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RS49
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2ND DRAFT

RS49

STOCKPILE CONCEPTUAL DESIGN

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EXECUTIVE SUMMARY

This 2nd Draft of RS49 presents the preliminary stockpile design for the PolyMet NorthMet Site (NorthMet Project) and incorporates responses to comments provided by the Minnesota Department of Natural Resources and other State of Minnesota and Federal agencies on the 1st draft of RS49. The stockpile design was conducted in general accordance with the PolyMet Mining Inc. (PolyMet) scope of work as defined in Work Task 1.4 *Conceptual Mine Waste Impoundment Design* of "*Recommended Scope of Services and Cost Estimate for Supporting Mine Waste Management Designs at the PolyMet Project, Minnesota" – Scope of Work* dated May, 2005. It is anticipated that the results of RS49 will be used to support the Environmental Impact Statement (EIS) impacts assessment. Note that the references to RS"xx" documents (RS18, RS23T, etc.) and detailed project description relate to work completed in support of the EIS.

Golder's preliminary stockpile designs utilize the stockpile layouts developed by Barr Engineering Co. (Barr) in the RS18 Mine Plan (Appendix E). RS49 incorporates preliminary foundation preparation design requirements, liner and cover system designs, and general development concepts. Golder will utilize the results from future geotechnical field investigations, the outcome of permitting discussions and the mutually agreed upon design criteria with the agencies to advance and finalize the design concepts presented herein. It is expected that any changes resulting from finalizing these designs will not result in substantial modifications in the proposed stockpile geometry and design methodologies.

The two general types of stockpile materials proposed for the NorthMet Project are waste rock and lean ore. The classification between the waste rock and lean ore is based upon economic criteria. The classification of waste rock into the categories summarized below is based on PolyMet's waste characterization program and reflects the predicted long-term geochemical behavior of the materials. As such, waste rock geochemical classifications are used to determine the type of liner and cover system regardless of whether the stockpiled material is waste rock or lean ore. Due to its mechanical and chemical properties, the lean ore is considered similar to waste rock for stockpile design purposes. Therefore, subsequent references to waste rock apply to both the waste rock and lean ore.

The presented stockpile design incorporates the concept of segregating different waste rock categories based on the following classification developed by PolyMet's geochemical consultants (SRK, 2007):

- Category 1 waste rock – Construction rock (%S<=0.12%). Used for construction applications as approved by regulatory agencies.

- Category 2 waste rock – Low reactivity (%S<=0.12% or %S<=0.31% if Cu/S<0.3), will not generate acid rock drainage (ARD) but can leach metals in excess of water discharge limits. Category 1 waste rock becomes Category 2 waste rock if not used for construction. Waste rock categories 1 and 2 combined comprise approximately 83 percent of the total waste rock;

- Category 3 waste rock and Category 3 lean ore – Medium reactivity (0.31%<%S<0.6% or 0.12%<%S<0.6% if Cu/S>0.3) is predicted to potentially generate ARD in the long term. This category comprises approximately 14 percent of the total waste rock;

- Category 4 waste rock and Category 4 lean ore – High reactivity (%S>0.6%, plus all Virginia Formation), is predicted to generate ARD in the short term. This category comprises approximately 3 percent of the total waste rock; and

- Till overburden represents the remainder of the non-ore volume and accounts for approximately 6 percent of the total excavated volume (non-ore volume including waste rock and overburden, due to stockpile construction). Based on RS18, the amount of overburden excavated during both stockpile and pit construction may be as high as 20 to 24 percent of the total non-ore volume assuming a bulking factor of 25% or less. Overburden is generally considered non-reactive material suitable for construction. Nonetheless, waste characterization of overburden soils will be conducted during construction and mining activities to determine the potential to leach metals. If the results indicate that till materials can leach metals in excess of water discharge limits, these soils will be placed on the lined portion of the Category 1/2 stockpile or stockpiles containing higher reactivity waste rock based on the determined overburden reactivity potential.

The segregated mine waste rock will be contained in engineered stockpiles with basal liner systems designed to minimize any leakage from the stockpiles to the environment. The preliminary design of the liner and closure cover systems presented herein incorporates the results of RS23T, which provides a qualitative assessment and decision matrix to recommend various liners and cover systems for each category of the NorthMet Stockpiles (Golder, 2007). In accordance with the objectives of RS23T, the designs for the various liner containment and cover systems are consistent with the level of environmental risk posed by the geochemical properties of the waste rock materials contained in each stockpile category. Reclamation evapotranspiration (ET) cover or alternative barrier systems will be constructed over each stockpile during mining operations to limit the flux of meteoric waters through the contained waste rock during the closure and post-closure periods, following the stockpile cover sequence proposed in RS18.

Each of the stockpile liner systems will need to be constructed on a geotechnically suitable foundation. The development concepts for foundation construction of all stockpiles include the following considerations:

1. Excavate and stockpile geotechnically unsuitable soils (e.g., organics, unconsolidated clays, etc.) for future use as a reclamation growth medium. It is anticipated that minor sub-excavation of unsuitable soils in the highland areas and considerable sub-excavation of unsuitable soils in the lowland areas will be required.

2. Develop foundation drainage to prevent the development of excess foundation pore pressures, based on the geotechnical conditions encountered.

3. Establish the foundation design grades required for seepage collection, stability and other design considerations by placing engineered fill. Engineered fill materials are anticipated to consist of excavated local till and/or Category 1 materials placed as structural fill in controlled compacted lifts.

4. Construct the liner system dependent upon the reactivity category of the waste rock.

5. Foundation grading will be developed to provide for gravity drainage and collection of any leakage from the stockpile to a series of lined collection sumps. The water collected in the sumps will be pumped to the Wastewater Treatment Facility (WWTF) to be constructed at the Mine Site or directed towards the mine pits (for more details, see RS22).

The overburden stockpiles will be constructed without engineered liner or cover systems. Nonetheless, confirmatory waste characterization testing will be conducted during operations and any overburden materials predicted to have the potential to leach metals in excess of water-quality discharge limits will be placed on the lined portion of the Category 1/2 stockpile or Categories 3 and 4 stockpiles based on the reactivity potential. Based on discussions between PolyMet's geochemical consultant (SRK) and the agencies, overburden disposal requirements would be based on sulfur and carbonate (or neutralization potential) analysis to determine potential for acid generation, and a short-term water extraction test to determine pH (and perhaps soluble metals) to estimate immediate leachability. All of these tests can be conducted in a mine laboratory and provide results in less than 24 hours.

The conceptual design provided herein is based on data obtained from the Phase I geotechnical field program (Golder, 2006) supplemented with data from the site drilling database and a geophysics program data. This Phase I field program was constrained to the highland areas due to disturbance limitations and logistical constraints, partially as a result of a warm winter during 2005/2006. The absence of freezing conditions prohibited access to the lowland areas. The Phase I geotechnical field program consisted of excavating 15 test trenches via a trackhoe to allow geotechnical logging and the collection of representative samples for laboratory testing. Additional geotechnical site characterization will be required to support a final level design. However, it is our opinion that the existing geotechnical database, in combination with the conservative assumptions used to develop the preliminary design presented in this RS49 report, is sufficient to technically support the preliminary stockpile designs and an EIS alternatives impact assessment.

Laboratory tests have been performed in accordance with American Society for Testing and Materials (ASTM) test methods to measure index properties of the samples recovered from the test trenches, to confirm field classifications, and for use in developing correlations with engineering properties of encountered soils. Additional testing performed on select soil samples included a consolidated-undrained (CU) triaxial shear test (ASTM D4767), a one-dimensional consolidation test (ASTM D2435), Standard Proctor tests (ASTM D698, Method A), and permeability tests (ASTM D5084). The site foundation glacial till soils encountered in the highland areas were typically silty sands with variable percentages of clay and gravels that were classified by the Unified Soil Classification System (USCS) as SM, SP, ML, and CL. The highland till soils, if properly drained, will generally provide a suitable foundation for stockpile development, although local subexcavation of unsuitable materials (organics, plastic clays, etc.) should be anticipated. The existing data on the foundation soils located in the lowland areas is limited, but the working hypothesis is that these soils are generally geotechnically unsuitable (e.g., contain plastic clays, organic soils, etc.) and will require excavation and stockpiling during site preparation activities for future use as reclamation growth medium soils. This is considered a very conservative assumption that has been adopted in part to compensate for the limited geotechnical information in the lowland areas. As indicated above, procurement of additional geotechnical data in these areas is problematic from both regulatory and logistical considerations. Future geotechnical field programs will need to occur during winter when the terrain is frozen.

The site exploration drilling database, drilling logs from soil borings and monitoring wells installed at the site, and geophysics data were used to develop a depth to bedrock isopach map (see Drawing 2). The depth to bedrock and the results from the Phase I geotechnical program were used by Golder to estimate earthwork quantities for stockpile development.

This document provides preliminary stockpile layouts at various stages of development, including years 1, 5, 10, 15, and end-of-mine (i.e., year 20) developed by Barr. The stockpile layouts are based on the mine production schedule outlined in RS18. These layouts assume that approximately 151 Mt of the low reactivity waste rock (Category 1 and 2) will be used for construction and in-pit disposal, as explained in more detail in RS18 Mine Plan (Appendix E). The preliminary stockpile design assumes an average porosity of 30 percent and a minimum 100-foot setback from property boundaries, with additional setback provided for critical corridor areas. The assumed stockpile porosity is based in part on the available data from nearby sites (Erie and AMAX stockpiles) reported by Hewett (1980) and in part on Golder's experience with similar projects. The stockpile footprints have been established to prioritize the more geotechnically favorable areas, particularly for the stockpiles containing waste rock categories 3 and 4 where construction of a geomembrane liner system will be required. In general, the stockpile layouts consider segregation of materials by design category and are developed to minimize hauling distances (e.g. the Lean Ore Surge Pile containing lean ore material will be located in the proximity to the rail-loadout area) while taking into consideration geotechnical and environmental concerns.

The stockpile footprint development areas are summarized in the following tables.

TABLE ES-1
STOCKPILE FOOTPRINT AREAS (SQUARE FEET)

Stockpile	Year 1	Year 5	Year 10	Year 15	Year 20
Category 1/2*	5,662,000	17,157,000	20,547,000	20,547,000	20,547,000
Category 3	258,000	1,116,000	2,041,000	3,136,000	3,136,000
Category 3 Lean Ore	1,541,000	2,779,000	4,257,000	6,830,000	6,830,000
Category 4	195,000	1,743,000	2,760,000	2,760,000	2,760,000
Lean Ore Surge Pile	2,375,000	2,375,000	2,375,000	2,375,000	2,375,000

* excludes Category 1/2 overburden area without liner system

TABLE ES-2
STOCKPILE FOOTPRINT AREAS (ACRES)

Stockpile	Year 1	Year 5	Year 10	Year 15	Year 20
Category 1/2*	130	394	472	472	472
Category 3	6	26	47	72	72
Category 3 Lean Ore	35	64	98	157	157
Category 4	4	40	63	63	63
Lean Ore Surge Pile	55	55	55	55	55

* excludes Category 1/2 overburden area without liner system

To be compliant with the Minnesota mining regulations *Minnesota Statutes 2005, Chapter 93* (the Regulations), the stockpile design will utilize foundation liner(s) and closure cover system encapsulation techniques. The specific encapsulation design for each category of stockpile is consistent with the recommendations given in the RS23T study, which evaluated the technical considerations, relative effectiveness and constructability for various liner and cover system alternatives for the waste rock stockpiles at PolyMet's NorthMet Project (Golder, 2007). The recommended liner systems are summarized as follows:

- Low reactivity waste rock (Category 1/2 Waste Rock Stockpile): A minimum of one foot of compacted soil liner with a maximum permeability of $5x10^{-7}$ cm/sec and an overliner drainage layer. It is anticipated that the liner material will consist of locally excavated till soils based on the available laboratory and site investigation data (Golder, 2006). If necessary, PolyMet will process the soil liner using bentonite admixing or other conventional techniques to meet the design specification of $5x10^{-7}$ cm/sec.

- Medium reactivity waste rock (Category 3 Waste Rock Stockpile): A compacted subgrade overlain by a geomembrane liner and an overliner drainage layer. The upper one foot of the prepared subgrade shall have a maximum permeability of $1x10^{-5}$ cm/sec. It is anticipated that local glacial till soils will meet the permeability requirements specified for the subgrade material based on the available laboratory and site investigation data (Golder, 2006). If necessary, foundation soils will be processed in accordance with conventional methods, e.g., bentonite admixing, to meet the subgrade design specification of $1x10^{-5}$ cm/sec.

- High reactivity waste rock (Category 3 Lean Ore and Category 4 Waste Rock Stockpiles and Lean Ore Surge Pile): A robust liner system is proposed, which consists of a minimum of one foot of compacted soil liner with a maximum permeability of $1x10^{-6}$ cm/sec overlain by a geomembrane liner and an overliner drainage layer. If necessary, foundation soils will be processed in accordance with conventional methods, e.g., screening of oversize material and bentonite admixing, to meet the soil liner design specification of $1x10^{-6}$ cm/sec.

Various reclamation cover and barrier systems were evaluated in RS23T for the proposed NorthMet Project (RS23T - Golder, 2007). Preliminary ET cover evaluations (see Appendix D) utilized a climate record from October 1, 1971 to September 30, 2001 (i.e., the period defining the climate normal; for more details, see RS73), with an average annual precipitation of approximately 29 inches. ET cover evaluations indicate that ET cover construction is feasible when using on-site soil materials. The soil-atmosphere model utilized for the ET cover simulations included the impacts of snow accumulation and snowmelt while conservatively neglecting the effects of sublimation and soil freezing. It is worth highlighting that the ET covers at the NorthMet Mine Site will be engineered to minimize infiltration of precipitation into stockpiles by enhancing runoff and evapotranspiration rates. The cover performance reported for similar climates and materials (e.g. Wilson et al, 2003) supports these preliminary evaluations. Based upon the results of the ET cover simulations, the following cover systems are recommended for each of the stockpile categories:

- Low reactivity stockpiles (Category 1/2 Waste Rock Stockpile): A 2-foot ET cover is recommended, which will be constructed of local till soils and revegetated to support an evergreen forest ecosystem. The estimated annual infiltration for a 2-foot thick, engineered cover with "average" material properties and without vegetation is approximately 10% of average annual precipitation. The ET cover performance improves as the mature coniferous forest ecosystem is established (see Appendix D). The long-term performance of proposed ET covers is expected to be superior to conventional barrier layers (Wilson et al., 2007).

- Medium reactivity stockpiles (Category 3 Waste Rock and Category 3 Lean Ore Stockpiles): A 3-foot ET cover is recommended on the 2.5(H):1(V) regraded reclamation outslopes, constructed of local till soils and revegetated to support evergreen forest ecosystem. A textured geomembrane barrier with an overlying 1.5-foot thick grass vegetated cover soil is proposed for the crest and bench areas. The estimated annual infiltration for the 3-foot thick, engineered ET cover on the stockpile slopes with "average" material properties and without vegetation is approximately 10% of average annual precipitation. The ET cover performance improves as the mature coniferous forest ecosystem is established (see Appendix D). The maximum annual infiltration for the flat areas covered with a textured geomembrane was estimated as 5% of average annual precipitation, based on the values reported in the literature [e.g., Benson (2002) and Wilson et al. (2003)].

- High reactivity stockpiles (Category 4 Waste Rock Stockpile and Lean Ore Surge Pile): A textured geomembrane liner with a 1.5-foot thick grass vegetated cover soil is proposed as the base case for the Category 4 reclamation cover system. The maximum annual infiltration was estimated as 5% of average annual precipitation, based on the values reported in the literature [e.g., Benson (2002) and Wilson et al. (2003)].

The results of liner leakage calculations and ET Cover Performance modeling are further discussed in the text, with more details provided in Appendices C and D. It should be emphasized that the estimated liner leakage rates do not account for the waste rock uptake potential. As a result, these leakage model results are conservative and are unlikely to occur because the stockpile materials will be placed dry of the field capacity moisture content, i.e., the minimum moisture content required to overcome the gravimetric surface tension so that gravity drainage of precipitation to the bottom of the stockpile can occur. The moisture content below which no drainage can occur is also referred to as specific retention (see e.g., Bear, 1972). The moisture content difference between the specific retention and the moisture content of the originally placed waste rock represents the quantity of water that is permanently lost, i.e., not available on a bulk basis for drainage, and is therefore directly related to the amount of time needed for a "break-through" of the wetting front. Hutchison and Ellison (1992) note that for waste rock placed with a moisture content below its specific retention value ".... possibly even for several months or years, the percolation will go toward raising the moisture content of the waste to levels at which leachate flow can ultimately occur." Golder anticipates that a minor percentage of short-circuiting may occur at stockpile boundaries, but the total waste rock uptake is likely to remain significant. For instance, 40 ft of material in a single lift at 5% retention (by volume) would need approximately one year for break-though assuming no evaporation and runoff losses. Therefore, the stockpile will essentially behave as a "sponge" with any precipitation being permanently lost as uptake until reaching the specific retention value.

The potential flux of meteoric waters through the stockpiles will be further reduced once the reclamation covers are constructed. It is the intent that reclamation cover systems will be constructed concurrent with operations, to the extent practical, in order to limit the flux of meteoric waters through the contained waste rock during the closure and post-closure periods. It is likely that a portion of the stockpile material will still be below the field capacity moisture content prior to placement of the cover system. This means that the maximum ponding on the liner system is likely to take place only after the cover systems are installed, and by then the drainage volume will be significantly reduced.

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1.0 INTRODUCTION

This 2nd Draft of RS49 presents the preliminary stockpile design for the PolyMet NorthMet Site (NorthMet Project) and incorporates responses to comments provided by the Minnesota Department of Natural Resources and other State of Minnesota and Federal agencies on the 1st draft of RS49. It is anticipated that the results of RS49 will be used to support an Environmental Impact Statement (EIS) impacts assessment. Golder will utilize the results from future geotechnical field investigations, the outcome of permitting discussions and the mutually agreed upon design criteria to advance and finalize the design concepts presented herein. It is expected that any changes resulting from finalizing the presented designs will not result in substantial modifications in the proposed stockpile geometry and design methodologies.

1.1 Scope of Work

The stockpile design was conducted in general accordance with the PolyMet Mining Inc. (PolyMet) scope of work as defined in Work Task 1.4 *Conceptual Mine Waste Impoundment Design* of "*Recommended Scope of Services and Cost Estimate for Supporting Mine Waste Management Designs at the PolyMet Project, Minnesota" – Scope of Work* dated May, 2005. Golder's preliminary stockpile designs utilize the stockpile footprint layouts developed by Barr Engineering Co. (Barr) in the RS18 Mine Plan (Appendix E). RS49 provides the preliminary design corresponding to the foundation preparation requirements, liner and cover system designs, and general development concepts for the NorthMet Stockpiles.

The segregated mine waste rock will be contained in engineered stockpiles with basal liner systems designed to minimize any leakage from the stockpiles to the environment. The preliminary liner and closure cover system designs presented herein incorporate the results of RS23T (Golder, 2007). RS23T presents a qualitative assessment and decision matrix developed to recommend various liner and cover systems for each of the NorthMet Stockpile categories. In accordance with the objectives of RS23T, the preliminary liner containment and cover system designs presented herein were developed to be consistent with the level of environmental risk posed by the geochemical properties of the waste rock materials contained in each stockpile category. A reclamation evapotranspiration (ET) cover or alternative closure barrier systems will be constructed over each stockpile during mining operations to limit the flux of meteoric waters through the contained waste rock during the closure and post-closure periods, following the reclamation sequence proposed in RS18.

Additional geotechnical site characterization will be required to support a final level design. However, it is our opinion that the existing geotechnical database, in combination with the conservative assumptions used to develop the preliminary design presented in this RS49 report, is sufficient to technically support the proposed stockpile designs for an EIS alternatives impact assessment. Available geotechnical information for the foundation areas of the proposed NorthMet stockpile locations includes data from the hydrogeologic borings completed by WDC Exploration & Wells for Barr (Appendix A) and the test trenching investigation completed by Golder in April 2006 (Appendix B). Access and drilling conditions at the site are difficult. Procurement of additional site geotechnical data will require access to the lowland areas that have both regulatory and logistical constraints. Additional data collection from these areas will need to occur during the winter when access can be accomplished while the terrain is frozen. The additional findings on subsurface soils are expected to be incorporated in the final design as more information becomes available. It is expected that changes resulting from the actual final design will not result in substantial modifications in the proposed stockpile geometry and design methodologies.

This section summarizes the recommended initial work scope, as well as a forecast for future work scope requirements to design and technically support lined mine waste rock stockpiles. The intent of this scoping program is to outline a three-phase program that considers the following design levels:

- A preliminary-level design that contains sufficient engineering detail to support the EIS impacts evaluation;
- Additional data will be compiled to support an advanced feasibility-level design; and
- Detailed engineering will then occur to address any gaps identified in the previous design efforts and to advance the design and specifications to a level that will support the bid procurement and construction requirements.

The work scope recommendations provided in this document are intended as a support document to the Detailed Project Description. The results of this phase of work will ultimately define the requirements for the advanced feasibility and detailed phases of engineering.

1.2 Future Work

The following studies are anticipated prior to final design and construction of stockpiles:

- Detailed characterization of native soils with respect to geotechnical classification, extent of unsuitable soil materials, and depth to bedrock and groundwater table;

- Identification and delineation of on-site borrow sources for liner and cover materials. Based on the estimated overburden volume of approximately 30,000,000 yd^3 (see RS18) obtained during pit and stockpile construction, there is a reasonable expectation that the quantity of overburden will be sufficient to provide borrow material for the construction of liner and cover systems (required borrow volume for the construction of liner and cover systems is estimated to approximately 5,000,000 yd^3);

- Delineation of areas to be used as stockpiles for liner and cover materials;

- Geotechnical analyses required to support the final design, e.g., stability, consolidation and soil cover models;

- Detailed characterization of geotechnical and hydraulic properties for liner and cover materials (for materials in the on-site areas identified as potential borrow sources);

- Detailed characterization of geotechnical and hydraulic properties for waste rock, ore and overburden materials;

- Detailed water balance for each stockpile to support the final sizing of the conveyance piping and sump systems used for stockpile seepage collection; and

- Issued for Construction (IFC) level Drawings and Specifications.

Further studies are anticipated as a part of the final closure and reclamation effort.

As noted previously, the logistical and environmental constraints with respect to access to lowland areas at the site require that the compilation of the required site geotechnical data for final design proceed on a phased approach. PolyMet is currently developing a detailed scope of work to address future geotechnical data collection requirements. It is important to emphasize that the design criteria require only the use of on-site materials for stockpile construction activities. On-site soils will be utilized and processed as required to meet the final design requirements. If on-site soils are not directly suitable, e.g. for use in liners, the soils will be processed (e.g., by removing oversize materials via a grizzly and potentially admixing with bentonite) to achieve required material properties. Considering the current depth to bedrock estimates (see Drawing 2), it is likely that the current stockpile and pit footprints and overburden processing area are sufficient to supply adequate borrow for construction. More detailed estimates of the available overburden material at different phases of construction are given in RS18.

The water balance for the mine site (including stockpiles) has been developed by Barr and is addressed in RS21 (overall Mine Site water balance), RS22 (Mine Site waste water management), and RS24 (Mine Site stormwater management).

2.0 SITE CONDITIONS

2.1 Evaluation of Existing Site Data

Prior to the Phase I field investigation discussed in Section 2.2, Golder reviewed existing site data that included the following:

- Boring logs conducted by Barr in March 2005;
- Depth to bedrock point data provided by PolyMet, based on electrical resistivity survey geophysics, geotechnical borings, and exploration borings; and
- Results from a regional cover performance study including glacial tills (Eger et al., 1999).

Barr conducted a monitoring well installation field program in March, 2005 (see Appendix A). The borings were advanced by WDC Exploration & Wells using rotasonic drilling methods. The boring locations are shown on Figure 1 with the boring logs included in Appendix A. Of the borings advanced, borings MW-05-09 and SB-05-10 are within the footprint of the proposed Category 1/2 Waste Rock Stockpile, while boring SB-05-04 is in its immediate vicinity (approximately 100 ft towards the West Pit). Boring SB-05-01 is in the proximity of the proposed Category 4 Waste Rock Stockpile and located approximately 70 feet towards the East Pit. In addition, boring MW-05-02 is located approximately 120 ft from the proposed Lean Ore Surge Pile towards the railroad.

Borings advanced in the vicinity or within the footprint of the Category 1/2 Waste Rock Stockpile encountered bedrock from 4 to 15 feet below the surface (see Appendix A). The thickest sequence of overburden soils encountered was 15 feet at SB-05-04, located in a lowland area. Boring SB-05-04 was advanced to a depth of 20 feet and encountered 2 feet of peat overlying clayey silt, silty clay (ML and CL materials), and sandy silt to a depth of 10 feet; this sequence was underlain by silty sand to a depth of 15 feet where bedrock was encountered. Boring MW-05-09 encountered sands and silty sands, with a layer of silty sand containing up to 40% of gravel, cobbles and boulders from 2 to 7 feet, and was terminated at 13 feet. Borings SB-05-10 and SB-05-10A encountered bedrock within 4 to 6.5 feet. Boring SB-05-10 was advanced to a depth of 14.5 feet, encountering approximately 1 foot of peat overlying silty sand to a depth of 4 feet where bedrock was encountered. Adjacent boring SB-05-10A encountered a thin layer of sandy clay at 4 to 6 feet depth underlain by bedrock.

Boring SB-05-01, located in the proximity of Category 4 Waste Rock Stockpile, was advanced to a depth of 19 feet, encountering approximately 5 feet of clay (CL) overlying organic-rich silty clay (OL) to a depth of 15 feet where bedrock was encountered.

Boring MW-05-02, located approximately 120 feet south of the Lean Ore Surge Pile, encountered approximately 6.5 feet of moist to wet sandy clay (CL) underlain by bedrock.

The site exploration drilling database, drilling logs from soil borings and monitoring wells installed at the site, and geophysics data supplemented with data from the Phase I field investigation (Section 2.2) were used to develop an estimated depth to bedrock isopach map. The depth to bedrock isopach map is presented in Drawing 2. The depth to bedrock isopach map was used to assist in siting the stockpiles in the geotechnically favorable locations.

Results from a regional cover performance study (Eger et al, 1999) monitored performance of several different capping options, i.e. waste rock covers constructed of glacial till and other materials. The study indicated that the on-site till soils might need limited processing to achieve acceptable cover performance. The study was limited in duration and scope; as such, the reported results were inconclusive with regard to the establishment of vegetation. The glacial till covers were constructed with a thickness of only one foot. Data from the test plot with the processed till material was reported as “unreliable.” As the minimum proposed cover ET cover thickness for the NorthMet Project is 2 feet with fully established vegetation, the results from the Eger et al.’s (1999) study cannot be directly used as an analog indicator of a long term ET cover performance at the NorthMet Mine Site.

2.2 Phase I Geotechnical Investigation

Golder conducted a Phase I geotechnical field and laboratory investigation in April 2006. The Phase I geotechnical investigation report is included as Appendix B, and summarized herein.

2.2.1 Field Investigation

A Phase I geotechnical field investigation was conducted in April 2006 to evaluate the subsurface conditions within the proposed stockpile footprints (Drawing 3 to 7). This Phase I program was constrained to terrains at higher elevations or highland areas due to disturbance and logistical constraints caused by the warm 2005/2006 winter conditions. The warm winter conditions prohibited access to the lowland areas, as these areas require frozen terrain for access to conduct the geotechnical investigations. The investigation program consisted of excavation of 15 test trenches (G06-TP1 through G06-TP15). The locations of the test trenches are shown on Figure 1. For stockpile design, the wetland delineation from RS14 and RS56 was used to develop excavation plans in lowland areas.

Test trenches were excavated using a John Deere 690 ELC trackhoe operated by Radotich Enterprises, LLC (Radotich). The test trenches were extended either to bedrock refusal or 20 feet, which was the limit of the trackhoe reach. Bedrock was encountered in 13 of the 15 test trenches at depths ranging from 3.5 to 15 feet, as summarized in Table 2.1. Each test trench was logged by an experienced geotechnical field technician. Soils samples were collected from each test trench for characterization and testing.

TABLE 2.1

SUMMARY OF DEPTH TO BEDROCK ENCOUNTERED DURING TEST TRENCH INVESTIGATION

Boring Number	Bedrock Depth Below Existing Grade (ft)
G06-TP1	Greater than 20
G06-TP2	13.0
G06-TP3	15.0
G06-TP4	13.5
G06-TP5	14.0
G06-TP6	Greater than 20
G06-TP7	3.5
G06-TP8	4.5
G06-TP9	8.5
G06-TP10	8.0
G06-TP11	6.0
G06-TP12	5.0
G06-TP13	9.0
G06-TP14	3.5
G06-TP15	11.5

The test trenches typically encountered up to 6 inches of topsoil over primarily silty sand with boulders and cobbles. Sandy lean clay over silty sand layers were encountered in test trench G06-TP5 located within the footprint of the proposed Category 1/2 Waste Rock Stockpile. The adjacent exploration trenches G06-TP4 and G06-TP6 are also located within the Category 1/2 Waste Rock

Stockpile and consist entirely of silty sands and sandy silts. All test trenches indicate soils with less than about 45% of gravel and coarser material, typically encountering soils with smaller percentage of gravel closer to the surface.

Test trenches G06-TP11 and G06-TP12 located at the western edge of the Category 3 Lean Ore Stockpile encountered bedrock from 5 to 6 feet from the surface. The surface layer of topsoil, within approximately 6 inches from the surface, was underlain by a 2.5 feet thick layer of silty sand with less than 50% of gravel or coarser materials. The percentage of gravel increased with depth at G06-TP11.

Test trenches G06-TP8 through G06-TP10, located within the central portion of the proposed Category 4 Waste Rock Stockpile, encountered bedrock from 4.5 to 8.5 feet from the surface. These trenches encountered from 2 feet (G06-TP8) to 3.5 feet (G06-TP9 and G06-TP10) of silty sand, with less than 50% of gravel or coarser materials. The silty sand was underlain by cleaner sands with a higher percentage of gravel. Test trenches G06-TP13 to G06-TP15, located along the southern edge of the proposed Category 4 Waste Rock Stockpile, encountered the bedrock from 3.5 to 11.5 feet, respectively. With the exception of the topsoil layer ranging in thickness from 6 to 12 inches, G06-TP13 to G06-TP15 soils were classified by the Unified Soil Classification System (USCS) as silty sands (SM) with less than 50% of gravel or coarser materials.

Groundwater was encountered at depths of 13 to 15 feet below the existing ground surface in test trenches G06-TP2 and G06-TP3, which are located on the southwest side of the proposed West Pit. The exploration trench G06-TP6 is located within the limits of the proposed Category 1/2 Waste Rock Stockpile and encountered groundwater at 15 feet depth. Groundwater was encountered at depths of 4 to 5 feet below the existing ground surface in test trenches G06-TP8, G06-TP9, G06-TP10, and G06-TP15 within the limits of the proposed Category 4 Waste Rock Stockpile footprint. Due to the existing slow draining site soils, it is likely that groundwater did not have time to fully stabilize within the test trenches prior to backfilling. Groundwater levels are expected to fluctuate seasonally. However, groundwater is often found at the soil/bedrock interface. Predicted groundwater levels and flow paths during operation and after closure are provided in Appendix B of RS22.

2.2.2 Laboratory Testing

Soil samples collected from the geotechnical investigation program were shipped to Braun Intertec Corporation (Braun Intertec) of Hibbing, Minnesota for index testing. Select samples were shipped to Golder's Soils Laboratory in Lakewood, Colorado for additional testing.

Soil samples were classified using the USCS. Laboratory tests were performed in accordance with American Society for Testing and Materials (ASTM) test methods to measure index properties of the samples recovered from the test trenches, to confirm field classifications, and for use in developing correlations with engineering properties of the soils encountered. Laboratory analyses conducted on the various soil samples consisted of the following:

- Sieve Analysis – ASTM C117/C136;
- Atterberg Limits – ASTM D4318;
- Natural Moisture Content – ASTM D2216;
- Standard Proctor Compaction – ASTM D698;
- Consolidated-Undrained (CU) Triaxial Compression – ASTM D4767;
- Falling Head Flexible-Wall Permeability Testing – ASTM D5084; and
- One-Dimensional Consolidation Testing – ASTM D2435.

The site foundation glacial till soils encountered in the highland areas were typically silty sands with variable percentages of clay and gravels that were classified by the USCS as SM, SP, ML, and CL. The fines content (percent passing the No. 200 sieve) of the soils encountered ranged from 2 to 52 percent. The majority of the soils collected were non-plastic. Measured in-situ moisture contents ranged from 7.2 to 26.9 percent.

CU triaxial testing and consolidation testing was conducted on an undisturbed Shelby tube sample of clay (CL) obtained from test trench G06-TP5 at a depth of 0.5 to 4.0 feet. In the CU test, the specimen is permitted to drain and consolidate under the confining pressure until the excess pore pressure is equal to zero. The in-situ effective stress strength parameters yielded an effective cohesion of zero with an effective friction angle of 34.6 degrees. The consolidation test indicated a coefficient of consolidation (C_v) of $5.3x10^{-1}$ to $9.6x10^{-1}$ square foot per day (ft^2/day) and a coefficient of compression (C_c) of 0.05 to 0.13 under the loading range of 1 to 16 kips per square foot (ksf).

Laboratory testing consisting of Standard Proctor compaction tests and falling head permeability tests was conducted on three samples of native soils to evaluate their potential use as a soil liner or compacted subgrade. The samples tested included sample G06-TP4 at a depth of 0.5 to 4.5 feet, sample G06-TP7 at a depth of 0.5 to 3.5 feet, and sample G06-TP13 at a depth of 4 to 9 feet. All three samples classified as silty sand (SM) according to the USCS. The maximum standard Proctor dry density of the samples ranged from 118.3 to 125.7 pounds per cubic foot (pcf) with an optimum moisture content ranging from 12.4 to 14.2 percent. Prior to permeability testing, the soil samples were remolded to 95 percent of the maximum standard Proctor dry density at the optimum moisture content. The permeability of the compacted native soils ranged from $1.1\text{x}10^{-7}$ to $2.0\text{x}10^{-7}$ cm/sec, indicating that the native soils are favorable for use as a compacted soil liner (see Appendix B). These relatively low permeability values are in accordance with the glacial till hydraulic conductivities reported in the literature (e.g. Wilson et al, 2003).

A relatively high fines content of native soils, with an exception of G06-TP8 sample collected from 2 to 4.5 feet, indicates that the native soils are good candidates for ET cover construction, which is further discussed in Section 3.2.3 and Appendix D. In addition, previous studies on glacial till covers (see e.g. Wilson et al., 2003) support the choice of glacial till as a favorable cover material.

3.0 STOCKPILE DESIGN CRITERIA AND CONCEPTS

This section provides the design concepts supporting the conceptual-level design of the waste rock and lean ore stockpiles and for the stripped overburden storage locations. The design criteria for the stockpiles follow the requirements outlined in Chapter 6132 of the Minnesota Rules (Office of the Revisor of Statutes, part 6132.2400, subpart 2, item B), summarized as follows:

- No lift shall exceed 40 feet in height;
- No bench shall be less than 30 feet, measured from the crest of the lower lift to the toe of the next lift;
- The sloped area between benches shall be no steeper than the angle of repose; and
- The sloped areas between benches shall be prepared to support vegetation.

The design criteria for the surface overburden material stockpiles are outlined in Chapter 6132 of the Minnesota Rules (Office of the Revisor of Statutes, part 6132.2400, subpart 2, item C) as follows:

- No lift shall exceed 40 feet in height;
- No bench shall be less than 30 feet wide, measured from the crest of the lower lift to the toe of the next lift;
- The sloped area between benches shall be no steeper than 2.5:1; and
- Runoff water shall either be temporarily stored on benches or removed by drainage control structures

3.1 Design Criteria

The following preliminary design criteria were used for stockpile design:

Waste Rock and Lean Ore Stockpile Geometry:

Maximum depth over liner: 250 feet for Category 1 and 2 rock; and 200 feet for Category 3 and 4 rock.

Minimum width at the top of stockpile: Approximately 150 feet, controlled by the minimum safe turning radius for operating mine haulage trucks.

Nominal angle of repose slopes: 1.4H:1V (horizontal:vertical) (assumed).

Limits of liner system where adjacent to overburden: Extend stockpile liner system a minimum of 50 feet beyond the vertical limits of mine waste where waste rock abuts overburden materials.

Grading considerations:

- For stockpiles containing Category 1, 2, and 3 materials: A prescribed 30 feet wide benches with nominal 40-foot lift height, per the regulatory requirements (Minnesota Rules, Chapter 6132, Office of the Revisor of Statutes, part 6132.2400, subpart 2, item B). The proposed design conforms to the regulatory requirements and provides for 2.5(H):1(V) regraded interbench outslopes, with a 30-ft wide reclamation bench on nominal 40-ft (vertical) intervals.

- For stockpiles containing Category 4 materials: Interbench outslopes will be regraded to 3.5(H):1(V) or flatter, with a 30-ft wide reclamation bench on nominal 40-ft (vertical) intervals.

Height of first lift (over liner): 15 feet.

Height of second lift (over liner): 25 feet.

Nominal lift height (over liner): 40 feet (per Minnesota Rules, Chapter 6132, Office of the Revisor of Statutes, part 6132.2400, subpart 2, item B).

Average dry density of waste rock: 1.7 tons per cubic yard. This number was based on a specific gravity of 2.9 for mine waste rock and an average stockpile porosity of 30%. The assumed stockpile porosity and specific gravity values used for the preliminary design are supported by Hewett (1980).

Design capacity requirements: Based on waste rock and lean ore type and origin, see Table 4.3.

Liner system: Risk based depending on reactivity category of the waste rock and lean ore.

Closure Cover Reclamation System:

- Category 1/2 Waste Rock Stockpile will utilize a vegetated store and release ET cover;

- Category 3 stockpiles (Category 3 Waste Rock and Category 3 Lean Ore Stockpiles) will have a barrier liner system on the crest and bench areas, and will have a vegetated ET cover on the regraded outslopes;

- A barrier system is recommended to be constructed on the crest and reconfigured outslopes for the Category 4 Waste Rock Stockpile (Note: the Lean Ore Surge Pile will be completely removed at the end of Year 20 and, thus, will not include a reclamation cover).

It should be noted that the use of ET covers for Category 3 and 4 stockpiles may be a viable alternative to a barrier layer should the results of the proposed ongoing monitoring of reclaimed portions of low and medium reactivity stockpiles with an ET cover system demonstrate an equivalent long-term performance of the ET cover to that of a barrier.

Number of expansion phases: To be determined.

Perimeter access road width (plus allowance for berms), for light truck traffic: 20 feet.

Overburden Material Stockpile Geometry:

Maximum stockpile height: 40 feet for temporary overburden storage area; and approximately 250 feet for Category 1/ 2 overburden (overburden material adjacent to Category 1/2 Waste Rock Stockpile).

Nominal overburden angle of repose slopes: 1.4H:1V (horizontal:vertical) (assumed).

