as the casing and finished with a hasp for attachment to the protective casing. Protective casings will only be installed at locations as directed by the OWNER'S REPRESENTATIVE.

4.11 Protective Casing Locks

The OWNER/OWNER's REPRESENTATIVE will provide locks for protective casings.

4.12 Protective Posts

Protective posts shall be 4-inch-diameter, schedule 40, 8 feet in length. Posts shall be filled with concrete. The exposed portion of the posts shall be painted with a compatible metal corrosion-resistant primer and red finish coat prior to delivery on site. Protective posts will only be installed at locations as directed by the OWNER'S REPRESENTATIVE.

5.0 PERFORMANCE

The INVESTIGATION CONTRACTOR shall practice good piezometer construction procedure that conform with ASTM or other procedures in these specifications. If, in the opinion of OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR'S procedure is inadequate to construct a useable piezometer, the INVESTIGATION CONTRACTOR shall change procedures to meet the requirements of these specifications. The piezometers shall be constructed in the borings specified on the previously referenced Figures.

5.1 Piezometer Locations

The general locations of the required piezometers are identified in the previously referenced Figures. The location will be staked for the INVESTIGATION CONTRACTOR by the OWNER'S REPRESENTIVE.

5.2 Boring Advancement

The INVESTIGATION CONTRACTOR shall employ hollow-stem auger or the approved drilling techniques at all piezometer locations to the required depth of penetration or to depths at which hollow-stem auger advancement ceases to be feasible. The hollow-stem auger shall be equipped with a retractable bottom plug, advanced with the lead auger, and removed prior to each sampling attempt. Auger with 6¼-inch inner diameter shall be used.

If rotary drilling methods are used beyond the ceased advancement of the hollow-stem auger, a minimum 5½-inch diameter hole shall be drilled with a noncoring type roller, fishtail, or other suitable bit.

5.3 Standpipe Piezometer Construction

The boring shall be advanced to the design depth with 6¼-inch minimum inside diameter, hollow-stem auger. Bentonite drilling mud shall not be used during boring advance. The piezometer tips and the riser pipe shall be assembled and installed so that the screen is at the design depth and the riser pipe extends 2 to 3 feet above the ground surface. The sand pack shall be installed, as the auger or casing is pulled back, in a manner that shall minimize segregation and ensure the sand pack fills, as nearly as practical, the annular space between the well screen and the borehole wall to a depth of 2 feet above the screen.

A bentonite pellet seal shall be placed above the sand pack to a depth of 4 feet above the top of the piezometer tip. The pellets shall be allowed to swell a minimum of ½ hour under a head of water prior to continuing the installation. Neat cement grout shall be placed above the seal to the ground surface by pumping under pressure through a tremie pipe. After 6 inches of grout have been placed in the borehole, the discharge point of the tremie pipe shall be maintained at 3 inches or more below the grout surface. The hollow-stem auger shall be withdrawn as necessary during the grouting process. Concrete full strength grout should be placed to within 5 feet of the ground surface. The annular space between the riser pipe and the borehole wall above the cement grout shall be filled with concrete. The concrete surface at ground level shall be sloped away from the riser pipe.

5.4 Piezometer Alignment and Clearance

Piezometers shall be sufficiently plumb, straight, and free from restrictions to allow a measuring device ¾ inch in diameter and 12 inches long to pass freely through the full

length of the piezometer. The INVESTIGATION CONTRACTOR shall prove the alignment and clearance are adequate prior to acceptance by OWNER'S REPRESENTIVE.

5.5 Piezometer Protection

The protective casing shall be installed to an approximate depth of 4 feet in the borehole. The exact depth shall be adjusted so that the top of the casing is even with the top of the capped riser pipe. The annulus between the protective casing and the borehole wall shall be filled with concrete grout from the ground surface to a depth of 5 feet. The grout surface outside the casing shall be sloped away from the casing. The annulus between the riser pipe and the protective casing shall be filled with grout to a level no more than 12 inches below the top of riser pipe. Piezometer protection shall only be installed at locations designated by the OWNER'S REPRESENTATIVE.

