POLYMET
MINING

NorthMet Project

Geotechnical Data Package
Volume 3 – Mine Site Stockpiles

Version 5 - Certified

Issue Date: July 11, 2016

This document was prepared for Poly Met Mining Inc. by
Barr Engineering Co. and Golder Associates Inc.

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

B Bronson

07/11/2016

Brent Bronson, P.E.
PE #46492

Date

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

Gordan Gjerapic

07/11/2016

Gordan Gjerapic, P.E.
PE #47209

Date

Table of Contents

Acronyms and Abbreviations

	Stands For
Golder	Golder Associates Inc.
IFC	Issued for Construction
LLDPE	linear low density polyethylene
PGA	peak ground acceleration
Project	NorthMet Project
SPT	standard penetration test
USCS	Unified Soil Classification System
USFS	U.S. Forest Service

1.0 Introduction

This Geotechnical Data Package – Volume 3 presents the geotechnical evaluations performed by Golder Associates Inc. (Golder) in support of the NorthMet Project (Project) waste rock stockpile designs presented in the Rock and Overburden Management Plan (Reference (1)) and the Water Management Plan – Mine Site (Reference (2)). This information is intended for use in preparing the Environmental Impact Statement, and to support Project permitting.

The overall plan for management of waste rock is to classify rock by its reactivity and place it in one of three stockpiles based on that classification. The lowest reactivity stockpile, Category 1, is a permanent stockpile. A groundwater containment system will be constructed to capture drainage from the Category 1 Waste Rock Stockpile (see Section 2.1.2 of Reference (1)), and the stockpile will be progressively reclaimed with an engineered geomembrane cover system (see Section 3.0 of Reference (3)). The two higher reactivity stockpiles, Category 2/3 and Category 4, are temporary stockpiles, and waste rock from these stockpiles will be relocated to the East Pit after mining ceases in the East Pit. Engineered liner systems will be constructed beneath the temporary stockpiles to capture drainage (see Section 2.1.3 of Reference (1)).

The Mine Site exploration drilling locations, soil borings, and geophysical testing locations used for stockpile foundation design are shown in Attachment A. The majority of the relevant geotechnical data has been collected from the accessible highland areas. Because the surface rights over most of the Mine Site are owned by the U.S. Forest Service (USFS), further access is restricted until completion of the proposed land exchange with the USFS. A Phase II Geotechnical Investigation Work Plan will be developed during permitting to provide the basis to finalize the stockpile Issued for Construction (IFC) designs. It is Golder’s opinion that the existing geotechnical database, in combination with knowledge of the regional surficial and bedrock geology and the conservative assumptions used to design the waste rock stockpile slopes and foundations, is sufficient to support a basic level engineering design and permitting for the proposed waste rock stockpiles. It is anticipated that any IFC level design modifications occurring after the current designs are finalized will not result in substantial modifications to the proposed stockpile geometry, design methodologies or performance.

1.1 Outline

This Geotechnical Data Package – Volume 3 presents the analyses and assumptions upon which recommendations are provided for the waste rock stockpile foundation preparation and liner system designs, and presents the methodology used to evaluate the slope stability of the recommended designs. The outline of this document is:

Section 1 Introduction

Section 2 Regulatory basis

Section 3	Existing conditions
Section 4	Physical properties of the materials
Section 5	Stockpile analysis and design inputs
Section 6	Stockpile analysis and design outcomes
Section 7	Certification

This document may evolve through the environmental review, permitting, operating and closure phases of the Project. A Revision History is included at the end of the document.

2.0 Regulatory Basis

Requirements for stockpile design and reactive mine waste are included in the Nonferrous Metallic Mineral Mining Minnesota Administrative Rules, MNDNR Rules parts 6132.2400 and 6132.2200, respectively. Variances from these rules or alternative plans require review and approval by the MNDNR. Minnesota Rules, part 6132.2400 states that Storage Piles (a.k.a. Stockpiles) must be designed and constructed to minimize hydrologic impacts, enhance the survival and propagation of vegetation, be structurally sound, control erosion, promote progressive reclamation, and recognize the conservation of mineral resources. Specific regulatory requirements for Stockpiles as excerpted from Minnesota Rules, part 6132.2400 are:

A. General design: All storage piles shall be designed and constructed according to the standards in subitems (1) to (4).

(1) When mine waste is deposited on areas with unstable foundations such as peat, muskeg, bedded lacustrine deposits, karst topography, active seismic and flood zones, and areas above or within a mine, a professional engineer, registered in this state and proficient in the design, construction, operation, and reclamation of facilities on unstable foundations, shall examine the foundation and design the storage piles to ensure stability.

(2) Practices such as the use of vegetated buffer strips, hay bale dikes, silt fences, or settling basins shall be used to control erosion.

(3) Rills or gullies shall be observed to determine dominant runoff flow paths, which shall be stabilized to control runoff.

(4) Storage piles containing reactive mine waste must also comply with the requirements of Minnesota Rules, part 6132.2200.

B. Rock storage piles: The final exterior slopes of lean ore, waste rock, and leached ore storage piles shall consist of benches and lifts as follows:

(1) No lift shall exceed 40 feet in height;

(2) No bench shall be less than 30 feet, measured from the crest of the lower lift to the toe of the next lift;

(3) The sloped area between benches shall be no steeper than the angle of repose; and

(4) When vegetation is required under Minnesota Rules, part 6132.2700, subpart 2, item A, subitem (13), the sloped areas between benches shall be prepared to support vegetation.

C. Surface overburden: Surface overburden shall be disposed of according to subitems (1) and (2).

(1) When surface overburden is generated, it shall be placed in layers on the completed tops and benches of lean ore and waste rock storage piles to enhance reclamation potential.

(2) If no completed tops or benches are available, or if such sites are not within economic haul distances of surface stripping activities, surface overburden storage piles shall be created so that the final exterior slopes shall consist of benches and lifts as follows:

(a) No lift shall exceed 40 feet in height;

(b) No bench width shall be less than 30 feet wide, measured from the crest of the lower lift to the toe of the next lift;

(c) The sloped area between benches shall be no steeper than 2.5:1; and

(d) Runoff water shall either be temporarily stored on benches or removed by drainage control structures.