Average overburden density: 1.84 tons per cubic yard. For conservatism, assume a bulking factor of 25% for stockpiled overburden material, i.e., there is no shrinkage or compaction during overburden placement.

Design capacity requirements: Based on the excavation plan (see Drawing 8). The excavation quantities required for stockpile development are summarized in the following table

TABLE 3.1

EXCAVATION QUANTITIES

Excavation Quantities:	1 year	5 yr	10 yr	15 yr	20 yr
Category 1/2*	869,000	3,802,000	4,730,000	4,730,000	4,730,000
Category 3	53,000	131,000	203,000	298,000	298,000
Category 3 Lean Ore	115,000	130,000	315,000	820,000	820,000
Category 4	30,000	146,000	234,000	234,000	234,000
Lean Ore Surge Pile	59,000	59,000	59,000	59,000	59,000

* excavation below proposed Category 1/2 liner system, i.e. no excavation below unlined overburden area

The excavation quantities in Table 3.1 were determined by subtracting the excavated foundation topography (Drawing 8) from the original (existing) topography (Drawing 1) over the area of the specific stockpile. In particular all lowland (wetland) area soils were considered unsuitable (see RS14 and RS56 for wetland delineation) and were excavated up to the maximum depth of 20 feet or until reaching bedrock. Additional information for overburden balance, including overburden stripping during pit construction, is provided in RS18.

Subgrade: Un-lined subgrade (native materials) with minimal or no surface preparation.

Grading considerations: A prescribed 30 feet wide benches with nominal 40-foot lift height, per the regulatory requirements (Minnesota Rules, Chapter 6132, Office of the Revisor of Statutes, part 6132.2400, subpart 2, item C) for the overburden material to dispose in the Category 1/2 Waste Rock Stockpile. The proposed design conforms to the regulatory requirements using the maximum of 2.5(H):1(V) regraded interbench outslopes for the Category 1/2 overburden stockpile.

Cover system: Reclaimed using native vegetation.

Number of expansion phases: To be determined.

Perimeter access road width (plus allowance for berms), for light truck traffic: 20 feet.

Stockpile Stability:

Minimum composite slope acceptable operational static factor of safety: 1.3.

Minimum composite slope acceptable operational pseudo-static factor of safety: 1.1.

Design operations earthquake peak ground acceleration: 0.05g or less. Assuming the return period of approximately 500 years, the peak ground acceleration for the NorthMet Mine Site should be less than 0.05g using the FEMA (2001) maps for the spectral accelerations with the 10% probability of exceedance in 50 years.

3.2 Stockpile Design Concepts

The two general types of stockpile materials proposed for the NorthMet Project are waste rock stockpiles and lean ore stockpiles. The classification of some of the waste rock into lean ore is an economic criterion. The classification of waste rock into the categories below is based on the waste characterization program conducted by PolyMet and reflects how the geochemistry of the rock is predicted to behave in the long-term. As such, waste rock classifications are used to determine the type of liner and cover system regardless of whether the stockpiled material is waste rock or lean ore. Based on its mechanical and chemical properties, the lean ore may be considered as a type of waste rock for stockpile design purposes. Therefore, subsequent references to waste rock apply to both the waste rock and lean ore.

The presented stockpile design incorporates the concept of segregating different waste rock categories based on the following classification developed by PolyMet's geochemical consultants (SRK, 2007):

- Category 1 waste rock – Construction rock (%S<=0.12%). Used for construction applications as approved by regulators;
- Category 2 waste rock – Low reactivity (%S<=0.12% or %S<=0.31% if Cu/S<0.3), will not generate acid rock drainage (ARD) but can leach metals in excess of water discharge limits. Category 1 waste rock becomes Category 2 waste rock if not used for construction. Waste rock categories 1 and 2 combined comprise approximately 83 percent of the total waste rock;
- Category 3 waste rock and Category 3 lean ore – Medium reactivity (0.31%<%S<0.6% or 0.12%<%S<0.6% if Cu/S>0.3) is predicted to potentially generate ARD in the long term. This category comprises approximately 14 percent of the total waste rock;

- Category 4 waste rock and Category 4 lean ore – High reactivity (%S>0.6%, plus all Virginia Formation), is predicted to generate ARD in the short term. This category comprises approximately 3 percent of the total waste rock; and

- Till waste represents the remainder of the non ore volume, approximately 6 percent of the total excavated volume (non-ore volume including waste rock and overburden, due to stockpile construction). Based on RS18, the amount of overburden excavated during both stockpile and pit construction may be as high as 20 to 24 percent of the total non-ore volume depending on an assumed bulking factor of 25% or less. Overburden is generally considered non-reactive material suitable for construction.

The segregated mine waste rock will be contained in engineered stockpiles with basal liner systems designed to minimize any leakage from the stockpiles to the environment. In addition, reclamation evapotranspiration (ET) cover or alternative barrier systems will be constructed over each stockpile concurrent with mining operations to limit the flux of meteoric waters through the contained waste rock during the closure and post-closure periods, following the stockpile cover sequence proposed in RS18. Both the basal liner and top reclamation barrier systems have been designed to be commensurate with the level of environmental risk posed by each geochemical waste rock category, as recommended by Golder (2007) in RS23T.

Each of the lined stockpile liner systems will need to be constructed on a geotechnically suitable foundation. The development concept for foundation construction of all stockpiles includes the following considerations and assumptions:

- Excavate and stockpile geotechnically unsuitable soils (e.g., organic soils, unconsolidated clays, etc.) for future use as a reclamation growth medium. It is anticipated that minor sub-excavation of unsuitable soils in the highland areas and that considerable sub-excavation of unsuitable soils in the lowland areas will be required. The proposed stockpiles will exert significant stress on foundation soils. The definition of geotechnically unsuitable soils as used herein refer to any foundation soil that may potentially undergo significant deformations, create stability problems or jeopardize the general integrity of the stockpile foundations during the loading process. In particular, soft clays or organic soils with low permeability, that may exhibit large deformations and development of excess pore pressure during the loading process, are considered unsuitable. These unsuitable soils require excavation and replacement with suitable soil materials.

- Develop foundation drainage to prevent the development of excess foundation pore pressures, based on the geotechnical conditions encountered.

- Establish the foundation design grades required for seepage collection, stability and other design considerations by placing engineered fill. Engineered fill materials are anticipated to consist of excavated local till and/or Category 1 waste rock placed as structural fill in controlled compacted lifts. For foundations constructed solely of local soils, i.e., without Category 1 materials, grading plans are expected to undergo limited modifications in order to further optimize construction quantities.

- Construct the liner system dependent upon the reactivity category of the waste rock.
- Foundation grading will be developed to provide for gravity drainage and collection of any leakage from the stockpile to a series of lined collection sumps. The water collected in the sumps will be pumped to the Wastewater Treatment Facility (WWTF) to be constructed at the Mine Site or directed towards the mine pits (for more details, see RS22).

The calculated construction quantities are summarized in Table 3.2.

TABLE 3.2

LINER CONSTRUCTION QUANTITIES

	Cut (yd^3)	**Fill (yd^3)**
Category 1/2	647,000	5,737,000
Category 3	159,000	677,000
Category 3 Lean Ore	196,000	984,000
Category 4	21,000	319,000
Lean Ore Surge Pile	43,000	78,000

The following sections present the general design concepts for stockpile development.

3.2.1 Foundation Preparation

Given the available geotechnical information at the site, which is particularly limited within the lowland areas, it has been conservatively assumed for this preliminary stockpile design that the foundation soils located in the lowland areas are generally unsuitable, while the foundation soils in the highland areas are generally acceptable for stockpile development. Foundation preparation concepts used to develop the design of all stockpiles assume the following general sequence: (1) excavate to bedrock within lowland areas, stockpiling organic soils and till material separately for future use as reclamation soils and structural fill; (2) fill areas required to meet the foundation grade requirements with the more granular till soils (structural fill); (3) use Category 1 material, if approved by regulatory agencies, in controlled compacted lifts to develop the base grading of the stockpiles; and (4) construct liner system dependent upon reactivity category of the stockpile. An underdrain system will need to be designed for each of the stockpiles to facilitate foundation drainage as illustrated on Detail 3, Drawing 12. This underdrain system is necessary for areas filled with native soils in order to prevent the development of excess foundation pore pressures.

Golder considers foundation underdrains to be a standard of practice for high stress mine waste applications with impermeable liner systems, particularly when sited in areas with a high groundwater table. The purpose of the underdrains is to provide gravity drainage for foundation materials in areas where elevated groundwater is encountered and to prevent or minimize the potential for excess pore pressures to develop from a rising phreatic surface as the facility is loaded. The design intent is not necessarily to promote consolidation, as surficial saturated clays would be considered unsuitable and removed. The underdrain system may not be necessary in areas where grading fill uses Category 1 material if this material has a relatively high hydraulic conductivity.

The underdrain system is conceptually designed with the 3-inch corrugated polyethylene pipes spaced at a nominal distance of 100 feet. The minimum slope of the underdrain pipes is 0.5%, approximately following the liner grades shown in Drawing 9. The spacing of the underdrains may be revised during final design as additional site characterization data becomes available, but this level of detail should not be necessary to evaluate environmental impacts. It is anticipated that the majority of foundation water collected by the underdrain system will be unimpacted. Nonetheless, the underdrain flows will be conveyed to collection sumps from where the water will be pumped to the WWTF (see RS24 and RS22). It should be noted that the design intent of the underdrain system is not for seepage collection. However, under ideal hydrogeological conditions, the potential exists that the liner seepage is captured by the underdrains.

3.2.2 Liner System Design Concepts

The basal liner barrier systems have been designed to be commensurate with the level of environmental risk posed by each geochemical waste rock category, as recommended by Golder, 2007 in RS23T.

Each of these selected liner systems was evaluated by conducting a liner seepage analysis. The methodology and results of these evaluations are provided in Appendix C. The selected liner systems are summarized as follows:

- Low reactivity waste rock (Categories 1/2 Waste Rock Stockpile): A minimum of one foot of compacted soil liner with a maximum permeability of

$5x10^{-7}$ centimeters per second (cm/sec) and an overliner drainage layer. An average annual leakage rate of 464 gallons per acre per day (gal/acre/day) is predicted for an open stockpile prior to final cover construction (see Appendix C). It is anticipated that the liner material will consist of locally excavated till soils based on the available laboratory and site investigation data (Golder, 2006). If necessary, PolyMet will process the soil liner materials using bentonite admixing or other techniques to meet the design specification of $5x10^{-7}$ cm/sec.

- Medium reactivity waste rock (Category 3 Waste Rock Stockpile): A compacted subgrade overlain by a geomembrane liner and an overliner drainage layer. The upper one foot of the prepared subgrade shall have a maximum permeability of $1x10^{-5}$ cm/sec. This will provide an average annual leakage rate of approximately 2 gal/acre/day prior to the stockpile being reclaimed (for more details on the leakage simulations, see Appendix C). It is anticipated that local glacial till soils will meet the permeability requirements specified for the subgrade material based on the available laboratory and site investigation data (Golder, 2006). This data indicates that the permeability of foundation soils is matrix supported, i.e. governed by matrix soils. If necessary, foundation soils will be processed in accordance with conventional methods, e.g., bentonite admixing, grizzly, etc., to meet the subgrade design specification of $1x10^{-5}$ cm/sec.

- High reactivity waste rock (Category 3 Lean Ore and Category 4 Waste Rock Stockpiles and Lean Ore Surge Pile): A robust liner system is proposed, which consists of a minimum of one foot of compacted soil liner with a maximum permeability of $1x10^{-6}$ cm/sec overlain by a geomembrane liner and an overliner drainage layer. This will provide an average annual leakage rate of approximately 0.1 gal/acre/day prior to the stockpile being reclaimed (for more details on the leakage simulations, see Appendix C). It is anticipated that the compacted soil liner will consist of locally excavated till soils based on the available laboratory and site investigation data. This assumption of using local material is also supported by the long-term permeability values for glacial till reported in the literature; e.g., Wilson et al. (2003) determined the mean field saturated conductivity for glacial till of $3x10^{-6}$ cm/sec when used for cover materials. As the liner soils are subject to much larger confining pressures, are overlain by the waste rock and are therefore protected from freeze, thaw and desiccation effects, the long-term liner permeability of $1x10^{-6}$ cm/sec for on-site soils is likely achievable.

The calculated liner leakage rates disregard the influence of the waste rock uptake potential. We consider this a very conservative assumption. It inherently over predicts the results of the leakage model because the stockpile materials will be placed dry of the specific retention moisture content (also referred to as field capacity; Bear, 1972), i.e., the minimum moisture content required to overcome the gravimetric surface tension so that gravity drainage of precipitation to the bottom of the stockpile can occur. The moisture content difference between the specific retention and the moisture content of the originally placed waste rock represents the quantity of water that is permanently lost, i.e., not available on a bulk basis for drainage, and is therefore directly related to the amount of time needed for a "break-through" of the wetting front. Hutchison and Ellison (1992) note that for waste rock placed at a moisture content below its specific retention value “.... possibly even for several months or years, the percolation will go toward raising the moisture content of the waste to levels at which leachate flow can ultimately occur.” Golder anticipates that a minor percentage of short-circuiting may occur at stockpile boundaries, but the total waste rock uptake is likely to remain significant. For instance, 40 ft of material in a single lift at 5% retention (by volume) would need approximately one year for break-though assuming no evaporation and runoff losses. Therefore, the overall stockpile will essentially behave as a “sponge” with any precipitation being permanently lost as uptake until reaching the specific retention value.

The potential flux of meteoric waters through the stockpiles will be further reduced once the reclamation covers are constructed. It is likely that much of the stockpile material will still be below its overall specific retention moisture content prior to placement of the cover system. This means that the maximum ponding on the basal liner system is likely to take place only after the reclamation cover systems are installed, and by then any potential drainage volume reaching the basal liner system will be significantly reduced.

Compacted waste rock and/or native soils are planned to be used for foundation grading. It is anticipated that the foundation soils may exhibit considerable settlement under the high-stress design conditions. As a result, it is recommended that a low linear density polyethylene (LLDPE) geomembrane, or similar elastic polymer, be used for the geomembrane component of the basal liner system for the Category 3 and 4 stockpiles due to its reliability to accommodate high strain deformations.

It is anticipated that structural fill will dominantly consist of native till soils compacted to 95% of the maximum density as determined by the Standard Proctor Compaction tests (ASTM D 698). Where Category 1 material is used to develop the foundation grades, rock fill placement will need to occur with controlled lifts placed in accordance with a specified rockfill compaction method.

The overliner drainage layer is expected to consist of crushed rock or processed gravel from site soils. The use of a crushed rock overliner has been a standard of practice for high stress mine waste applications for decades; e.g., crushed ore has been used extensively in heap leach liner system applications for over 20 years. The overliner drainage layer is required as a buffer to protect the geomembrane (for Category 3 and 4 Stockpiles) from damage during placement of the waste rock, from wildlife, and from the elements (e.g., UV radiation, wind, storm flows etc.). For angular overliner materials, a geomembrane loading test shall be conducted during final design to support specification of the acceptable geomembrane thickness (see e.g. Lupo and Morrison, 2005).

The overliner also contains the solution collection piping network as shown on Details 5 and 6, Drawing 12.

3.2.2.1 Potential Impact of Precipitation Uptake on Predicted Liner Leakage Values

No operational water balance quantifying the permanent uptake for the stockpiles has been conducted for this preliminary design, as the material characteristics required to define this parameter have not been characterized. In particular, to define the uptake potential, one needs to determine the expected moisture content of the materials placed on the stockpiles and their corresponding specific retention moisture contents. From Golder's experience on other similar projects, the difference between the initial moisture content of the waste rock and its specific retention value is generally in the range of 1% to 5% by weight, depending on the material's specific properties. The uptake potential at the NorthMet Site can be illustrated using the following procedure:

1. Assuming that the drainable porosity of the NorthMet's "in-place" mine rock is directly related to the volume of fractures, one may estimate the "fracture" or secondary porosity (for the "in-place" mine rock) from Fetter (1994), Davis (1969) and Brace et al. (1966). Davis (1969) noted that intact plutonic rocks typically have a very low porosity as they are formed of interlocking crystals. Fracturing, however, increases porosity of crystalline rock by about 2% to 5% [Davis (1969) and Brace et al. (1966)]. Assuming that the NorthMet deposit fractures are saturated and that the average drainable porosity is n=5%, one can now determine the "in-place" gravimetric moisture content of bulk mined rock as:

$$w_{MR} = \frac{n\,S_r}{(1-n)\,G_s} = \frac{5\% \times 100\%}{(1-5\%) \times 2.9} = 1.8\%\,,$$

   where S_r denotes the degree of saturation and G_s is the specific gravity of mined rock. The assumed specific gravity value of 2.9 considers the average of 864 core samples (2.94) and the resultant average of 43,207 blocks (2.86), both of which round to 2.9. Note that the above analysis assumes that the drainable porosity of the "in-place" rock (prior to mining) is governed by fractures (secondary porosity) and that no water is lost from fractures during mining operation (e.g., due to dewatering, blasting and transport).

2. Estimate the specific retention value for the waste rock (post mining waste material) from Hutchison and Ellison (1992) referring to the typical values

reported by Brady (1974) and Hanks and Ashcroft (1980). Based on Hutchison and Ellison (1992), the waste rock specific retention by weight is likely to be 10% or lower. If one assumes a relatively coarse grained waste rock, the specific retention by weight may conservatively be estimated as w_{SR}=5%.

3. The waste rock uptake potential can now be determined as the difference between the specific retention of the bulk waste rock material and the moisture content of the "in-place" rock as:

$$\Delta w_{UPTAKE} = w_{SR} - w_{MR} = 5\% - 1.8\% = 3.2\%,$$

yielding the uptake potential by volume of

$$\Delta n_{UPTAKE} = G_s \Delta w_{UPTAKE} (1 - n_{WASTE\ ROCK}) = 2.9 \times 3.2\% \times (1 - 0.3) = 6.5\%.$$

The waste rock porosity, $n_{WASTE\ ROCK}$, of 30% was estimated based on Hewett (1980) who reported the porosity of 1/3 for relatively short stockpiles (40 to 120 ft for Erie and 13 ft for AMAX stockpiles).

3.2.3 Cover System Design Concepts

Based on RS23T (Golder, 2007), a vegetated store and release evapotranspiration (ET) cover system is recommended for the closure and reclamation of the Category 1/2 Waste Rock Stockpile and for the outslopes of Category 3 stockpiles. A liner barrier system is proposed for the crest and benches of Category 3 Waste Rock and Category 3 Lean Ore Stockpiles and the entire surface area of Category 4 Waste Rock Stockpile. At this time, it is anticipated that the liner barrier for the closure cover will consist of a textured 60-mil geomembrane overlain by 1.5-ft of cover soils vegetated by grass species.

ET cover simulations were evaluated for the NorthMet site using hydraulic properties derived from grain-size distribution curves for on-site soils determined during geotechnical field investigation (see Appendix B). The soil-water characteristic curves (SWCCs) were determined by comparing the lab determined grain-size distributions for on-site soils with the similar soils from the SoilVision database (SoilVision Ltd., 2006), as discussed in more detail in Appendix D. The SWCC data for these "similar" soils from the SoilVision database were then used to establish the likely bounds of SWCC parameters (mean, upper and lower bound) utilized in ET cover modeling. The ET cover models utilized a 30-year climate period from 1971 to 2000 with an average annual precipitation of approximately 29 inches. The model accounts for snow accumulation and snowmelt while neglecting sublimation and soil freezing for added conservatism. Consequently, the model allows for the spring-flush to readily infiltrate the model soil column as it neglects hydraulic conductivity reduction caused by soil freezing, therefore yielding conservative infiltration estimates.

The climate records used for soil-atmosphere (water balance) modeling are summarized in Table 3.3. A more detailed description of the employed soil-atmosphere model can be found in Appendix D.

TABLE 3.3

ANNUAL EXTREME PRECIPITATION AND PET VALUES

	Annual Values		
	Average	**Max.**	**Min.**
Precipitation (inch)	29.2	41.8	20.3
PET (inch)	21.0	22.8	19.4

The ET cover infiltration was calculated for the bare cover (i.e., immediately after installation of the cover system, before vegetation growth), grass covers and covers with the established forest ecosystem. The long-term ET cover infiltration estimates for a 2-foot cover are summarized in Tables 3.4 and 3.5.

TABLE 3.4

AVERAGE ANNUAL INFILTRATION FOR 2-FOOT ET COVER, AS A PERCENT OF ANNUAL PRECIPITATION

Vegetation **SWCC**	**Bare Cover**	**Grass**	**Forest**
Lower Bound	0.9%	<0.1%	<0.1%
Mean	6.8%	2.3%	0.4%
Upper Bound	22.5%	20.0%	17.9%

TABLE 3.5

AVERAGE ANNUAL INFILTRATION FOR 2-FOOT ET COVER (GAL/ACRE/DAY)

Vegetation **SWCC**	**Bare Cover**	**Grass**	**Forest**
Lower Bound	20	1	1
Mean	147	49	9
Upper Bound	488	434	389

The infiltration estimates for ET cover simulations with the cover thickness of 2 and 3 feet are shown in the following table:

TABLE 3.6

AVERAGE ANNUAL INFILTRATION FOR DIFFERENT COVER THICKNESSES

Simulation	Infiltration for 2-ft. ET Cover		Infiltration for 3-ft. ET Cover	
	(% precip.)	(gal/acre/day)	(% precip.)	(gal/acre/day)
Mean SWCC Bare Cover	6.8%	147	6.6%	144
Mean SWCC Forest Cover	0.4%	9	0.1%	3

A more detailed discussion on ET cover modeling is included in Appendix D.

As documented in Appendix D, the amount of precipitation infiltrating through the store and release ET cover depends on cover thickness, subgrade material and vegetation. The most significant factors influencing infiltration are the type of subgrade material and presence of vegetative species. Based on the preliminary ET cover modeling (Appendix D), the infiltration rates for the vegetated cover may be reduced up to hundred times comparatively to the cover without vegetation. Benson et al. (2002) reports a case study with a percolation rate decreasing by more than 25 times as trees became established in an ET cover system. The ET covers at the NorthMet Mine Site will be engineered to minimize infiltration of precipitation into stockpiles by enhancing runoff and evapotranspiration rates. For finer materials that are capable of retaining significant amounts of moisture at higher suctions, it might be necessary to construct thicker covers in order to mobilize the root uptake potential and reduce infiltration. It is recommended that, to the extent practical, glacial till with favorable soil-water retention characteristics be selectively stockpiled for reclamation cover soils.

The presented infiltration quantities should be viewed as likely upper bound estimates due to the following conservative assumptions:

1. The mature forest simulations assume complete cessation of transpiration during the dormant period for deciduous understory species, whereas in practice, the transpiration continues during the winter period due to the presence of evergreen species;

2. Snowmelt scenarios conservatively neglect the snow pack losses due to sublimation, therefore, the modeled spring snowmelt quantities are larger than in reality, yielding conservative infiltration estimates;

3. Effects of soil freezing were neglected whereas in reality, the soils may remain fully or partially frozen during the snowmelt events, potentially leading to significantly smaller infiltration (higher runoff) estimates; and

4. Precipitation events in all ET cover simulations start at midnight and are typically over before dawn when the evaporation module is activated. In practice, at least some of the rain events occur during the daytime allowing the water from the surface soil layers to evaporate more readily at the cessation of precipitation.

Based on the values reported in the literature [e.g., Benson (2002) and Wilson et al. (2003)], the maximum annual infiltration for the stockpiles with a geomembrane cover was estimated to 5% of annual precipitation.

3.2.4 Closure Design Concepts

Each of the stockpiles will be designed to minimize erosion of the overburden slopes in order to facilitate closure criteria, promote the post-closure land use and minimize the need for the active site care and maintenance during the post-closure period.

The closure process will progressively start with the reclamation of the stockpile platforms and slopes as soon as they become inactive. Closure will involve the seeding and planting of all stockpiles, access roads and perimeter disturbance areas.

Prior to revegetation of the stockpile surfaces, the stockpile will be locally contoured to provide some topographic variety to the surface and to assist in the development of a surface drainage network. For the outslopes where ET covers will be constructed, i.e., Category 1/2 Waste Rock, Category 3 Waste Rock and Category 3 Lean Ore Stockpiles, the slope between benches will be reduced to 2.5H:1V to facilitate placement of a reclamation cover. For the Category 4 Waste Rock Stockpile where textured geomembrane will be used as part of the cover, the interbench slopes will be reduced to 3.5(H):1(V) or flatter. Drainage channels will be constructed on nominal 30-foot wide benches, constructed on nominal 40-foot vertical intervals at typical 2% gradients. A drainage system utilizing the benches will be developed to manage the flow of non-contact unimpacted storm water (i.e., water that has not contacted waste rock). When reclamation contouring is completed, a layer of reclamation soil will be placed over the stockpile surface. ET covers will then be seeded with grass, and planted with shrubs and trees selected to support the site specific ET cover requirements. Vegetation for the Category 4

Waste Rock Stockpile and for Category 3 Waste Rock and Category 3 Lean Ore Stockpiles on tops and benches will likely be limited to grass species due to the presence of the geomembrane barrier.

It is expected that the results from more detailed geotechnical and infiltration studies may have an impact on the eventual closure plan, and as such, the closure design has not been advanced beyond that indicated for this preliminary design. As appropriate, the results of these studies will be integrated into the final design to enhance the environmental performance of the closure plan.

3.3 Lean Ore Surge Pile Design Concepts

The Lean Ore Surge Pile footprint designed by Barr to be consistent with the mine plan is illustrated on Drawings 3 to 7. The general design concepts considered for the Lean Ore Surge Pile are the same as for the Category 4 waste rock material. However, the Lean Ore Surge Pile design differs from the other stockpiles containing the waste rock material as this stockpile is expected to be completely removed at the end of the last year of mining operations (i.e., year 20). In addition, the Lean Ore Surge Pile design should conform to specific overliner requirements based on the anticipated operating mine equipment, which will be developed in greater detail as a part of the final design. The extents of the Lean Ore Surge Pile shown in the Drawings 3 to 7 are based on the maximum past contained volume as summarized in the following table:

TABLE 3.7

LEAN ORE SURGE PILE DESIGN VOLUMES

Year	Available Lean Ore (tons)*	Available Lean Ore (yd^3)*	Design Volume (yd^3)**
0	78,335	45,676	
1	49,512	28,870	3,715,000
2	304,154	177,349	
3	2,527,204	1,473,588	
4	1,316,710	767,761	
5	2,328,414	1,357,676	3,715,000
6	3,247,633	1,893,664	
7	4,296,702	2,505,366	
8	2,495,381	1,455,033	
9	1,895,133	1,105,034	
10	4,228,544	2,465,623	3,715,000
11	3,669,298	2,139,532	
12	4,725,205	2,755,222	
13	5,488,638	3,200,372	
14	5,080,370	2,962,315	
15	257,559	150,180	3,715,000
16	0	0	
17	3,983,317	2,322,634	
18	3,963,941	2,311,336	
19	4,078,693	2,378,247	
20	0	0	0

* Lean Ore quantities determined from the mining schedule as summarized in RS18

** Lean Ore Stockpile Capacity as shown in Drawings

3.3.1 Foundation Preparation

Foundation preparation is to be consistent with the recommendations for Category 4 Waste Rock Stockpile discussed in Section 3.2.1.

3.3.2 Lean Ore Surge Pile Liner System Design Concepts

The liner system for the Lean Ore Surge Pile is the same as that proposed for the Category 4 Waste Rock Stockpile discussed in Section 3.2.2.

3.3.3 Lean Ore Surge Pile Cover System Design and Closure Concepts

The Lean Ore Surge Pile material is expected to be completely removed prior to closure eliminating acid-generating potential. If the ore is not processed, it is expected to be placed in the Category 4 Waste Rock Stockpile.

3.4 Seepage Management

The stockpile subgrades will be designed and constructed to promote positive drainage of any future stockpile seepage towards the lined Drainage Sumps (Sumps). Preliminary locations of the Sumps are shown in Drawing 9, with a typical Sump design shown as Detail 2 on Drawing 12. Liner grades in Drawing 9 have been designed with the intention to minimize the number of Sump collection points. Alternatively, the proposed grading plan may be compartmentalized using berms if it is desired to collect the overliner flow over a specific area. In particular, a build-up of liner partitions is a construction option if a Demonstration Area is required for regulatory considerations.

A sump liner system for the Category 1/2 Waste Rock Stockpile Sump is shown on Drawing 12 as Detail 7. A similar liner system for the Category 3 Waste Rock, Category 3 Lean Ore and Category 4 Waste Rock Stockpiles and Lean Ore Surge Pile Sumps is shown on Drawing 12 as Detail 8. As shown on Detail 7, a single composite liner system is recommended for the Category 1/2 Waste Rock Stockpile Sump consisting of an upper 60-mil HDPE geomembrane overlying a 1-foot thick soil liner. A double composite liner system consisting of an upper 60-mil HDPE primary liner, a geonet leak collection and recovery system (LCRS), and a 60-mil HDPE secondary liner that overlies a 1-foot thick soil liner is proposed for the Category 3 Waste Rock, Category 3 Lean Ore and Category 4 Waste Rock Stockpiles and Lean Ore Surge Pile Sumps.

Any stockpile seepage collected in the Sumps will be conveyed via pumping to the impacted water circuit (i.e., process water) for treatment at the Mine Site Waste Water Treatment Facility (WWTF) (see RS22).

3.5 Surface Water Management

Detailed surface water and runoff process water management and conveyance channel design is beyond the scope of this document but is discussed in RS22. The surface water management for the stockpiles will consist of zero discharge from the Mine Site for the unreclaimed portions of the stockpiles, where all precipitation will be captured by the overliner and perimeter drainage systems and conveyed to a series of sumps, from where it will be pumped to the water treatment circuit. The crests of all active and reclaimed stockpiles will be backsloped away from the crest to prevent breakout of ponded water from eroding the outslopes. In addition, crest berms (Detail 3, Drawing 13) will be constructed along the operational crest perimeters to provide further assurance that surface runoff from active areas will not overflow onto the outslopes from the crest, including potential reclaimed areas that may exist below. Outslope drainage from non-reclaimed outslopes will also be managed using channels constructed on the inboard side of the haul roads, as illustrated on Detail 4 on Drawing 13.

Unimpacted stormwater runoff from the closure cover will be managed using a system of top channels (Detail 5, Drawing 13) and outslope channels (Detail 2, Drawing 13) that covey runoff to a series of spillway downdrains (Detail 6, Drawing 13). These channels will be designed to convey the calculated theoretical peak design flows and will be sized as a part of the final design. Outslope channels will be constructed on the regraded outslope reclamation benches and will be spaced to limit the sheet flow distance, e.g., to a nominal slope length of 100 to 150 feet in length. The spillways will drain to a series of perimeter diversion channels located along the toe of the regraded stockpiles.

4.0 STOCKPILE DEVELOPMENT

The stockpile development is expected to proceed concurrently with the pit development. Layouts for each of the stockpiles have been developed for the end of operating years 1, 5, 10, 15, and 20 as illustrated on Drawings 3 to 7, in accordance with RS18. The stockpile development can be summarized as follows:

- Category 1/2 Waste Rock Stockpile – contains Categories 1 / 2 waste rock derived from the East, West and Central pits during the first 11 years of production. As the proposed mining sequence exhausts the East Pit in year 11 and Central Pit in Year 13, Category 1/2 waste rock will be subaqueously disposed of in the combined East and Central Pit, rendering the Category 1/2 Waste Rock Stockpile available for early full reclamation;

- Category 3 Waste Rock Stockpile – contains Category 3 waste rock from the East, West and Central pits and is expected to remain operational throughout the mine life;

- Category 3 Lean Ore Stockpile – Contains Category 3 lean ore derived from the East, West and Central pits and is expected to remain operational throughout the mine life;

- Category 4 Waste Rock Stockpile – Contains Category 4 waste rock derived from the East, West and Central pits and is expected to remain operational throughout the mine life; and

- Lean Ore Surge Pile – Contains lean ore derived from the East, West and Central pits and is expected to remain operational throughout the mine life.

In accordance with the design criteria, these stockpiles provide for an average rock porosity of 30 percent and a minimum 100-foot setback from property boundaries, with additional setback provided for critical corridor areas. The stockpile footprints were established to prioritize the more geotechnically favorable areas, particularly for the stockpiles containing Category 3 and 4 materials where construction of a geomembrane liner system will be required. The stockpile layouts also consider segregation of mine waste rock by reactivity category, pit location and pit ramp location to minimize hauling distances.

The stockpile footprint development areas are summarized in the following tables in both square feet and acres.

TABLE 4.1

STOCKPILE FOOTPRINT AREAS (SQUARE FEET)

Stockpile	Year 1	Year 5	Year 10	Year 15	Year 20
Category 1/2 *	5,662,000	17,157,000	20,547,000	20,547,000	20,547,000
Category 3	258,000	1,116,000	2,041,000	3,136,000	3,136,000
Category 3 Lean Ore	1,541,000	2,779,000	4,257,000	6,830,000	6,830,000
Category 4	195,000	1,743,000	2,760,000	2,760,000	2,760,000
Lean Ore Surge Pile	2,375,000	2,375,000	2,375,000	2,375,000	2,375,000

* excludes Category 1/2 overburden area without liner system

TABLE 4.2

STOCKPILE FOOTPRINT AREAS (ACRES)

Stockpile	Year 1	Year 5	Year 10	Year 15	Year 20
Category 1/2 *	130	394	472	472	472
Category 3	6	26	47	72	72
Category 3 Lean Ore	35	64	98	157	157
Category 4	4	40	63	63	63
Lean Ore Surge Pile	55	55	55	55	55

* excludes Category 1/2 overburden area without liner system

The stockpiles layouts were provided by Barr (see RS18) based on the mine schedule provided by PolyMet and assuming the average waste rock porosity of 30 percent. The calculated stockpile capacities are summarized in the following table:

TABLE 4.3

ROCK STOCKPILE CAPACITY REQUIREMENTS

Stockpile	Stockpile Capacity (yd^3)				
	Year 1	Year 5	Year 10	Year 15	Year 20
Category 1/2 *	2,100,000	39,300,000	76,381,000	99,483,000	99,483,000
Category 3	249,000	1,776,000	3,572,000	6,037,000	8,605,000
Category 3 Lean Ore	2,159,000	5,760,000	10,931,000	21,577,000	27,324,000
Category 4	176,000	3,412,000	5,587,000	6,167,000	7,129,000
Lean Ore Surge Pile	3,715,000	3,715,000	3,715,000	3,715,000	0

* excludes Category 1/2 overburden volume

5.0 USE OF THIS REPORT

This conceptual-level report has been prepared exclusively for the use of PolyMet for the specific application to the NorthMet Site. The intent of this document is to provide a conceptual-level design to support the requirements of the Detailed Project Description. No third-party engineer or consultant shall be entitled to rely on any of the information, conclusions, or opinions contained in this report without the written approval of Golder and PolyMet.

Golder sincerely appreciates the opportunity to support PolyMet on the NorthMet Project. Please contact the undersigned with any questions or comments on the information contained in this report.

Respectfully submitted,

GOLDER ASSOCIATES INC.