5.6 Protective Posts

If requested by the OWNER's REPRESENTATIVE, protective posts painted red shall be placed 2 feet from the protective casing in a manner as to protect the piezometer from incoming traffic. The posts shall be set 2 feet into the ground in 12-inch-diameter boreholes. The annulus between the boreholes and the posts and the inside of the posts shall be filled with concrete. Protective posts shall only be installed at locations designated by the OWNER'S REPRESENTATIVE.

5.7 Care and Maintenance of Piezometers

During the course of drilling, the INVESTIGATION CONTRACTOR shall be responsible for the care and maintenance of the piezometers and shall maintain the site in such a condition and protect the piezometers in such a manner that no undesirable materials are spilled, dripped, or introduced into the borehole by any means.

5.8 Borehole Abandonment

If for any reason a borehole or piezometer cannot be completed, the INVESTIGATION CONTRACTOR shall contact OWNER'S REPRESENTIVE for permission to abandon it. The INVESTIGATION CONTRACTOR shall not abandon any borehole without being directed to do so. Borehole abandonment includes removing all screens, casing, and/or tools from the borehole, sealing the borehole as nearly as possible for its full length with tremied cement grout, and restoring the site. If the INVESTIGATION CONTRACTOR abandons a borehole without being directed to do so by OWNER, no payment for work performed on that borehole or piezometer shall be made.

6.0 MEASUREMENT AND PAYMENT

Payment for all materials, equipment, supplies, and labor necessary to perform the work requested under the terms of this Contract will be made according to EXHIBIT D, SCHEDULE OF UNIT

PRICES, included with the Contract Documents. All functions not specifically covered by a pay item shall be considered incidental to the work performed. Payment shall be made only for those items ordered or approved by OWNER and meeting the contract requirements.

6.1 Furnish and Install Porous Tip for Standpipe Piezometers

Standpipe piezometer tip payment will be measured per porous tip installed. No more than one tip shall be installed at each piezometer location. Payment shall be on a unit price basis and shall constitute full compensation for all labor, equipment, and materials required for piezometer installation and development including but not limited to the porous tip, casing adapters, development, and all other items and operations required for tip construction.

6.2 Furnish and Install Casing for Standpipe Piezometers

Standpipe piezometer payment shall be measured per foot of casing installed. Payment shall be on a unit price basis and shall constitute full compensation for all labor, equipment, and materials including sand pack, bentonite, and grout required for standpipe piezometer installation and development including but not limited to the casing adapters, development, and all other items and operations required for tip construction. Borehole advancement for piezometer installation is not included in payment for piezometer installation and development but shall be paid as described under Borehole Advancement by Hollow-stem Auger.

6.3 Setup on a Soil Boring – Piezometer

Payment for setting up on an additional boring at the direction of the OWNER'S REPRESENTATIVE for the purpose of installing a piezometer with hollow-stem auger or water rotary methods will be measured by the boring. Payment will be at the unit price per boring and will constitute full compensation for all labor, equipment, and materials required to move the drill rig and other equipment between borings, to arrange for utility clearance at the boring location, to establish the necessary work zones, and to set up at a boring location in preparation for drilling.

6.4 Borehole Advancement

Borehole advancement by 6¼-inch hollow-stem auger will be measured for payment to the nearest foot from the ground surface to the bottom of the auger. Payment will be by the unit price per foot and will constitute full compensation for all labor, equipment, and materials required to set and remove the auger. Borehole advancement and payment shall include SPT sampling.

6.5 Furnish and Install Stick-up Protective Covers

Payment will be made for each casing installation, including the cost of the casing themselves, the concrete, and all labor and materials required to assemble and install the casing.