D. Mixed storage piles: Lean ore and waste rock shall not be used to cover surface overburden storage piles to avoid compliance with sloping and vegetation requirements. This shall not preclude the abutting of lean ore or waste rock storage piles with surface overburden storage piles or the placement of lean ore or waste rock lifts on top of surface overburden pads or lifts.

E. Alternative design: Based on acceptable research, the commissioner shall approve other measures that satisfy subpart 1.

Minnesota Rules, part 6132.2200 Reactive Mine Waste applicable to Stockpile design require that Reactive Mine Waste shall be mined, disposed of, and reclaimed to prevent the release of substances that result in the adverse impacts on natural resources. A reactive mine waste storage facility must be designed by professional engineers registered in Minnesota proficient in the design, construction, operation, and reclamation of facilities for the storage of reactive mine waste, to either:

(1) Modify the physical or chemical characteristics of the mine waste, or store it in an environment, such that the waste is no longer reactive; or

(2) During construction to the extent practicable, and at closure, permanently prevent substantially all water from moving through or over the mine waste and provide for the collection and disposal of any remaining residual waters that drain from the mine waste in compliance with federal and state standards.

The State of Minnesota requires submittal, review, and state approval of a quality control/quality assurance program for liner systems prior to construction. In addition, the State of Minnesota requires submittal of a construction documentation report that summarizes the details of the facility construction and presents the results of the quality assurance testing. Quality assurance testing is most often performed by the facility design engineer and a qualified independent testing laboratory. Quality assurance for facilities like the stockpile liners typically includes:

- Density testing of compacted structural fill materials.
- Peel and shear strength testing of seems in the geomembrane liner and/or cover systems.
- Overall confirmation of materials compliance with specifications.
- Construction surveying to confirm facility line and grade compliance with specifications.
- Maintenance of construction observation records and a photographic record of construction activities.
- Documentation of any variation from agency approved plans and specifications and the basis by which the variation is deemed acceptable to the facility design engineer.

Permit issuance for the facility will depend on compliance with an approved QA/QC plan. A construction QA/QC plan will be developed during permitting and submitted for agency approval.

3.0 Existing Site Conditions

3.1 Existing Site Data

The existing site conditions were evaluated using the site data summarized below:

- boring logs from a drilling program conducted by Barr in March 2005
- data from a Phase I field investigation conducted by Golder in April 2006
- data from a geotechnical investigation conducted by Barr in January 2008
- data from an overburden geotechnical investigation conducted by Barr in February 2010
- depth to bedrock point data obtained prior to March 2005, provided by Poly Met Mining Inc., based on electrical resistivity survey geophysics, geotechnical borings, and exploration borings
- Wetland delineation at the Mine Site conducted by Barr in 2006 (Reference (4))

Geotechnical boring locations by Barr (2005 and 2008) and test trench locations by Golder (2006) are shown in Attachment A.

Barr conducted a monitoring well installation program in March 2005. Eleven borings were completed as summarized in Table 3-1. The borings were advanced by WDC Exploration & Wells using rotasonic drilling methods. The advanced borings indicated bedrock depths ranging from 4 feet to more than 28.5 feet. The boring logs from the 2005 well installation program are included in Attachment B.

Golder conducted a Phase I geotechnical field and laboratory investigation in April 2006 to evaluate the subsurface conditions within the proposed stockpile footprints. The investigation program consisted of fifteen (15) test trenches (G06-TP1 through G06-TP15) excavated to depths ranging between 3.5 and 20 feet. Test trenches were excavated using a John Deere 690 ELC trackhoe operated by Radotich Enterprises, LLC. 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. The Phase I geotechnical investigation report is included as Attachment C.

Barr conducted a rotasonic drilling program in January 2008 as a part of the Overburden Characterization Plan in support of the EIS. Twenty-four borings were advanced (RS-01B to RS-20A). Twenty-two borings were completed using an 8-inch diameter rotasonic core with a miniature all-terrain rig operated by Boart Longyear Company. The depth at which bedrock was encountered ranged from 5 to 33 feet, as summarized in Table 3-1. In addition, two borings were completed using a hollow stem hand auger. The hand auger borings encountered boulder refusal at 0.5 and 2.0 feet, respectively. Borehole logs from the January 2008 geotechnical investigation conducted by Barr and the accompanying in-laboratory material test data are included as Attachment D.

Barr conducted a standard penetration test (SPT) and pressure meter test program in February 2010 as a part of overburden characterization in support of the DEIS. Four SPT borings and offset hollow stem auger borings for pressure meter testing and sample recovery were advanced (J003, J010, J027 and J037). Borings and testing were completed by American Engineering Testing, Inc. Borehole logs, pressure meter test data and soil test data from the February 2010 geotechnical investigation conducted by Barr are included as Attachment E. Barr (2010) data are generally consistent with findings from previous investigations.

Table 3-1 Depth to Bedrock Data from Geotechnical Borings by Barr (2005, 2008) and Test Trench Investigations by Golder (2006)

Barr (2005)		Golder (2006)		Barr (2008)	
Boring Number	Bedrock Depth Below Existing Grade (feet)	Boring Number	Bedrock Depth Below Existing Grade (feet)	Boring Number	Bedrock Depth Below Existing Grade (feet)
MW-05-02	5.0	GATP-06-1	> 20	RS-01B	20.5
MW-05-08	> 28.5	GATP-06-2	13.0	RS-03	22.0
MW-05-09	12.5	GATP-06-3	15.0	RS-04	25.0
SB-05-01	15.0	GATP-06-4	13.5	RS-05A	13.0
SB-05-03	16.0	GATP-06-5	14.0	RS-05B	> 5.0
SB-05-04	15.0	GATP-06-6	> 20	RS-06A	> 21.0
SB-05-05	8.0	GATP-06-7	3.5	RS-06R	21.0
SB-05-06	14.5	GATP-06-8	4.5	RS-07	11.0
SB-05-07	13.0	GATP-06-9	8.5	RS-07R	9.5
SB-05-10	4.0	GATP-06-10	8.0	RS-08A	11.0
SB-05-10A	6.0	GATP-06-11	6.0	RS-09	8.0
		GATP-06-12	5.0	RS-10	14.0
		GATP-06-13	9.0	RS-11	33.0
		GATP-06-14	3.5	RS-12	22.0
		GATP-06-15	11.5	RS-13	8.0
				RS-14A	5.0
				RS-14B	5.0
				RS-15A-E	> 0.5