Gordan Gjerapic B Bronson

Gordan Gjerapic, Ph.D., P.E. Brent R. Bronson, P.E.
Geotechnical Engineer Principal

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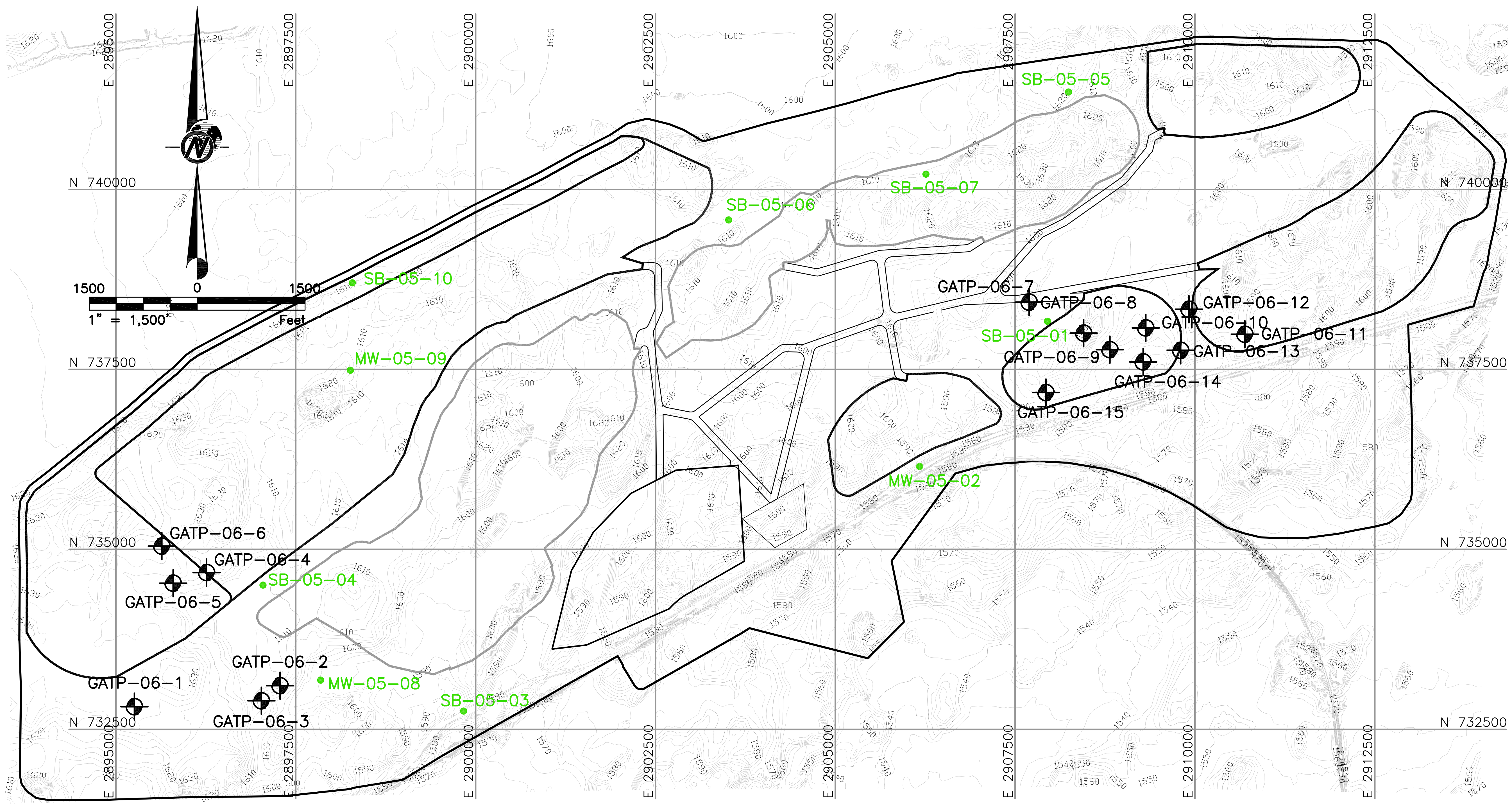
FIGURES



LEGEND

GATP-06-8 ⊕	GOLDER TEST PIT, APRIL 2006
MW-05-08 ●	WDC EXPLORATION AND WELLS BORING/WELL, MARCH 2005
—1610—	EXISTING TOPOGRAPHY (SEE NOTE 1)
▬ (grey)	PIT BOUNDARIES (SEE NOTE 2)
▬ (black)	LEAN ORE, OVERBURDEN SOIL AND WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)

NOTES:

1. SITE TOPOGRAPHY PROVIDED BY POLYMET MINING COMPANY.
2. PIT AND STOCKPILE FOOTPRINTS PROVIDED BY BARR ENIGNEERING, AUGUST 2007

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
B	10/3/07	GG	ISSUED WITH RS49 REPORT	GG	GG	BRB
A	6/6/06	KFM	ISSUED WITH GEOTECHNICAL REPORT	KFM	KFM	BRB

PROJECT
POLYMET MINING CORPORATION
MINE WASTE STOCKPILE DESIGN
HOYT LAKES, MINNESOTA

TITLE

FIELD INVESTIGATION LOCATIONS

Golder Associates
Denver, Colorado

PROJECT No.		053-2209	FILE No.	0532209B007
DESIGN	GG	10/3/2007	SCALE AS SHOWN	REV. A
CADD	GG	10/3/2007		
CHECK	KFM	10/3/2007		
REVIEW	BRB	10/3/2007		

FIGURE 1

Dwg Name: J:\05JOBS\053-2209 P ... TestTrench-Oct-23-2007.dwg
Layout Name: 11x17 Machine: NOT SET
Last Update: Oct 23, 2007 19:00 By: GGJerapic
Last Plot: Oct 23, 2007 19:04 By: GGJerapic

DRAWINGS

APPENDIX A

BORING LOGS PROVIDED BY BARR ENGINEERING

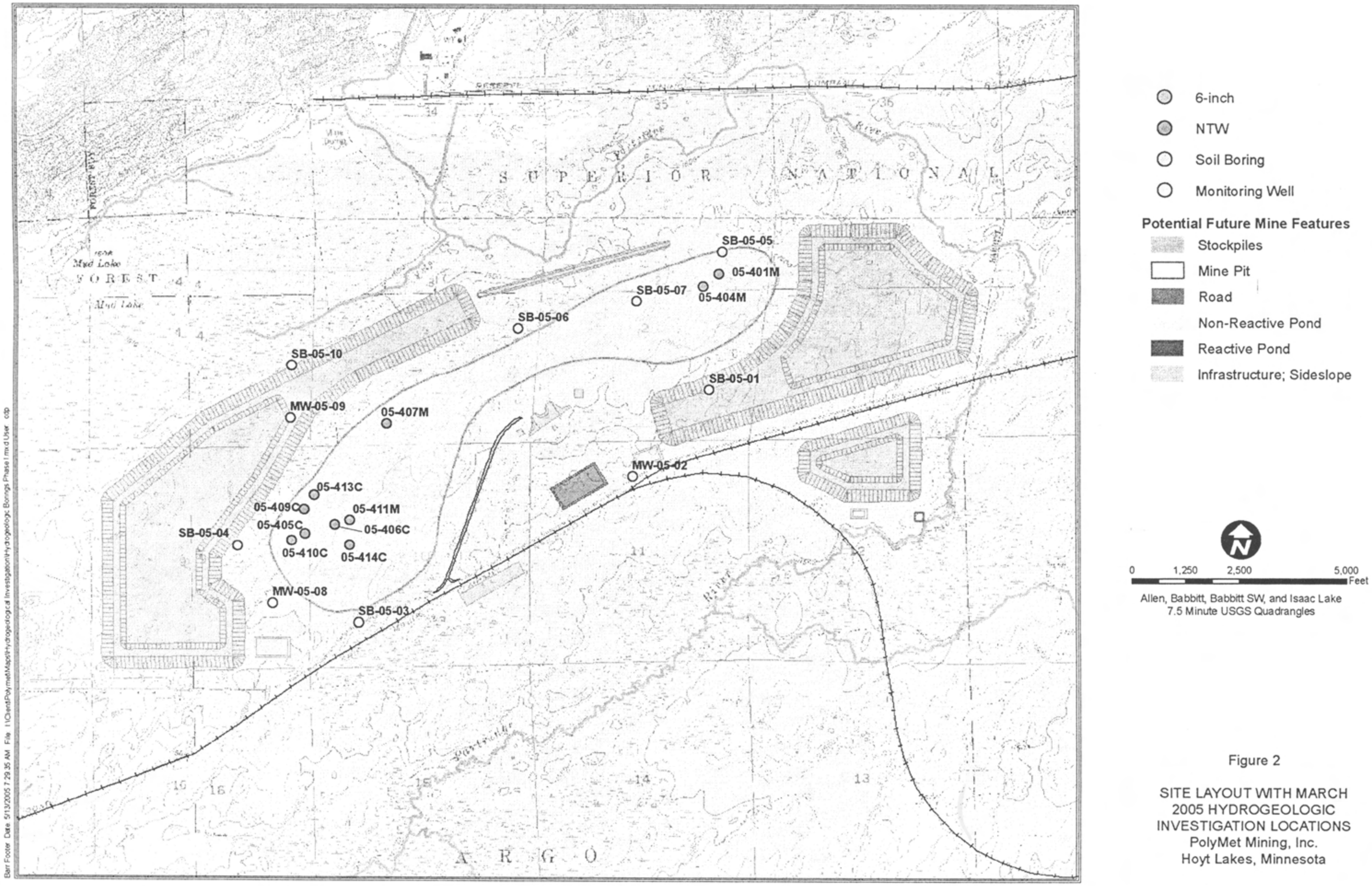


Figure 2

SITE LAYOUT WITH MARCH
2005 HYDROGEOLOGIC
INVESTIGATION LOCATIONS
PolyMet Mining, Inc.
Hoyt Lakes, Minnesota

LOG OF Boring SB-05-01

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/13/05 Ended 3/13/05
Logged By Jere Mohr

Elevation --
Total Depth 19.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
				Wet	CL		Light brown to gray clayey topsoil with rocks (~25%), wet at 1' bgs.	
				Wet	CL		Grayish-brown silty clay, wet.	
5					OL		Reddish-brown organic-rich silty clay.	5
10				Wet	OL		Dark brown to gray organic-rich silty clay. Rocky at ~10'. Rock is fine-grained black (Virginia Formation).	10
15				Wet			Black fine-grained rock (Virginia Formation).	15
							End of Boring - 19 feet	

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Temp well screen (5') set from 10-15' bgs. Allowed to collapse to ~8' bgs, then bentonite chips.

Additional data may have been collected in the field which is not included on this log.

LOG OF WELL MW-05-02

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation

Project Name PolyMet Hydrogeologic Investigation

Number 23/69-862

Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells

Drill Method Rotasonic

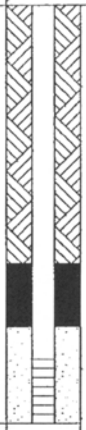
Drilling Started 3/14/05 Ended 3/15/05

Logged By Jere Mohr

Elevation --

Total Depth 18.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	WELL OR PIEZOMETER CONSTRUCTION DETAIL	DEPTH FEET
5					CL	▨	Medium brown sandy clay, upper 1' wet, then moist, very moist at 5'. Chunks of black crystalline rock at 5'.	PRO. CASING Diameter: **6 inches** Type: **Steel** Interval: **0-4 ft bgs** RISER CASING Diameter: **2 inches** Type: **PVC** Interval: **0-5 ft bgs** GROUT Type: **Cement** Interval: **0-4 ft bgs** SEAL Type: **Bentonite** Interval: **4-5 ft bgs** SANDPACK Type: **Red Flint** Interval: **5-6.5 ft bgs** SCREEN Diameter: **2 inches** Type: **PVC** Interval: **5.5-6.5 ft bgs**	5
10 15							Duluth Complex gabbro.		10 15
							End of Boring - 18 feet		



Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks

Additional data may have been collected in the field which is not included on this log.

LOG OF BORING SB-05-03

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation

Project Name PolyMet Hydrogeologic Investigation

Number 23/69-862

Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells

Drill Method Rotasonic

Drilling Started 3/15/05 Ended 3/15/05

Logged By Jere Mohr

Elevation --

Total Depth 20.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
				Moist	CL	▨	Reddish-brown sandy clay with cobbles.	
5				Wet	CL	▨	Dark brown to gray sandy clay.	5
				Moist	CL	▨	Reddish brown sandy clay with ~30% rocks/cobbles (Virginia Formation).	
10				Wet	SM	⁞	Gray-brown silty sand.	10
				Moist	CL	▨	Gray sandy clay with ~20% rocks/pebbles.	
							Boulder (no recovery).	
15					CL	▨	Very dense gray clay.	15
20							Fine grained black rock (Virginia Formation).	20
							End of Boring - 20.5 feet	

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Temp well screen (5') set from 7.5' to 12.5' bgs.

LOG OF Boring SB-05-04

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site
Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/7/05 Ended 3/8/05
Logged By Mark Hagley
Elevation --
Total Depth 20.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
					PT	■	Peat/wetland vegetation, frozen.	
5					ML		Tan - brown clayey silt, uniform, moist to wet.	5
					CL	▨	Dark-gray silty clay, dense.	
					ML		Dark-gray, sandy silt with ~10% cobbles (up to 2" diameter)	
10					SM		Gray silty fine sand with 10-20% coarse gravel and cobbles (<1/2" to 3+").	10
15							Greenish-black crystalline rock - Duluth Complex gabbro.	15
							End of Boring - 20 feet	

BARR

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Temp well screen (5') set from ~15-20' bgs, allowed to collapse from 14-20', bentonite chips from 2-14' bgs.

Additional data may have been collected in the field which is not included on this log.

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/13/05 Ended 3/13/05
Logged By Jere Mohr

LOG OF Boring SB-05-05

DRAFT

SHEET 1 OF 1

Elevation --
Total Depth 18.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
				Moist	CL	▨	Dark brown to black clayey topsoil.	
5							Dark black fine-grained rock (boulder).	5
				Dry	SM	░	Medium brown silty sand.	
10 15				Dry			Dark black fine-grained rock.	10 15
							End of Boring - 18 feet	

BARR
Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks No temp well set - dry borehole.

Additional data may have been collected in the field which is not included on this log.

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/14/05 Ended 3/14/05
Logged By Jere Mohr

LOG OF Boring SB-05-06

DRAFT

SHEET 1 OF 1

Elevation --
Total Depth 16.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
					OL		Organic rich dark brown clay. Frozen to 4'.	
				Wet	OL		Very loose organic rich clay.	
5							Boulder - minimal recovery. Granite recovered from ~9' bgs.	5
10				Wet	SM		Light brown silty coarse sand with pebbles.	10
				Wet	CL	▨	Light brown silty clay with ~25% pebbles.	
15							Black fine-grained rock.	15
							End of Boring - 16 feet	

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Temp well screen (5') set from 11.5 to 15.5'.

LOG OF Boring SB-05-07

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/12/05 Ended 3/12/05
Logged By Mark Hagley

Elevation --
Total Depth 17.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
				Moist	SM		Brown silty sand with 10-20% cobbles and boulders (up to 4" diameter). Frost to 1.5', moist below.	
5					SM		Gray/brown silty sand with trace of clay and 10-20% cobbles (<1/2" to 4").	5
10					ML		Dark gray sandy silt with cobbles.	10
					SC	▨	Very dense brown clayey sand with ~15% gravel and cobbles (to 1"). (Till)	
15							Green/black coarse crystalline rock (Duluth Complex gabbro).	15
							End of Boring - 17 feet	

BARR
Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Temp well screen (5') set from 8-13' bgs, allowed to collapse up to 6.2', then bentonite chips above.

Additional data may have been collected in the field which is not included on this log.

LOG OF WELL MW-05-08

DRAFT

SHEET 1 OF 1

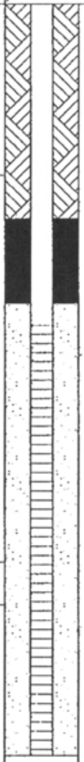
Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/16/05 Ended 3/16/05
Logged By Jere Mohr

Elevation --
Total Depth 28.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION
				Wet @ 6"	SM		Light brown medium to coarse silty sand.
5 10				Wet	SP		Dark brown, well-sorted medium sand.
				Wet	SP		Dark brown, well-sorted fine to medium sand.
15				Wet	SP		Grayish brown well-sorted fine to medium sand with silt.
20 25				Wet Wet	CL		Gray silty clay with granite and mafic rock fragments and pebbles. (Till)
							End of Boring - 28.5 feet

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: **6 inches**
Type: **Steel**
Interval: **0-5 ft bgs**

RISER CASING
Diameter: **2 inches**
Type: **PVC**
Interval: **0-7.5 ft bgs**

GROUT
Type: **Cement**
Interval: **0-5 ft bgs**

SEAL
Type: **Bentonite**
Interval: **5-7 ft bgs**

SANDPACK
Type: **Red Flint**
Interval: **7-17 ft bgs**

SCREEN
Diameter: **2 inches**
Type: **PVC**
Interval: **7.5-17.5 ft bgs**
Natural formation allowed to cave below 17.5' bgs

DEPTH FEET: 5, 10, 15, 20, 25

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Well installed in adjacent boring (boring not logged) due to loss of casing in MW-05-08. Heaving sand - difficult drilling and well installation.

Additional data may have been collected in the field which is not included on this log.

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/10/05 Ended 3/11/05
Logged By Mark Hagley

LOG OF WELL MW-05-09

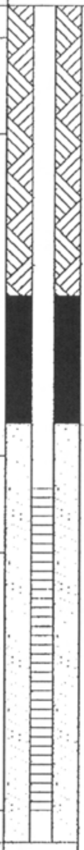
DRAFT

SHEET 1 OF 1

Elevation --
Total Depth 13.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION
							Topsoil.
					SP		Brown, fine-grained sand with 5-10% gravel, moist.
5				Dry	SM		Gray-brown, fine-grained silty sand with up to 40% gravel, cobbles and boulders (angular), dry. Very difficult drilling (highly compacted).
				Wet	SP		Brown, medium to coarse sand, uniform, wet.
10				Moist/Wet	SM		Brown silty sand with some clay and trace of gravel and cobbles, moist/wet.
							Gray-black, fine grained crystalline rock, magnetic (Iron formation) assumed to be a boulder. End of Boring - 13 feet
15							

WELL OR PIEZOMETER CONSTRUCTION DETAIL



PRO. CASING
Diameter: 6 inches
Type: Steel
Interval: 0-4.5 ft bgs

RISER CASING
Diameter: 2 inches
Type: PVC
Interval: 0-7.5 ft bgs

GROUT
Type: Cement
Interval: 0-4.5 ft bgs

SEAL
Type: Bentonite
Interval: 4.5-6.5 ft bgs

SANDPACK
Type: Red Flint
Interval: 6.5-13 ft bgs

SCREEN
Diameter: 2 inches
Type: PVC
Interval: 7.5-12.5 ft bgs

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/9/05 Ended 3/10/05
Logged By Mark Hagley

LOG OF Boring SB-05-10

DRAFT

SHEET 1 OF 1

Elevation --
Total Depth 14.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
					PT	■	Peat/Organic material. Frozen.	
					SM	░	Fine-grained silty sand, brown, with 5-10% gravel and cobbles (up to 1/2", angular).	
5							Dark gray, fine-grained crystalline rock. Argillite (Virginia Formation).	5
10								10
15							End of Boring - 14.5 feet	15

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks No temporary well set in boring; set in adjacent boring SB-05-10A

Additional data may have been collected in the field which is not included on this log.

LOG OF WELL SB-05-10A

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name PolyMet Hydrogeologic Investigation
Number 23/69-862
Location NorthMet Mine Site

Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/10/05 Ended 3/10/05
Logged By Mark Hagley

Elevation --
Total Depth 6.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	SAMP. NUMBER	Discoloration-Odor-Sheen	Moisture	ASTM	LITHOLOGY	DESCRIPTION	DEPTH FEET
	↓				PT	■	Peat/Organic material. Frozen.	
	↓				SM	░	Fine-grained silty sand, brown, with 5-10% gravel and cobbles (up to 1/2", angular).	
5	↓				CL	▨	Dark brown sandy clay with <5% angular gravel and cobbles (<1/2").	5
							End of Boring - 6 feet	
10								10
15								15

Barr Engineering
4700 W 77th Street
Minneapolis, MN 55435
Telephone: 952-832-2600
Fax: 952-832-2601

Remarks Temp well screen (4') set from 2-6' bgs, allowed to collapse to ~1.5' bgs, then bentonite chips to surface.

Additional data may have been collected in the field which is not included on this log.

APPENDIX B

PHASE I GEOTECHNICAL FIELD INVESTIGATION

Golder Associates Inc.

1346 West Arrowhead Road, #304
Duluth, MN USA 55811
Telephone (218) 724-0088
Fax (218) 724-0089

REPORT ON

PHASE I GEOTECHNICAL FIELD INVESTIGATION POLYMET NORTHMET SITE NEAR BABBITT, MINNESOTA

Submitted to:

PolyMet Mining Corporation
P. O. Box 475, County Road No. 666
Hoyt Lakes, Minnesota 55750-0475

Submitted by:

Golder Associates Inc.
1346 West Arrowhead Road, #304
Duluth, Minnesota 55803

Distribution:

1 Copy – PolyMet Mining Corporation – Richard Patelke, Project Geologist
1 Copy – PolyMet Mining Corporation – Jim Scott, Assistant Project Manager
1 Copy – Barr Engineering – Nancy Dent
1 Copy – Golder Associates Inc. – Denver, Colorado
1 Copy – Golder Associates Inc. – Duluth, Minnesota

August 29, 2006 053-2209.002

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1.0 INTRODUCTION

This report presents the results of the test trenching exploration and geotechnical laboratory testing program conducted by Golder Associates Inc. (Golder) for the proposed waste stockpiles at PolyMet Mining Corporation's (PolyMet) NorthMet Project near Babbitt, Minnesota. Our work was performed in general accordance with our written proposal dated May 31, 2005. The preliminary selection of test trench locations was determined during a site visit on March 1, 2006. This site visit was performed by Amy Thorson and Brent Bronson of Golder, and Richard Patelke and Jim Scott of PolyMet. The number and location of test trenches was limited to areas accessible from existing logging trails and excluding wetlands (i.e., highland areas only). The purpose of this investigation was to determine subsurface soil conditions for use in providing waste stockpile design recommendations.

Prior to scheduling exploration work, permission was requested from the United States Forest Service (USFS). On March 11, the USFS published a Legal Notice in the Mesabi Daily News regarding the intended services and allowed a 30-day public comment period. After this 30-day period, plus the required 5-day waiting period for any mailed responses, Golder commenced the test trenching operations on April 17, 2006. Presented in this report are field observations and geotechnical laboratory test results.

2.0 FIELD INVESTIGATION

On April 7, 2006, the test trench locations were sited on foot by Amy Thorson and Matt Krzewinski of Golder, accompanied in part by Steven Goertz of PolyMet. The purpose of this trip was primarily to verify access after snow melt and to compare the intended locations to wetland maps which were provided after the March 1, 2006 site visit. The 15 selected test trench locations were staked with lath and electronically recorded with GPS. Table 1 lists the northing and easting coordinates for the test trench locations per the NADA83, UTM datum. The test trench locations are illustrated on Figure 1.

TABLE 1
TEST TRENCH LOCATIONS

Boring Number	**Easting**	**Northing**
	West Stockpile Area	
G06-TP1	574,936	5,272,811
G06-TP2	575,553	5,272,900
G06-TP3	575,474	5,272,836
G06-TP4	575,242	5,273,379
G06-TP5	575,100	5,273,334
G06-TP6	575,052	5,273,491
	Pre-Production Area	
G06-TP7	578,727	5,274,524
G06-TP8	578,958	5,274,393
G06-TP9	579,069	5,274,323
G06-TP15	578,799	5,274,143
	East Stockpile Area	
G06-TP10	579,221	5,274,415
G06-TP11	579,641	5,274,388
G06-TP12	579,404	5,274,494
G06-TP13	579,369	5,274,320
G06-TP14	579,210	5,274,271

The subsurface exploration program was advanced on April 18 and 19, 2006, by Robert Radotich of Radotich Enterprises, LLC (Radotich) with the test trenches logged and sampled by Matt Krzewinski of Golder. The program consisted of Radotich moving a wide tracked backhoe up the existing logging roads and then around and/or in-between existing trees within existing clear cut areas to access the previously marked trench locations. The actual trenching process consisted of the backhoe removing the soil from an area with a maximum dimension of 5 feet wide by 15 feet long and 20 feet deep. The soil was stockpiled beside the trench in separate piles according to depth it was encountered, where it was visually classified and sampled by the Golder technician. Upon completion, the soils were carefully replaced in the trench in the same layers as it was removed.

3.0 SUBSURFACE CONDITIONS

The subsurface conditions encountered at the site are depicted in detail on the Logs of Test Trenches included in Appendix A of this report. The logs also indicate the test trench number, date, and name of the technician that logged the test trenches. The soils were described in general accordance with Golder's protocols and field-classified according to ASTM D2488. The boundaries between different soil types shown on the logs are approximate because the actual transition between soil layers may be gradual. Samples of representative soils were obtained from the test trenches. See Appendix C for further information on soil classification procedures utilized by Golder.

The test trenches encountered up to 6 inches of topsoil over primarily silty sand with boulders and cobbles. Test trenches G06-TP5 and G06-TP6 at the north end of the West Stockpile encountered layers of sandy lean clay and sandy silt. Test trenches G06-TP8 through G06-TP10 near the intersection of the Preproduction Stockpile and the East Stockpile, encoungered layers of sand with silt and course grained sand. The trenches were extended to either auger refusal on bedrock, or 20 feet, which was the limit of the backhoe reach. Table 2 summarizes the depth of bedrock at each test trench location.

TABLE 2
SUMMARY OF BEDROCK DEPTHS

Boring Number	Bedrock Depth Below Existing Grade (ft)
G06-TP1	Greater than 20
G06-TP2	13.0
G06-TP3	15.0
G06-TP4	13.5
G06-TP5	14.0
G06-TP6	Greater than 20
G06-TP7	3.5
G06-TP8	4.5
G06-TP9	8.5
G06-TP10	8.0
G06-TP11	6.0
G06-TP12	5.0
G06-TP13	9.0
G06-TP14	3.5
G06-TP15	11.5

Groundwater was encountered in approximately one-half of the test trenches during our field investigation. Groundwater was encountered at depths of 13 to 15 feet below the existing ground surface in test trenches G06-TP2, G06-TP3, and G06-TP5 located in the proposed West Waste Stockpile footprint. Groundwater was encountered at depths of 4 to 5 feet below the existing ground surface in test trenches G06-TP8, G06-TP9, G06-TP10, and G06-TP15 in and near the proposed Pre-Production Waste Stockpile footprint. Due to the existing slow draining site soils, it is likely that groundwater did not have time to stabilize within the test trenches prior to backfilling the trenches. Groundwater levels should be expected to fluctuate both seasonally and with changes in precipitation. Groundwater is often found at the soil/bedrock interface.

4.0 LABORATORY TESTING

Laboratory tests were performed to measure index properties of the samples recovered from the test trenches to confirm field classifications and for use in developing correlations with engineering properties of soils encountered. Sieve analysis and moisture content tests were conducted by Braun Intertec Corporation (Braun Intertec) of Hibbing, Minnesota on each soil type obtained, in accordance with American Society for Testing and Materials (ASTM) Test Methods ASTM C-117, C-136, and D2216. Atterberg Limits were determined by Braun Intertec on three of the samples in accordance with ASTM Test Method D4318. Based on test results, soils were characterized according to the Unified Soil Classification System (USCS). The complete sieve analysis and Atterberg Limit test results are included in Appendix B. Table 3 summarizes the percent passing the #200 sieve, the moisture content, plasticity index, and visual classification of each sample.

TABLE 3
SUMMARY OF INDEX TEST RESULTS

Test Trench Number	Sample Depth below Existing Grade (ft)	Passing # 200 (%)	Moisture Content (%)	Plasticity Index	USCS Classification
G06-TP1	3 – 12	28.6	7.7	-	SM
G06-TP1	12 – 20	37.5	8.5	-	SM
G06-TP2	9 – 13	35.6	16.5	-	SM
G06-TP4	0.5 – 4.5	31.3	7.2	0	SM
G06-TP4	4.5 – 13.5	39.3	7.2	-	SM
G06-TP5	0.5 – 4	51.4	10.1	9	CL
G06-TP5	6 – 14	47.0	12.2	-	SM
G06-TP6	15 – 20	51.7	13.0	-	ML
G06-TP7	0.5 – 3.5	26.5	12.4	-	SM
G06-TP8	2 – 4.5	1.8	7.3	-	SP
G06-TP11	3 – 6	23.9	21.5	-	SM
G06-TP13	4 – 9	26.0	8.0	2	SM
G06-TP14	0.5 – 3.5	46.8	26.9	-	SM
G06-TP15	4 – 11.5	38.8	18.7	-	SM

Additional testing was performed on the fine-grained sample collected from 0.5 to 4 feet below grade in Test Trench G06-TP5. This soil sample was shipped to Golder's soils laboratory in Lakewood, Colorado for additional testing which included a one-dimensional consolidation test (ASTM D2435) and a consolidated-undrained (CU) triaxial shear test (ASTM D4767). These test results are summarized and presented graphically in Appendix B.

The CU triaxial shear test was conducted on a sample extruded from an undisturbed Shelby tube sample. The sample was placed in a triaxial compression chamber, subjected to a confining pressure, and then loaded axially to failure. In the CU test, the test specimen is permitted to drain and consolidate under the confining pressure until the excess pore pressure is equal to zero. The deviator stress is then slowly applied to failure, but the specimen's drainage is not permitted. The in-situ effective stress strength parameters yielded an effective cohesion of zero with an effective friction angle of 34.6 degrees.

The consolidation test was conducted on an undisturbed sample of native clayey soil. The test indicated a coefficient of consolidation (C_v) of 5.3 x 10^{-1} to 9.6 x 10^{-1} square foot per day (ft^2/day) and a coefficient of compression (C_c) of 0.05 to 0.13 under the loading range of 1 to 16 kips per square foot (ksf).

Additional testing was also performed on three select samples representing three different foundation soil types (per visual classification). Standard Proctor tests and permeability tests were performed by Braun Intertec on the 0.5- to 4.5-foot sample from test trench G06-TP4, the 0.5- to 3.5-foot sample from test trench G06-TP7, and the 4- to 9-foot sample from test trench G06-TP13. These test results are presented in Appendix B.

The Standard Proctor tests were performed in accordance with ASTM Test Method D698, Method A. The maximum standard Proctor dry density of the site soils ranges from 118.3 to 125.7 pounds per cubic foot (pcf) with an optimum moisture content ranging from 12.4 to 14.2 percent.

Falling head permeability tests were performed in accordance with ASTM Test Method D5084. Permeability test samples were compacted to 95 percent of the maximum standard Proctor dry density at the optimum moisture content. The full test results are summarized and presented graphically in Appendix B. Table 4 summarizes the permeability values for each sample, along with its visual classification. Based on the results the Phase I field geotechnical field and permeability testing program, it is possible that the site soils may be excavated and placed as low permeability soil liner, as the permeability ranges from 1.1 x 10^{-7} to 2.0 x 10^{-7} cm/sec. The availability and characteristics of the site soils for use as a soil liner should be further evaluated as part of the Phase II field program conducted to support final design.

TABLE 4
SUMMARY OF PERMEABILITY TEST RESULTS

Test Trench Number	Sample Depth (Below Existing Grade)	Coefficient of Permeability at 95% Compaction	USCS Visual Classification
G06-TP4	0.5 – 4.5 ft	1.35×10^{-7} cm/sec	SM
G06-TP7	0.5 – 3.5 ft	2.04×10^{-7} cm/sec	SM
G06-TP13	4 – 9 ft	1.06×10^{-7} cm/sec	SM

5.0 CLOSING

We appreciate the opportunity to provide engineering design support to PolyMet Mining Corporation for the NorthMet Project. If you have questions or require additional information, please contact Brent Bronson at (303) 980-0540.

Sincerely,

GOLDER ASSOCIATES, INC.

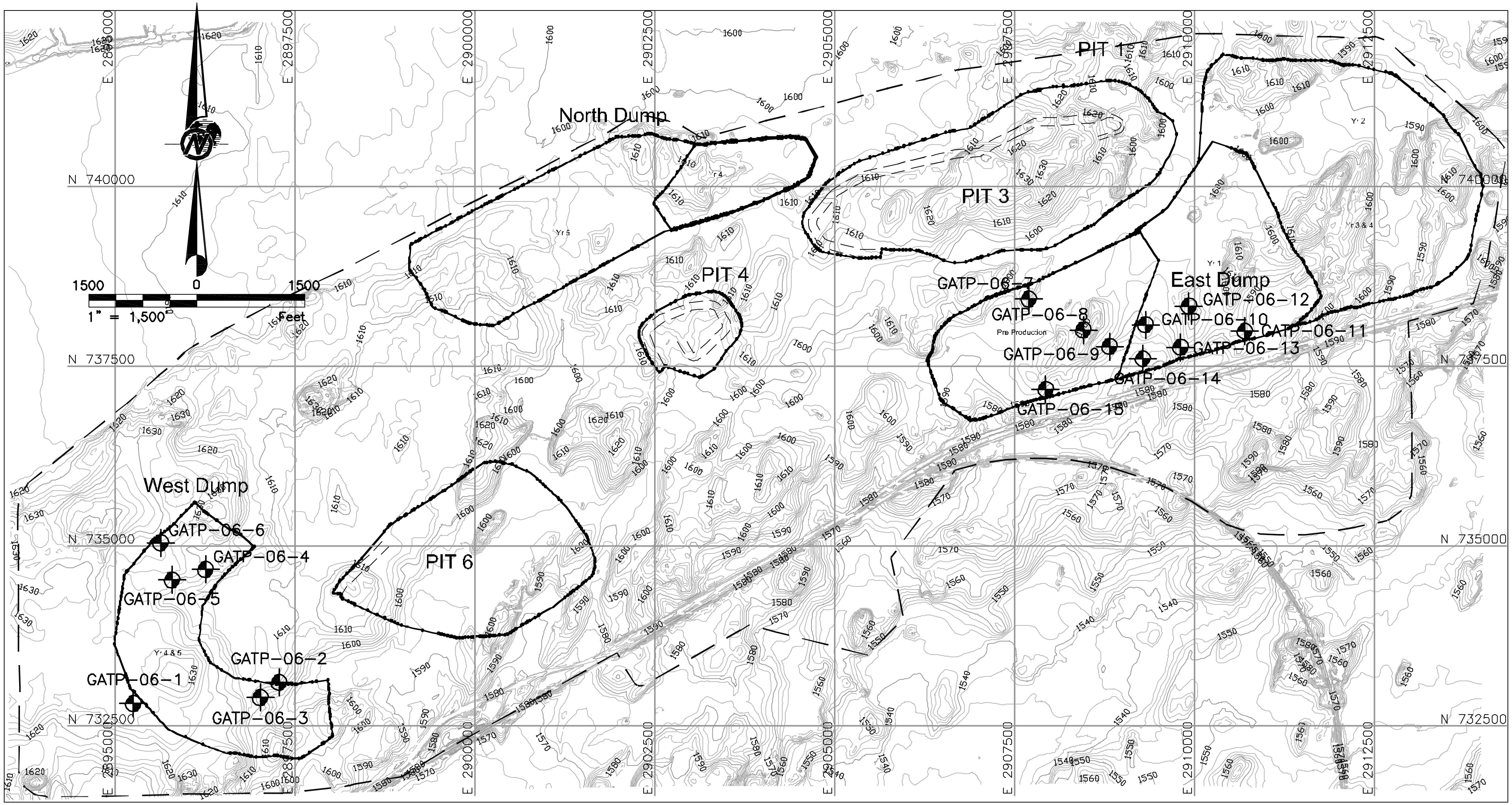
Amy Thorson

Amy C. Thorson, P.E.
Senior Engineer
MN License No. 42917

Bronson

Brent R. Bronson, P.E.
Principal and Project Manager

FIGURES



LEGEND

———	WASTE DUMP / PIT BOUNDARIES
— — —	PROJECT BOUNDARY
═══	EXISTING TOPOGRAPHY
= = = = = =	EXISTING ROADS
GATP-06-8 ⊕	GOLDER TEST PIT, APRIL 2006

NOTES:

1. SITE TOPOGRAPHY PROVIDED BY POLYMET MINING COMPANY.
2. WASTE STOCKPILE FOOTPRINTS PROVIDED BY POLYMET MINE PLANNERS, FEBRUARY 2006

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
A	6/6/06	KFM	ISSUED WITH GEOTECHNICAL REPORT	KFM	KFM	BRB

PROJECT
POLYMET MINING CORPORATION
MINE WASTE STOCKPILE DESIGN
HOYT LAKES, MINNESOTA

TITLE

TEST TRENCH LOCATION MAP

Golder Associates
Denver, Colorado

PROJECT No.	053-2209	
DESIGN	DLG	3/22/06
CADD	DLG	3/23/06
CHECK	KFM	3/23/06
REVIEW	BRB	3/23/06

FILE No. 0532209A007
SCALE AS SHOWN
REV. A

FIGURE 1

Dwg Name: N:\05\053-2209\0532209A007.dwg
Layout Name: 11x17 Machine: NOT SET
Last Update: Jun 08, 2006 17:38 By:
Last Plot: Aug 14, 2006 10:58 By: jroberts

APPENDIX A

LOGS OF TEST TRENCHES

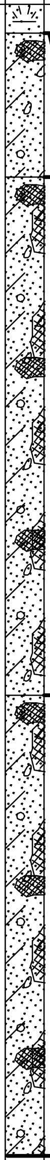
Golder Associates

LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP1
Project POLYMET
Total Depth 20 feet
Project Number 053-2209
Date Begin 4/18/06
Date End 4/18/06
Station / Location West Area, 5272811N, 574936E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data		
Depth in (ft.)		
Time		
Date		
Symbol		

Method	Depth in (Feet)		Sample Data Method	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
	0								0.0 - 0.5 Topsoil
	1								0.5 - 3.0 Moist, brown, silty SAND with little to some gravel, cobbles (SM)
	2		GRAB	1					
	3								3.0 - 12.0 Moist, light brown, silty SAND with gravel, few cobbles and boulders (SM)
	4								
	5								
	6								
	7		GRAB	2					
	8								
	9								
Excavaton	10								
	11								
	12								12.0 - 20.0 Moist to wet, gray, silty SAND, little to some gravel, cobbles and boulders (SM)
	13								
	14								
	15								
	16		GRAB	3					
	17								
	18								
	19								
	20							BOH 20 ft.	
	21								Notes: No bedrock encountered.
	22								
	23								
	24								
	25								

CHECKED: DATE:

Golder Associates

LOG OF TEST TRENCH

Sheet Number 1 of 1

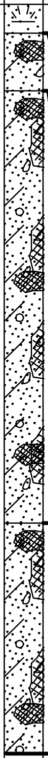
Test Pit Number G06-TP2
Total Depth 13 feet
Date Begin 4/18/06
Date End 4/18/06

Project POLYMET
Project Number 053-2209

Station / Location West Area, 5272900N, 575553E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data		
Depth in (ft.)	13	
Time	09:20	
Date	4/18/06	
Symbol	▼	

Method	Depth in (Feet)		Sample Data Method	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0		GRAB	1					0.0 - 0.5 Topsoil
	0.5								0.5 - 1.5 Moist, reddish-brown, silty SAND with little gravel, few cobbles (SM)
	1.5		GRAB	2					1.5 - 9.0 Moist, brown, silty SAND, little to some gravel, little silt, cobbles and boulders (SM)
	9		GRAB	3					9.0 - 13.0 Wet, brown, silty SAND, some silt, with gravel, cobbles and boulders (SM)
	13						▼	BOH 13 ft.	



Notes:
Bedrock encountered at 13.0 feet.

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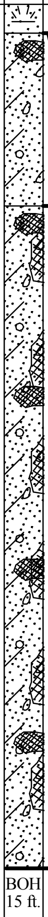
Golder Associates

LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP3
Total Depth 15 feet
Date Begin 4/18/06
Date End 4/18/06
Project POLYMET
Project Number 053-2209
Station / Location West Area, 5272836N, 575474E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data		
Depth in (ft.)	13	
Time	08:55	
Date	4/18/06	
Symbol	▼	



Method	Depth in (Feet)		Sample Data Method	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0								0.0 - 0.5 Topsoil
	0.5 - 3.5		GRAB	1					0.5 - 3.5 Moist, reddish-brown, silty SAND with gravel, few cobbles (SM)
	3.5 - 15.0		GRAB	2			▼ 13		3.5 - 15.0 Moist to wet, grayish brown, silty SAND, some silt, with gravel, cobbles and boulders (SM)
	15							BOH 15 ft.	Notes: Bedrock encountered at 15.0 feet.

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Golder Associates

LOG OF TEST TRENCH

Sheet Number 1 of 1

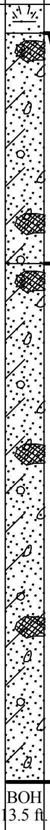
Test Pit Number G06-TP4
Total Depth 13.5 feet
Date Begin 4/17/06
Date End 4/17/06

Project POLYMET
Project Number 053-2209

Station / Location West Area, 5273379N, 575242E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)		
Time		
Date		
Symbol		



Method	Depth in (Feet)		Sample Data Method	Sample Data Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
	0								0.0 - 0.5 Topsoil
	1								0.5 - 4.5 Moist to wet, brown, silty SAND with gravel, little silt, cobbles (SM)
	2		GRAB	1					
	3								
	4								
	5								4.5 - 13.5 Moist, grayish-brown, silty SAND, some gravel, few cobbles, some silt (SM)
	6								
Excavation	7								
	8								
	9		GRAB	2					
	10								
	11								
	12								
	13								
	14							BOH 13.5 ft.	
	15								Notes: Bedrock encountered at 13.5 feet.
	16								
	17								
	18								
	19								
	20								
	21								
	22								
	23								
	24								
	25								

CHECKED: DATE:

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LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP5
Total Depth 14 feet
Date Begin 4/17/06
Date End 4/17/06
Project POLYMET
Project Number 053-2209
Station / Location West Area, 5273334N, 575100E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)		
Time		
Date		
Symbol		

Method	Depth in (Feet)	Sample Data: Method	Sample Data: Number	Loc. Sampled	Water Level	SUBSURFACE MATERIAL
Excavation	0.0 - 0.5					Topsoil
	0.5 - 4.0	GRAB	1			Moist, light brown, sandy lean CLAY, little gravel, (CL)
	4.0 - 6.0	GRAB	2			Moist, reddish-brown, silty SAND, some gravel, few cobbles, little to some silt (SM)
	6.0 - 14.0	GRAB	3			Moist to wet, gray, silty SAND, some silt, some gravel (SM)

BOH 14 ft.

Notes:
Bedrock encountered at 14.0 feet.