6.6 Furnish and Install Protective Posts

Payment will be made for each post installation, including the cost of the posts themselves, the concrete, and all labor and materials required to assemble and install the posts.

Exhibit C

Technical Specifications – Inclinometer Installations

TECHNICAL SPECIFICATIONS
INCLINOMETER INSTALLATION

1.0 SCOPE

The work covered under this section of the Technical Specifications consists of furnishing all labor, materials, equipment, and performing all operations necessary to install inclinometers. The location of inclinometer installations are shown on Large Figures 4 through 9 of the Tailings Basin Geotechnical Instrumentation and Monitoring Plan (Plan). Minor adjustments to the proposed locations and elevations may be made in the field by the OWNER'S REPRESENTATIVE.

2.0 REFERENCE STANDARDS

2.1 ASTM C150 Specifications for Portland Cement

2.2 ASTM D-6230 Standard Test Method for Monitoring Ground Movement Using Probe-Type Inclinometers

In case of conflict between these Technical Specifications and the above standards, the Technical Specifications will prevail.

3.0 SUBMITTALS

3.1 Concrete sand product sheet

3.2 Portland cement product sheet.

3.3 Bentonite product data sheet.

3.4 Inclinometer casing data sheets.

3.5 Drilling fluid addition product sheet.

4.0 MATERIALS

4.1 Drilling Fluid

Drilling fluid shall be drilling mud, a combination of potable water and bentonite. Potable water is defined as water that is safe for human consumption in that it is free from impurities in amounts sufficient to cause disease or harmful physiological effects. Other additives may not be added to maintain a stable hole.

4.2 Portland Cement

Portland Cement (Type I) shall meet the requirements of ASTM C-150.

4.3 Bentonite

Bentonite shall be finely ground, premium-grade bentonite, equal to Quick Gel manufactured by NL Baroid Industries, Inc. of Houston, Texas or approved equal. The bentonite shall be free from lumps and objectionable material that would prevent easy mixing into a smooth fluid of unmixed bentonite.

4.4 Inclinometer Casing

Inclinometer casings shall have an outside diameter of 3.34 inches (85 mm) and be constructed of ABS plastic with a load rating of 1,400 pounds. An example of an acceptable product casing is manufactured by Slope Indicator Company (CPI large diameter casing) or as approved by the OWNER'S REPRESENTATIVE. Approval of material is required prior to ordering materials.

4.5 Inclinometer Protection

Inclinometer protection shall consist of a steel casing that shall be embedded into the ground surface and extended over the protruding portions of the inclinometer casing. The tops of the protective casing shall extend no more than 3 feet above the ground surface and should be embedded a minimum of 4 feet below ground. The protective casing shall consist of Schedule 40 steel and be at least 8 inches in diameter. The protective casing shall have a locking cover. The exposed portion of the casing shall be painted with a compatible metal corrosion-resistant primer and a red finish coat prior to delivery on-site. The protective casing cap shall be a painted overlapping steel cap of the same quality as the casing and finished with a hasp for attachment to the protective casing.

4.6 Inclinometer Cement-Bentonite Grout Backfill

The grout for backfilling the inclinometer boreholes shall consist of a mixture of Portland Cement (one bag approximately 94 pounds) to 29 gallons of water to a minimum 30 pounds of Quick Gel bentonite as needed. Water and cement shall be mixed first. The bentonite shall be added slowly under high agitation to make grout creamy, yet pumpable. This yields a cement-water-bentonite ratio by weight of 1:2.5:0.3. Modifications to the cement-bentonite grout mix design including increased water and bentonite or cement should be anticipated in the field in order to accurately represent similar strength as the in-situ soil and prevent segregation of cement. These modifications shall be approved by the OWNER'S REPRESENTATIVE.