Barr (2005)		Golder (2006)		Barr (2008)	
Boring Number	Bedrock Depth Below Existing Grade (feet)	Boring Number	Bedrock Depth Below Existing Grade (feet)	Boring Number	Bedrock Depth Below Existing Grade (feet)
				RS-16A-C	> 2.0
				RS-17A	> 8.0
				RS-17B	11.2
				RS-18A	8.0
				RS-19A	9.0
				RS-20A	6.5

Note: Excludes Barr 2010 data; Barr 2010 borings were terminated above bedrock or at auger refusal. Auger refusal on cobble, boulder or bedrock was not confirmed.

The site exploration drilling database, test pit logs, drilling logs from soil borings and monitoring wells, and geophysics data were used to develop an estimated depth to bedrock isopach map presented in Attachment A.

Barr completed additional rotasonic borings in 2011 and 2012 for monitoring well installations. This data has not been used for the analyses presented herein and is therefore not attached, but will be considered during preparation of IFC designs.

Collected soil samples from the Golder (2006) and Barr (2008 and 2010) field programs were classified using the Unified Soil Classification System (USCS). In-laboratory material classification tests were performed in accordance with ASTM methodologies to obtain index properties of the samples recovered from the test trenches and boreholes, to confirm field classifications, and for use in developing correlations with engineering properties of the soils encountered. In-laboratory tests conducted on subgrade materials sampled during these field programs included the following:

- Sieve Analysis – ASTM C117/C136 (Golder, 2006 and Barr, 2008);
- Atterberg Limits – ASTM D4318 (Golder, 2006 and Barr, 2008);
- Natural Moisture Content – ASTM (Golder, 2006 and Barr, 2008);
- Standard Proctor Compaction – ASTM D698 (Golder, 2006);
- Consolidated-Undrained (CU) Triaxial Compression – ASTM D4767 (Golder, 2006);
- Falling Head Flexible-Wall Permeability Testing – ASTM D5084 (Golder, 2006); and

- One-Dimensional Consolidation Testing – ASTM D2435 (Golder, 2006).

Copies of test reports for the in-laboratory material testing are provided in Attachment C, Attachment D, and Attachment E.

3.2 Site Conditions for Category 1 Waste Rock Stockpile

The Category 1 Waste Rock Stockpile footprint encompasses 508 acres during operations, and 526 acres reclaimed. For the Category 1 Waste Rock Stockpile and for all other stockpiles some discrepancies may exist between footprint areas reported herein relative to footprint areas reported in other documents. This is the result of varying document preparation dates and/or versions. No effort has been made to align document submittal dates. Hence, some footprint size variations between versions can be expected.

Wetland delineation within the Category 1 Waste Rock Stockpile footprint is presented in Attachment A. Geotechnical classification of subsurface soils within the vicinity of the Category 1 Waste Rock Stockpile footprint is based on the borehole logs (Barr 2005, 2008 and 2010) and test pit logs (Golder, 2006). Geotechnical borings and test pits within or in the vicinity of the Category 1 Waste Rock Stockpile are summarized in Table 3-2. Additional depth to bedrock information in the vicinity of the Category 1 Waste Rock Stockpile is presented in Attachment F.

Table 3-2 Category 1 Waste Rock Stockpile Boring and Test Pits

Borehole/Test Pit	Location(1)	Bedrock Depth (feet)	Soil types
MW-05-09	WL/HL	12.5	0.5 feet topsoil; 1.5 feet of sand (w/ 5-10% gravel); 5 feet of silty sand (w/ <40% cobbles and boulders); 1.5 feet sand; 4 feet silty sand (trace gravel and cobbles)
SB-05-04	WL	15	2 feet of peat; 5.5 feet of clayey silt; 1 feet of silty clay; 1.5 feet of sandy silt (w/ 10% cobbles); 5 feet of silty sand (w/ 10-20% coarse gravel and cobbles)
SB-05-10	WL/HL	4.0	1 feet peat; 3 feet of silty sand (with 5-10% gravel and cobbles)
GATP-06-04	WL	13.5	0.5 feet topsoil; 13 feet of silty sand (mixed w/ gravel and cobbles)
GATP-06-05	HL	14.0	0.5 feet topsoil; 3.5 feet of lean clay (sandy w/ 15-20% gravel), 2 feet of silty sand (w/ 30-45% gravel), 8 feet of silty sand.
GATP-06-06	HL	>20	0.5 feet of topsoil; 14.5 feet of silty sand (mixed w/ gravel, cobbles and boulders); 5 feet layer of sandy silt

Borehole/Test Pit	Location(1)	Bedrock Depth (feet)	Soil types
RS-15A-E	HL	>0.5	Peat over sandy silt (refusal on boulder)
RS-16A-C	HL	>2.0	Silty sand (refusal on boulder)
J003	WL	--	2.5 feet peat and organic silt; 3.6 feet coarse alluvium; 21.0 feet silty sand w/gravel
J010	HL	--	2.3 feet fill; 15.9 feet silty sand w/gravel; 0.5 feet obstruction (possible bedrock)
J027	WL	--	7.0 feet peat; 0.7 feet organic silt; 16.9 feet silty sand w/gravel (w/ apparent cobbles)
J037	HL	--	0.5 feet topsoil; 12.0 feet sandy silt and silty sand w/gravel; 0.4 feet obstruction (possible bedrock)

(1) WL – wetland, HL – highland, WL/HL – wetland/highland boundary

Results from the in-laboratory material classification testing on the samples collected during Golder (2006) and Barr (2008 and 2010) geotechnical investigations are summarized in Table 3-3.