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LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP6
Total Depth 20 feet
Date Begin 4/17/06
Date End 4/17/06

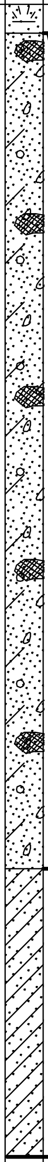
Project POLYMET
Project Number 053-2209

Station / Location West Area, 5273491N, 575052E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)	15	
Time	17:30	
Date	4/17/06	
Symbol	▼	

Method	Depth in (Feet)		Sample Data: Method	Sample Data: Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0.0 - 0.5								**0.0 - 0.5** Topsoil
	0.5 - 15.0		GRAB	1					**0.5 - 15.0** Moist, brown, silty SAND with gravel, little to some silt, few cobbles and boulders (SM)
	15.0 - 20.0		GRAB	2			▼ (15)		**15.0 - 20.0** Waterbearing, gray, sandy SILT (ML)
	20							BOH 20 ft.	Notes: No bedrock encountered



BOH
20 ft.

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LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP7
Total Depth 3.5 feet
Date Begin 4/17/06
Date End 4/17/06

Project POLYMET
Project Number 053-2209

Station / Location Pre-Production Area, 5274524N, 578727E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)		
Time		
Date		
Symbol		

Method	Depth in (Feet)		Sample Data: Method	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0 - 3.5		GRAB	1					0.0 - 0.5 Topsoil 0.5 - 3.5 Moist, brown, silty SAND with gravel, little silt, few cobbles and boulders (SM)
	3.5							BOH 3.5 ft.	Notes: Bedrock encountered at 3.5 feet

Depth scale: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

CHECKED: DATE:

LOG OF TEST TRENCH

Sheet Number 1 of 1

Project POLYMET
Project Number 053-2209

Test Pit Number G06-TP8
Total Depth 4.5 feet
Date Begin 4/17/06
Date End 4/17/06

Station / Location Pre-Production Area, 5274393N, 578958E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)	4.5	
Time	10:45	
Date	4/17/06	
Symbol	▼	

Method	Depth in (Feet)		Sample Data: Method	Sample Data: Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0.0 - 2.0		GRAB	1					0.0 - 2.0 Moist, reddish-brown, silty SAND, little gravel, little to some silt (SM)
	2.0 - 4.5		GRAB	2			▼		2.0 - 4.5 Moist, brown, medium to coarse grained SAND and GRAVEL, trace silt, (SP)
	4.5							BOH 4.5 ft.	Notes: Bedrock encountered at 4.5 feet

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LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP9
Total Depth 8.5 feet
Date Begin 4/17/06
Date End 4/17/06

Project POLYMET
Project Number 053-2209

Station / Location Pre-Production Area, 5274323N, 579069E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)	4.5	
Time	11:40	
Date	4/17/06	
Symbol	▼	

Method	Depth in (Feet)		Sample Data Method	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0.0 - 0.5								0.0 - 0.5 Topsoil
	0.5 - 4.0		GRAB	1					0.5 - 4.0 Moist, brown, silty SAND, little to some gravel, some silt, few cobbles and boulders (SM)
	4.0 - 8.5		GRAB	2			▼		4.0 - 8.5 Wet, brown, medium to coarse grained SAND and GRAVEL, little silt, few cobbles (SP-SM)

BOH
8.5 ft.

Depth in (Feet): 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Notes:
Bedrock encountered at 8.5 feet

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LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP10
Total Depth 8 feet
Date Begin 4/17/06
Date End 4/17/06

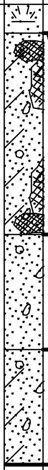
Project POLYMET
Project Number 053-2209

Station / Location East Area, 5274415N, 579221E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)	4	
Time	11:10	
Date	4/17/06	
Symbol	▼	

Method	Depth in (Feet)		Sample Data: Method	Sample Data: Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0 – 0.5								0.0 - 0.5 Topsoil
	0.5 – 4		GRAB	1					0.5 - 4.0 Moist, brown, silty SAND, little gravel, some silt, few cobbles (SM)
	4 – 6		GRAB	2			▼ (4)		4.0 - 6.0 Wet, brown, medium to coarse grained SAND and GRAVEL, trace silt (SP)
	6 – 8		GRAB	3					6.0 - 8.0 Wet, brown, silty SAND with gravel, little silt, some gravel (SP-SM)
	8							BOH 8 ft.	



Depth scale: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Notes:
Bedrock encountered at 8.0 feet

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DATE:

LOG OF TEST TRENCH

Golder Associates

Sheet Number 1 of 1

Test Pit Number G06-TP11
Total Depth 6 feet
Date Begin 4/17/06
Date End 4/17/06

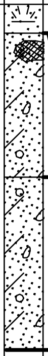
Project POLYMET
Project Number 053-2209

Station / Location East Area, 5274388N, 579641E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)		
Time		
Date		
Symbol		

Method	Depth in (Feet)		Sample Data Method	Sample Data Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0 – 0.5								0.0 - 0.5 Topsoil
	0.5 – 3		GRAB	1					0.5 - 3.0 Moist, reddish-brown, silty SAND with gravel, some silt, cobbles (SM)
	3 – 6		GRAB	2					3.0 - 6.0 Moist to wet, brown, fine to coarse grained silty SAND and GRAVEL, (SM)
	6							BOH 6 ft.	
	7								Notes: Bedrock encountered at 6.0 feet



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LOG OF TEST TRENCH

Sheet Number 1 of 1

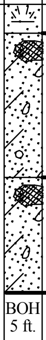
Project POLYMET
Project Number 053-2209

Test Pit Number G06-TP12
Total Depth 5 feet
Date Begin 4/17/06
Date End 4/17/06

Station / Location East Area, 5274494N, 579404E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)		
Time		
Date		
Symbol		



Method	Depth in (Feet)		Sample Data Method	Sample Data Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL	
Excavation	0								0.0 - 0.5 Topsoil	0
	1		GRAB	1					0.5 - 3.0 Moist, brown, silty SAND with gravel, little to some silt, cobbles (SM)	1
	2									2
	3		GRAB	2					3.0 - 5.0 Moist, grayish-brown, silty SAND with gravel, little to some silt, few cobbles (SM)	3
	4									4
	5							BOH 5 ft.		5
	6								Notes: Bedrock encountered at 5.0 feet	6
	7									7
	8									8
	9									9
	10									10
	11									11
	12									12
	13									13
	14									14
	15									15
	16									16
	17									17
	18									18
	19									19
	20									20
	21									21
	22									22
	23									23
	24									24
	25									25

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LOG OF TEST TRENCH

Sheet Number 1 of 1

Test Pit Number G06-TP13
Total Depth 9 feet
Date Begin 4/17/06
Date End 4/17/06

Project POLYMET
Project Number 053-2209

Station / Location East Area, 5274320N, 579369E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data		
Depth in (ft.)		
Time		
Date		
Symbol		

Method	Depth in (Feet)		Sample Data: Method	Sample Data: Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL	
Excavation	0		GRAB	1					0.0 - 0.5 Topsoil	0
	1								0.5 - 4.0 Moist, reddish-brown, silty SAND with gravel, little to some silt, few cobbles and boulders (SM)	1
	2									2
	3									3
	4		GRAB	2					4.0 - 9.0 Moist to wet, grayish-brown, silty SAND with gravel, little to some silt, few cobbles and boulders (SM)	4
	5									5
	6									6
	7									7
	8									8
	9							BOH 9 ft.		9
	10								Notes: Bedrock encountered at 9.0 feet	10
	11									11
	12									12
	13									13
	14									14
	15									15
	16									16
	17									17
	18									18
	19									19
	20									20
	21									21
	22									22
	23									23
	24									24
	25									25

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LOG OF TEST TRENCH

Sheet Number 1 of 1

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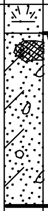
Project POLYMET
Project Number 053-2209

Test Pit Number G06-TP14
Total Depth 3.5 feet
Date Begin 4/17/06
Date End 4/17/06

Station / Location East Area, 5274271N, 579210E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data		
Depth in (ft.)		
Time		
Date		
Symbol		



Method	Depth in (Feet)		Sample Data: Method	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0		GRAB	1					0.0 - 0.5 Topsoil
	1								0.5 - 3.5 Wet, reddish-brown, silty SAND, little gravel, some silt, few cobbles (SM)
	2								
	3								
	4							BOH 3.5 ft.	Notes: Bedrock encountered at 3.5 feet
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								
	13								
	14								
	15								
	16								
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	25								

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LOG OF TEST TRENCH

Sheet Number 1 of 1

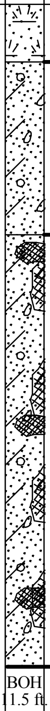
Test Pit Number G06-TP15
Total Depth 11.5 feet
Date Begin 4/17/06
Date End 4/17/06

Project POLYMET
Project Number 053-2209

Station / Location Pre-Production Area, 5274143N, 578799E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)	5	
Time	09:40	
Date	4/17/06	
Symbol	▼	



Method	Depth in (Feet)		Sample Data: Method	Sample Data: Number	Sample Data	Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL	
Excavation	0								0.0 - 1.0 Topsoil	0
	1								1.0 - 4.0 Moist, brown, silty SAND with gravel, some gravel, some silt (SM)	1
	2		GRAB	1						2
	3									3
	4								4.0 - 11.5 Moist, grayish-brown, silty SAND with little gravel, little to some silt, cobbles and boulders (SM)	4
	5						▼			5
	6									6
	7		GRAB	2						7
	8									8
	9									9
	10									10
	11									11
	12							BOH 11.5 ft.	Notes: Bedrock encountered at 11.5 feet	12
	13									13
	14									14
	15									15
	16									16
	17									17
	18									18
	19									19
	20									20
	21									21
	22									22
	23									23
	24									24
	25									25

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DATE:

APPENDIX B

SIEVE ANALYSES
ONE-DIMENSIONAL CONSOLIDATION
TRIAXIAL SHEAR TEST REPORT
MOISTURE DENSITY RELATIONSHIPS
PERMEABILITY TEST DATA

BRAUN INTERTEC REVISED

Braun Intertec Corporation
3404 15th Ave East
Suite 2
Hibbing, MN 55746

Phone: 218.263.8869
Fax: 218.263.6700
Web: braunintertec.com

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 6

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-26-06

Classification: SM--SILTY SAND, fine to medium grained, with GRAVEL, brown

Sample Location: TP #1, Sample #2, 3'-12'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	89
#4	82
#10	74
#20	64
#40	55
#100	39
#200	28.6

Remarks: Natural moisture content = 7.7%

Mark W. Gothard
Project Manager

BRAUN
INTERTEC

Braun Intertec Corporation
3404 15th Ave East
Suite 2
Hibbing, MN 55746

Phone: 218.263.8869
Fax: 218.263.6700
Web: braunintertec.com

REVISED

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.:	7
Date Sampled:	N/A
Date Received:	4-19-06
Date Tested:	4-27-06
Classification:	SM– SILTY SAND, very fine to fine grained, with some Gravel, grayish brown
Sample Location:	TP #1, Sample #3, 12'-20'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	91
#4	87
#10	80
#20	72
#40	64
#100	48
#200	37.5

Remarks: Natural moisture content = 8.5%

Lynn K fu
Mark W. Gothard
Project Manager

BRAUN
INTERTEC

Braun Intertec Corporation
3404 15th Ave East
Suite 2
Hibbing, MN 55746

Phone: 218.263.8869
Fax: 218.263.6700
Web: braunintertec.com

REVISED

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.:	13
Date Sampled:	N/A
Date Received:	4-19-06
Date Tested:	4-28-06
Classification:	SM – SILTY SAND, fine grained, brown
Sample Location:	TP #2, Sample #3, 9'-13'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	98
#4	96
#10	89
#20	79
#40	69
#100	49
#200	35.6

Remarks: Natural moisture content = 16.5%

Mark W. Gothard
Project Manager

BRAUN
INTERTEC

Braun Intertec Corporation
3404 15th Ave East
Suite 2
Hibbing, MN 55746

Phone: 218.263.8869
Fax: 218.263.6700
Web: braunintertec.com

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 22, 2006

Project No.: HB-06-01173

Client:
Ms. Amy C. Thorson, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

REVISED

Braun Sample No.: 4

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-26-06

Classification: SM – SILTY SAND, fine- to medium-grained, brown

Sample Location: TP #4, Sample #1, 1/2'-4 1/2'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	98
#4	92
#10	83
#20	72
#40	62
#100	44
#200	31.3

Remarks: Natural moisture content = 7.2%
LL=7, PL=7, PI=0

Mark W. Gothard, PE
Project Manager

BRAUN INTERTEC

Braun Intertec Corporation
3404 15th Ave East
Suite 2
Hibbing, MN 55746

Phone: 218.263.8869
Fax: 218.263.6700
Web: braunintertec.com

REVISED

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 2

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-25-06

Classification: SM – SILTY SAND, fine grained, with a little Gravel, grayish brown

Sample Location: TP #4, Sample #2, 4 1/2-13 1/2'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	94
#4	89
#10	82
#20	73
#40	65
#100	49
#200	39.3

Remarks: Natural moisture content = 7.2%

Mark W. Gothard
Project Manager

BRAUN
INTERTEC

Braun Intertec Corporation
3404 15th Ave East
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Hibbing, MN 55746

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Web: brauninertec.com

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: April 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 8

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-27-06

Classification: CL – SANDY LEAN CLAY, with a little gravel, grayish brown

Sample Location: TP #5, Sample #1, 0.5'-4'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	93
#4	87
#10	81
#20	75
#40	69
#100	61
#200	51.4

Remarks: Natural moisture content = 10.1%, LL=25, PL=16, PI=9

Mark W. Gothard
Project Manager

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REVISED

Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.:	14
Date Sampled:	N/A
Date Received:	4-19-06
Date Tested:	4-28-06
Classification:	SM – SILTY SAND, fine grained, gray
Sample Location:	TP #5, Sample #3, 6'-14'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	100
#4	99
#10	96
#20	89
#40	80
#100	62
#200	47.0

Remarks: Natural moisture content = 12.2%

Mark W. Gothard
Project Manager

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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: April 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 10

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-27-06

Classification: ML-S – SANDY SILT, gray

Sample Location: TP #6, Sample #2, 15'-20'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	100
#4	100
#10	99
#20	96
#40	90
#100	69
#200	51.7

Remarks: Natural moisture content = 13.0%

Mark W. Gothard
Project Manager

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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: April 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 11

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-27-06

Classification: SM – SILTY SAND, fine to medium grained, with GRAVEL, brown

Sample Location: TP #7, Sample #1, 0.5'-3.5'

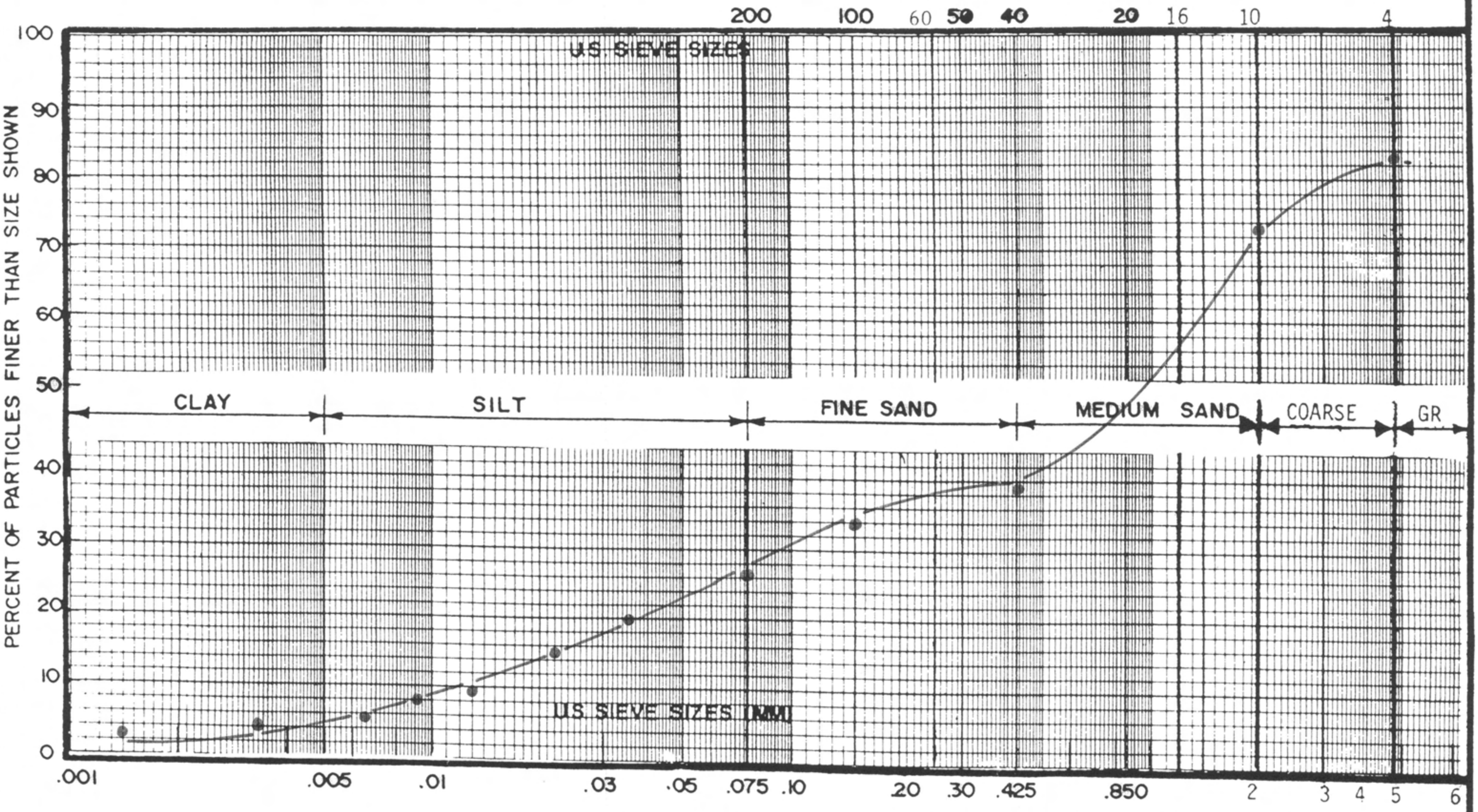
Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	92
#4	83
#10	73
#20	60
#40	39
#100	34
#200	26.5

Remarks: Natural moisture content = 12.4%

Mark W. Gothard
Project Manager

GRAIN SIZE ACCUMULATION CURVE



GOLDER PROJECT #053-2209.002

BRAUN
ENGINEERING TESTING

PROJECT: HB-06-01173
TEST PIT SAMPLES, HOYT LAKES, MN
NOTES: TP # 7, SAMPLE #1, 1/2'-3 1/2' (BRAUN #1)

GRAVEL		17
C. SAND	10	57
M. SAND	34	
F. SAND	13	
SILT		22
CLAY		4

CLASSIFICATION:
SM - SILTY SAND, WITH GRAVEL
LL=20, PL=17, PI=3

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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: April 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.:	1
Date Sampled:	N/A
Date Received:	4-19-06
Date Tested:	4-25-06
Classification:	SP – POORLY GRADED SAND, fine to coarse grained, with GRAVEL, brown
Sample Location:	TP #8, Sample #2, 2-4 1/2'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	71
#4	60
#10	47
#20	24
#40	13
#100	4
#200	1.8

Remarks: Natural moisture content = 7.3%

Mark W. Gothard
Project Manager

BRAUN
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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: April 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 3

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-26-06

Classification: SM – SILTY SAND, fine to coarse grained, with a little Gravel, brown

Sample Location: TP #11, Sample #2, 3'-6'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	97
#4	90
#10	77
#20	68
#40	52
#100	34
#200	23.9

Remarks: Natural moisture content = 21.5%

Mark W. Gothard
Project Manager

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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 22, 2006

Project No.: HB-06-01173

Client:
Ms. Amy C. Thorson, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

REVISED

Field Data:

Braun Sample No.: 5

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-26-06

Classification: SM– SILTY SAND, fine to medium grained, with GRAVEL, brown

Sample Location: TP #13, Sample #2, 4'-9'

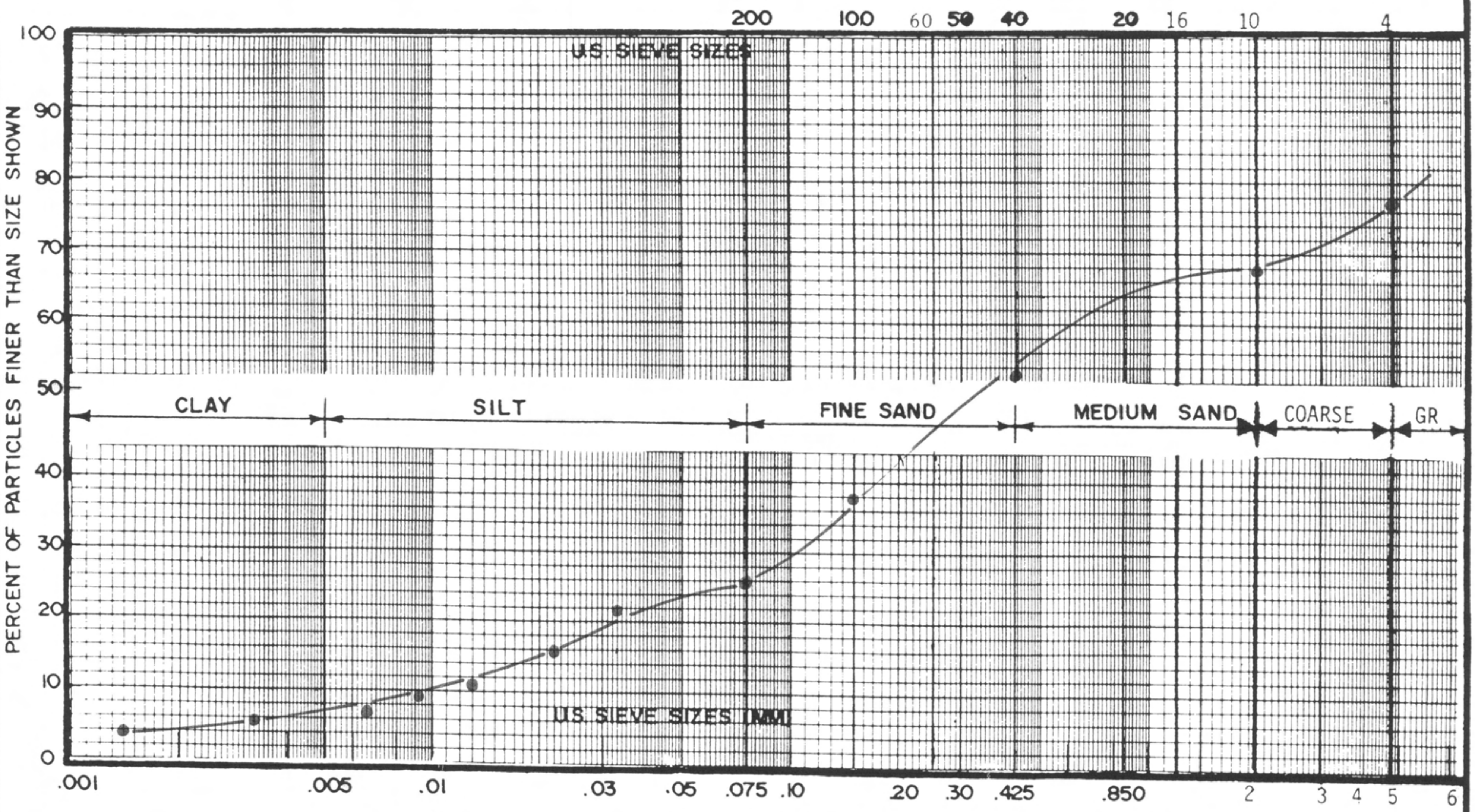
Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	83
#4	77
#10	68
#20	60
#40	53
#100	38
#200	26.0

Remarks: Natural moisture content = 8.0%
LL=10, PL=8, PI=2

Mark W. Gothard, PE
Project Manager

GRAIN SIZE ACCUMULATION CURVE



GOLDER PROJECT #053-2209.002

BRAUN
ENGINEERING TESTING

PROJECT: HB-06-01173
TEST PIT SAMPLES, HOYT
LAKES, MN

NOTES: TP #13, SAMPLE
#2, 4'-9' (BRAUN #5)

GRAVEL		23
C. SAND	9	51
M. SAND	15	
F. SAND	27	
SILT		19
CLAY		7

CLASSIFICATION:
SM - SILTY SAND,
WITH GRAVEL

BRAUN INTERTEC REVISED

Braun Intertec Corporation
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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 12

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-28-06

Classification: SM – SILTY SAND, fine grained, reddish brown

Sample Location: TP #14, Sample #1, 0.5'-3.5'

Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	100
#4	100
#10	99
#20	97
#40	33
#100	67
#200	46.8

Remarks: Natural moisture content = 26.9%

Mark W. Gothard
Project Manager

BRAUN INTERTEC REVISED

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Sieve Analysis of Aggregate Sample
AASHTO T27 & T11

Date: August 28, 2006

Project No.: HB-06-01173

Client: Ms. Amy C. Smith, PE
Senior Engineer, Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road, Box #304
Duluth, MN 55811

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota (Golder Project # 053-2209.002)

Field Data:

Braun Sample No.: 9

Date Sampled: N/A

Date Received: 4-19-06

Date Tested: 4-27-06

Classification: SM – SILTY SAND, fine to medium grained, with a little gravel

Sample Location: TP #15, Sample #2, 4'-11.5'

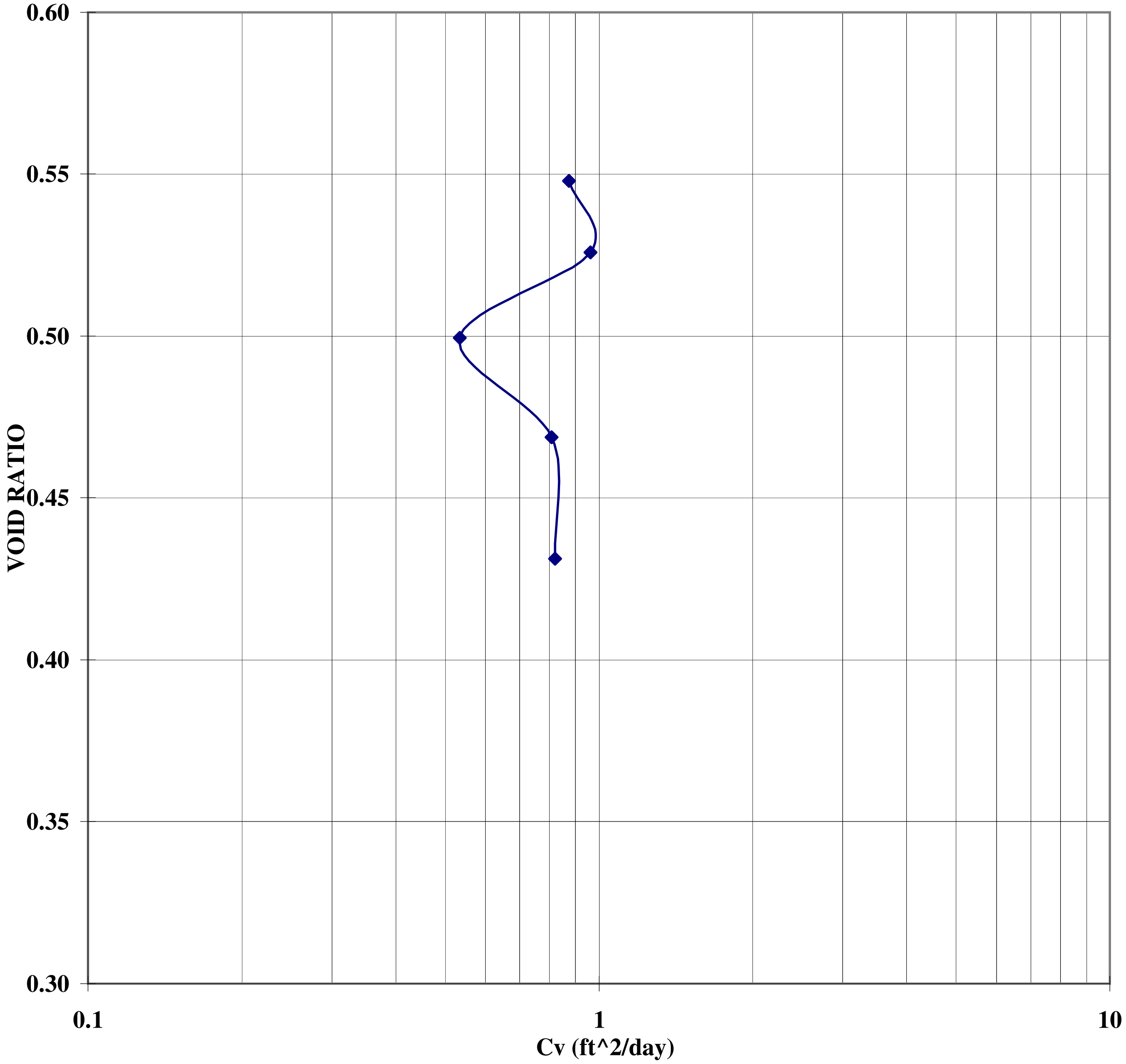
Laboratory Results:

Sieve Size	% Passing
3/4"	100
3/8"	94
#4	88
#10	79
#20	70
#40	61
#100	48
#200	38.8

Remarks: Natural moisture content = 18.7%

Mark W. Gothard
Project Manager

ONE-DIMENSIONAL CONSOLIDATION



SAMPLE #:	**G06-TP5 @ 0.5'-4'**
DESCRIPTION:	Olive brown clayey sand

DATE	5/16/2006
TECH	RT
REVIEW	JEO

Polymet/Mine Waste Impound Dsgn/MN
053-2209

GOLDER ASSOCIATES INC.
LAKEWOOD, COLORADO

Sample # =	G06-TP5		Sample # =	G06-TP5		Sample # =	G06-TP5	
Point # =	1		Point # =	2		Point # =	3	
	Initial			**Initial**			**Initial**	
Length =	14.73	cm	Length =	14.73	cm	Length =	14.73	cm
Diameter =	7.22	cm	Diameter =	7.22	cm	Diameter =	7.22	cm
Wet Weight =	1293.70	g	Wet Weight =	1293.70	g	Wet Weight =	1293.70	g
Area =	40.9	cm^2	Area =	40.9	cm^2	Area =	40.9	cm^2
Sample Area =	6.35	in^2	Sample Area =	6.35	in^2	Sample Area =	6.35	in^2
Volume =	603.1	cm^3	Volume =	603.1	cm^3	Volume =	603.1	cm^3
Moisture Content =	17.3%		Moisture Content =	17.3%		Moisture Content =	17.3%	
Specific Gravity =	-		Specific Gravity =	-		Specific Gravity =	-	
Dry Weight of Solids =	1102.90	g	Dry Weight of Solids =	1102.90	g	Dry Weight of Solids =	1102.90	g
Wet Unit Weight =	2.15	g/cm^3	Wet Unit Weight =	2.15	g/cm^3	Wet Unit Weight =	2.15	g/cm^3
Dry Unit Weight =	1.83	g/cm^3	Dry Unit Weight =	1.83	g/cm^3	Dry Unit Weight =	1.83	g/cm^3
Wet Unit Weight =	133.9	pcf	Wet Unit Weight =	133.9	pcf	Wet Unit Weight =	133.9	pcf
Dry Unit Weight =	114.1	pcf	Dry Unit Weight =	114.1	pcf	Dry Unit Weight =	114.1	pcf
Cell Pressure =	75	psi	Cell Pressure =	100	psi	Cell Pressure =	150	psi
Back Pressure =	50	psi	Back Pressure =	50	psi	Back Pressure =	50	psi
Confining Pressure =	25	psi	Confining Pressure =	50	psi	Confining Pressure =	100	psi

Notes: Sample visually described as: clay, olive brown, sandy to very sandy, part clayey sand, scattered small gravel and very dark gray claystone/shale fragments.
Specimen was undisturbed Shelby tube sample.
Failure defined as maximum principal stress ratio.
Strain rate was 0.05 mm/min.
Test was a staged triaxial shear test.

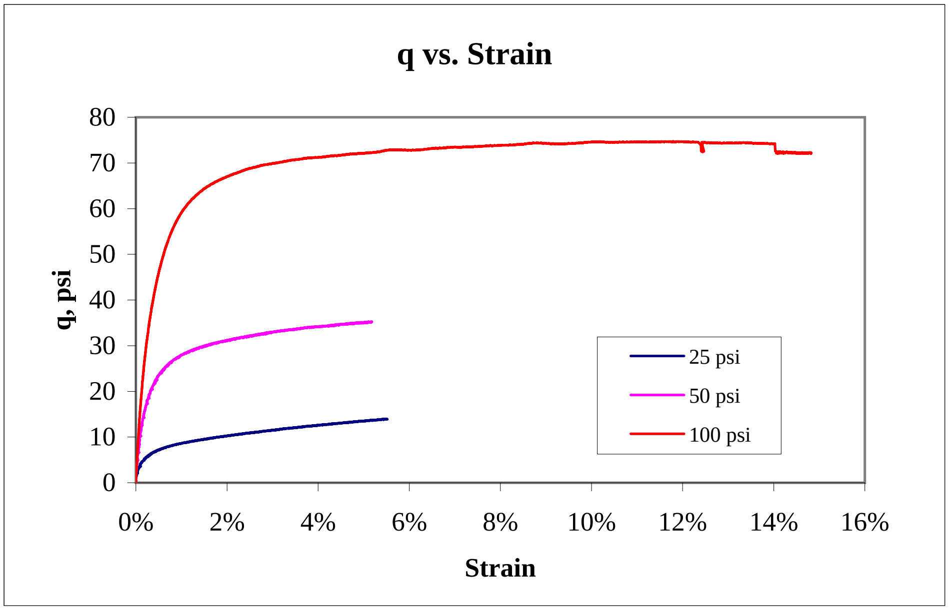
Golder Associates, Inc.
Denver, Colorado

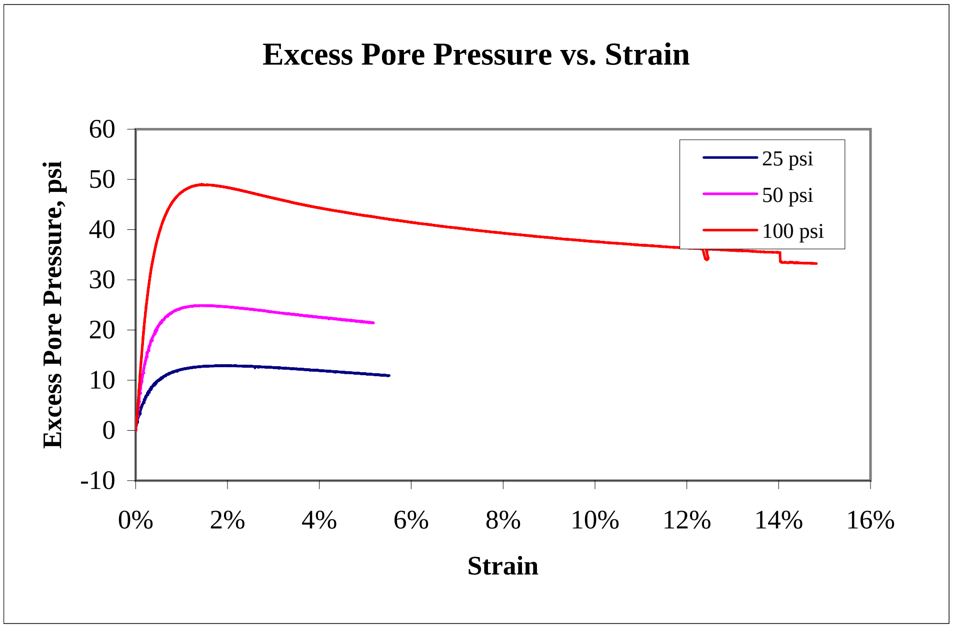
Job Short Title:
Polymet Minnesota

Title:

TRIAXIAL SHEAR TEST REPORT
SAMPLE DATA AND CALCULATIONS

	Reviewed:	**Date:**	**Job Number:**	**Figure:**
G06 - TP5 1A 0.5 -4'	**JEO**	**5/12/2006**	**053-2209**	**1**





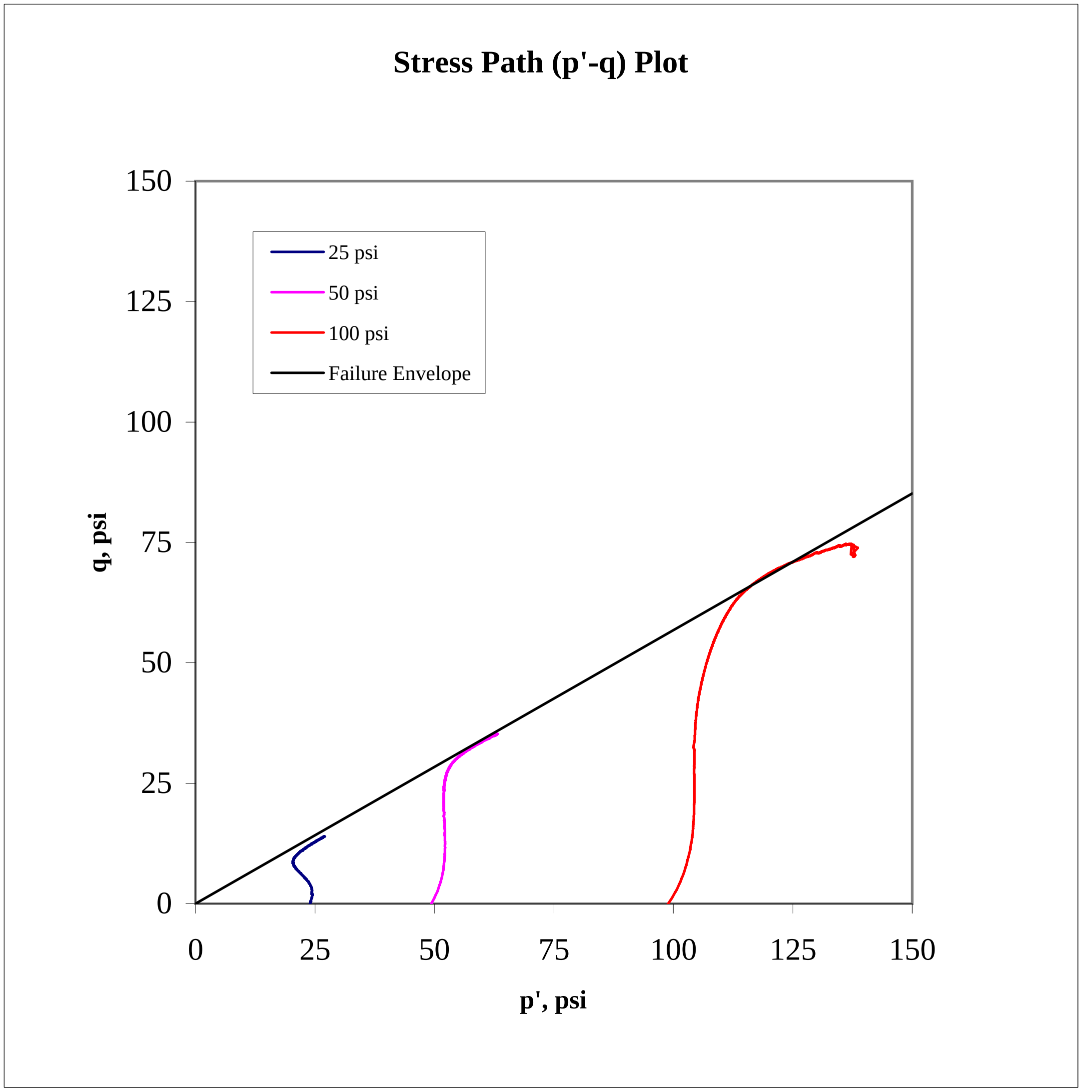
Golder Associates, Inc.
Denver, Colorado