4.7 Inclinometer Casing Buoyancy – Anchors

The INVESTIGATION CONTRACTOR shall utilize one of the following options for overcoming inclinometer casing buoyancy, "floating," while placing cement-bentonite grout:

- Casing anchors, such as Durham Geo Slope Indicator Casing Anchors, sized to the appropriate casing diameter, or approved equal.
- Temporary suspension of a steel pipe or drill rods inside the casing.
- Weight pre-attached to the bottom of the casing.
- Grouting the borehole, with casing installed, in stages.

The INVESTIGATION CONTRACTOR shall not apply force to the top of the inclinometer casing to overcome buoyancy.

Barite or any substance considered a contaminant by the EPA is not allowed to be used as a weighted solution inside the inclinometer casing.

4.8 Inclinometer Grout Valves

Grout valves (with or without casing anchors) used to provide a means of cement-bentonite grouting the inclinometer casing in narrow annulus space situations shall consist of Durham Geo Slope Indicator Casing Valves, sized to the appropriate casing diameter, or approved equal.

4.9 Protective Casing Locks

Locks for protective casings will be provided by OWNER'S REPRESENTATIVE.

4.10 Protective Posts

Protective posts shall be 12-inch diameter, schedule 40, 8 feet in length. Posts shall be filled with concrete. The exposed portion of the posts shall be painted with a compatible metal corrosion-resistant primer and red finish coat prior to delivery on site. Protective posts will only be installed at locations as directed by the OWNER'S REPRESENTATIVE.

4.11 Concrete Grout for Protective Casings

The concrete grout for protective casings shall consist of Portland cement (three bags approximately 94 pounds) to 30 gallons of water. This yields a cement-water ratio by weight of 1:1.1.

5.0 PERFORMANCE

The INVESTIGATION CONTRACTOR shall practice good drilling procedure that conforms with ASTM or other procedures specified in these Contract Documents. If, in the opinion of OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR'S procedure is inadequate to obtain samples or install the inclinometer correctly, the INVESTIGATION CONTRACTOR shall change procedures to meet the requirements of these specifications. The inclinometer shall be constructed in the borings specified in the previously referenced Figures.

5.1 Inclinometer Location

The locations of the required inclinometers are shown on the previously referenced Figures. The locations will be staked/identified for the INVESTIGATION CONTRACTOR by OWNER'S REPRESENTATIVE.

5.2 Boring Advancement

The INVESTIGATION CONTRACTOR shall employ hollow-stem auger techniques at the inclinometer locations to depths at which hollow-stem auger advancement ceases to be feasible. The hollow-stem auger shall be equipped with a retractable bottom plug, advanced with the lead auger, and removed prior to each sampling attempt. The diameter of the hollow-stem auger shall be sufficient to accommodate split-barrel samplers, tremie tube for grouting, and inclinometer casings.

In the case that a boring started with hollow-stem auger cannot be completed by the hollow-stem auger method due to heaving sands, extremely hard drilling conditions, cobbles or boulders, bedrock or other conditions that make auger advancement unfeasible, the INVESTIGATION CONTRACTOR shall notify the OWNER'S REPRESENTATIVE and shall extend the boring by mud-rotary methods in the same borehole, leaving the auger in place as a temporary casing until the boring has been completed.

5.3 Inclinometer Installation

The inclinometer shall be installed in the borehole and grouted in place with a minimum of 2 feet within bedrock or as directed by the OWNER'S REPRESENTATIVE. A casing anchor and/or grout plug shall be installed on the tip of casing as directed by the OWNER'S REPRESENTATIVE. The inclinometer shall be constructed such that no more than 3 feet and no less than 2 feet stick up above the ground surface. Inclinometer grout shall be placed from the base of the inclinometer to the ground surface by pumping under pressure through a tremie pipe/pipe attached to the grout valve gasket at the tip of the inclinometer casing. After 6 inches of grout have been placed in the borehole, the discharge point of the tremie pipe shall be maintained at 3 inches or more below the grout surface. The hollow-stem auger borehole casing shall be withdrawn as necessary during the grouting process. Augers shall not be spun upon removal from the ground.