Table 3-3 Geotechnical Classification Results for Category 1 Waste Rock Stockpile Soils

Sample	USCS Class.	% Gravel	% Sand	% Fines	LL[(1)]	PL[(1)]	PI[(1)]
TP#4, Sample #1, 0.5' to 4.5'	SM	8.0	60.7	31.3	7	7	0
TP#4, Sample #2, 4.5' to 13.5'	SM w/ little gravel	11.0	49.7	39.3	n/a	n/a	n/a
TP#5, Sample #1, 0.5’ to 4.0’	CL	13.0	35.6	51.4	25	16	9
TP#5, Sample #1, 6.0’ to 14’	SM	1.0	52.0	47.0	n/a	n/a	n/a
TP#6, Sample #2, 15' to 20'	ML sandy	0.0	48.3	51.7	n/a	n/a	n/a
RS-15A-E, 0’ to 0.5’	ML sandy w/organics	1.0	46.3	52.7	NP	NP	NP
RS-16A-C. 0’ to 2.0’	Silty Sand (SM)	0.4	68.4	31.2	NP	NP	NP
J003, 4.5’ to 6.0’	CL-ML/CL	0.0	32.6	67.4	NT	NT	NT
J003, 19.5’ to 21.0’	SC	12.0	53.1	34.9	NT	NT	NT
J010, 4.5’ to 6.0’	SM	13.7	55.5	30.8	NP	NP	NP
J010, 9.5’ to 11.0’	SM	12.9	55.3	31.8	NP	NP	NP
J027, 12.0’ to 13.5’	SM	28.0	50.9	21.1	NP	NP	NP
J027, 22.0’ to 23.5’	SM	8.3	60.5	31.2	NP	NP	NP
J037, 9.5’ to 11.0’	SM	18.7	48.7	32.6	NP	NP	NP

(1) NP – non-plastic soil; NT – not tested for plasticity

Borings advanced in the vicinity of and within the footprint of the Category 1 Waste Rock Stockpile indicate bedrock depths ranging from 4 feet to over 20 feet below the surface (Table 3-2). On the basis of the bedrock isopach map shown in Attachment A, depth to bedrock may be somewhat greater in the central and southwestern portions of the stockpile footprint. Soils in the highland areas are glacial tills in origin and typically consist of sandy silts and silty sands with varying amounts of coarser material and occasional layers of sandy clays. Existing data indicates that lowland areas contain horizons of glacial, alluvial and lacustrine deposits. The upper soil horizons in the lowland deposits contain relatively finer grained soils, e.g., peat, organic clays and silts.

3.3 Site Conditions for Category 2/3 Waste Rock Stockpile

The Category 2/3 Waste Rock Stockpile area encompasses 180 acres. Wetland delineation within the Category 2/3 Waste Rock Stockpile footprint is presented in Attachment A. Geotechnical classification of subsurface soils within the Category 2/3 Waste Rock Stockpile footprint is based on the test pit samples collected by Golder in 2006 and the rotasonic drill testing by Barr in January 2008. Geotechnical borings and test pits in the vicinity (within approximately 100 feet) of the Category 2/3 Waste Rock Stockpile footprint are summarized in Table 3-4. Additional depth to bedrock information in the vicinity of the Category 2/3 Waste Rock Stockpile is presented in Attachment F.

Table 3-4 Category 2/3 Waste Rock Stockpile Borings

Borehole	Location⁽¹⁾	Bedrock Depth (feet)	Soil types
SB-05-01	HL/WL	15.0	4 feet topsoil (low plast. clay w/ 25% coarse fraction); 1 feet of silty clay; 3 feet of silty clay w/ organics ; 7 feet silty clay w/ organics (rocky last 5 feet before bedrock)
RS-11	WL	33	9.5 feet peat; 7.5 feet silty sand (w/ gravel, cobbles and organics); 8 feet gravelly sand with silt (w/ cobbles); 8 feet sand to silty sand (w/ gravel, cobbles and boulders)
RS-17A	HL	>8	1 feet topsoil; 3.5 feet gravelly silty sand; 1.5 feet silty gravel w/ sand; 1 feet silty sand w/ gravel (refusal on boulder)
RS-17B	HL	11.2	1 feet topsoil; 3.5 feet gravelly silty sand; 1.5 feet silty gravel w/ sand; 1 feet silty sand w/ gravel; 1 feet boulder; 3.2 feet sand (w/ silt and gravel)
GATP-06-8	HL	4.5	2 feet silty sand (w/ little gravel); 2.5 feet sand and gravel (trace silt)
GATP-06-9	HL	8.5	0.5 feet of topsoil; 3.5 feet of silty sand (mixed w/ little gravel, cobbles and boulders); 4.5 feet sand and gravel (little silt, few cobbles)
GATP-06-10	HL	8.0	0.5 feet of topsoil; 3.5 feet of silty sand (w/ little gravel, few cobbles); 2.0 feet sand and gravel; 2 feet silty sand (some gravel)
GATP-06-11	HL	6.0	0.5 feet topsoil; 5.5 feet of silty sand (mixed w/ gravel and cobbles)
GATP-06-12	HL	5.0	0.5 feet topsoil; 4.5 feet of silty sand (mixed w/ gravel and cobbles)
GATP-06-13	HL	9.0	0.5 feet of topsoil; 8.5 feet of silty sand (w/ gravel, few cobbles and boulders);
GATP-06-14	WL	3.5	0.5 feet of topsoil; 3.0 feet of silty sand (w/ little gravel, few cobbles);
GATP-06-15	HL	11.5	1.0 feet of topsoil; 3.0 feet of silty sand (w/ gravel); 7.5 feet of silty sand (w/ little gravel, cobbles and boulders);

(1) WL – wetland, HL – highland, WL/HL – wetland/highland boundary

Results from the in-laboratory material classification testing on the samples collected during the Barr (2008) geotechnical investigation are summarized in Table 3-5.