Job Short Title: Polymet Minnesota

Title:

C-U TRIAXIAL SHEAR DATA
q AND EXCESS PORE PRESSURE PLOTS

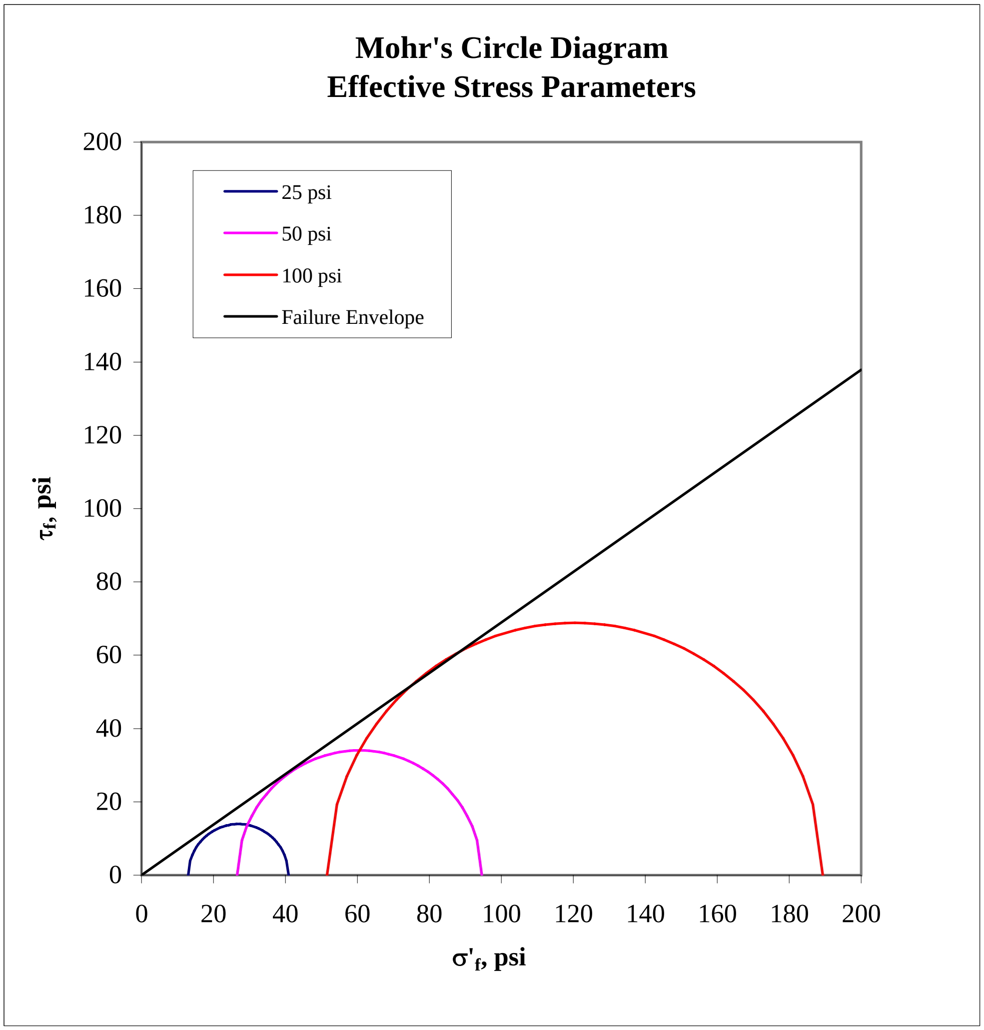
Sample Number:	Reviewed:	Date:	Job Number:	Figure:
G06 - TP5 1A 0.5 -4'	JEO	05/12/06	053-2209	2



Stress Path Parameters

ψ' = 29.6 degrees
a' = 0.0 psi

Golder Associates, Inc. **Denver, Colorado**	**Title:** **C-U TRIAXIAL SHEAR DATA** **STRESS PATH PLOT**			
Job Short Title: **Polymet Minnesota**				
Sample Number: **G06 - TP5 1A 0.5 -4'**	**Reviewed:** **JEO**	**Date:** **5/12/2006**	**Job Number:** **053-2209**	**Figure:** **3**



Effective Stress Shear Strength Parameters

ϕ' = 34.6 degrees
c' = 0.0 psi

Golder Associates, Inc. **Denver, Colorado**	**Title:** **C-U TRIAXIAL SHEAR DATA** **MOHR'S CIRCLE DIAGRAM**
Job Short Title: **Polymet Minnesota**	

Sample Number: **G06 - TP5 1A 0.5 -4'**	**Reviewed:** **JEO**	**Date:** **5/12/2006**	**Job Number:** **053-2209**	**Figure:** **4**

Consolidated-Undrained Triaxial Lab Data
From: GOLDER ASSOCIATES, INC.
Project: **Polymet Minnesota**
Project Number: **053-2209**

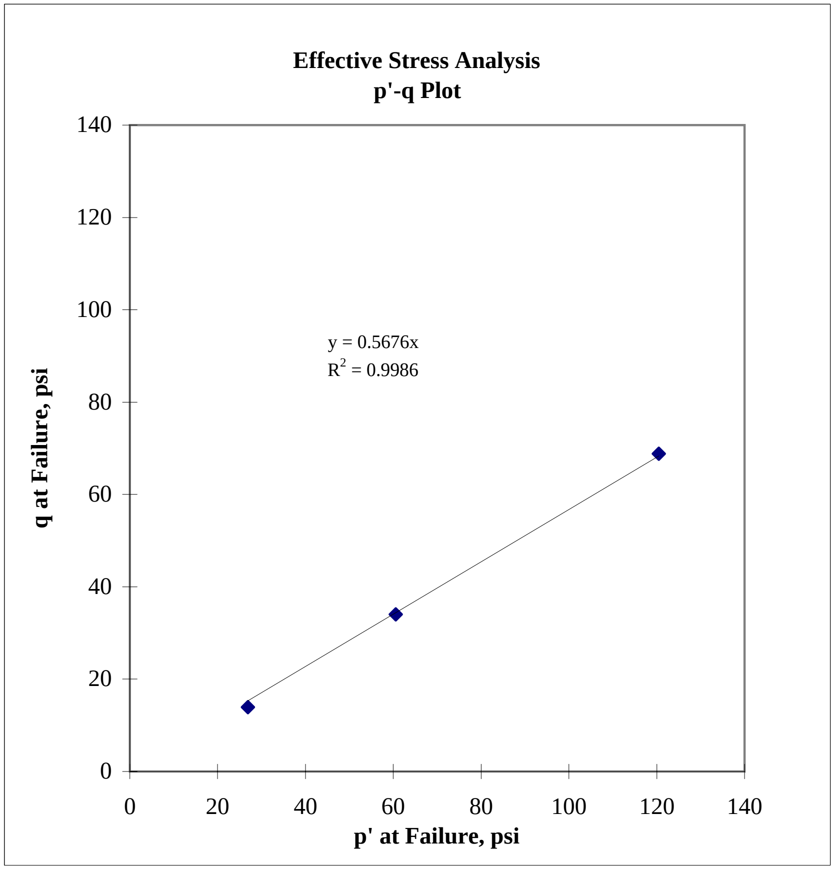
Sample Number G06 - TP5 1A 0.5 -4'

Effective Stress Analysis

Point Number	p' (psi)	q (psi)
1	26.9	13.9
2	60.6	34.0
3	120.4	68.8

tan(ψ') = **0.5676**
a' = **0.0** **psi**

ϕ' = **34.6** **degrees**
c' = **0.0** **psi**



Consolidated-Undrained Triaxial Lab Data
From: GOLDER ASSOCIATES, INC.
Project: **Polymet Minnesota**
Project Number: **053-2209**

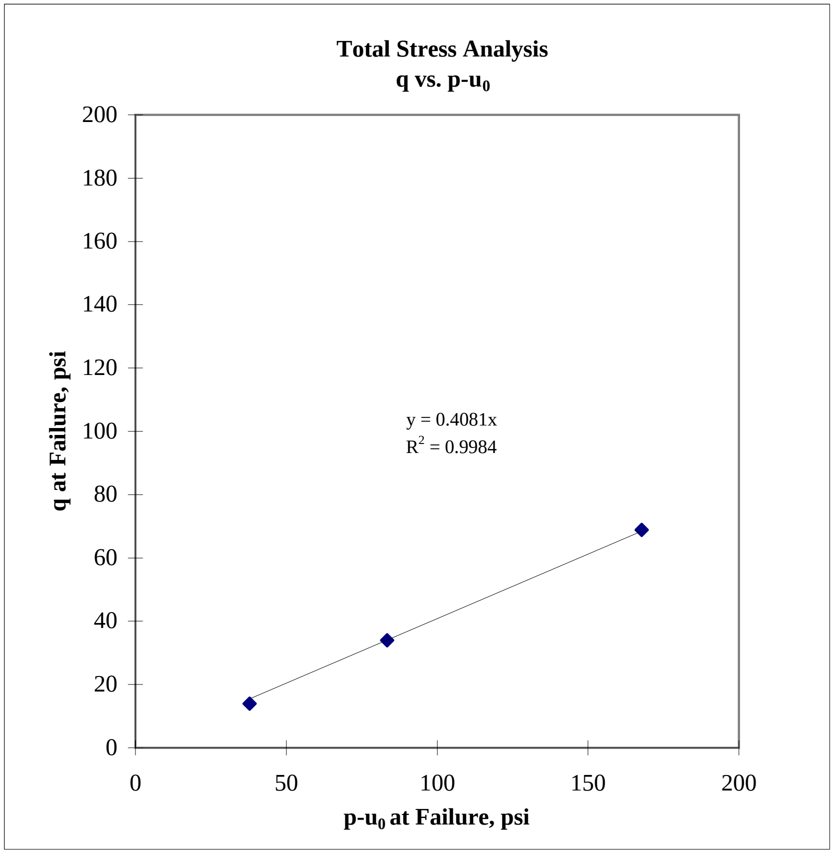
Sample Number G06 - TP5 1A 0.5 -4'

Total Stress Analysis

Point Number	$p-u_o$ (psi)	q (psi)
1	37.9	13.9
2	83.4	34.0
3	167.8	68.8

$\tan(\psi)$ = **0.41**
a = **0.0** **psi**

ϕ = **24.1** **degrees**
c = **0.0** **psi**



Consolidated-Undrained Triaxial Lab Data
From: GOLDER ASSOCIATES, INC.
Project: Polymet Minnesota
Project Number: 053-2209

Mohr-Coulomb Failure Criteria:

$$\tau_{ff} = c' + \sigma'_{ff} \tan(\phi')$$
$$\tau_{ff} = c + \sigma_{ff} \tan(\phi)$$

Where:
c', c = effective and total stress cohesion intercepts
ϕ', ϕ = effective and total stress friction angles
τ_{ff} = shear strength on the failure surface at failure
σ'_{ff}, σ_{ff} = effective and total normal stresses on the failure surface at failure

Stress Path Space:

$$q = \frac{\sigma_1 - \sigma_3}{2} \qquad p' = \frac{\sigma'_1 + \sigma'_3}{2} \qquad p = \frac{\sigma_1 + \sigma_3}{2}$$

Where:
q = maximum shear stress
p', p = mean effective and total stresses
σ'_1, σ_1 = effective and total axial stresses
σ'_3, σ_3 = effective and total confining stresses

Stress Path Failure Criteria:

$$q = a' + p' \tan(\psi')$$
$$q = a + (p - u_0) \tan(\psi)$$

Where:
a', a = intercepts of the q-axis in effective stress and total stress spaces
ψ', ψ = angles of the failure envelopes in effective stress and total stress spaces
q = maximum shear stress at failure
p' = mean effective stress at failure
$p-u_0$ = mean total stress at failure minus the initial pore pressure

The relationships between ψ and ϕ and a and c are as follows:

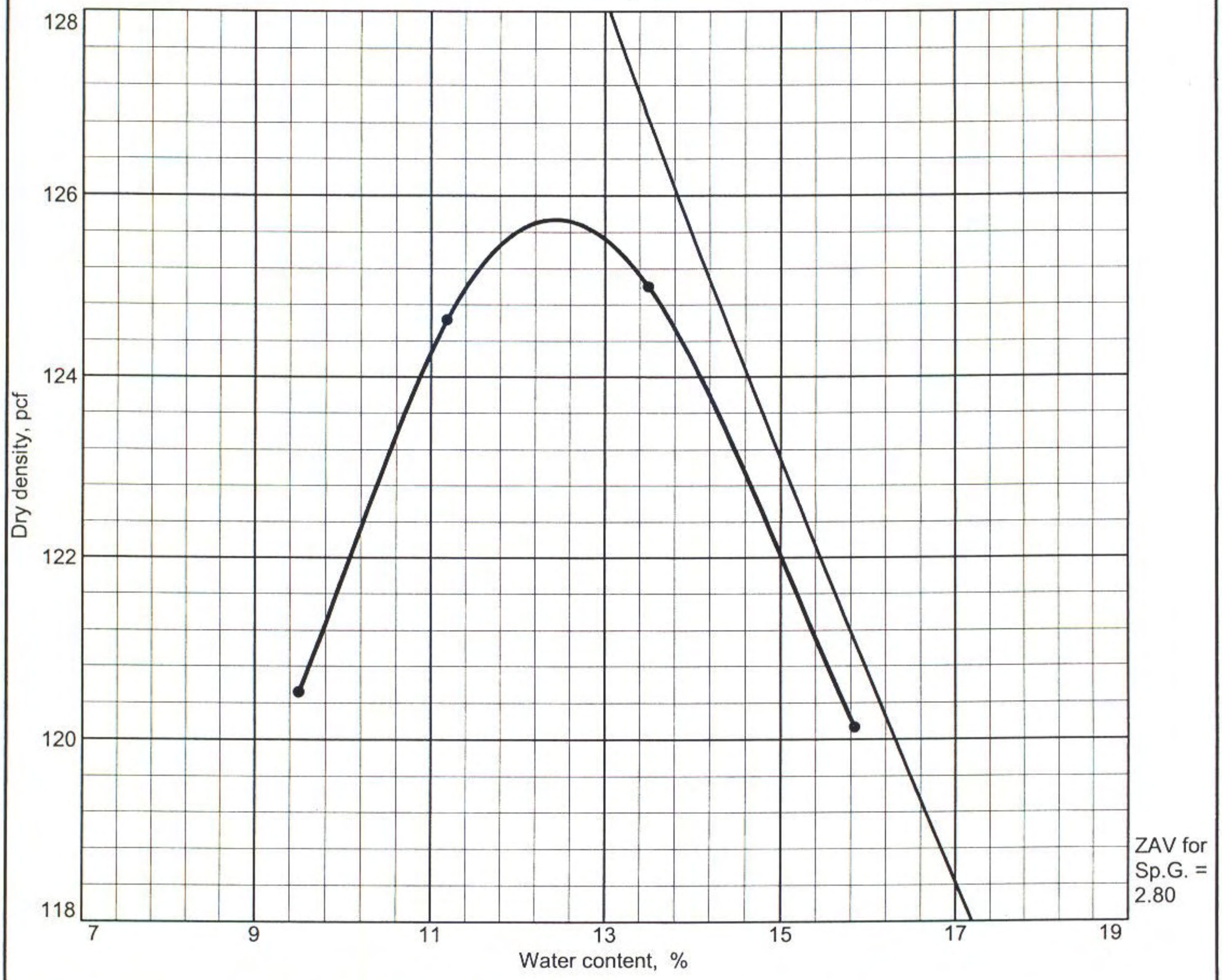
$$\tan(\psi) = \sin(\phi)$$
$$a = c \cos(\phi)$$

The relationships between ψ' and ϕ' and a' and c' are as follows:

$$\tan(\psi') = \sin(\phi')$$
$$a' = c' \cos(\phi')$$

Staged Triaxial Shear Test		Boring Number	G06-TP5
Polymet/ Minnesota		Sample Depth	0.5-4'
053-2209			

Moisture-Density Relationship



Test specification: ASTM D 698-00a Method A Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
N.A.								

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 125.7 pcf Optimum moisture = 12.4 %	SC-SM Silty clayey sand, brown

Project No.: HB-06-01173 **Client:** Golder and Assoc.
Project: Polymet

● **Source:** **Sample No.:** P-3 **Elev./Depth:** N.A.

Remarks:
Test Pit #4, sample #1; 0.5-4.5'

BRAUN INTERTEC

BRAUN
INTERTEC

Permeability Test Data

Date: August 11, 2006

Client: Ms. Amy C. Thorson, PE, Senior Engineer
Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road
Box #304
Duluth, MN 55811

Project: HB-06-01173

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota

(Golder Project #053-2209.002)

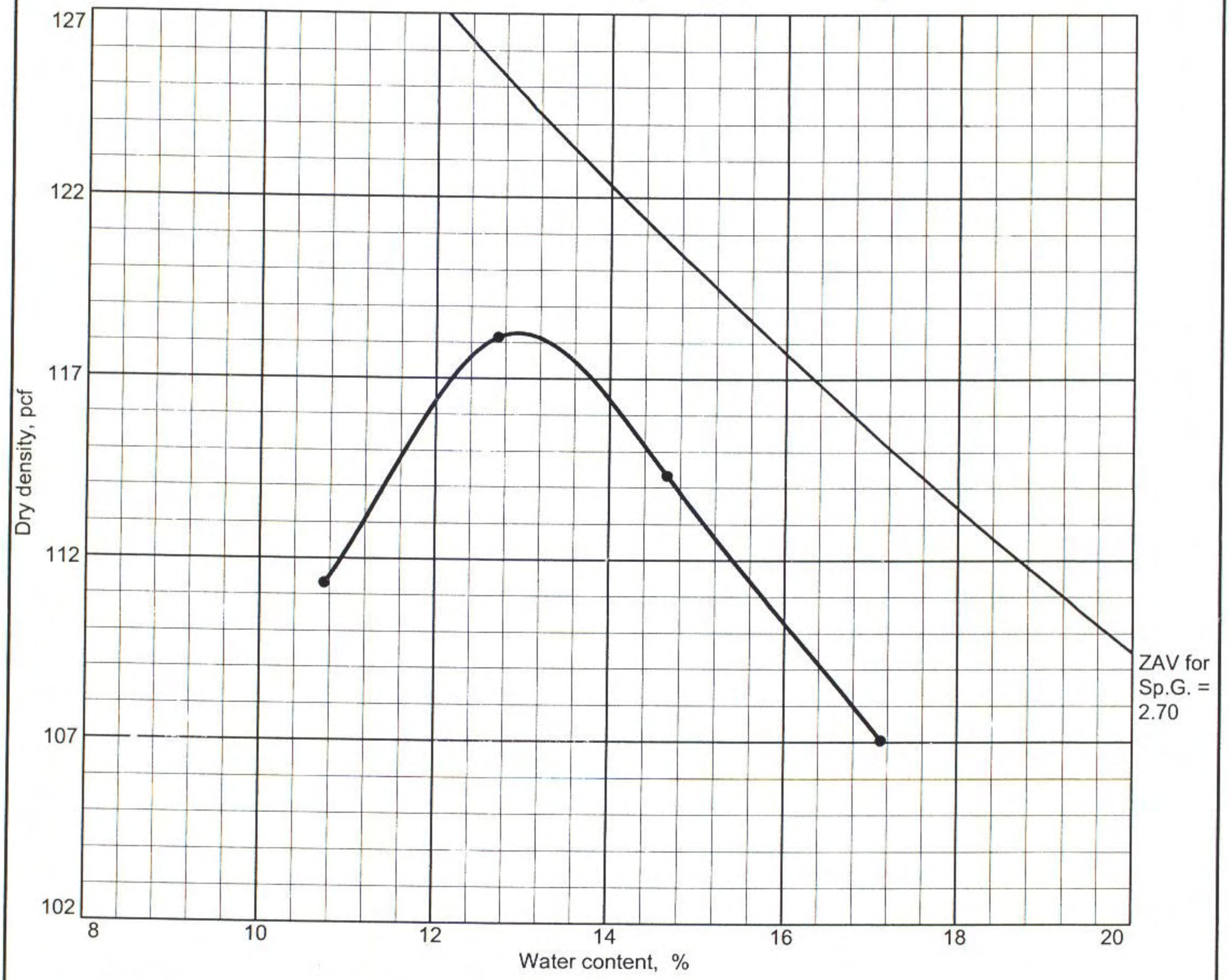
Sample Number: 3
Date Sampled: N/A
Sample Location: TP #4, Sample #1, 0.5-4.5'
Soil Classification: SC-SM – Silty Clayey Sand, brown
Type of Test: Falling Head (ASTM D 5084)
Standard Proctor: Max. Density (pcf): 125.7
Optimum Moisture (%): 12.4
Density of Sample (pcf): 119.4
Percent Compaction (%) 95
Specimen Height (cm): 3.99
Specimen Diameter (cm): 3.80
Max. Head Differential (ft): 4.0
Confining Pressure (effective-psi): 2.0
Coefficient of Permeability: K@ 20° C (cm/sec) 1.35 x 10^{-7}

Notes:

Respectfully Submitted,
BRAUN INTERTEC CORPORATION

Gregory N. Laine
Project Manager

Moisture-Density Relationship



Test specification: ASTM D 698-00a Method A Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
N.A.								

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 118.3 pcf Optimum moisture = 12.9 %	SM- Silty sand, fine grained,brown

Project No.: HB-06-01173 **Client:** Golder and Assoc.

Project: Polymet

● **Source:** **Sample No.:** P-2 **Elev./Depth:** N.A.

Remarks:

Test Pit #7, sample#1, 0.5-3.5"

BRAUN INTERTEC

BRAUN
INTERTEC

Permeability Test Data

Date: August 11, 2006

Client: Ms. Amy C. Thorson, PE, Senior Engineer
Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road
Box #304
Duluth, MN 55811

Project: HB-06-01173

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota

(Golder Project #053-2209.002)

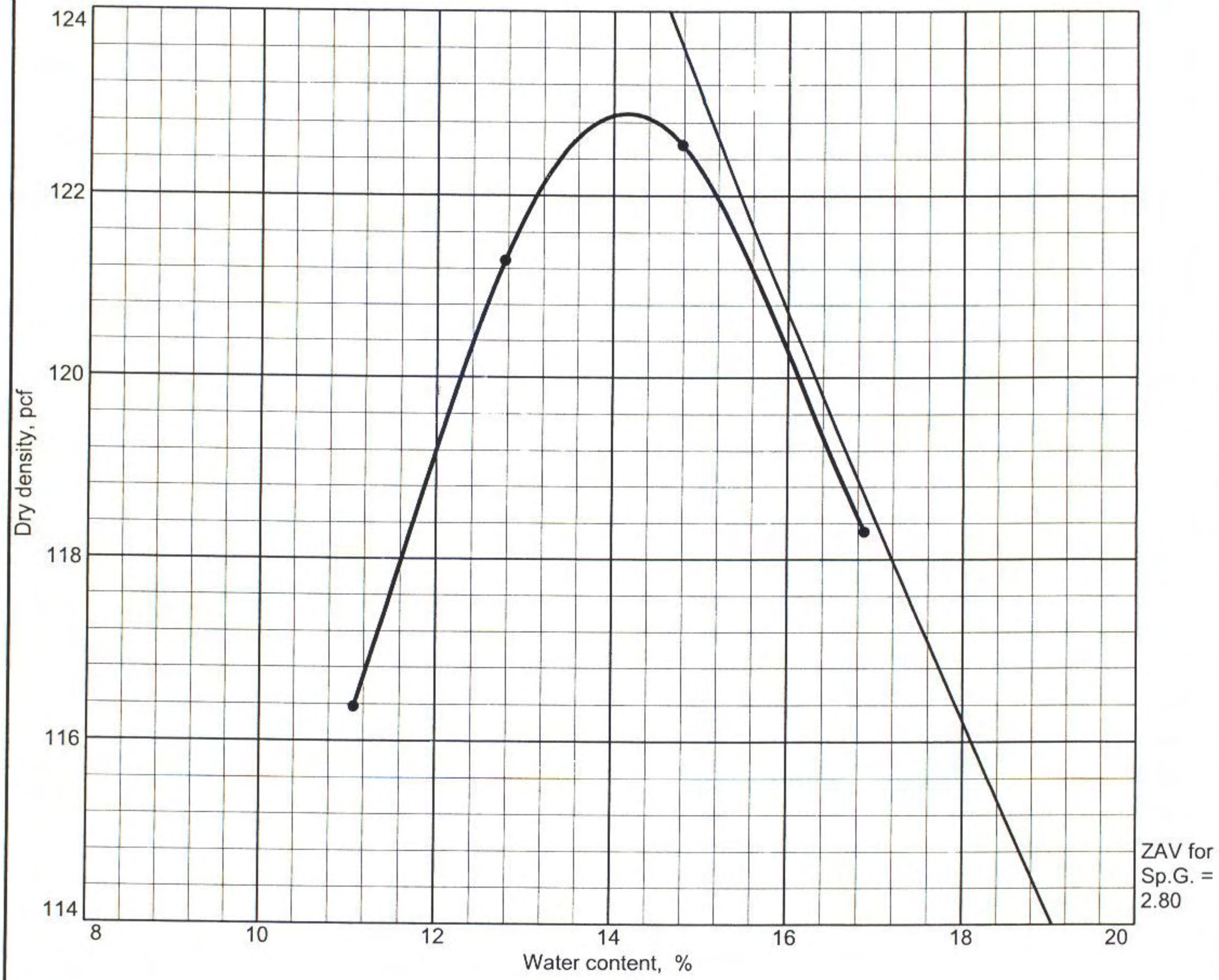
Sample Number:	2
Date Sampled:	N/A
Sample Location:	TP #7, Sample #1, 0.5-3.5'
Soil Classification:	SM – Silty Sand, brown
Type of Test:	Falling Head (ASTM D 5084)
Standard Proctor: Max. Density (pcf):	118.3
Optimum Moisture (%):	12.9
Density of Sample (pcf):	112.4
Percent Compaction (%)	95
Specimen Height (cm):	10.21
Specimen Diameter (cm):	9.65
Coefficient of Permeability: K@ 20° C (cm/sec)	2.04×10^{-7}

Notes:

Respectfully Submitted,
BRAUN INTERTEC CORPORATION

Gregory N. Laine
Project Manager

Moisture-Density Relationship



Test specification: ASTM D 698-00a Method A Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
N.A.				2.80				

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 122.9 pcf Optimum moisture = 14.2 %	SC- Clayey sand, brown

Project No.: HB-06-01173 **Client:** Golder and Assoc.

Project: Polymet

● **Source:** **Sample No.:** P-1 **Elev./Depth:** N.A.

Remarks:

TP-13, sample #2, 4-9'

BRAUN℠
INTERTEC

BRAUN
INTERTEC

Permeability Test Data

Date: August 11, 2006

Client: Ms. Amy C. Thorson, PE, Senior Engineer
Manager Duluth Operations
Golder Associates, Inc.
1346 West Arrowhead Road
Box #304
Duluth, MN 55811

Project: HB-06-01173

Project Description: Test Pit Samples, Hoyt Lakes, Minnesota

(Golder Project #053-2209.002)

Sample Number:	1
Date Sampled:	N/A
Sample Location:	TP #13, Sample #2, 4-9'
Soil Classification:	SC – Clayey Sand, brown
Type of Test:	Falling Head (ASTM D 5084)
Standard Proctor: Max. Density (pcf):	122.9
Optimum Moisture (%):	14.2
Density of Sample (pcf):	116.8
Percent Compaction (%)	95
Specimen Height (cm):	10.41
Specimen Diameter (cm):	9.65
Coefficient of Permeability: K@ 20° C (cm/sec)	$1.06x\ 10^{-7}$

Notes:

Respectfully Submitted,
BRAUN INTERTEC CORPORATION

Gregory N. Laine
Project Manager

APPENDIX C

SOIL CLASSIFICATION/LEGEND
ASTM CLASSIFICATION/INDEX

Unified Soil Classification System

CRITERIA FOR ASSIGNING GROUP SYMBOLS AND NAMES			SOIL CLASSIFICATION AND GENERALIZED GROUP DESCRIPTIONS	
COARSE - GRAINED SOILS More than 50% retained on No. 200 Sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVELS Less than 5% fines^{C}	GW	Well-graded Gravels^{F}
			GP	Poorly-graded Gravels^{F}
		GRAVELS WITH FINES More than 12% fines^{C}	GM	Gravel and Silt Mixtures$^{F, G, H}$
			GC	Gravel and Clay Mixtures$^{F, G, H}$
	SANDS 50% or more of coarse fraction passes No. 4 Sieve	CLEAN SANDS Less than 5% fines^{D}	SW	Well-graded Sands^{I}
			SP	Poorly-graded Sands^{I}
		SANDS WITH FINES More than 12% fines^{D}	SM	Sand and Silt Mixtures$^{G, H, I}$
			SC	Sand and Clay Mixtures$^{G, H, I}$
FINE- GRAINED SOILS 50% or more passes the No. 200 Sieve	SILT AND CLAYS Liquid limit less than 50	INORGANIC	CL	Low-plasticity Clays$^{K, L, M}$
			ML	Non/Low-Plasticity Silts$^{K, L, M}$
		ORGANIC	OL	Non/Low-Plasticity Organic Clays$^{K, L, M, N}$, Non/Low-Plastic Organic Silts$^{K, L, M, N}$
	SILTS AND CLAYS Liquid limit greater than 50	INORGANIC	CH	High-plasticity Clays$^{K, L, M}$
			MH	High-plasticity Silts$^{K, L, M}$
		ORGANIC	OH	High-plast. Org. Clays$^{K, L, M, P}$ High-plast. Organic Silts$^{K, L, M, Q}$
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat

See notes Figure A-1b

Laboratory Tests

Test	Designation
Moisture	(1)
Density	D
Grain Size	G
Hydrometer	H
Atterberg Limits	(1)
Consolidation	C
Unconfined	U
UU Triax	UU
CU Triax	CU
CD Triax	CD
Permeability	P

(1) Moisture and Atterberg Limits plotted on boring log.

Criteria for Describing Moisture Condition

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

Relative Density or Consistency Utilizing Standard Penetration Test Values

Cohesionless Soils $^{(a)}$			Cohesive Soils $^{(b)}$			
Density$^{(c)}$	N_1, blows/ft.$^{(c)}$	Relative Density (%)	Consistency	N_1, blows/ft.$^{(c)}$	Undrained $^{(d)}$ Shear Strength	Torvane tsf
Very loose	0 to 4	0 -15	Very soft	0 to 2	<250	<0.1
Loose	4 to 10	15 - 35	soft	2 to 4	250 - 500	0.1 - 0.3
Compact	10 to 30	35 - 65	firm	4 to 8	500 - 1000	0.3 - 0.5
Dense	30 to 50	65 - 85	stiff	8 to 15	1000 - 2000	0.5 - 1.0
Very Dense	over 50	>85	Very Stiff	15 to 30	2000 - 4000	1.0 - 2.0
			Hard	over 30	>4000	>2.0

(a) Soils consisting of gravel, sand, and silt, either separately or in combination possessing no characteristics of plasticity, and exhibiting drained behavior.

(b) Soils possessing the characteristics of plasticity, and exhibiting undrained behavior.

(c) Refer to text of ASTM D 1586-84 for a definition of N; in normally consolidated cohesionless soils Relative Density terms are based on N values corrected for overburden pressures (N_1). N values may be affected by a number of factors including material size, depth, drilling method, and bore-hole disturbance. N values are only an approximate guide to the consistency of cohesive soils.

(d) Undrained shear strength = 1/2 unconfined compression strength.

Silt and Clay Descriptions

Description	Typical Unified Designation
Silt	ML (non-plastic)
Clayey Silt	CL-ML (low-plasticity)
Silty Clay	CL
Clay	CH
Plastic Silt	MH
Organic Soils	OL, OH, PT

Samples

SS	SPT Sampler (2 in. O.D.)
SSO	Oversize SPT (2.5 in. O.D.)
HD	Heavy Duty Spoon (3.0 in. O.D.)
SH	Shelby Tube
P	Pitcher Sampler
B	Bulk
C	Cored
RC	Air Rotary Cuttings
AC	Auger Core
CUT	Auger Cuttings

1. SS drive samples advanced with 140 lb. hammer with a 30 in. drop.

2. HD drive samples are advanced with 300 lb. hammer with a 30 in. drop.

3. SSO drive samples advanced with 140 lb. manner with a 30 in. drop.

Descriptive Terminology Denoting Component Proportions

Descriptive Terms	Range of Proportion
Trace	0 - 5%
Few	5 - 10%
Little	15 - 20%
Some	30 - 45%

Component Definitions by Gradation

Component	Size Range
Boulders	Above 12 in.
Cobbles	3 in. to 12 in.
Gravel	3 in. to No. 4 (4.76mm)
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 (4.76mm)
Sand	No. 4 (4.76mm) to No. 200 (0.074mm)
Coarse sand	No. 4 (4.76mm) to No. 10 (2.0mm)
Medium sand	No. 10 (2.0mm to No. 40 (0.42mm)
Fine sand	No. 40 (0.42mm) to No. 200 (0.074mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

REVISED: 01/02

Golder Associates

Figure C-1

ASTM SOIL CLASSIFICATION / LEGEND

FILE NAME: SOILS/ASTM_SOILCLASS.CDR

CRITERIA FOR ASSIGNING GROUP SYMBOLS AND GROUP NAMES USING LABOR ATORY TESTS				SOIL CLASSIFICATION	
				Group Symbol	Group Name
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines ^{C}	Cu$\geq$4 and 1$\leq$ Cc$\leq$3^E	GW	Well-graded gravel ^{F}
			Cu <4 and/or 1> Cc>3 ^{E}	GP	Poorly graded gravel ^{F}
		Gravels with Fines More than 12% fines ^{C}	Fines classify as ML or MH	GM	Silty gravel $^{F, G, H}$
			Fines classify as Cl or Ch	GC	Clayey gravel $^{F, G, H}$
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines ^{D}	Cu$\geq$6 and 1$\leq$Cc$\leq$3^E	SW	Well-graded sand ^{I}
			Cu < 6 and/or 1 > Cc > 3 ^{E}	SP	Poorly graded sand ^{I}
		Sands with Fines More than 12% fines ^{D}	Fines classify as ML or Mh	SM	Silty sand $^{G, H, I}$
			Fines classify as Cl or Ch	SC	Clayey sand $^{G, H, I}$
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line ^{J}	CL	Lean clay $^{K, L, M}$
			PI < 4 or plots below "A" line ^{J}	ML	Silt $^{K, L, M}$
		Organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}}$ <0.75	OL	Organic clay $^{K, L, M, N}$ Organic silt $^{K, L, M, O}$
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay $^{K, L, M}$
			PI plots below "A" line	MH	Elastic silt $^{K, L, M}$
		Organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}}$ <0.75	OH	Organic clay $^{K, L, M, P}$ Organic silt $^{K, L, M, Q}$
HIGHLY ORGANIC SOILS		Primarily organic matter, dark in color, and organic odor			Peat

[A] Based on the material passing the 3-in. (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D] Sands with 5 to 12% fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10} \quad Cu = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains $\geq$15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic add "with organic fines" to group name.

[I] If soil contains $\geq$15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[K] If soil contains $\geq$15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

[L] If soil contains $\geq$30% plus No. 200, predominantly sand, add "sandy" to group name.

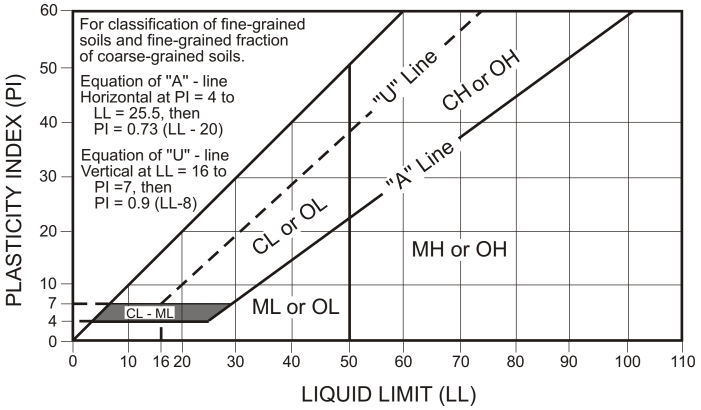
[M] If soil contains $\geq$30% plus No. 200, predominantly gravel, add "gravelly" to group name.

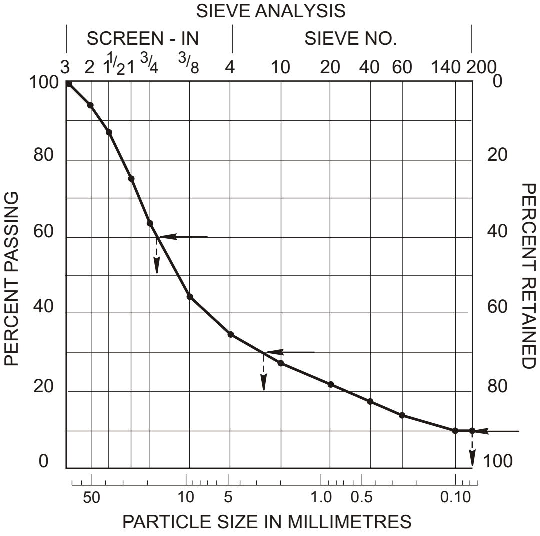
[N] PI $\geq$4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.





$$Cu = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \qquad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

REVISED: 03/02

Golder Associates

Figure C-2

ASTM D2487-93
ASTM CLASSIFICATION INDEX

APPENDIX C

LINER LEAKAGE EVALUATION

APPENDIX C

LINER LEAKAGE EVALUATIONS

1.0 INTRODUCTION

This appendix summarizes the approach and results of liner leakage evaluations for the proposed waste rock stockpiles at the PolyMet NorthMet Site located near Babbitt, Minnesota evaluated using the HELP (Hydrologic Evaluation of Landfill Performance) model. The selection of the liner system and cover systems that were evaluated for performance by HELP is consistent with the results of RS23T.