The inclinometer shall be installed so that the difference in alignment of any section is no greater than 3 percent of the depth to that part. If the inclinometer is not installed to meet this tolerance, the INVESTIGATION CONTRACTOR shall abandon the location and install a new inclinometer at a location identified by the OWNER'S REPRESENTATIVE at no additional cost to the OWNER. The verification of verticality shall be made after the grout has set and two datasets are collected.

After installation, the casing groove spiral shall not exceed 1 degree per 10 feet of length; the orientation of the grooves at the top of the casing shall be within 10 degrees of the planned orientation (A-0 grooves in the downhill direction perpendicular to the slope).

5.4 Inclinometer Protection

The protective casing shall be installed to an approximate depth of 4 feet in the borehole. The exact depth shall be adjusted so that the top of the casing is even with the top of the inclinometer casing. The annulus between the protective casing and the borehole wall shall be filled with concrete grout from the ground surface to a depth of 5 feet. The concrete grout surface outside the casing shall be sloped away from the casing. The annulus between the inclinometer casing and the protective casing shall be filled with concrete grout to a level no more than 12 inches below the top of inclinometer casing.

5.4 Protective Posts

If requested by the OWNER's REPRESENTATIVE, protective posts painted red shall be placed 2 feet from the protective casing in a manner as to protect the inclinometer from incoming traffic. The posts shall be set 2 feet into the ground in 12-inch-diameter boreholes. The annulus between the boreholes and the posts and the inside of the posts shall be filled with concrete. Protective posts shall only be installed at locations designated by the OWNER'S REPRESENTATIVE.

5.5 Borehole Abandonment

If for any reason a borehole or inclinometer cannot be completed, the INVESTIGATION CONTRACTOR shall contact OWNER'S REPRESENTATIVE for permission to abandon it. The INVESTIGATION CONTRACTOR shall not abandon any borehole without being directed to do so by the OWNER'S REPRESENTATIVE. Borehole abandonment includes removing all casing, and/or tools from the borehole, sealing the borehole as nearly as possible for its full length with tremied cement grout and restoring the site. If the INVESTIGATION CONTRACTOR abandons a borehole without being directed to do so by OWNER'S REPRESENTATIVE, no payment for work performed on that borehole or piezometer shall be made.

6.0 MEASUREMENT AND PAYMENT

Payment for all materials, equipment, supplies, and labor necessary to perform the work requested under the terms of this Contract will be made according to EXHIBIT D, SCHEDULE OF UNIT PRICES, included with the Contract Documents. All functions not specifically covered by a pay item will be considered incidental to the work performed. Payment will be made only for those

items ordered or approved by OWNER'S REPRESENTATIVE and meeting the contract requirements.

6.1 Furnish and Install Inclinometer Casing

Inclinometer casing payment shall be measured per foot of casing installed. Payment shall be on a unit price basis and shall constitute full compensation for all labor, equipment, and materials including grout required for inclinometer installation, and all other items and operations required for inclinometer installation. Borehole advancement with soil sampling for inclinometer installation is not included in payment for inclinometer installation but shall be paid as described under Borehole Advancement and Sampling in Section.

6.2 Furnish and Install Protective Casing for Inclinometers

Payment will be made for each casing installation, including the cost of the casing themselves, the concrete, and all labor and materials required to assemble and install the casing.

6.3 Furnish and Install Protective Posts

Payment will be made for each post installation, including the cost of the posts themselves, the concrete, and all labor and materials required to assemble and install the posts.

6.4 Furnish and Install Casing Anchors

Payment will be made for each casing anchor installation, including the cost of the anchors, and all labor and materials required to assemble and install the anchors.

6.5 Furnish and Install Grout Valves

Payment will be made for each grout valve installation, including the cost of the grout valves themselves, the concrete, and all labor and materials required to assemble and install the grout valves.