Table 3-5 Geotechnical Classification Results for Category 2/3 Waste Rock Stockpile Soils

Sample	USCS Class.	% Gravel	% Sand	% Fines	LL(1)	PL(1)	PI(1)
TP#8, Sample #2, 2' to 4.5'	SP w/ gravel	40	58.2	1.8	n/a	n/a	n/a
TP#11, Sample #2, 3' to 6'	SM w/ little gravel	10	66.1	23.9	n/a	n/a	n/a
TP#13, Sample #2, 4' to 9'	SM w/ gravel	23	51	26	10	8	2
TP#14, Sample #2, 0.5' to 3.5'	SM	0	53.2	46.8	n/a	n/a	n/a
TP#15, Sample #2, 4' to 11.5'	SM w/ little gravel	12	49.2	38.8	n/a	n/a	n/a
RS-11, 9.5’ to 10’	SM w/ gravel	42.8	43.1	14.1	NP	NP	NP
RS-11. 17’ to 25’	SP-SM (gravelly)	34.8	59.0	6.2	NP	NP	NP
RS-11. 25’ to 28’	SP-SM (gravelly)	23.0	66.8	10.2	NP	NP	NP
RS-11, 28’ to 31’	SM w/ gravel	34.2	46.8	19.0	NP	NP	NP
RS-11. 31’ to 33’	SM w/ gravel	39.1	46.4	14.5	NP	NP	NP
RS-17, 2.5’ to 4.5’	SM (gravelly)	30.2	37.0	32.8	16.2	15.5	0.7
RS-17, 4.5’ to 6’	GM w/ sand	43.8	43.0	13.2	NP	NP	NP
RS-17, 6’ to 7’	SM (gravelly)	19.9	40.0	40.1	NP	NP	NP

(1) NP – non-plastic soil

Borings advanced within the footprint of the Category 2/3 Waste Rock Stockpile indicate bedrock depths ranging from 3.5 to 33 feet below the surface (Table 3-4) Noting that the RS-11 boring, which encountered the greatest depth of overburden, is located north of the northwestern stockpile boundary; the maximum soil depth within the Category 2/3 Waste Rock Stockpile footprint is estimated at 22 feet using the depth to bedrock isopach map (Attachment A). Soils in the highland areas typically consist of sands and gravel with varying amount of silt. Lowland areas are anticipated to contain surficial peat, fine grained soils and organics, underlain by glacial and alluvial deposits.

3.4 Site Conditions for Category 4 Waste Rock Stockpile

The Category 4 Waste Rock Stockpile area encompasses 57 acres. Wetland delineation within the Category 4 Waste Rock Stockpile footprint is presented in Attachment A. Geotechnical classification of subsurface soils within the Category 4 Waste Rock Stockpile footprint is based on the rotasonic drilling program by Barr in January 2008. Borings developed within the immediate vicinity of the Category 4 Waste Rock Stockpile footprint (i.e., less than 150 feet from the stockpile) are summarized in Table 3-6. Additional depth to bedrock information in the vicinity of the Category 4 Waste Rock Stockpile is presented in Attachment F.

Table 3-6 Category 4 Waste Rock Stockpile Test Pits

Test Pit	Location(1)	Bedrock Depth (feet)	Soil types
RS-05A	HL	13.0	10 feet of silty sand w/ gravel; 3 feet of silty gravel
RS-05B	HL	>5	5 feet of silty sand w/ gravel
RS-09	HL	8.0	1 feet topsoil; 6 feet of silty sand (w/ gravel); 1 feet of sandy lean clay
RS-12	HL	22.0	2 feet sandy silt w/ organics; 3.5 feet of fine sand (w/ cobbles); 16.5 feet of silty sand (w/ varying amount of gravel and cobbles)

(1) WL – wetland, HL – highland, WL/HL – wetland/highland boundary

Results from the in-laboratory material classification testing on the highland samples collected during the Barr (2008) geotechnical investigation are summarized in Table 3-7.

Table 3-7 Geotechnical Classification Results for Category 4 Waste Rock Stockpile Soils

Sample	USCS Class.	% Gravel	% Sand	% Fines	LL(1)	PL(1)	PI(1)
RS-05A, 6’ to 11.5’	SM w/ gravel	37.9	36.2	25.9	NP	NP	NP
RS-05A, 10’ to 11.5’	GM w/ sand	64.3	23.1	12.6	NP	NP	NP
RS-05A, 11.5’ to 13’	GM w/ sand	61.0	24.0	15.0	14.3	13.1	1.2
RS-09, 1’ to 7’	SM w/ gravel	31.7	50.2	18.1	NP	NP	NP
RS-12, 5.5’ to 10’	SM w/ gravel	21.7	55.3	23.0	NP	NP	NP
RS-12, 10’ to 15’	SM w/ gravel	26.0	53.3	20.7	NP	NP	NP

(1) NP – non-plastic soil

Borings advanced in the vicinity or within the footprint of the Category 4 Waste Rock Stockpile indicate bedrock depths between 5.0 and 22.0 feet below the surface (Table 3-6) with the maximum depth of 26 feet indicated by the depth to bedrock map (Attachment A) As indicated in Table 3-6, the Category 4 Stockpile is primarily founded upon highland soils, which typically consist of sands and gravels with varying amounts of silt, cobbles and boulders. Because the soil samples were collected only in the highland areas at the northeastern and the southwestern end of the stockpile, they may differ from foundation soils at other locations within the Category 4 Waste Rock Stockpile footprint, especially in wetland areas.

3.5 Site Conditions for Ore Surge Pile

The Ore Surge Pile encompasses 31 acres. Wetland delineation within the Ore Surge Pile footprint is presented in Attachment A. Geotechnical classification of subsurface soils within the Ore Surge Pile footprint is based on the rotasonic investigation completed by Barr in 2008. Geotechnical borings and test pits within the Ore Surge Pile are summarized in Table 3-8. Additional depth to bedrock information in the vicinity of the Ore Surge Pile is presented in Attachment F.