2.0 INPUT PARAMETERS

All simulations use a 100 year weather record for Duluth, Minnesota, synthetically generated by HELP. In order to provide a conservative approach and to match potential evapotranspiration estimates by Baker et al. (1979), wind speed and solar radiation data generated by HELP were reduced by 50%. The following material parameters were used for HELP simulations:

TABLE 2.1

MATERIAL PARAMETERS FOR MODELING SCENARIOS WITHOUT FINAL COVER

Materials	HELP No.	ksat (cm/s)	Thickness (inch)	Drainage Grades and Geomembrane Defects
Waste rock	21	3.00E-01	480	
Overliner (50ft, 100 ft drains)	21	3.00E-01	12	0.2% slope (0.5% for Cat. 4 liner)
Geomembrane	36	4.00E-13	0.08	4 holes, 1 pinhole per acre
Soil liner Category 1/2	16	5.00E-07	12	
Subgrade Category 3	16	1.00E-05	12	
Soil liner Category 4	16	1.00E-06	12	

As indicated in Table 2.1, the lower model boundary for the Category 3 Waste Rock Stockpile consists of an 80 mil geomembrane placed on a 12 inch thick subgrade material. The composite liner system evaluated for Category 4 stockpiles (including Category 3 Lean Ore Stockpile) consisted of an 80 mil geomembrane over a 12 inch thick soil liner with a permeability of 10^{-6} cm/sec. The HELP model for the Category 1/2 Waste Rock Stockpile simulated a 12 inch thick soil liner with a permeability of $5x10^{-7}$ cm/s. All liners are overlain by 12 inches of the overliner material and 40 ft of the stockpile waste rock. To conservatively account for localized settlement of subgrade materials, the overliner slope was defined at 0.2% for HELP simulations considering Category 1/2 Waste Rock and Category 3 Waste Rock Stockpiles, even though the minimum design criteria for foundation gradients are expected to be higher than 0.2%. The simulated liner gradient for Category 4 stockpiles was slightly increased, assuming an average liner grade of 0.5%. This is still considered conservative as the Category 4 stockpiles (including Category 3 Lean Ore Stockpile) are smaller, exert lower effective stresses due to lower height of the waste rock, and are located in more geotechnically favorable areas. In addition, the average liner grades for Category 4 stockpiles (Category 4 Waste Rock and Category 3 Lean Ore Stockpiles and Lean Ore Surge Pile) are expected to be greater than 0.5%.

The various modeling scenarios considering open stockpiles, i.e., stockpiles without a cover system, are summarized in Table 2.2:

TABLE 2.2
MODELING SCENARIOS FOR OPEN STOCKPILES

Stockpile	Type	Liner Grade (%)	Drainage Length (ft)
Category 1/2	Open Stockpile	0.2	100
Category 3	Open Stockpile	0.2	100
Category 4	Open Stockpile	0.5	50

HELP parameters used to simulate reclamation cover materials are summarized in Table 2.3.

TABLE 2.3
RECLAMATION COVER MATERIALS

Cover Materials	HELP No.	ksat (cm/s)	Thickness (inch)	Geomembrane Defects
Vegetated layer (for geomembrane covers)	10	1.20E-04	18	
Vegetated layer (Category 1/2 ET cover)	10	1.00E-05	24	
Vegetated layer (Category 3 ET cover)	10	1.00E-05	36	
Geomembrane	36	4.00E-13	0.06	4 holes/acre, 1 pinholes/acre

As indicated in Table 2.4, all HELP model simulations for the Category 1/2 Waste Rock Stockpile utilized an ET cover with a thickness of 2 feet. HELP model simulations for Category 3 waste rock considered two cover types: 1) an ET cover with a thickness of 3 feet on the outslopes; and 2) a 60 mil thick geomembrane cover system on the crest areas and benches overlain by an 18-inch vegetative layer. Similarly, cover system simulations for Category 4 stockpiles utilized a 60-mil geomembrane cover system overlain by an 18 inch of vegetated topsoil layer.

TABLE 2.4

MODELING SCENARIOS FOR RECLAIMED STOCKPILES

Stockpile	**Type**	**Reclamation Cover**	**Thickness**
Category 1/2 (ET)	Reclaimed Stockpile	ET cover	2 ft
Category 3 (ET)	Reclaimed Stockpile	ET cover	3 ft
Category 3 (Geo)	Reclaimed Stockpile	Geomembrane Cover	60 mil
Category 4 (Geo)	Reclaimed Stockpile	Geomembrane Cover	60 mil

3.0 RESULTS

HELP results for open stockpiles are summarized in Tables 3.1 to 3.3.

TABLE 3.1

AVERAGE ANNUAL PRECIPITATION, RUNOFF AND EVAPORATION VALUES FOR OPEN STOCKPILES

Avg. Annual Precipitation (inch)	**Avg. Annual Runoff (inch)**	**Avg. Annual Evaporation (inch)**
29.2	3.9	12.4

One should note that the runoff value in Table 3.1 denotes the runoff from the stockpile surface and does not account for the lateral drainage collected at the base of the stockpile (see Table 3.2).

TABLE 3.2

LATERAL DRAINAGE, PERCOLATION AND HEAD ON LINER FOR OPEN STOCKPILES

Stockpile	Avg. Annual Lateral Drainage (inch)	Avg. Annual Percolation (inch)	Avg. Annual Head on Liner (inch)	Peak Daily Percolation (inch)	Peak Daily Head on Liner (inch)
Category 1/2	6.50	6.24	0.49	2.0E-02	2.80
Category 3	13.05	0.03	0.93	<0.001	3.18
Category 4	13.07	<0.01	0.21	<0.001	1.20

TABLE 3.3

SUMMARY OF CALCULATED PERCOLATION RATES FOR OPEN STOCKPILES

Stockpile	Avg. Annual Percolation (gal/acre/day)
Category 1/2	464
Category 3	2.0
Category 4	0.1

The HELP simulation results for the reclaimed stockpiles are summarized in Tables 3.4 to 3.6.

TABLE 3.4

AVERAGE ANNUAL PRECIPITATION, RUNOFF AND EVAPORATION VALUES FOR RECLAIMED STOCKPILES

Stockpile	Avg. Annual Precipitation (inch)	Avg. Annual Runoff (inch)	Avg. Annual Evaporation (inch)
Category 1/2 (ET)	29.2	11.7	15.0
Category 3 (ET)	29.2	11.4	15.1
Category 3 (Geo)	29.2	11.3	16.4
Category 4 (Geo)	29.2	11.3	16.4

TABLE 3.5

LATERAL DRAINAGE, PERCOLATION AND HEAD ON LINER FOR RECLAIMED STOCKPILES

Stockpile	Avg. Annual Lateral Drainage (inch)	Avg. Annual Percolation (inch)	Avg. Annual Head on Liner (inch)	Peak Daily Percolation (inch)	Peak Daily Head on Liner (inch)
Category 1/2 (ET)	0.03	2.3	<0.1	0.017	0.6
Category 3 (ET)	0.01	<0.01	0.2	<0.001	0.8
Category 3 (Geo)	1.36	<0.01	0.1	<0.001	0.6
Category 4 (Geo)	1.37	<0.01	<0.1	<0.001	0.1

TABLE 3.6

SUMMARY OF CALCULATED PERCOLATION RATES FOR RECLAIMED STOCKPILES

Stockpile	Avg. Annual Percolation (gal/acre/day)
Category 1/2 (ET)	171.1
Category 3 (ET)	0.5
Category 3 (Geo)	0.3
Category 4 (Geo)	<0.1

Note that the Category 3 Lean Ore Stockpile is constructed using a Category 4 liner system. Consequently, the expected annual percolation rates for the reclaimed Category 3 Lean Ore Stockpile is not likely to exceed 0.1 gal/acre/day.

4.0 CONCLUSIONS

HELP model simulations indicate an average annual percolation rate for the open Category 1/2 Waste Rock Stockpile of 464 gal/acre/day. The maximum calculated daily head for open Category 1/2 Waste Rock Stockpile assuming the conservative liner gradient of 0.2% is 2.8 inches. For the reclaimed Category 1/2 Waste Rock Stockpile, the calculated annual percolation rate is 171 gal/acre/day. In general, the head on the liner is expected to decrease for steeper liner grades effectively increasing lateral drainage and decreasing percolation. One should note that a case study considering glacial till covers constructed in a similar climate reported percolation rates in the order of 5% of annual precipitation (see Appendix D). The average annual percolation rate of 5% or less is also supported by a more detailed soil-atmosphere modeling utilizing site-specific geotechnical conditions (see UNSAT-H results in Appendix D). Consequently, one may conclude that the average annual percolation rates for the reclaimed Category 1/2 stockpiles with established vegetation are not likely to exceed 100 gal/acre/day.

HELP simulations for open Category 3 stockpiles indicate average annual percolation rates of approximately 2 gal/acre/day. The maximum calculated daily head for the open Category 3 Waste Rock Stockpile is 3.2 inches. The calculated average annual percolation rate for the reclaimed Category 3 stockpiles is in between 0.3 and 0.5 gal/acre/day. As the Category 3 Lean Ore Stockpile is constructed with a Category 4 liner system, the average annual percolation rate for this stockpile is not likely to exceed 0.1 gal/acre/day.

The average annual percolation rate for open Category 4 stockpiles is approximately 0.1 gal/acre/day. The maximum calculated daily head for the Category 4 liner is 1.2 inches. For the reclaimed Category 4 stockpiles, the average annual percolation rate is likely to be significantly less than 0.1 gal/acre/day.

APPENDIX D

EVAPOTRANSPIRATION COVER MODELING RESULTS

APPENDIX D

ET COVER MODELING METHODOLOGY AND RESULTS FOR STOCKPILES

1.0 INTRODUCTION

This Appendix summarizes the approach and results of the Soil Cover modeling conducted by Golder Associates Inc. (Golder) to support a preliminary design and to evaluate the effectiveness of using store and release reclamation covers for the proposed waste rock stockpiles at the PolyMet NorthMet Mine Site located near Babbitt, Minnesota.

1.1 Objectives

Use a vadose zone model to estimate infiltration through the evapotranspiration (ET) cover. This memorandum describes the approach and ET cover simulations conducted to evaluate the following effects on infiltration:

- Climate;
- Cover thickness;
- Variation in material properties (coarse, fine); and
- Variation in vegetation properties.

2.0 MODELING

This section discusses:

- Model Code;
- Climate;
- Material properties;
- Vegetation properties; and
- Modeling scenarios considered.

2.1 Model Code

The simulations were conducted using the computer model code UNSAT-H. The UNSAT-H code version 3.01 (Fayer, 2000) was developed by the Pacific Northwest National Laboratory and was designed to simulate water and heat transport processes in one dimension. UNSAT-H is a finite difference model that can simulate the flow of liquid water and water vapor, the surface energy balance, soil-water extraction by plants, infiltration, water storage, water redistribution and deep drainage. The model code is widely accepted by the professional community for cover performance. The UNSAT-H has been recommended by the EPA for the hydraulic analysis and design for the RCRA/CERCLA final covers (EPA, 2002).

2.2 Climate

2.2.1 Climate Conditions

Climate conditions were simulated using the climate record from October 1, 1971 to September 30, 2001 provided by Barr Engineering on September 17, 2007. This period corresponds to the definition of the climate normal by the Climate Prediction Center of the National Weather Service (NWS). Daily precipitation data were used as a direct input into the model. Potential evapotranspiration (PET) values were calculated using the Hargreaves et al. (1985) methodology as outlined in Allen et al. (1998). The calculated PET values were scaled to match the average annual PET of 21 inches at the NorthMet site based on predictions by Baker et al. (1979). The average annual precipitation and PET values are summarized in the following table:

TABLE 2.1

AVERAGE PRECIPITATION AND PET VALUES FROM 1971 to 2000

Average Annual Precipitation (inch)	Average Annual PET (inch)	Record
29.19	21.01	10/1/1971 to 9/30/2001

2.2.2 Climate Data Used for Modeling

To realistically evaluate a long-term ET cover performance, one needs to attain “steady-state” soil conditions, i.e., a state of partial-saturation in which the cover soil material experiences seasonal fluctuations around some average moisture content. The PolyMet UNSAT-H simulations utilized the 30 year record from water year 1971 to water year 2000 to evaluate long-term infiltration estimates. For conservatism, the initial suction of 1.0 kPa was used for all simulations resulting in wet initial conditions.

The average monthly values used for UNSAT-H simulations are summarized in the following table

TABLE 2.2

AVERAGE ANNUAL CLIMATE VALUES – Water year 1971 to water year 2000

Month	**Precip. (inch)**	**Evap. (inch)**	**T_{max} (^{0}F)**	**T_{min} (^{0}F)**	**T_{avg} (^{0}F)**
January	0.9	0.1	16.3	-10.6	2.8
February	0.8	0.3	23.9	-5.4	9.2
March	1.2	0.9	36.0	8.7	22.4
April	1.8	2.1	50.9	23.2	37.0
May	3.0	3.6	65.7	34.9	50.3
June	4.1	4.2	73.2	43.5	58.4
July	4.3	4.5	77.5	48.4	63.0
August	4.2	2.8	75.3	46.3	60.8
September	3.5	0.8	64.6	37.7	51.2
October	2.8	1.2	52.0	28.3	40.2
November	1.7	0.4	34.1	14.0	24.0
December	0.9	0.1	20.6	-3.5	8.6
Annual	**29.2**	**21.0**	**49.2**	**22.1**	**35.7**

The range of recorded annual precipitation and calculated annual PET values used for UNSAT-H simulations are outlined in Table 2.3.

TABLE 2.3

RANGE OF ANNUAL PRECIPITATION AND PET VALUES

	Annual Values		
	Average	**Max.**	**Min.**
Precipitation (inch)	29.2	41.8	20.3
PET (inch)	21.0	22.8	19.4

The degree-day method was employed to determine snowmelt rates (e.g., Kustas et al., 1994) utilizing the degree-day coefficients, *a*, of 0.4 *cm/°C*. All UNSAT-H simulations were conducted assuming no freezing of surface soils during the winter season providing conservative drainage estimates.

2.3 Material Properties

Material properties for UNSAT-H simulations were estimated from laboratory data for on-site soils determined during geotechnical field investigation (Golder, 2006). Laboratory data used to estimate soil-water characteristic curves (SWCCs) and hydraulic conductivities from Golder (2006) are summarized in the following table:

TABLE 2.5

LABORATORY PROPERTIES

Sample	USCS Class.	% Gravel	% Sand	% Fines	k @ 95% Proctor (cm/s)
TP#1, Sample #3, 12' to 20'	SM w/ gravel	18	53.4	28.6	
TP#1, Sample #3, 12' to 20'	SM w/ some gravel	13	49.5	37.5	
TP#2, Sample #3, 9' to 13'	SM	4	60.4	35.6	
TP#4, Sample #1, 0.5' to 4.5'	SM	8	60.7	31.3	1.35E-07
TP#4, Sample #2, 4.5' to 13.5'	SM w/ little gravel	11	49.7	39.3	
TP#5, Sample #1, 0.5' to 4'	CL sandy w/ little gravel	13	35.6	51.4	
TP#5, Sample #3, 6' to 14'	SM	1	52	47	
TP#6, Sample #2, 15' to 20'	ML sandy	0	48.3	51.7	
TP#7, Sample #1, 0.5' to 3.5'	SM w/ gravel	17	56.5	26.5	2.04E-07
TP#8, Sample#2, 2' to 4.5'	SP w/ gravel	40	58.2	1.8	
TP#11, Sample#2, 3' to 6'	SM w/ little gravel	10	66.1	23.9	
TP#13, Sample#2, 4' to 9'	SM w/ gravel	23	51	26	1.06E-07
TP#14, Sample#2, 0.5' to 3.5'	SM	0	67	33	
TP#15, Sample#2, 4' to 11.5'	SM w/ little gravel	12	49.2	38.8	

Soil-water characteristic curves were determined by comparing the lab determined grain-size distributions for on-site soils containing more than 20% of fines with soils in the SoilVision (2006) database as shown in the attached figures at the end of this Appendix D. The SWCCs data from the SoilVision database were then used to establish the likely range of van Genuchten parameters (van Genuchten, 1980) shown in the following table:

TABLE 2.6

HYDRAULIC PROPERTIES USED FOR UNSAT-H SIMULATION

Material Type Estimate	SWCC Limit	alpha (1/cm)	N (-)	θr (-)	θsat (-)	Ksat (cm/s)
Type 1	Lower	0.0408	1.17	0.000	0.400	$1.0x10^{-5}$
Type 2	Mean	0.0102	1.28	0.045	0.450	$1.0x10^{-5}$
Type 3	Upper	0.0031	1.50	0.100	0.500	$1.0x10^{-5}$

The saturated conductivity values in Table 2.6 were estimated based on the Kozeny-Carman equation (e.g., Freeze and Cherry, 1979) and assuming loosely placed material containing macro-pores that are likely to increase the hydraulic conductivity values by approximately one order of magnitude. The estimated hydraulic conductivity value of $1x10^{-5}$ cm/s is believed to be conservative based on the reported long-term saturated conductivity values for glacial till materials. Wilson et al. (2003) report a mean conductivity value of less than $3x10^{-6}$ cm/s. Stockdill et al. (2006) also report hydraulic conductivities for ET covers constructed of glacial till on the order of $1x10^{-6}$ cm/s or lower.

Types 1, 2 and 3 in Table 2.6 correspond to different SWCCs used for UNSAT-H modeling. SWCCs data from the SoilVision database and the corresponding van Genuchten curves used for modeling are shown in Figure 4 at the end of this appendix.

2.4 Vegetation Parameters

2.4.1 Leaf Area Index (LAI)

LAI was estimated from the Worldwide Historical Estimates of Leaf Area Index 1932-2000 database (Oak Ridge National Laboratory 2001), available on-line sources and HELP recommendations (Schroeder et al., 1994). The estimated LAI values are likely to represent conservative estimates for the established grass or forest covers. In particular, the forest cover was conservatively modeled with a zero LAI outside the growing season assuming that no winter transpiration from evergreen species occurs. In addition, both grass and forest covers were simulated assuming 20% of bare ground surface which is likely to result in greater than anticipated, i.e. conservative, infiltration estimates. The LAI values used for UNSAT-H simulations are displayed in the following table.

TABLE 2.7

ANNUAL VARIATION OF LAI

Julian Day	LAI Grass	LAI Forest
1 to 144	0.0	0.0
144 to 261	2.0	4.0
261 to 365	0.0	0.0

2.4.2 Plant Limiting Moisture

The model requires input of Plant Limiting Moisture, defined as the suction below which plant stomata begin to close, reducing transpiration. A suction of -100 kPa is generally accepted as the Plant Limiting Moisture suction. Wilting point is the suction below which plants can no longer extract moisture from the soil and will permanently wilt. This value is generally considered to equal -1500 kPa, although some specie can extract moisture at much lower suctions.

2.4.3 Root Depth Functions

The model requires input of maximum rooting depth as it varies annually, and the shape of the root distribution. Root depth for a mature evergreen forest ecosystem is not expected to vary significantly seasonally. Overall root depth for evergreen forest was estimated as 3.5 meters (Canadell and others, 1996). For grass covers, the root depth was limited to 3 ft. The root distribution is often estimated using the following equation.

$$Y(d) = 1-B^{d}$$

Where:

Y = the cumulative root fraction
d = depth in cm
B = an extinction parameter.

Larger B values correspond to a greater proportion of roots at depth. The B value of 0.976 was used for UNSAT-H simulations when modeling a mature evergreen forest (Jackson and others, 1996). The root depth parameters for grass covers were adopted from UNSAT-H manual and extended to 3 ft.

From the root length density function used in UNSAT-H,

$$\rho_{rL} = a\exp(-bz) + c\,,$$

where z is the root depth and a, b and c are fitting parameters, one can construct the corresponding cumulative root length density function

$$Y_{rL}(d) = \int_0^d \left[a\exp(-bz) + c\right] \cdot dz$$

Parameters a, b and c used for UNSAT-H modeling were obtained by fitting Y with Y_{rL} obtaining the following values:

TABLE 2.8

ROOT DENSITY FUNCTION PARAMETERS

Vegetation	***a***	***b***	***c***
Forest	$2.43x10^{-2}$	$2.43x10^{-2}$	0.000
Grass	$1.08x10^{-1}$	$1.29x10^{-1}$	$1.85x10^{-3}$

2.5 Modeling Scenarios

Modeling scenarios analyzed in UNSAT-H are summarized in the following table for the range of site specific soils identified in Table 2.6 (e.g., Types 1, 2 and 3):

TABLE 2.9

MODELING SCENARIOS

Cover Thickness Subgrade	**2 ft.**	**3 ft.**	**4 ft.**
Type 1 (Lower Bound SWCC)	Bare/Grass/Forest	Bare/Grass/Forest	Bare/Grass/Forest
Type 2 (Mean SWCC)	Bare/Grass/Forest	Bare/Grass/Forest	Bare/Grass/Forest
Type 3 (Upper Bound SWCC)	Bare/Grass/Forest	Bare/Grass/Forest	Bare/Grass/Forest

Modeling scenarios summarized in Table 2.9 are created to estimate infiltration during various stages of vegetation development. “Bare” scenarios are expected to simulate performance of bare covers, i.e. cover performance during early stages or prior to the establishment of vegetation. Consequently, “Grass” scenarios are expected to provide an indication of the reclamation cover performance during early and intermediate stages of vegetation development while “Forest” scenarios simulate the long-term cover performance (i.e. ET covers performance with fully established vegetation).

3.0 RESULTS

To quantify the influence of vegetation, it is useful to evaluate infiltration through an equivalent bare ET cover. The UNSAT-H results for bare covers are shown in the following tables:

TABLE 3.1

AVERAGE ANNUAL INFILTRATION FOR BARE COVER (INCH/YEAR)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	0.3	0.3	0.3
Type 2	2.0	1.9	1.9
Type 3	6.6	6.4	6.3

TABLE 3.2

AVERAGE ANNUAL INFILTRATION FOR BARE COVER (% PRECIPITATION)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	0.9%	0.9%	1.0%
Type 2	6.8%	6.6%	6.6%
Type 3	22.5%	22.0%	21.7%

TABLE 3.3

AVERAGE ANNUAL INFILTRATION FOR BARE COVER (GAL/ACRE/DAY)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	20	20	21
Type 2	147	144	143
Type 3	488	478	470

The UNSAT-H results for grass covers are shown in the following tables:

TABLE 3.4

AVERAGE ANNUAL INFILTRATION FOR GRASS COVER (INCH)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	<0.1	<0.1	<0.1
Type 2	0.7	0.4	0.2
Type 3	5.8	5.5	5.2

TABLE 3.5

AVERAGE ANNUAL INFILTRATION FOR GRASS COVER (% PRECIPITATION)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	<0.1%	0.1%	0.1%
Type 2	2.3%	1.4%	0.7%
Type 3	20.0%	18.8%	17.9%

TABLE 3.6

AVERAGE ANNUAL INFILTRATION FOR GRASS COVER (GAL/ACRE/DAY)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	1	1	1
Type 2	49	31	15
Type 3	434	409	389

The UNSAT-H results for forest covers are shown in the following tables:

TABLE 3.7

AVERAGE ANNUAL INFILTRATION FOR FOREST COVER (INCH/YEAR)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	<0.1	<0.1	<0.1
Type 2	0.1	<0.1	<0.1
Type 3	5.2	4.6	4.3

TABLE 3.8

AVERAGE ANNUAL INFILTRATION FOR FOREST COVER (% PRECIPITATION)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	<0.1%	<0.1%	0.1%
Type 2	0.4%	0.1%	0.2%
Type 3	17.9%	15.8%	14.7%

TABLE 3.9

AVERAGE ANNUAL INFILTRATION FOR FOREST COVER (GAL/ACRE/DAY)

Cover Thickness Subgrade Type	2 ft.	3 ft.	4 ft.
Type 1	1	1	1
Type 2	9	3	4
Type 3	389	344	320

4.0 INTERPRETATION

The amount of precipitation infiltrating through the store and release cover depends on cover thickness, subgrade material and vegetation. The most significant factors influencing infiltration are the type of subgrade material and presence of vegetative species. Based on the results in Tables 3.1 to 3.9, the infiltration rates for the vegetated cover may be reduced up to hundred times comparatively to the cover without vegetation. For finer materials that are capable of retaining significant amount of moisture at higher suctions (Type 3), it might be necessary to construct thicker covers in order to mobilize the root uptake potential and reduce infiltration. It is recommended that, to the extent practical, soil cover material types 1 and 2 be selectively stockpiled for reclamation cover soils.

5.0 SUMMARY AND CONCLUSIONS

The presence of a reclamation vegetation cover is predicted to significantly reduce the infiltration rates and is likely to improve over time as the mature ecosystem is established. The ET cover modeling results indicate the importance of the cover material hydraulic properties. Therefore, during final design, it is recommended that a comprehensive site specific laboratory program is conducted to characterize the cover material hydraulic properties. The infiltration quantities presented in this study should be viewed as likely upper bound estimates due to several conservative assumptions: 1) the mature forest simulations assume cessation of transpiration during the dormant period for deciduous understory species, whereas in practice, the transpiration continues during the winter period due to the presence of evergreen species; 2) Snowmelt scenarios conservatively neglect the snow pack losses due to sublimation, therefore, the modeled spring snowmelt quantities are larger than in reality, yielding conservative infiltration estimate; 3) Effects of soil freezing were neglected whereas in reality, the soil may remain fully of partially frozen during the snowmelt events, potentially leading to significantly smaller infiltration estimates; 4) Precipitation events in all UNSAT-H simulations start at midnight and are typically over before dawn when the evaporation module is activated. In practice, at least some of the rain events occur during the daytime allowing the water from the surface soil layers to evaporate more readily at the cessation of precipitation.

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APPENDIX E

RS18 MINE PLAN

Errata to Draft 02 - RS18 Mine Plan
PolyMet Mining Inc.

October 23, 2007-10-23

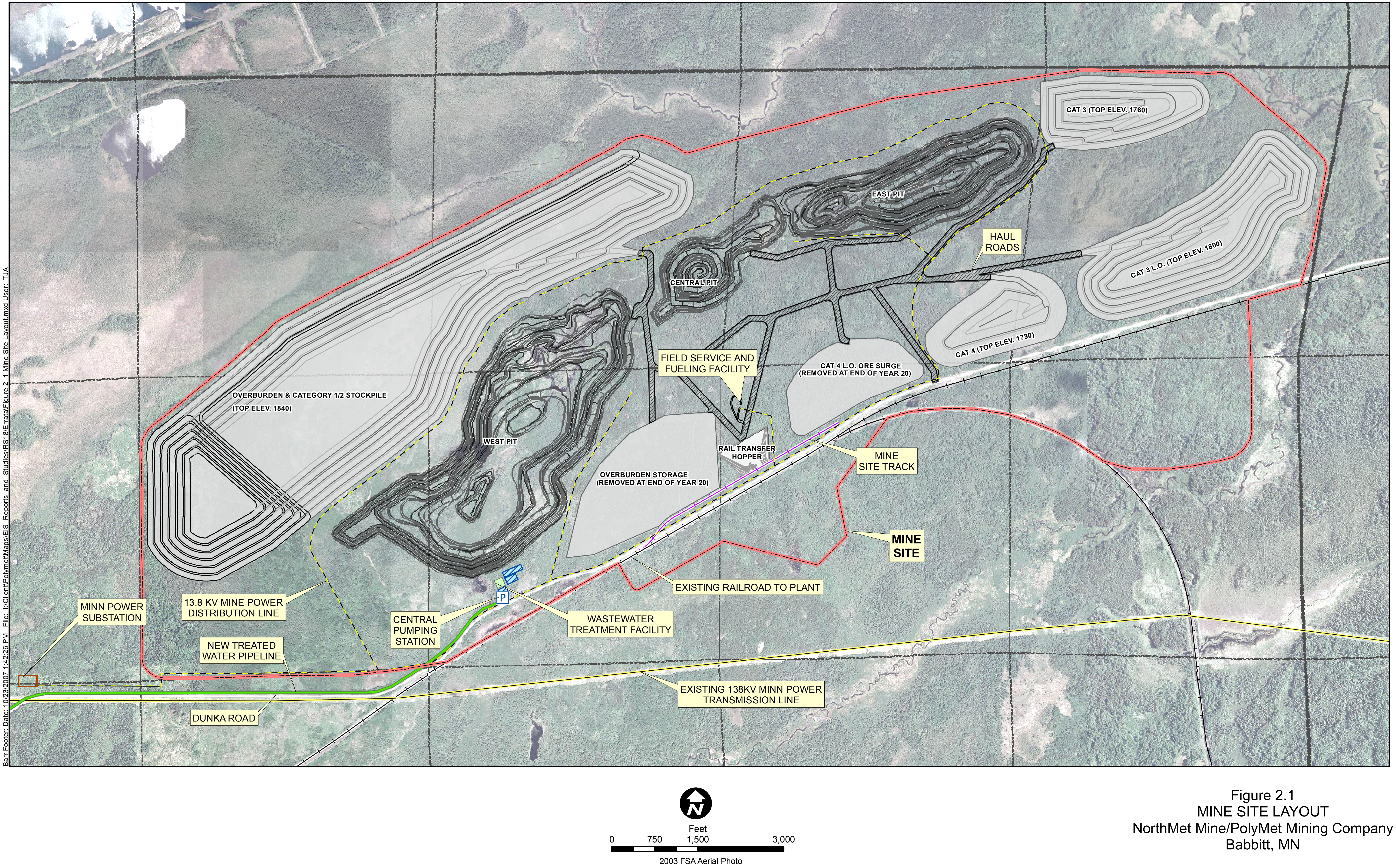
The following typographical errors have been identified in the main text of Draft 02 - RS18 Mine Plan:

- On page 4, fourth and fifth lines of first paragraph:
    - It says "An average waste/ore stripping ratio is estimated at 1.85, which will result in ***the removal of about 20.3 MT of waste rock and 1.4 MT of glacial till annually***."
    - It should say "An average waste/ore stripping ratio is estimated at 1.85, which will result in ***approximately 19.7 MT of average annual waste rock movement and 1.4 MT of glacial till annually removed***."

- On page 8, last sentence of first paragraph:
    - It says "This category comprises approximately ***15*** percent of the total waste rock volume."
    - It should say "This category comprises approximately ***14*** percent of the total waste rock volume."

- On page 8, last sentence of second paragraph:
    - It says "This category comprises approximately ***two*** percent of the total waste rock volume."
    - It should say "This category comprises approximately ***three*** percent of the total waste rock volume."

In addition, Figure 2.1 – Mine Site Layout – NorthMet Mine/PolyMet Mining Company – Babbitt, Minnesota has been updated and is attached at the end of this Errata.



2003 FSA Aerial Photo

Figure 2.1
MINE SITE LAYOUT
NorthMet Mine/PolyMet Mining Company
Babbitt, MN

Barr Footer: Date: 10/23/2007 1:42:26 PM File: I:\Client\Polymet\Maps\EIS Reports and Studies\RS18\Errata\Figure 2 1 Mine Site Layout.mxd User: TJA

RS18 Mine Plan

PolyMet Mining Inc.

September 2007

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PolyMet—RS18 Mine Plan

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Project Location and Setting

PolyMet's land ownership interests comprise surface ownership, which includes a former taconite processing plant, now known as the Erie Plant, and mineral rights, which cover a large, polymetallic deposit known as the NorthMet deposit which lies approximately eight miles to the east of the Erie Plant at Latitude 47º 36′ north, Longitude 91º 58′.

PolyMet has acquired by contract for deed, surface ownership of approximately 14,400 acres of real property (see Figure 1.2) and the former LTVSMC (LTV Steel Mining Company) Taconite Processing Plant, comprising selected parts of a taconite processing facility formerly owned by Cliffs Erie LLC. This property includes crushing and concentrating facilities, tailings basin, warehouses, repair shops, and office buildings that will be re-used by PolyMet and space to construct new, hydrometallurgical—processing facilities. PolyMet also acquired a fleet of 120-ore cars that will be used for rail transport of ore.

Although there has not been any prior mining on the site, the NorthMet deposit is surrounded by mining and industrial activity. The Northshore taconite open pit, which is situated less than two miles to the north, is currently active. This open pit reportedly has remaining reserves sufficient to sustain an operation for 50 years or more. There are several former LTVSMC waste-rock stockpiles and idled taconite open pits less than four miles to the west of the PolyMet site. A now-depleted taconite open pit, known as the Dunka Pit, and its associated waste stockpiles are situated approximately eight and a half miles to the east.

The entire area has been extensively and repeatedly logged over many years with the result that there is no old-growth timber in the area. Parts of the NorthMet site itself have been clear-felled, some as recently as last year.

The Dunka Road, which runs eastwards from the Erie Plant site past the NorthMet deposit and on towards the Dunka Pit, is the only road access to the mine site and is privately owned. Access to the Dunka Road is via a security gate manned 24 hours a day; therefore, there is no public access to the mine site. The nearest permanent dwellings to the NorthMet deposit are at the City of Babbitt, approximately six and a half miles to the north.

A Minnesota Power 138kV power line runs near the Dunka Road in the vicinity of the mine site and an agreement is in place for Minnesota Power to provide a 138kV to 13.8kV substation at the mine site.

A trackage usage agreement is in place that allows PolyMet to connect to the Cliffs Erie private railroad and transport ore from the mine site to the primary crusher on a combination of Cliffs Erie and PolyMet track.

Advantage will be taken of the mine's proximity to former LTVSMC facilities to minimize additional environmental impacts resulting from construction of mine infrastructure. In particular, rather than construct new mine infrastructure and facilities at NorthMet, it is planned to refurbish and reactivate two former LTVSMC facilities known as the Area 1 Workshops and the Area 2 Workshops. The Area 1 Shops comprise heavy mine equipment maintenance facilities located approximately one mile west of the Erie Plant. This facility will be refurbished and reactivated as a mine equipment maintenance and repair facility and obviates the need to construct a new facility at the mine. The Area 2 Shops, situated about six miles to the west of NorthMet, comprise workshops and railroad maintenance and service facilities. These, too, will be refurbished and reactivated to provide office and change-room facilities for mine and railroad operations personnel. An existing, but now idle, locomotive service and refueling facility at the Area 2 Shops will be reactivated and restored to its former use. An existing, but now idle, car service and maintenance facility at the General Shops will be reactivated and restored to its former use. With regard to the mine site, PolyMet's strategy has been to avoid new construction wherever possible, even if this will be at the expense of operating costs.

Open Pit Mine

The NorthMet deposit will be developed using open pit methods similar to those currently in use at other locations on the Iron Range. At full, steady state production, an average daily ore mining rate of 32,000 tons per day will be achieved. This is equivalent to an average annual ore production of 11.7 million tons (MT). An average waste/ore stripping ratio is estimated at 1.85, which will result in the removal of about 20.3 MT of waste rock and 1.4 MT of glacial till annually. The total amount of material moved annually will be approximately 33.4 MT. The mine will operate 24 hours per day, 365 days per year. Mining will be carried out using diesel or electric powered blast-hole drills and excavators and diesel-powered front-end loaders, haul trucks, and auxiliary equipment. Ore-grade material will be truck-hauled from the pit to a rapid train-loading facility (rail transfer hopper) to provide live buffer storage capacity between the truck haulage operation from the mine and the rail haulage operation to the primary crusher. Ore will then be loaded into railcars and rail-hauled to the processing plant. Waste rock and lean ore will be truck-hauled to waste-rock stockpiles. Stockpiled waste rock will be categorized based on chemical parameters and will be placed on lined stockpiles according to the specifications of the Waste Rock Management Plan (RS43).

Key Mining Operation Parameters

Full mine production will be preceded by a period of pre-production mine development of about nine months and then a gradual ramp-up of output to reach full capacity. The mine ramp-up rate will be determined by the commissioning and ramp-up activities in the ore beneficiation plant.

Pre-production mine development will include the following activities:

- Upgrading of the existing Dunka Road (gravel) for safe use.
- Construction of site access roads.
- Construction of surface water exclusion dikes. (RS25)
- Clearance of vegetation and harvesting of commercial timber by a third party.
- Removal and stockpiling of topsoil and organic matter for later use in site re-vegetation.

- Construction of mine infrastructure, including a mine wastewater treatment plant, central pumping station, rail transfer hopper, power line, water pipeline to plant site, and the mine-field service, lubrication, and re-fueling facility.

- Construction of engineered foundation and liner system for waste-rock stockpiles. (RS49)

- Construction of surface water collection and drainage ditches, water collection ponds, and settlement sumps. (RS21, 22, and 24)

- Removal of glacial till overburden from areas to be mined during the first one to two years of mining to expose underlying bedrock.

- Continued pre-production in-fill drilling for further delineation of ore and waste zones and for detailed planning and scheduling of pre-stripping and early-phase production mining activities.

- Pre-stripping of waste rock to expose sufficient ore to maintain production once construction is completed.

- Construction of a railroad-connection spur from the rail-transfer hopper to the existing railroad line.

Maintenance and upgrading of the existing Dunka Road, including the site access road, will be carried out prior to any mining activities. This activity will be out-sourced and the contractor will provide a mobile crushing plant to prepare road stone and construction aggregate from locally available construction quality rock. Construction rock sources will be from PolyMet-owned taconite mining waste rock and overburden stockpiles from LTVSMC Area 5 (see Figure 2.2) and/or from mine site overburden removal.

Mine roads will also be constructed at this time. Category 1 waste rock produced during the pre-production waste stripping operation will be crushed and screened and used for mine-site and haul-road construction, as approved by Mn/DNR. If sufficient material is not available or the use of Category 1 waste rock is not approved, rock will be obtained from PolyMet-owned taconite waste rock stockpiles at Area 5 or by screening/crushing rocks from the overburden at the Mine Site.

Disturbances within the project area will be caused by mining and waste-rock stockpiling, the creation of site access roads and mine haul roads, the construction of a rail spur off the existing railroad, and the construction of other mine infrastructure. While most elements of mine development must be complete by the start of mining operations, vegetation clearance, topsoil removal, overburden stripping, and construction of the impermeable base to stockpiles will be done progressively with no more ground disturbed at any one time than is necessary.

One of the principle requirements of the mine pre-production development phase will be to define and expose sufficient ore to provide a buffer between ore mining and waste rock removal. In a mature pit of this type, it is not uncommon to carry up to 12 months of exposed ore that is available for mining without further waste-rock stripping. Exposed ore will consist of blasted, drilled not blasted, and exposed ores that are ready for drilling and blasting. The percentage of blasted ore, drilled not blasted, and exposed ore will essentially change daily. For example, overburden stripping today will increase the amount of exposed ore and waste rock; ore that is exposed today may be drilled tomorrow. Since the plant feed rate will build up progressively as metallurgical operations ramp up, mining will be scheduled so that the amount of exposed ore available in the pit also progressively increases to provide an adequate production buffer between mining and metallurgical operations. In this case, the ramp-up to full mine production will be governed by the rate of production ramp-up in the beneficiation plant. Thus, in-pit broken and exposed ore stocks will be built up progressively during the pre-production and ramp-up periods to provide an adequate stock of readily accessible ore to ensure continuity of plant feed.