Table 3-8 Ore Surge Pile Borings

Borehole/Test Pit	Location(1)	Bedrock Depth (feet)	Soil types
MW-05-02	HL	5.0	5.0 feet of sandy clay
RS-08A	HL	11.0	11.0 feet of silty sand (w/ gravel)
RS-18A	HL	8.0	0.5 feet topsoil; 2.5 feet of silty or silty clay (w/ 10% gravel); 2 feet of clayey sand (w/ gravel); 3 feet gravelly silty sand
RS-19A	HL	9.0	1 feet surface boulder; 2.5 feet silty sand (w/ little gravel); 2.5 feet silty sand w/ gravel; 3 feet gravel and cobbles with sand
RS-20A	HL	6.5	2.5 feet silty sand (fine grained); 4 feet of silty sand (mixed w/ gravel, cobbles and boulders)

(1) WL – wetland, HL – highland, WL/HL – wetland/highland boundary

Results from the in-laboratory material classification testing on the highland samples collected during the Barr (2008) geotechnical investigation are summarized in Table 3-9.

Table 3-9 Geotechnical Classification Results for Ore Surge Pile Soils

Sample	USCS Class.	% Gravel	% Sand	% Fines	LL(1)	PL(1)	PI(1)
RS-08A, 5' to 11'	SM w/ gravel	30.5	42.5	27.0	NP	NP	NP
RS-18, 0' to 5'	SC-SM w/ gravel	26.1	44.1	29.8	23.1	17.1	6
RS-18. 5' to 8'	SM w/ gravel	31.6	47.1	21.3	NP	NP	NP
RS-19. 1.5' to 3.5'	SM w/ little gravel	13.0	47.0	40.0	19.1	17.8	1.3
RS-19, 1' to 6'	SM/SC-SM w/ gravel	22.4	45.0	32.6	19.7	16.1	3.6
RS-20. 2' to 3'	SM w/ gravel	25.4	41.5	33.1	NP	NP	NP
RS-20, 2' to 4.5'	SM w/ gravel	28.9	41.4	29.7	15.5	15.4	0.1

(1) NP – non-plastic soil

Borings advanced in the vicinity or within the footprint of the Ore Surge Pile indicate bedrock depths ranging from 5.0 to 11.0 feet below the surface (Table 3-8), with soil depths up to 12 feet indicated on the depth to bedrock map (Attachment A). However, the soil samples were collected only from the highland areas of the stockpile and may differ from foundation soils at other locations within the Ore Surge Pile stockpile footprint, especially from soils within the lowland areas located on the eastern side of the stockpile.

3.6 Site Conditions Summary

The geotechnical investigations conducted by Golder (2006) and Barr (2008 and 2010) indicate that the site foundation glacial till (overburden) soils were typically silty sands with variable percentages of clay and gravels, which classify according to the USCS as SM, SP, ML, SC and CL. The fines content (percent passing the No. 200 sieve) of the soils encountered ranged from 2% to 67%. The majority of the soils collected were non-plastic. Measured in-situ moisture contents for non-peat material ranged from 1.0% to 26.9%. The permeability of the tested undisturbed native soils ranged from $3.1x10^{-7}$ to $9.4x10^{-7}$ cm/sec. The permeability of the tested compacted native soils ranged from $1.1x10^{-7}$ to $2.0x10^{-7}$ cm/sec, indicating that the native soils are favorable for use as a compacted soil liner.

Typically, the native glacial tills have sufficiently high fines content, with an exception of the G06-TP8 sample collected from 2 to 4.5 feet, and are considered good candidates for stockpile cover construction. Cover design is discussed in Reference (1).

To optimize stockpile liner designs, additional geotechnical site characterization will be obtained to support an IFC level design. However, collection of additional site geotechnical data will require access to the lowland areas that have both regulatory and logistical constraints. In particular, no additional site disturbance can occur to obtain additional data until the land exchange and appropriate permitting is completed. As a result, the Phase II Geotechnical Investigation will be completed following completion of the land exchange and appropriate permitting, after the site is dewatered, prior to stockpile construction. This will include additional soil borings and test trenches as appropriate. The overall plan is to excavate and replace unsuitable foundation soils as part of stockpile development. Hence, additional subsurface exploration work will yield information required for annual project planning and for geotechnical analysis updates where needed. However, it is Golder's opinion that the existing geotechnical database, in combination with the requirements for stockpile liner construction subsequently stated herein, is sufficient to technically support the proposed stockpile designs for permitting. Furthermore, because the site geology and subsurface characteristics are generally understood, additional exploration will primarily be for the purpose of stockpile design optimization, confirmation of the design assumptions and earthwork balance computations.

The Phase II Geotechnical Investigation will have the following objectives:

- confirm the Phase I geotechnical classification of native soils, the locations of unsuitable soil materials, and the depth to bedrock and groundwater, and characterize the critical lowland areas prior to or in conjunction with IFC design and construction
- identify and delineate on-site borrow sources for liner and cover materials
- obtain additional samples of site overburden and waste rock materials for in-laboratory testing (if considered necessary) to confirm stability, consolidation, liner durability, and processing requirements
- update geotechnical and groundwater flow characterization analyses required to support the IFC design (i.e., to optimize the sizing and spacing of foundation underdrains, to optimize liner grades)
- provide additional site characterization information to support the bid procurement and construction requirements

As noted previously, the existing geotechnical database, in combination with the requirements for stockpile liner construction (i.e., for lined stockpiles remove all unsuitable foundation materials) subsequently stated herein and knowledge of the local geology is sufficient to technically support the proposed stockpile basic level designs for permitting. It is anticipated that upon completion of project permitting activities, Phase II Geotechnical Investigation activities will proceed in parallel with initial stockpile construction activities to support the IFC level of design.

4.0 Physical Properties of Materials

4.1 On-Site Soils

Golder’s 2006 Phase I Geotechnical Investigation and in-laboratory material testing programs and Barr’s 2010 overburden geotechnical investigation and material testing programs were conducted to provide preliminary estimates of the shear strength, permeability and consolidation parameters of the Mine Site soils. At the time that Golder’s analyses were performed, only the 2006 data were available. Therefore, the following paragraphs describe only the Phase I Geotechnical Investigation test data in greater detail. However, the additional data collected by Barr in 2010 are presented in Attachment E and are reasonably consistent with that collected in 2006. Data for Peat is provided but not relevant to lined stockpile design because Peat is considered an unsuitable foundation material and will be removed prior to construction of lined stockpiles.