The mine-site layout is shown in Figure 2.1. The rail transfer hopper will be located at original ground elevation and about 1000 feet from the southern edge of the ultimate pit (1000 feet is an adequate clearance to avoid possible damage from blast-fly rock). As ore is excavated, waste rock and lean ore will also have to be excavated.

Equipment fueling and minor service will be done at the mine site. A field service, lubrication, and re-fueling facility will be provided in the vicinity of the rail transfer hopper. This facility will consist of a roofed structure with enclosed sides but open at each end to allow equipment to drive through. The structure will be provided with a reinforced concrete floor suitably graded to allow drainage to a sump to collect any spillage and oil-contaminated water. The sump will periodically be pumped out by a suitably licensed disposal contractor. In addition to refueling systems, there will also be dispensing equipment for lubricating and hydraulic oils. The building will contain limited-capacity storage tanks. Bulk oil storage tanks, enclosed with a suitable spill containment system, will be provided a safe distance away. Interior and area lighting will be provided to enable safe operation at nighttime. Emergency shut-off valves will also be provided. A metering system will accurately record the amount of fuel oil dispensed to each vehicle.

A mine wastewater treatment plant and central pumping station will be located south of the west pit location. Mine-pit dewatering, stockpile-liner drainage, surface-water runoff from the rail transfer hopper area and surface-water runoff from stockpiles that have not been covered will all be pumped to the mine wastewater treatment plant for treatment prior to reaching the central pumping station from where all mine site water will be pumped to the tailings basin. Water management systems are detailed in RS29T.

A key concept in waste-rock stockpile design is the distinction between waste rock that will not generate acid drainage or drainage with metal concentrations in excess of appropriate water quality discharge limits and rock that may generate acid drainage or drainage with metal concentrations in excess of appropriate water quality discharge limits. Waste rock will be categorized according to its geochemical properties and acid-generating and metals-leaching capability. A density of 2.45 short tons per cubic yard (in place) was used for all waste rock/lean ore stockpile design, and a porosity of 30 percent was also used. Overburden densities were calculated to be 1.84 short tons per cubic yard, and a porosity of 20 percent was used. There are four categories of waste rock and one category of overburden:

- **Category 1—**(construction rock) sulphur content less than or equal to 0.12%S. (construction rock at alternate %S cut-offs can be found in Appendix A) This material will not generate ARD but may leach heavy metals. This material comprises approximately 70 percent of the total waste rock and can be used as a construction material at the mine site as approved by the Mn/DNR.

- **Category 2—**sulphur content is less than or equal to 0.12%S or greater than 0.12%S but less than or equal to 0.31%S with a Cu/S ratio of less than or equal to 0.3. This material will not generate ARD but may leach heavy metals that result in drainage with heavy metal concentrations in excess of water quality discharge limits. Category 2 material comprises approximately 13 percent of the total waste-rock volume.

- **Category 3—**material with greater than 0.12%S with a Cu/S ratio of more than 0.3 or a sulphur content greater than 0.31%S but less than or equal to 0.6%S. This material may eventually generate ARD and may leach heavy metals that result in drainage with heavy metal concentrations in excess of appropriate water quality discharge limits. This category comprises approximately 15 percent of the total waste rock volume.

- **Category 4—**material with greater than 0.6%S and all Virginia Formation rock which will generate ARD rapidly and leach heavy metals that result in drainage with heavy metal concentrations in excess of water quality discharge limits. This category comprises approximately two percent of the total waste rock volume.

> Category 3 and Category 4 are further subdivided into waste rock and lean ore with the criteria for lean ore being economic rather than geochemical. Lean ore is material that is not economic at the time of mining but could become economic in the foreseeable future.

Overburden—loose or consolidated material such as glacial till, clay, peat, and soils that overlie sulphide deposits may contain metals that have been leached out of the deposit. Waste characterization will be done to determine the values of leached metals (Cu, Ni, Co, Zn) in the overburden that may result in releaching to the degree that a water-quality discharge limit will be exceeded. If these values exceed discharge limits, the overburden will be placed on the lined portion of the Category 1/2 stockpile or used in approved construction applications. If the limits are not exceeded, the overburden will be placed on the unlined portion of the Category 1/2 stockpile or used in Mn/DNR-approved construction applications.

Once bedrock is exposed, a significant amount of Category 1 waste rock will be generated and used for aspects of mine infrastructure civil construction to form the base of waste-rock stockpiles and provide fill and sheeting material for construction as approved by Mn/DNR. Some major construction activities and approximate quantities include: construction of in-pit haul roads (10 MT), pit access roads (0.7 MT), stockpile foundations (20 MT), the rail transfer hopper platform (0.6 MT). Other activities that will necessitate construction rock include: railroad bedding, culvert bedding, and safety berming in the mine area.

Stockpiles will be located around the pit perimeter. Category 1/2 waste-rock stockpiles and Category 3 waste-rock stockpiles will be north of the mine pits. Both the Category 3 and 4 lean-ore stockpiles and the Category 4 waste-rock stockpile will be south of the mine pits nearer the rail transfer hopper. Surface overburden will be permanently stockpiled within the west end of the Category 1/2 stockpile. A smaller overburden screening/sorting/storage area will be located near the rail transfer hopper for reclamation use. The stockpiles will be built progressively upward and outward on an "as required" basis to minimize the up-front impact on the environment. This will allow staged development, wetlands mitigation, and reclamation. As one stockpile area fills, a new stockpile area will be opened. Once the new area is in use, the former area will be reclaimed. Current plans are for the active areas to be large enough to contain three to four year's production of waste rock and lean ore.

Pit Design and Schedule

Mine plan maps, which include the pit and stockpile outlines and mining infrastructure, are shown in Figures 3.1 through 3.5 and depict years 1, 5, 10, 15, and 20 of mine operation. Cross-sections of both the proposed pits and stockpiles are shown in Figures 3.6 and 3.7. The pit configuration and mining plan are based on computer modeling using data from exploration drilling analyzed and included in the model to date. The data collected from drilling conducted prior to the start of mining will add definition to the mine model and, hence, mine scheduling. The pit configuration, staging, and stockpile layout will be progressively refined prior to the start of mining and throughout the 20-year life of the mine. Prices of metals, energy, labor, and other factors determine the optimum mine plan; as these change, the mine plan will be adjusted. It is not expected that these changes will result in a significant change in environmental impact.

Several basic parameters shape the final mine configuration: the northwest edge of the mine is constrained by the northward extent of the Duluth Complex, which hosts the mineral deposit. The footwall (northwest) side of the pit will follow the mineralization, which dips southeast at about 25 degrees and roughly parallels the top of the Virginia Formation. The overall slope of the south wall of the pit is based on geotechnical design data, which was collected during the drilling program. The mine will be developed in a series of benches, which will be accessed by ramps and is wide enough to accommodate broken ore, mine traffic, and water sumps. Geotechnical criteria for mine pit design are detailed in RS09.

Table 3.A shows tons of ore moved for years 0 through 20. Because of the distribution of ore in the deposit and the need to develop access to the working faces of the pit and the need to deliver a steady annual flow of ore to the process plant, a lean ore surge pile is required. Ore will flow into and out of this pile, which will reach a maximum tonnage of 5.5 MT in year 13. The lean ore surge pile will contain Category 4 material and will be lined and managed accordingly.

Table 3.A Ore Movement

Ore Movement					
			Lean Ore Surge Pile		
Year	**Mined**	**To Plant**	**To**	**From**	**Balance**
0	78,335		78,335	0	78,335
1	6,468,692	6,497,515	0	28,823	49,512
2	11,934,642	11,680,000	254,642	0	304,154
3	13,903,050	11,680,000	2,223,050	0	2,527,204
4	10,469,506	11,680,000	0	1,210,494	1,316,710
5	12,691,704	11,680,000	1,011,704	0	2,328,414
6	12,599,220	11,680,000	919,220	0	3,247,633
7	12,729,069	11,680,000	1,049,069	0	4,296,702
8	9,878,679	11,680,000	0	1,801,321	2,495,381
9	11,079,752	11,680,000	0	600,248	1,895,133
10	14,013,411	11,680,000	2,333,411	0	4,228,544
11	11,120,755	11,680,000	0	559,245	3,669,298
12	12,735,906	11,680,000	1,055,906	0	4,725,205
13	12,443,434	11,680,000	763,434	0	5,488,638
14	11,271,732	11,680,000	0	408,268	5,080,370
15	6,857,189	11,680,000	0	4,822,811	257,559
16	11,422,441	11,680,000	0	257,559	0
17	15,663,317	11,680,000	3,983,317	0	3,983,317
18	11,660,624	11,680,000	0	19,376	3,963,941
19	11,794,752	11,680,000	114,752	0	4,078,693
20	7,286,269	11,364,962	0	4,078,693	0
Total	**228,102,477**	**228,102,477**	**13,786,839**	**13,786,839**	**0**

Table 3.B shows tons of waste rock moved for years 0 through 20 by category. About 83 percent of the waste rock is Category 1 or 2, 14.3 percent is Category 3, and 2.7 percent is Category 4. Category 1 and Category 2 waste rock will be commingled into one stockpile. There is sufficient Category 3 lean ore to warrant a separate Category 3 lean ore stockpile so that lean ore can be recovered later. Category 4 lean ore will be placed in the lean ore surge pile near the rail transfer hopper.

Table 3.B Waste Rock Movement

Waste Rock Mined						
Year	**Cat 1/2**	**Cat 3**	**Cat 3 Lean Ore**	**Cat 4**	**Cat 4 Lean Ore**	**Total**
0	18,203	0	0	74,559	0	92,762
1	6,187,320	214,660	1,605,061	8,208	0	8,015,248
2	16,503,153	225,169	1,793,557	252,209	9,005	18,783,092
3	13,715,483	597,893	2,129,494	1,254,741	0	17,697,612
4	14,636,063	854,261	1,701,833	1,025,464	0	18,217,621
5	22,776,226	561,879	1,070,203	1,173,278	71,027	25,652,613
6	17,198,285	627,254	1,347,766	1,398,799	124,855	20,696,959
7	10,907,307	469,536	1,288,444	637,857	140,799	13,443,943
8	28,131,562	743,072	2,495,861	498,023	160,832	32,029,350
9	15,480,940	604,242	1,093,809	581,364	125,119	17,885,475
10	18,988,087	431,299	1,769,310	464,726	178,297	21,831,718
11	11,078,713	703,394	1,251,543	653,878	186,248	13,873,776
12	20,819,956	1,243,567	3,202,453	188,528	187,144	25,641,648
13	16,077,320	1,027,466	2,861,908	98,160	158,747	20,223,601
14	14,286,631	919,439	2,330,837	26,241	88,532	17,651,680
15	22,878,678	860,386	4,775,347	77,016	34,564	28,625,991
16	18,526,917	547,644	3,650,319	110,320	88,755	22,923,956
17	14,580,631	715,639	1,491,121	59,945	168,404	17,015,740
18	17,036,139	931,031	1,903,476	58,422	52,919	19,981,987
19	13,620,063	886,215	1,605,809	59,243	8,723	16,180,054
20	13,625,514	1,591,732	2,101,973	191,726	106,190	17,617,135
Total	**327,073,193**	**14,755,777**	**41,470,125**	**8,892,706**	**1,890,162**	**394,081,962**

Table 3.C shows the overburden balance in cubic yards for 20 years of production. Overburden stripping will be greatest at the initial stages of the project as the mine pit and stockpile footprints will be exposed down to bedrock. Approved and suitable overburden will be used as construction material for stockpile foundation and liner system construction also during these initial years. As stockpile footprint perimeters are reached, suitable and approved overburden can also be used for final reclamation of stockpile slopes and benches. See Appendix B for potential construction applications.

Approved and suitable overburden will be placed in the overburden storage area for screening and segregating before being used for either foundation/liner system construction or reclamation. The overburden balance does not account for the percentage of organic materials. However, these organic materials will be of important use as a reclamation material, in which fertilizing and seeding can be greatly diminished in final reclamation. If this organic material is found in measurable quantities during stripping operations, it will immediately be placed in areas of need of final reclamation covering. If those areas are exhausted, this organic material will be stockpiled in the overburden storage area for use when conditions allow.

Table 3.C Overburden Balance

	Overburden Balance (CY)					
	Overburden Stripping (Cut)		Overburden Use (Fill)			**cumulative**
	in place	20% porosity	foundation	reclamation	balance	**balance**
Year 0-1	6,122,968	7,653,711	1,687,944	-	5,965,766	5,965,766
Year 2-5	7,928,418	9,910,522	2,703,440	652,139	6,554,944	12,520,710
Year 6-10	9,615,833	12,019,791	2,861,302	1,323,179	7,835,310	20,356,021
Year 11-15	4,223,566	5,279,457	791,386	2,318,214	2,169,858	22,525,878
Year 16-20	-	-	-	962,028	(962,028)	21,563,851
Total	27,890,785	34,863,481	8,044,071	5,255,559	21,563,851	

Table 3.D shows tons of waste rock placed in stockpiles or the east pit for years 0 through 20. Various mining sequences were investigated and an opportunity to minimize project impact was explored and has been selected. The proposed mining sequence exhausts the east pit in year 11 and thus would allow for waste rock to be disposed subaqueously in the east pit. 151 MT, about 38 percent of the Category 1/2 waste rock will be available for in-pit disposal after year 11. To ensure that all in-pit stockpiled material remain subaqueous, capacity calculations were done at a stockpiled depth five feet below the final water elevation, and this calculated capacity for in-pit stockpiling in the east pit was 125 MT. The remaining 26 MT of Category 1/2 waste rock would be consumed as approved construction rock during initial construction (32 MT required – see Appendix C for potential construction applications). If additional Category 1/2 waste rock were required to be stockpiled, an addition 40-foot lift could be placed upon the Category 1/2 stockpile (13 MT) without significant impact to water balance or water chemistry. A second additional lift would add another 10 MT; a third would add another 7 MT. As a contingency, any additional Category 1/2 waste rock could also be stockpiled within selected areas of the west pit between year 122 and year 20. During in-pit disposal, the water level will be managed so that the disposal will essentially be subaqueous. This has been taken into account in the pit water chemistry model (RS31).

The final design for pit backfilling will be to fill the pit to an elevation such that a layer of overburden can be placed on top of the waste rock and the top of the overburden layer will be at an elevation near the water elevation to generate wetlands. The lean ore surge pile and the overburden storage area will also be reclaimed to create wetlands. The details of these plans and other closure plans are in RS52.

Table 3.D Waste-Rock Stockpiles

Waste-Rock Stockpiles						
Year	**Cat 1/2**	**Cat 3**	**Cat 3 Lean Ore**	**Cat 4**	**Cat 4 Lean Ore**	**In Pit/ Construction**
0	18,203	0	0	74,559	0	
1	6,187,320	214,660	1,605,061	8,208	0	
2	16,503,153	225,169	1,793,557	252,209	9,005	
3	13,715,483	597,893	2,129,494	1,254,741	0	
4	14,636,063	854,261	1,701,833	1,025,464	0	
5	22,776,226	561,879	1,070,203	1,173,278	71,027	
6	17,198,285	627,254	1,347,766	1,398,799	124,855	
7	10,907,307	469,536	1,288,444	637,857	140,799	
8	28,131,562	743,072	2,495,861	498,023	160,832	
9	15,480,940	604,242	1,093,809	581,364	125,119	
10	18,988,087	431,299	1,769,310	464,726	178,297	
11	11,078,713	703,394	1,251,543	653,878	186,248	
12	0	1,243,567	3,202,453	188,528	187,144	20,819,956
13	0	1,027,466	2,861,908	98,160	158,747	16,077,320
14	0	919,439	2,330,837	26,241	88,532	14,286,631
15	0	860,386	4,775,347	77,016	34,564	22,878,678
16	0	547,644	3,650,319	110,320	88,755	18,526,917
17	0	715,639	1,491,121	59,945	168,404	14,580,631
18	0	931,031	1,903,476	58,422	52,919	17,036,139
19	0	886,215	1,605,809	59,243	8,723	13,620,063
20	0	1,591,732	2,101,973	191,726	106,190	13,625,514
Total	**175,621,343**	**14,755,777**	**41,470,125**	**8,892,706**	**1,890,162**	**151,451,850**

Appendix A

Construction Rock - Alternate %S Cutoffs

	< 0.02%S					< 0.05%S					< 0.12%S				
		%S	%Cu	%Ni	ppm Co		%S	%Cu	%Ni	ppm Co		%S	%Cu	%Ni	ppm Co
year	Tons	Avg	Avg	Avg	Avg	Tons	Avg	Avg	Avg	Avg	Tons	Avg	Avg	Avg	Avg
0	18,203	0.01	0.01	0.02	41	18,203	0.01	0.01	0.02	41	18,203	0.01	0.01	0.02	41
1	94,310	0.01	0.01	0.03	65	3,023,646	0.03	0.02	0.03	57	5,921,357	0.05	0.03	0.03	54
2	285,463	0.01	0.01	0.02	43	7,499,615	0.03	0.02	0.03	58	15,985,922	0.05	0.03	0.03	55
3	114,396	0.01	0.01	0.01	34	3,152,591	0.03	0.02	0.02	53	12,546,335	0.06	0.03	0.02	53
4	208,183	0.01	0.01	0.02	43	3,409,641	0.03	0.01	0.01	42	12,819,476	0.06	0.03	0.02	46
5	76,181	0.01	0.01	0.01	41	5,956,051	0.04	0.01	0.02	43	20,880,328	0.06	0.02	0.02	47
6						2,682,881	0.04	0.02	0.02	44	14,843,973	0.06	0.03	0.02	49
7	148,923	0.01	0.01	0.01	47	2,616,799	0.03	0.01	0.02	48	9,369,308	0.06	0.03	0.02	50
8	150,553	0.01	0.01	0.03	57	9,512,754	0.03	0.02	0.02	53	25,268,423	0.05	0.02	0.02	52
9						4,811,799	0.03	0.02	0.02	51	13,636,590	0.06	0.03	0.02	52
10	18,621	0.01	0.01	0.02	43	7,018,959	0.03	0.02	0.02	54	17,427,921	0.05	0.02	0.02	53
11	76,264	0.01	0.01	0.01	34	3,674,788	0.03	0.02	0.03	56	9,461,426	0.05	0.02	0.02	53
12	37,746	0.01	0.01	0.02	46	3,808,769	0.03	0.02	0.02	53	16,870,997	0.06	0.03	0.02	51
13						1,668,670	0.03	0.02	0.02	50	11,920,613	0.07	0.03	0.02	50
14						1,613,352	0.03	0.02	0.02	48	11,107,525	0.07	0.03	0.02	50
15	38,132	0.01	0.01	0.01	35	5,163,185	0.03	0.02	0.03	58	20,390,217	0.07	0.03	0.03	55
16						5,818,319	0.03	0.02	0.03	58	16,644,003	0.06	0.03	0.03	57
17	57,045	0.01	0.01	0.02	43	4,809,550	0.03	0.02	0.02	54	12,389,603	0.06	0.02	0.02	54
18	19,227	0.01	0.01	0.03	54	4,910,490	0.03	0.02	0.02	52	13,742,093	0.06	0.02	0.02	52
19	131,874	0.01	0.01	0.03	53	3,213,710	0.03	0.02	0.02	51	10,777,140	0.06	0.03	0.02	49
20	38,005	0.01	0.01	0.03	53	3,020,632	0.03	0.01	0.02	45	9,654,787	0.06	0.02	0.02	47
tot	1,513,127					87,404,406					281,676,240				
avg		0.01	0.01	0.02	46		0.03	0.02	0.02	52		0.06	0.03	0.02	52

Appendix B

Potential Construction Overburden Applications

Potential Application	Rationale	Estimated Tons
Top Cover for Roads in Pit	Operations: Water contacting this material flows into the pit and is collected and pumped to the Mine Site WWTF. Closure: Most of this material will be submerged. Water contacting this material will flow into the pits, which are part of the water treatment system.	0.7 MT
Top Cover for Roads from Pit to Stockpiles and Rail Transfer Hopper	Operations: Water contacting this material is part of the process water system (isolated from the stormwater system by ditches and dikes) and is collected and pumped to the Mine Site WWTF. Closure: Roads not needed for access will be reclaimed. Water that contacts this material will drain to the pits, which are part of the water treatment system.	0.7 MT
Rail Transfer Hopper and Ore Handling Area Foundation	Operations: Water contacting this material is part of the process water system (isolated from the stormwater system by ditches and dikes) and is collected and pumped to the Mine Site WWTF. Closure: The ore handling area will be reclaimed and a cover system placed on the Rail Transfer Facility.	0.6 MT
Ore Surge Pile Foundation and Liner System	Operations: Water contacting this material is part of the process water system (isolated from the stormwater system by ditches and dikes) and is collected and pumped to the Mine Site WWTF. Closure: The ore surge pile will be reclaimed	0.8 MT
Category 1 / 2 Waste Rock Stockpile Foundation and Liner System	Operations: Water contacting this material is collected in the liner and foundation drains and becomes part of the process water system and is collected and pumped to the Mine Site WWTF. Closure: Potential for water contact is further reduced because of the stockpile cover system. Water that contacts this rock will drain to the pits, which are part of the water treatment system.	6.2 MT

Potential Construction Overburden Applications

Potential Application	**Rationale**	**Estimated Tons**
Category 3 and 4 Stockpile Foundations and Liner Systems	Operations: Water contacting this material is collected in the liner and foundation drains and becomes part of the process water system and is collected and pumped to the Mine Site WWTF. Closure: Potential for water contact is further reduced because of the stockpile cover system.	1.8 MT
Stockpile Reclamation and Cover systems	Closure: Water percolating through this material will be collected on the stockpile liner system. Water running on the material will be in contact with a vegetation system.	5.3 MT

Appendix C

Potential Construction Rock Applications

Potential Application	**Rationale**	**Estimated Tons**
Ramps and Roads in Pit	Operations: Water contacting this rock flows into the pit and is collected and pumped to the Mine Site WWTF. Closure: Most of this rock will be submerged. Water contacting this rock will flow into the pits, which are part of the water treatment system.	10 MT
Roads from Pit to Stockpiles and Rail Transfer Hopper	Operations: Water contacting this rock is part of the process water system (isolated from the stormwater system by ditches and dikes) and is collected and pumped to the Mine Site WWTF. Closure: Roads not needed for access will be reclaimed. Water that contacts this rock will drain to the pits, which are part of the water treatment system.	0.7 MT
Rail Transfer Hopper and Ore Handling Area Foundation	Operations: Water contacting this rock is part of the process water system (isolated from the stormwater system by ditches and dikes) and is collected and pumped to the Mine Site WWTF. Closure: The ore handling area will be reclaimed and a cover system placed on the Rail Transfer Facility.	0.6 MT
Ore Surge Pile Foundation	Operations: Water contacting this rock is part of the process water system (isolated from the stormwater system by ditches and dikes) and is collected and pumped to the Mine Site WWTF. Closure: The ore surge pile will be removed and reclaimed	0.8 MT

Potential Construction Rock Applications

Potential Application	Rationale	Estimated Tons
Category 1 / 2 Waste Rock Stockpile Foundation	Operations: Water contact with this rock is limited because the rock is below the stockpile liner system. Water contacting this rock is collected in the foundation drains and becomes part of the process water system and is collected and pumped to the Mine Site WWTF. Closure: Potential for water contact is further reduced because of the stockpile cover system. Water that contacts this rock will drain to the pits, which are part of the water treatment system.	7.8 MT
Category 3 and 4 Stockpile Foundations	Operations: Water contact with this rock is limited because the rock is below the stockpile liner system. Water contacting this rock is collected in the foundation drains and becomes part of the process water system and is collected and pumped to the Mine Site WWTF. Closure: Potential for water contact is further reduced because of the stockpile cover system.	1.1 MT

Appendix D

Stockpile	Location	Lease	CY	Crude Iron	Mag Fe	Iron	Sil
5020	Deposited on SE-SW, SW-SE 36-60-14, NE-NW, NW-NE 1-59-14	Fee	1,719,080	26	9	53	18
5021	Deposited on E1/2-SW, SE1/4 36-60-14	3012	1,117,948	25	10	55	18
5021	Deposited on E1/2-SW, SE1/4 36-60-14	Fee	1,007,578	27	11	56	17
5021	Deposited on E1/2-SW, SE1/4 36-60-14	L'year 2	1,663,946	25	10	55	18
5022	Deposited on SE-NW, SW-NE, NW-SE & NE-SW 1-59-14	Fee	1,364,519	27	10	56	16
5023	Deposited on SW-NW, SE-NW 1-59-14	Fee	201,900	28	10	56	19
5024	Deposited on NW1/4 1-59-14	Fee	772,626	27	10	56	18
5025	Deposited on NE-NW & SE-NW 1-59-14	Fee	194,220	28	10	56	19
5026	Deposited on NW-SW & SW-NW 1-59-14 & SE-NE & NE-SE 2-59-14	Fee	1,161,515	27	10	56	19
5026	Deposited on NW-SW & SW-NW 1-59-14 & SE-NE & NE-SE 2-59-14	Steph 1a	65,885	26	10	54	17
5027	Deposited on NW-SE, NE-SE & SW-SE 2-59-14	Fee	411,681	27	10	56	18
5027	Deposited on NW-SE, NE-SE & SW-SE 2-59-14	Steph 1a	648,239	26	10	54	17
5028	Deposited on SW-NE & NW-SE 2-59-14	Fee	188,430	28	10	56	19
5029	Deposited on NW-NE & SW-NE 2-59-14	Fee	344,902	27	10	56	19
5029	Deposited on NW-NE & SW-NE 2-59-14	Steph 1a	4,980	26	10	54	17
5030	Deposited on NW-NE & SW-NE 1-59-14	Fee	380,430	27	10	56	18
5031	Deposited on NW-SE, SW-SE & SE-SW 2-59-14	Fee	2,197	28	10	56	19
5031	Deposited on NW-SE, SW-SE & SE-SW 2-59-14	Steph 1a	409,051	26	10	54	17
5032	Deposited on NW-SW & NE-SW 1-59-14	Fee	167,643	28	10	56	19
5032	Deposited on NW-SW & NE-SW 1-59-14	Steph 1a	30,332	26	10	54	17
4006	Deposited on NE-SW 1-59-14	Fee	54,266	26	14	58	17
4008	Deposited on SE-NW, SW-NE & NW-SE 12-59-14	duNord 1	98,301	26	12	56	19
4008	Deposited on SE-NW, SW-NE & NW-SE 12-59-14	Fee	1,184,941	29	16	59	15
4010	Deposited on SE-SE 1-59-14 & NE-NE 12-59-14	Fee	59,419	26	16	56	18

Figures

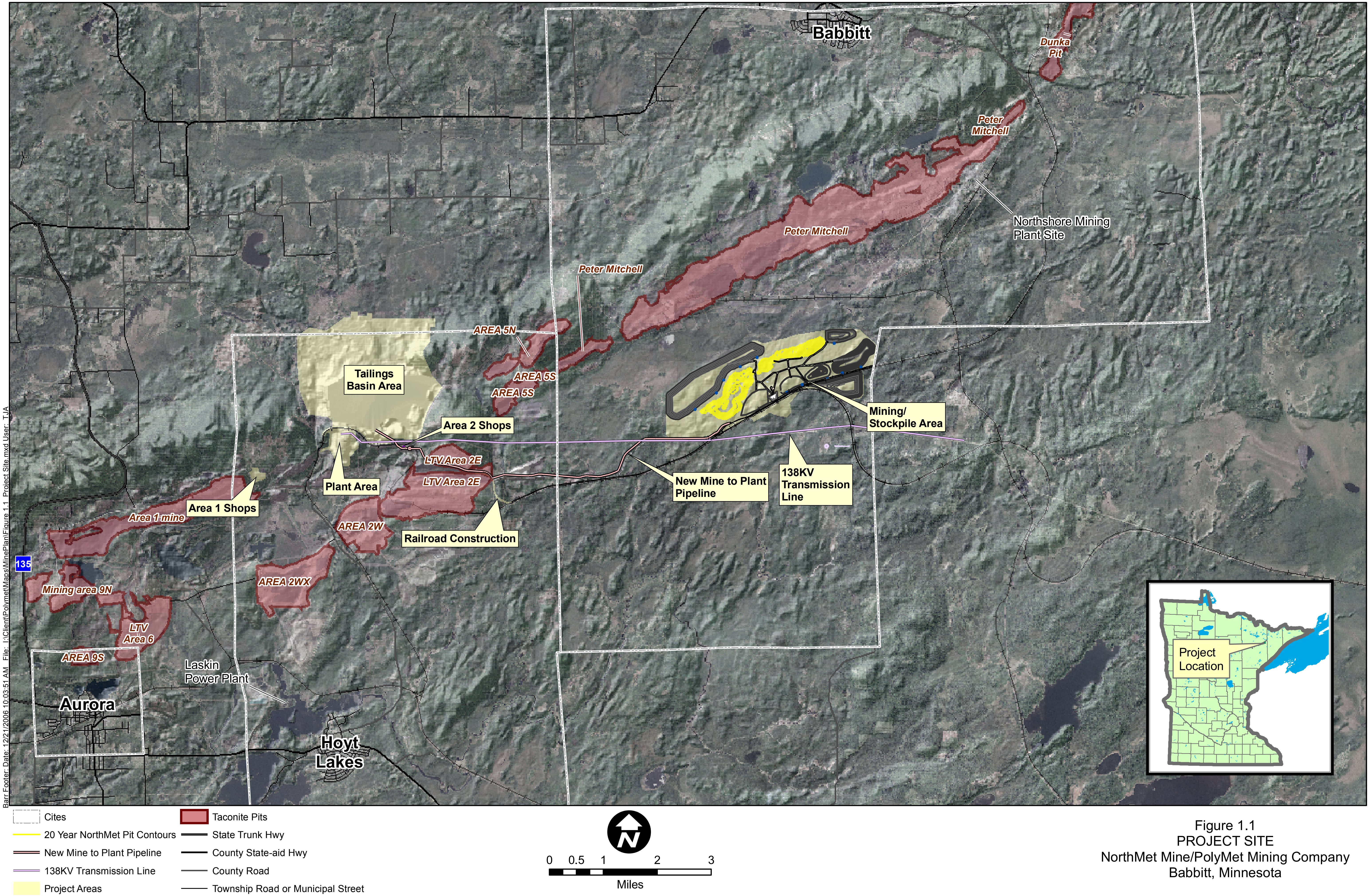
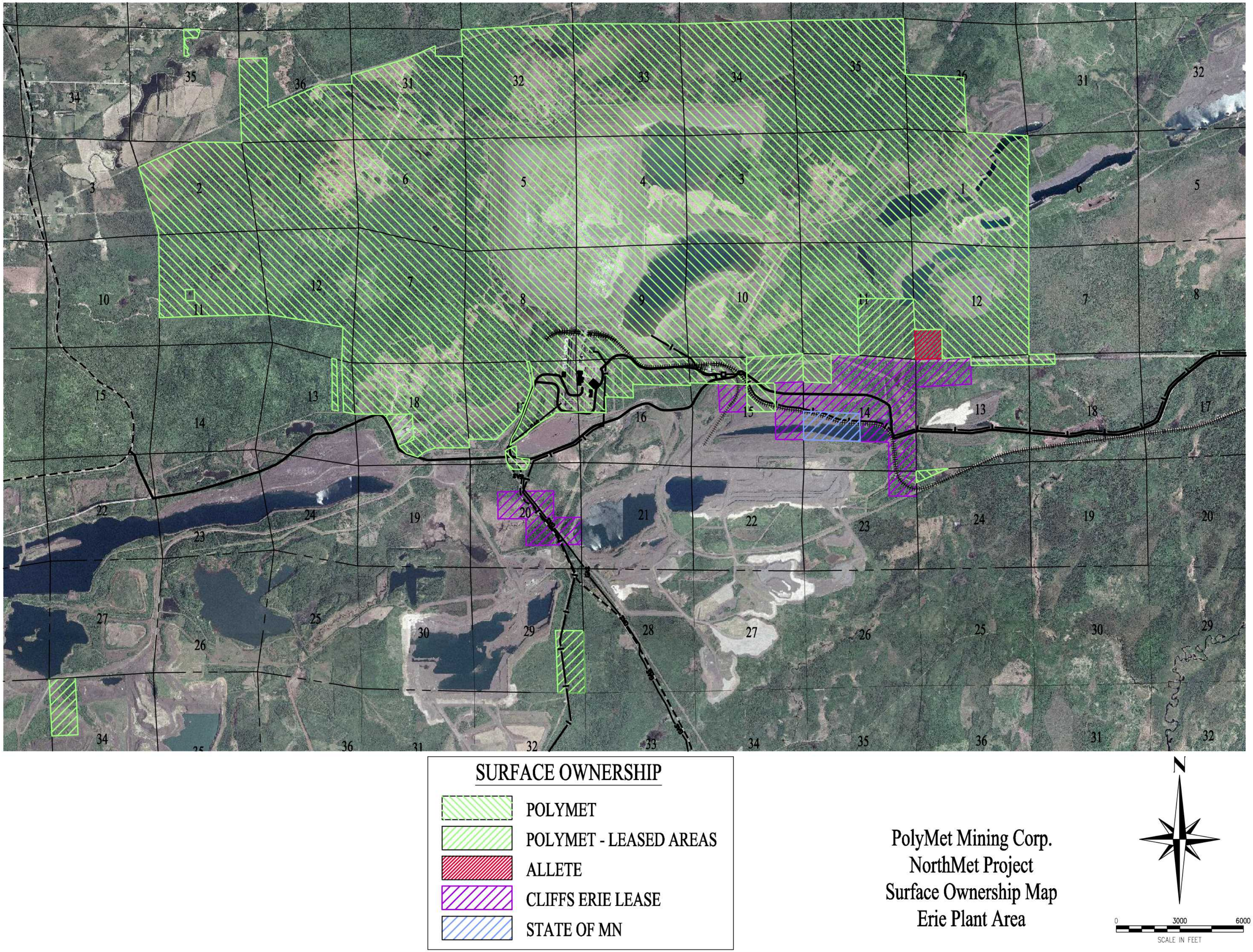


Figure 1.1
PROJECT SITE
NorthMet Mine/PolyMet Mining Company
Babbitt, Minnesota



PolyMet Mining Corp.
NorthMet Project
Surface Ownership Map
Erie Plant Area

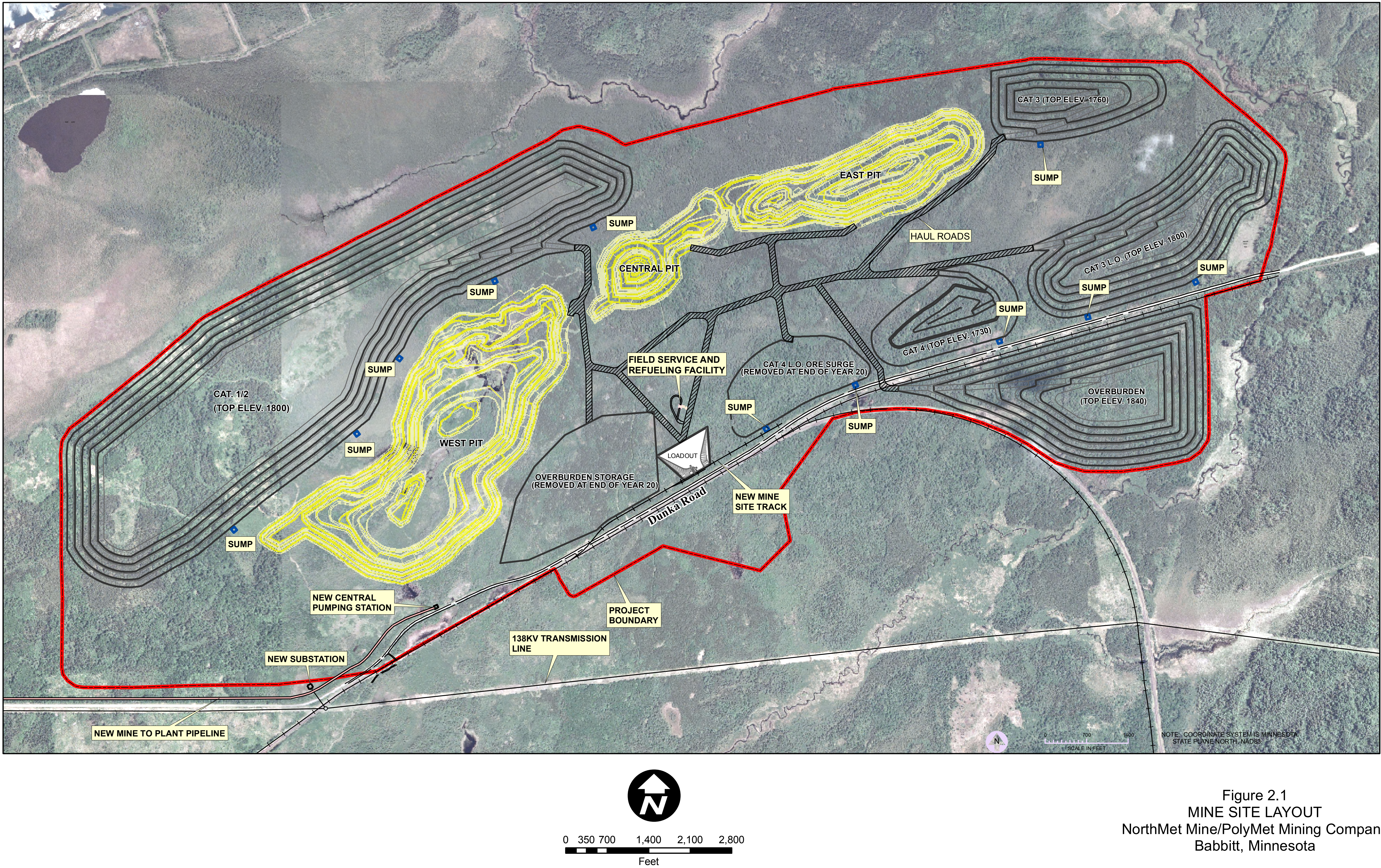
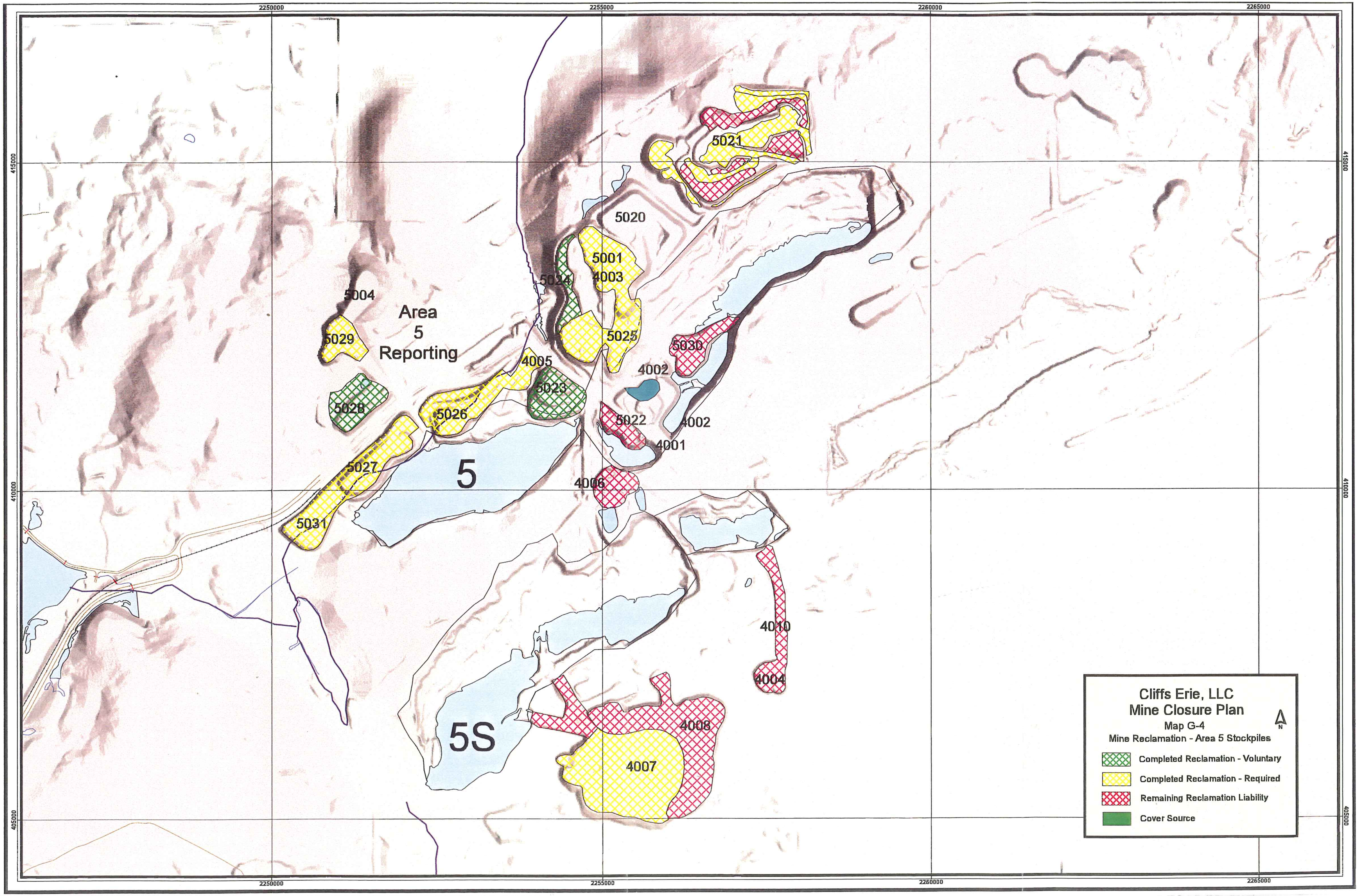


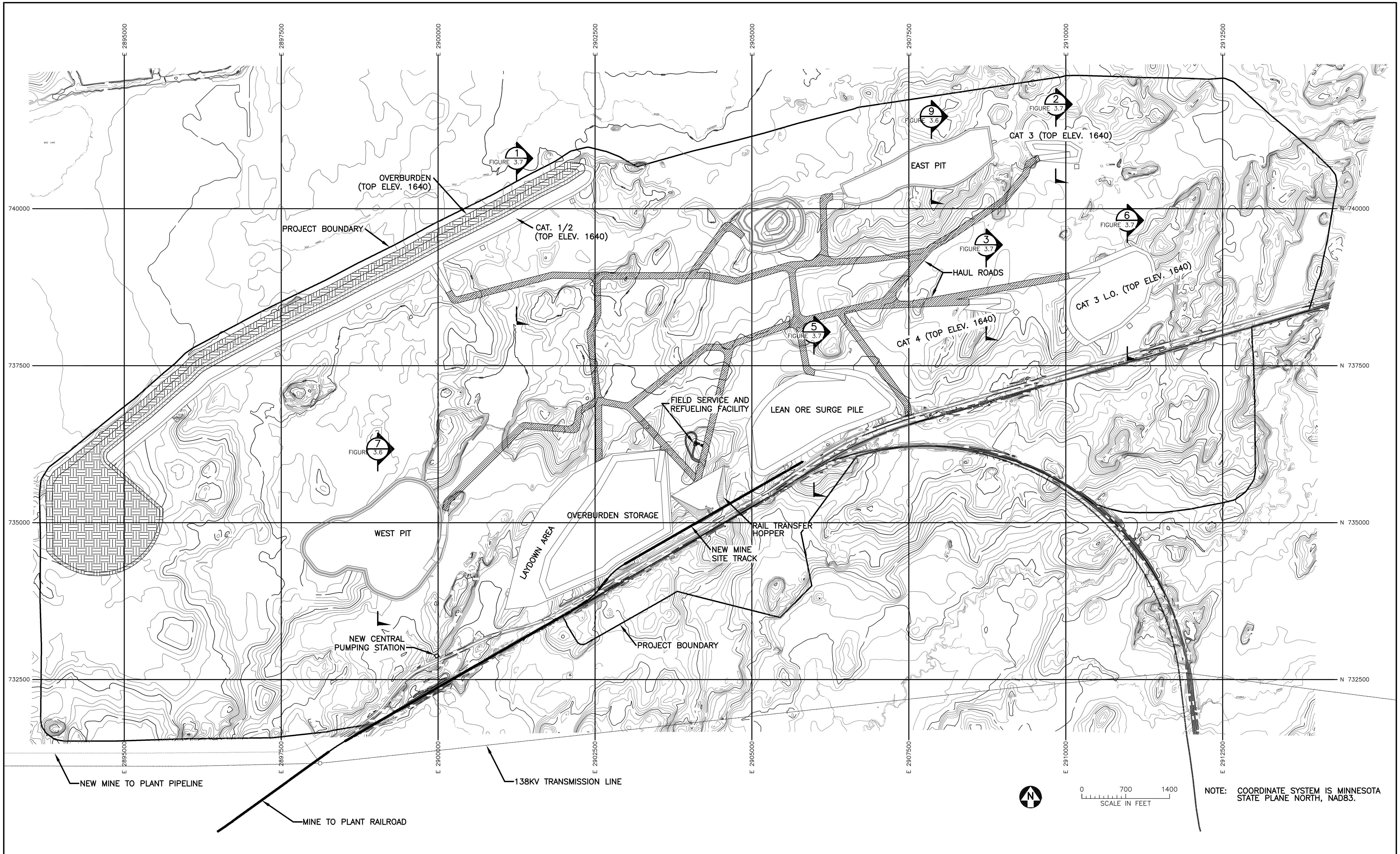
Figure 2.1
MINE SITE LAYOUT
NorthMet Mine/PolyMet Mining Company
Babbitt, Minnesota



Cliffs Erie, LLC
Mine Closure Plan

Map G-4

Mine Reclamation - Area 5 Stockpiles



NOTE: COORDINATE SYSTEM IS MINNESOTA STATE PLANE NORTH, NAD83.

Scale	AS SHOWN
Date	11/29/06
Drawn	GSJ
Checked	
Designed	TMA
Approved	

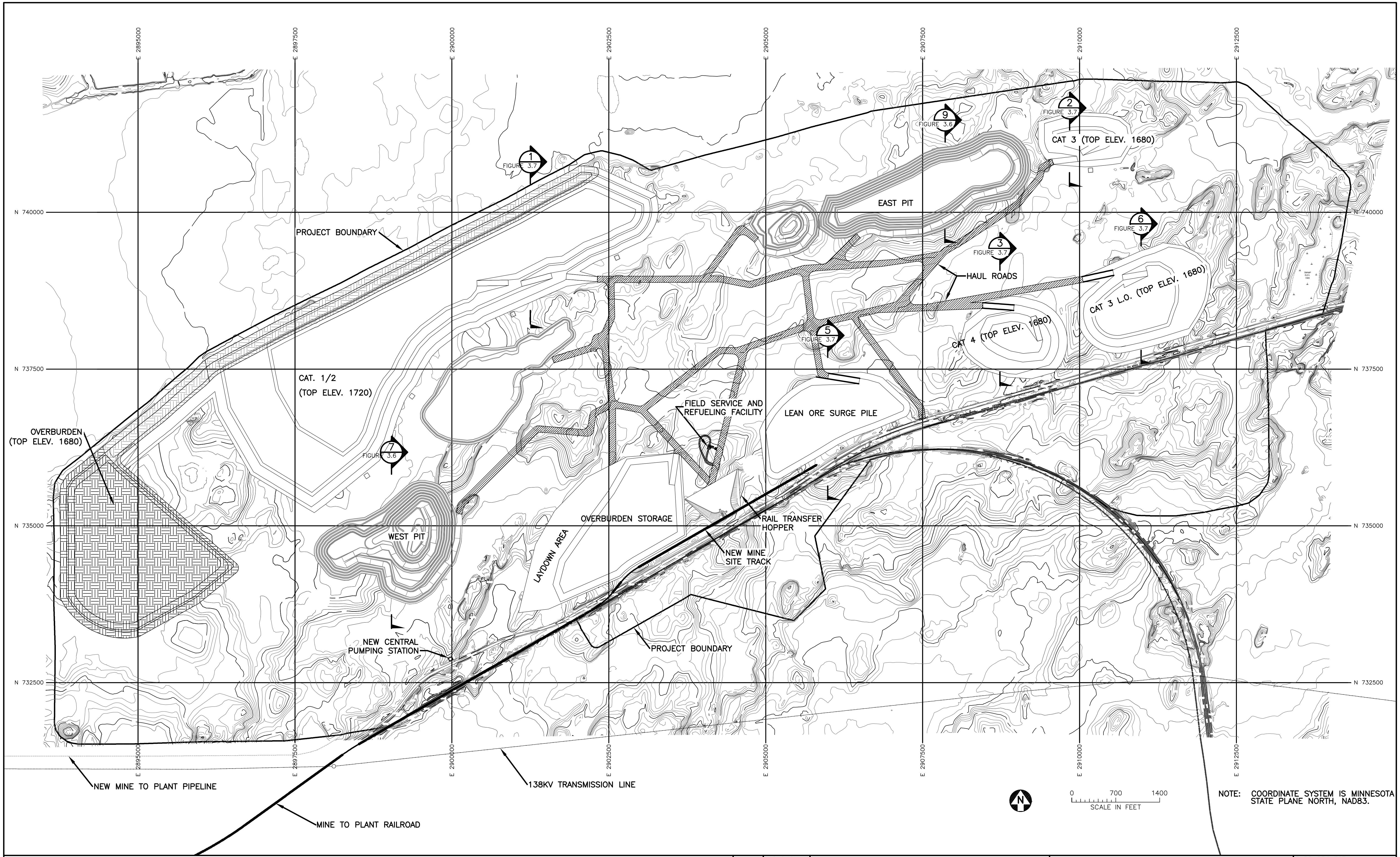
POLYMET MINING INC.
HOYT LAKES, MINNESOTA

NORTHMET MINE SITE

PIT AND STOCKPILE PLAN YEAR 1

BARR PROJECT No.
23/69-862
CLIENT PROJECT No.

DWG. No.
FIGURE 3.1
REV. No.
A



Scale	AS SHOWN
Date	11/27/06
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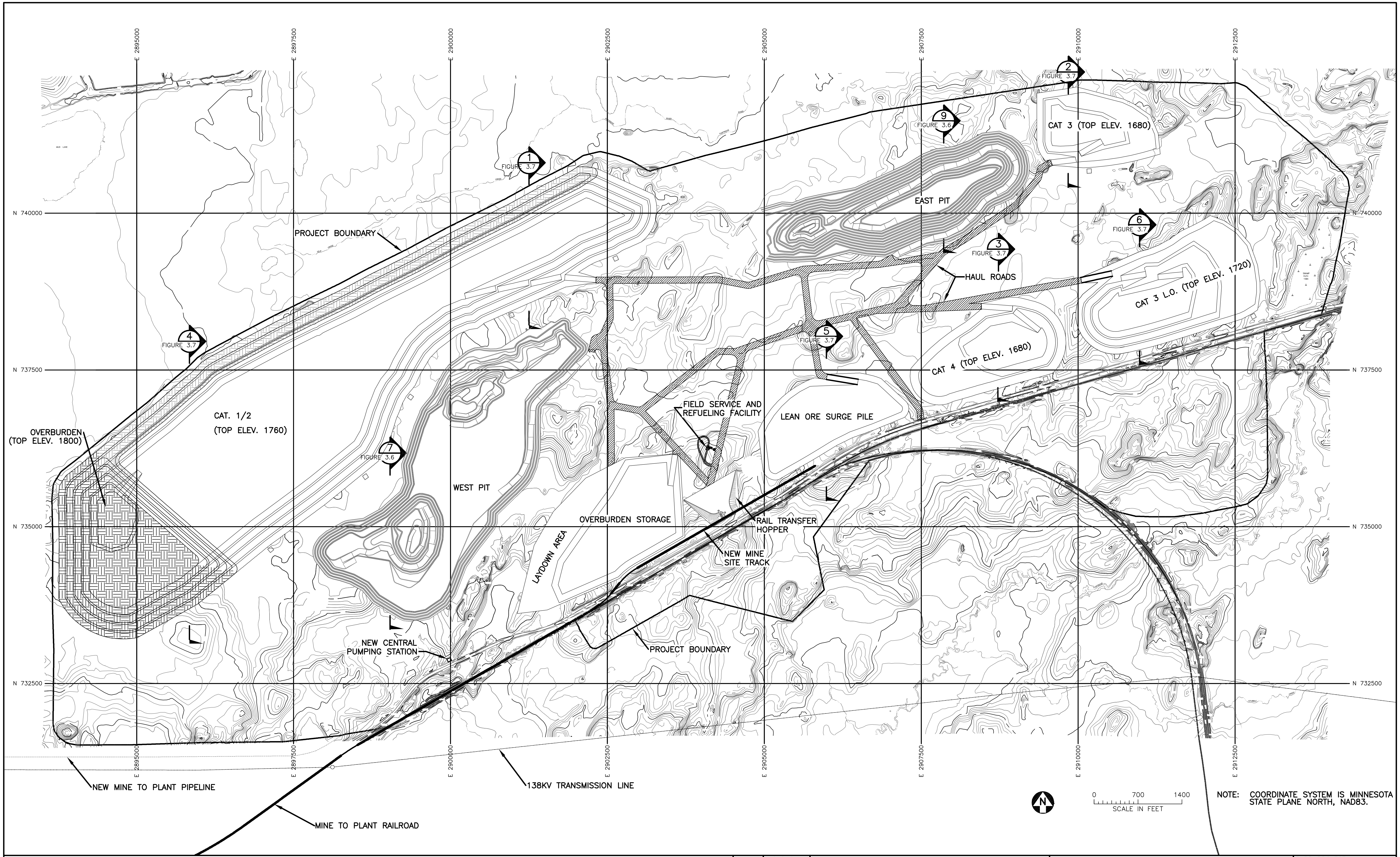
POLYMET MINING INC.
HOYT LAKES, MINNESOTA

NORTHMET MINE SITE

PIT AND STOCKPILE PLAN YEAR 5

BARR PROJECT No.
23/69-862
CLIENT PROJECT No.

DWG. No. FIGURE 3.2
REV. No. A



Scale	AS SHOWN
Date	11/27/06
Drawn	GSJ
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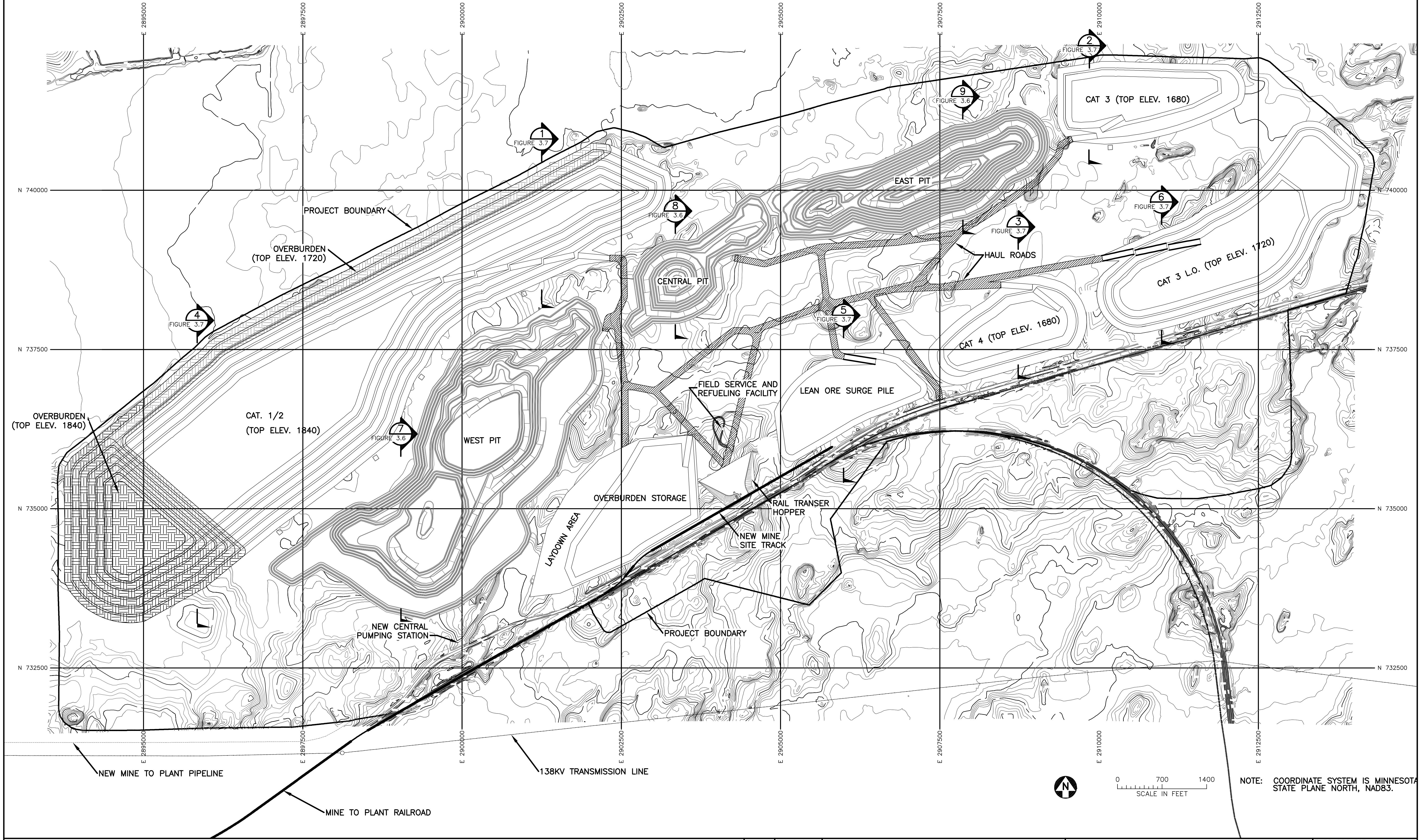
POLYMET MINING INC.
HOYT LAKES, MINNESOTA

NORTHMET MINE SITE

PIT AND STOCKPILE PLAN YEAR 10

BARR PROJECT No.
23/69-862
CLIENT PROJECT No.

DWG. No. FIGURE 3.3
REV. No. A



NOTE: COORDINATE SYSTEM IS MINNESOTA STATE PLANE NORTH, NAD83.

Scale	AS SHOWN
Date	11/27/06
Drawn	GSJ
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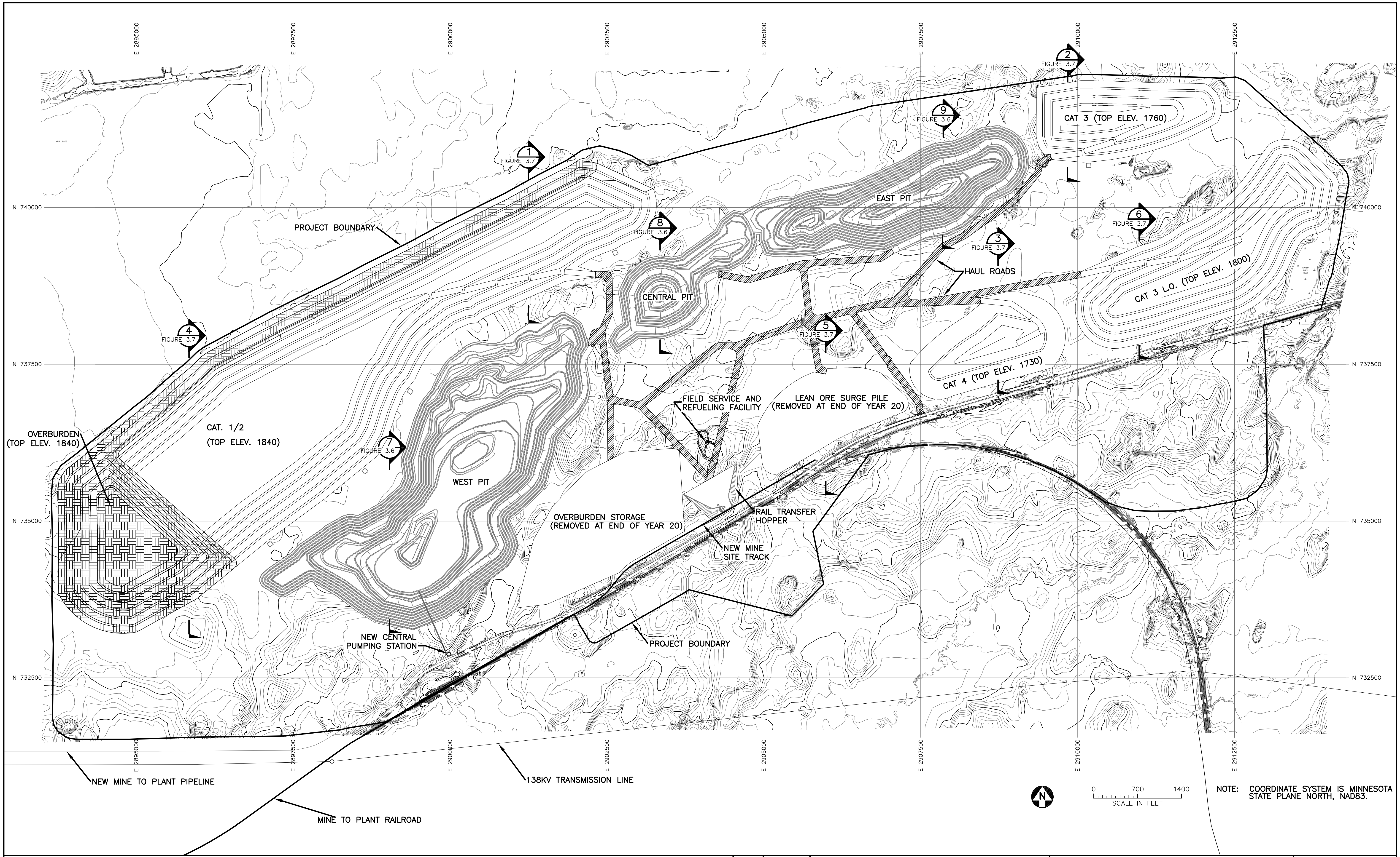
POLYMET MINING INC.
HOYT LAKES, MINNESOTA

NORTHMET MINE SITE

PIT AND STOCKPILE PLAN YEAR 15

BARR PROJECT No.
23/69-862
CLIENT PROJECT No.

DWG. No.
FIGURE 3.4
REV. No.
A



NOTE: COORDINATE SYSTEM IS MINNESOTA STATE PLANE NORTH, NAD83.

Scale	AS SHOWN
Date	11/17/06
Drawn	GSJ
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POLYMET MINING INC.
HOYT LAKES, MINNESOTA

NORTHMET MINE SITE

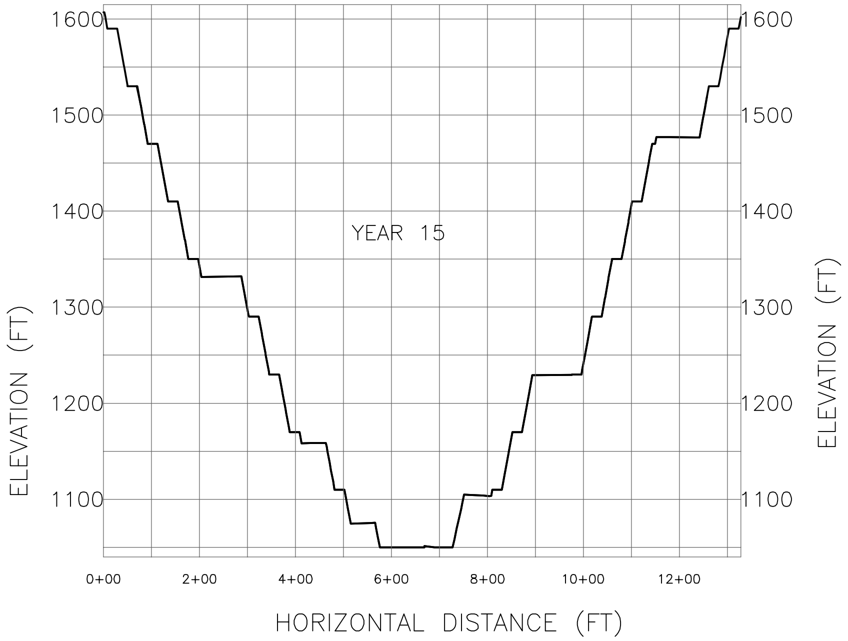
PIT AND STOCKPILE PLAN YEAR 20

BARR PROJECT No. 23/69-862
CLIENT PROJECT No.
DWG. No. FIGURE 3.5
REV. No. A

8 SECTION: CENTRAL PIT

FIGURE 3.1-5

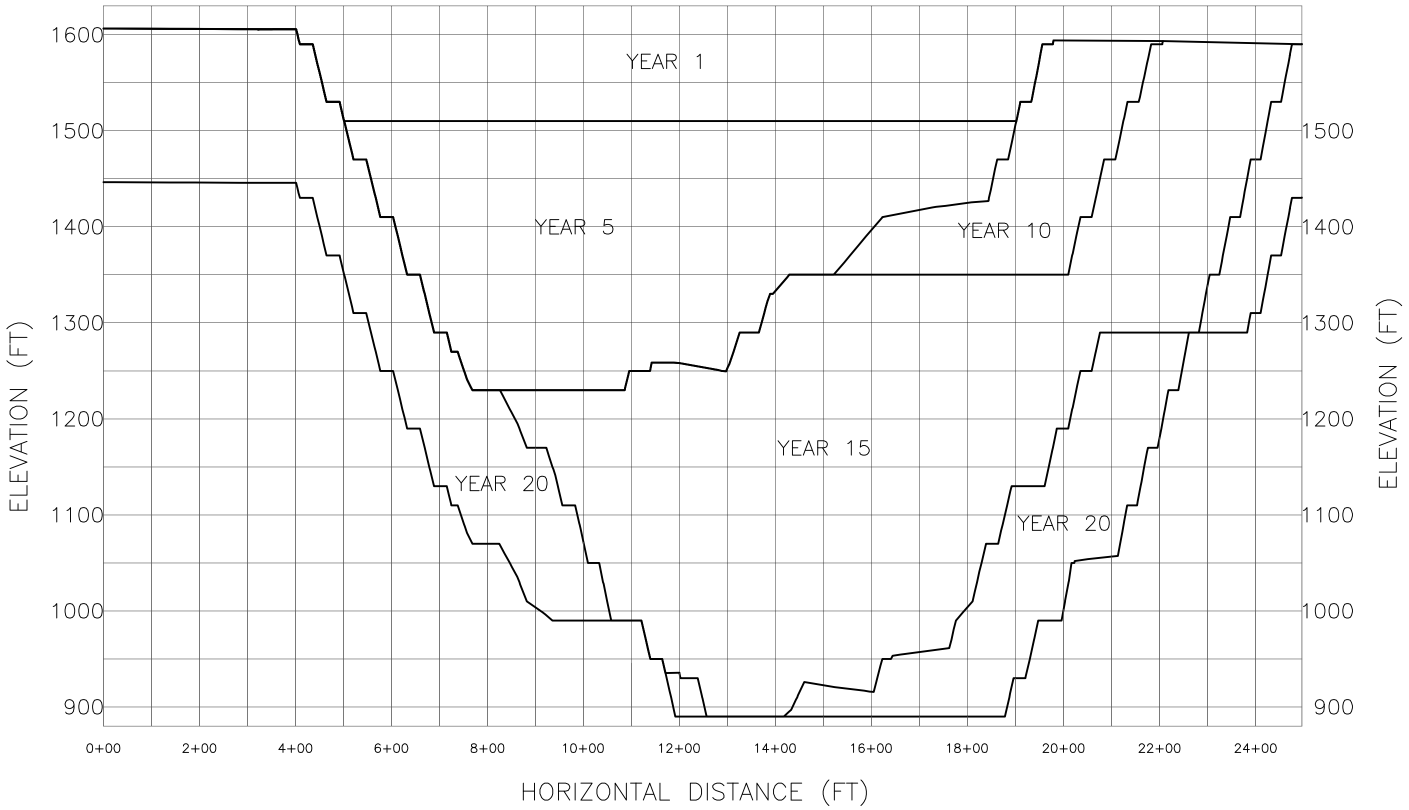
2:1 VERTICAL EXAGGERATION



7 SECTION: WEST PIT

FIGURE 3.1-5

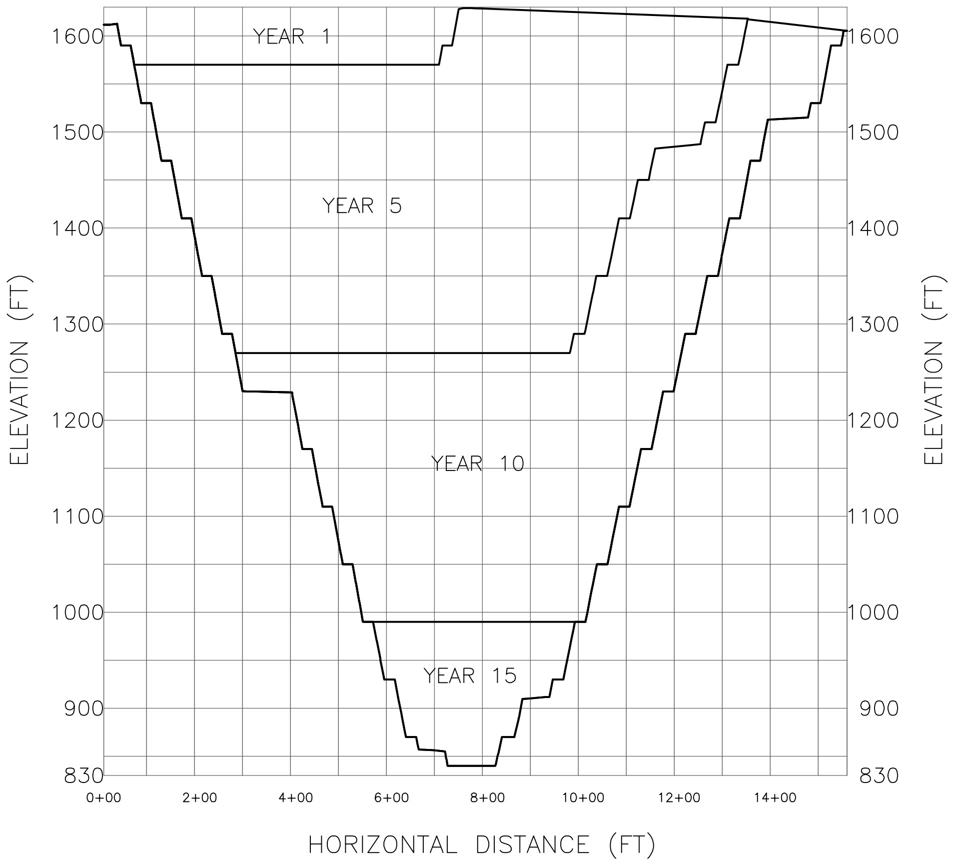
2:1 VERTICAL EXAGGERATION

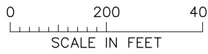


9 SECTION: EAST PIT

FIGURE 3.1-5

2:1 VERTICAL EXAGGERATION





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Designed	TMA
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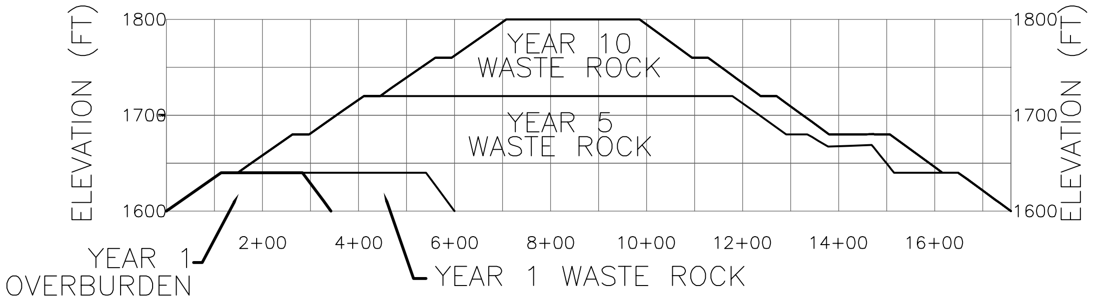
POLYMET MINING INC.
HOYT LAKES, MINNESOTA

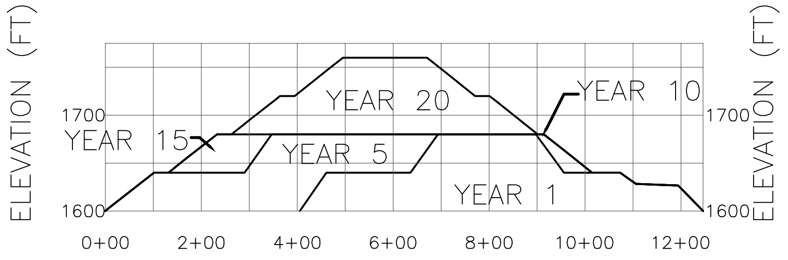
NORTHMET MINE SITE

PIT AND STOCKPILE CROSS SECTIONS

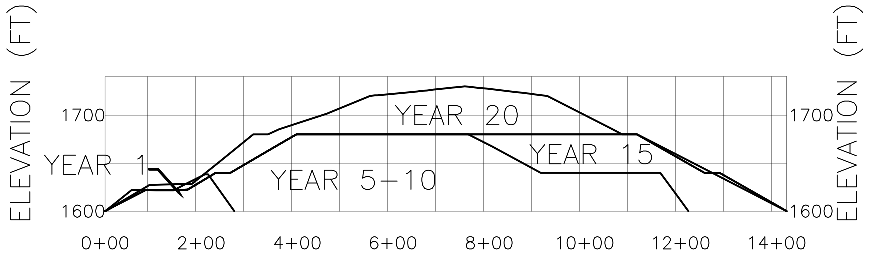
BARR PROJECT No. **23/69-862**
CLIENT PROJECT No.
DWG. No. **FIGURE 3.6**
REV. No. **A**



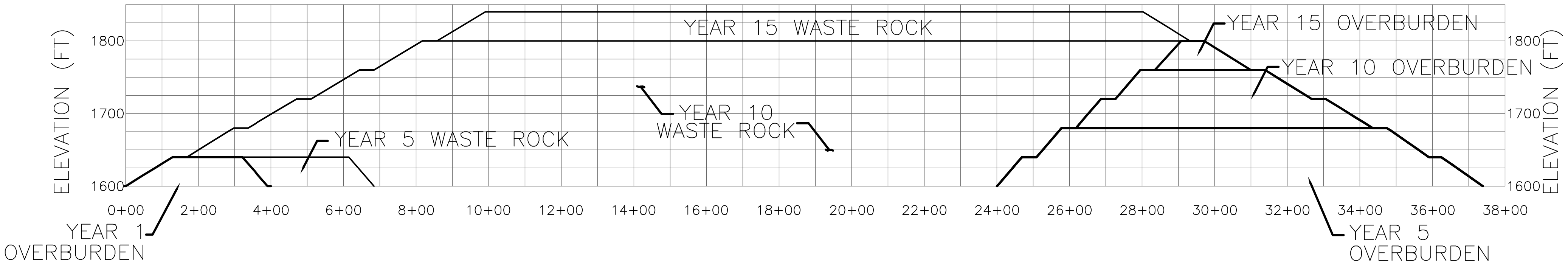
1 SECTION: CATEGORY 1/2 STOCKPILE
FIGURE 3.1–3.5
2:1 VERTICAL EXAGGERATION



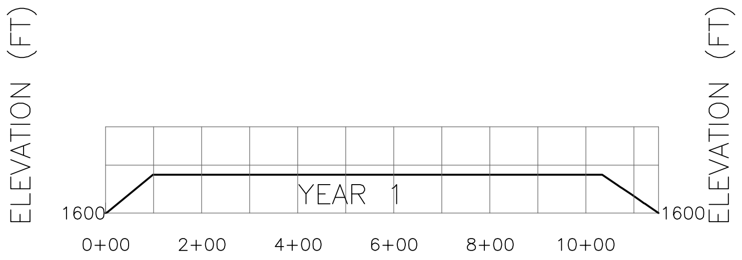
2 SECTION: CATEGORY 3 STOCKPILE
FIGURE 3.1–3.5
2:1 VERTICAL EXAGGERATION



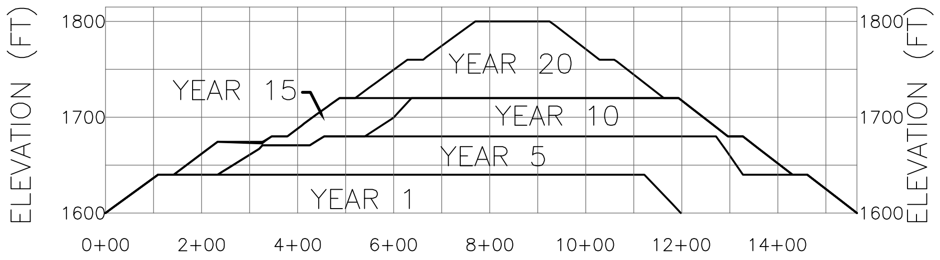
3 SECTION: CATEGORY 4 STOCKPILE
FIGURE 3.1–3.5
2:1 VERTICAL EXAGGERATION



4 SECTION: CATEGORY 1/2 STOCKPILE
FIGURE 3.3–3.5
2:1 VERTICAL EXAGGERATION



5 SECTION: CATEGORY 4 LEAN ORE SURGE STOCKPILE
FIGURE 3.1–3.5
2:1 VERTICAL EXAGGERATION



6 SECTION: CATEGORY 3 LEAN ORE STOCKPILE
FIGURE 3.1–3.5
2:1 VERTICAL EXAGGERATION

0 200 400
SCALE IN FEET

Scale	AS SHOWN
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Designed	TMA
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POLYMET MINING INC.
HOYT LAKES, MINNESOTA

NORTHMET MINE SITE

PIT AND STOCKPILE CROSS SECTIONS

BARR PROJECT No.
23/69–862
CLIENT PROJECT No.
DWG. No.
FIGURE 3.7
REV. No.
A