Consolidated-undrained (CU) triaxial testing (ASTM D4767) and one-dimensional consolidation testing (ASTM D2435) was conducted on a relatively undisturbed Shelby tube sample of lean 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 ($feet^2/day$) 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.

In-laboratory material testing included Standard Proctor (ASTM D698) and falling head permeability (ASTM D5084) tests on three samples of native soils to evaluate their potential use as a soil liner and/or the anticipated hydraulic performance as a 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 with an optimum moisture content ranging from 12.4 to 14.2%. Prior to permeability testing, the soil samples were remolded to 95% of the maximum standard Proctor dry density at the optimum moisture content. The permeability of the compacted native soils ranged from $1.1x10^{-7}$ to $2.0x10^{-7}$ cm/sec.

4.2 Waste Rock and Ore

For waste rock and ore stockpile analysis and design, the following physical properties are used:

Mean specific gravity: 2.93

Average dry density of waste rock: 1.90 tons per cubic yard (2.47 tons per cubic yard in place).

Average waste rock porosity (assumed): 23% (30% swell).

Granular Drainage Material 1: Minimum 2 feet of minus one and one-quarter-inch (1.25-inch) crushed rock or native gravelly materials with a minimum permeability of $1x10^{-2}$ cm/s at 190 psi (to be confirmed by lab testing during the Phase II Geotechnical Investigation). This layer is also referred to as an overliner drainage layer. Maximum vertical stress on liner imposed by equipment not to exceed 8 psi; this criterion requires a minimum 6 feet of overliner material (Granular Drainage Material 1) required for a CAT 992 loader to operate on top of this material at Ore Surge Pile location.

Underdrain permeability: Minimum $1x10^{-2}$ cm/s.

Compacted Subgrade: Consists of native till soils with upper one (1) foot compacted to a dry density equal to or greater than 95% of the standard Proctor maximum dry density (ASTM D698).

Category 2/3 Waste Rock Stockpile Liner (Category 2 Liner)**:** Consists of native till soils compacted to a dry density equal to or greater than 95% of the standard Proctor maximum dry density (ASTM D698) and to achieve a permeability of equal or less than $1x10^{-5}$ cm/s. Bentonite admixing may be required to achieve the required maximum permeability. A non-soil component, consisting of a geomembrane liner, will be placed immediately above the soil liner to produce the Category 2/3 Waste Rock Stockpile composite liner system.

Category 4 Waste Rock Stockpile Liner (Category 1 Liner): Consists of native till soils compacted to a dry density equal to or greater than 95% of the standard Proctor maximum dry density (ASTM D698) and to achieve a permeability of equal or less than $1x10^{-6}$ cm/s. Bentonite admixing may be required to achieve the required maximum permeability. A non-soil component, consisting of a geomembrane liner, will be placed immediately above the soil liner to produce the Category 4 Waste Rock Stockpile composite liner system

Category 1 Waste Rock Stockpile Cover: Consists of a geomembrane hydraulic barrier layer underlain by native till soils processed as needed for use as geomembrane foundation layer material, with native soils of varying type and organic content placed in layers above the geomembrane hydraulic barrier layer to control surface water runoff and infiltration and to support establishment of a dense vegetative final cover surface layer.

5.0 Stockpile Analysis and Design Inputs

The design intent is to use on-site materials and manufactured geomembranes for stockpile liner and cover construction. On-site soils will be utilized and processed as required to meet the design requirements. If on-site soils are not directly suitable for the specified application, the soils will be processed to achieve required material properties (i.e., for liners, a grizzly may need to be used to remove oversized materials and bentonite may be admixed to reduce permeability). The following paragraphs present the design criteria and data used for stockpile analysis and design.

5.1 Climatic Data

The following climatic data were used for stockpile design and analysis:

- average annual precipitation: 29 inches
- average annual PET: 21 inches.
- Climate period for modeling: 1971 to 2000.

5.2 Stockpile Geometry

Stockpile geometry for analysis is as follows:

- minimum width at the top of stockpile: approximately 150 feet or as controlled by the minimum safe turning radius for operating mine haulage trucks
- perimeter access road width (plus allowance for berms) for light truck traffic**:** 20 feet
- nominal angle of repose slopes: 1.4H:1V (horizontal:vertical) (assumed)
- maximum slope for stockpile foundation excavation: 2H:1V
- grading considerations at closure:
    - for the Category 1 Waste Rock Stockpile: 3.75H:1V regraded interbench slopes for the geomembrane cover
    - regrading is not considered for Categories 2/3 and 4 Waste Rock Stockpiles or the Ore Surge Pile as these are temporary stockpiles
- height of first lift (over geomembrane, where located): 15 feet
- height of second lift (over geomembrane, where located): 25 feet

- nominal lift height (after initial two lifts over geomembrane and where no geomembrane is located): 40 feet
- maximum stockpile heights and interbench slope configurations considered for stability analyses are:
    - 160 feet at interbench slope angles of 1.4H:1V and 2.5H:1V
    - 200 feet at interbench slope angle of 3H:1V
    - 240 feet at interbench slope angle of 3.75H:1V

5.3 Stockpile Liner Systems and Foundations

The following information on stockpile liner systems and foundations was used for analysis:

- number of development phases: to be determined
- minimum grade for foundation underdrains: 0.5%
- minimum grade for drainage collection overliner: 0.5%
- liner system design, including piping and underliner and overliner collection points as presented in Section 2.1.3 of Reference (1))
- liner system geomembrane: 80 mil linear low density polyethylene (LLDPE)

5.4 Permanent Stockpile Development Sequence

For the Category 1 Waste Rock Stockpile, the basic engineering design assumes all unsuitable soils will be excavated and replaced with structural fill within the initial 100 feet inward from the toe limits (i.e., within 100 feet along the stockpile perimeter) for stability considerations. The perimeter stability will be confirmed based on the results of the Phase II Geotechnical Investigation.

The Category 1 Waste Rock Stockpile will be unlined. Drainage will be collected by a groundwater containment system constructed around the perimeter of the stockpile, as described in Section 2.1.2 of Reference (1)). The containment system will be installed in increments, with each increment installed prior to placement of waste rock in the stockpile segment adjacent increment.

5.5 Temporary Stockpile Development Sequence

Each of the liner systems for the temporary stockpiles will need to be constructed on a geotechnically-suitable foundation. The Phase II geotechnical program will be conducted to confirm the subgrade conditions and, if considered necessary, to collect samples for laboratory testing. Following the Phase II geotechnical program, stockpile stability will be verified and anticipated consolidation settlements will be estimated to confirm the grading plan. As noted previously and described further below, unsuitable foundation soils will be removed from beneath lined stockpiles, thereby adding flexibility to the approach taken during the Phase II Geotechnical Investigation program.

The development concept for stockpile liners includes the following considerations and assumptions:

- conduct Phase II Geotechnical Investigation to verify or modify the design as necessary, based on the encountered geotechnical conditions
- drain the site to allow access for construction equipment
- perform clearing and grubbing activities within stockpile footprints
- excavate and stockpile geotechnical-unsuitable soils (e.g., organic soils, high-plasticity soils, unconsolidated clays) for future use as a construction material or reclamation growth medium – leave structurally suitable materials (e.g., non-organic soils, over-consolidated low plasticity clays) in place above bedrock – excavation and re-compaction of these materials is not required
- place structural fill as required to meet the foundation grade requirements (granular soils, low plasticity cohesive soils and Category 1 Waste Rock)
- compact structural fill materials to 95% of the maximum dry density determined by the Standard Proctor test (or to other percentage as may be specified in final construction plans and specifications)
- develop foundation drainage to minimize the potential for development of excess foundation pore water pressures, based on the geotechnical conditions encountered (Section 5.5.1)
- establish the foundation design grades required for drainage collection, stability and other design considerations by placing engineered fill
- construct the liner system dependent upon the reactivity category of the waste rock
- develop foundation grading to provide gravity drainage and collection of drainage from the stockpile to a series of collection sumps. The water collected in the sumps will be managed as described in Reference (2)
- construct overliner cover and drainage system to facilitate drainage collection and to minimize the potential for leaks in the stockpile liner system

It is anticipated that minor sub-excavation of unsuitable soils in the highland areas and that more 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 refers to any foundation soil that may potentially undergo significant deformations, create stability problems, and/or jeopardize the general integrity of the stockpile foundations during stockpile use and after closure. In particular, soft clays or organic soils with low permeability that may exhibit large deformations and development of excess pore water pressure during the loading process are considered unsuitable. These unsuitable soils require excavation and replacement with structural fill. Structural fill materials are anticipated to consist of excavated local till and/or where approved for use, Category 1 Waste Rock, placed as 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.

5.5.1 Underdrain System

An underdrain system may be necessary in order to provide foundation drainage to facilitate construction of the liner systems and to minimize the potential for development of excess foundation pore water pressures as the stockpiles are loaded The purpose of the underdrain system is to provide gravity drainage for foundation materials in areas where elevated groundwater is encountered after routine construction dewatering has ceased, and to prevent or minimize the potential for excess pore water pressures to develop as the facility is loaded. The underdrain system may not be necessary in areas where grading fill uses Category 1 material, or in areas where granular moraine soils are present.

Preliminary designs for underdrain systems for the Category 2/3 stockpile, the Category 4 stockpile, and the Ore Surge Pile are presented in Attachment G. Design calculations, which were completed in 2008, used stockpile dimensions which differ slightly from the most current stockpile designs presented in Reference (1). Effects of these slight differences on design of underdrain systems will be resolved, and the extent and location of the underdrain system will be modified based on the results of the Phase II Geotechnical Investigation and/or conditions encountered during construction.

The preliminary underdrain design (Attachment G) includes minimum 4-inch diameter corrugated polyethylene pipes spaced at a nominal distance of 100 feet. This preliminary design is based on a minimum slope of the underdrain pipes of 0.5%, approximately following the liner grades. It is anticipated that the foundation water collected by the underdrain system will be of suitable water quality for off-site discharge through the stormwater system. Nonetheless, the underdrains will be configured to also accommodate water conveyance to the overliner sumps from where the water can be pumped to the mine Waste Water Treatment Facility. The design intent of the underdrain system is not for leakage collection; however, the potential exists that liner leakage, if it occurs, would be captured by the underdrains.

5.5.2 Liner System

The stockpile liner systems are designed to be commensurate with the level of environmental risk posed by each waste rock category, and considering the expected operating conditions of the stockpiles. Liner systems are detailed in Reference (1), and summarized in Table 5-1. The Ore Surge Pile requires a thicker overliner than the other temporary stockpiles to meet the design criteria of 8-psi maximum vertical stress on the liner based on the anticipated mine equipment operating on the overliner.

Table 5-1 Stockpile Liner System Design

Stockpile	Liner System
Category 1 Waste Rock Stockpile	No liner; drainage collection system at stockpile perimeter
Category 2/3 Waste Rock Stockpile	12-inch thick compacted (1x10^{-5} cm/s) subgrade (Category 2 Liner) overlain by 80 mil LLDPE geomembrane, covered by a 24-inch overliner drainage layer
Category 4 Waste Rock Stockpile	12-inch thick compacted (1x10^{-6} cm/s) subgrade (Category 1 Liner) overlain by 80 mil LLDPE geomembrane, covered by a 24-inch overliner drainage layer
Ore Surge Pile	12-inch thick compacted (1x10^{-6} cm/s) subgrade (Category 1 Liner) overlain by 80 mil LLDPE geomembrane, covered by a 6-foot overliner drainage layer

5.6 Stockpile Reclamation

The Category 1 Waste Rock Stockpile will be progressively reclaimed, starting in Mine Year 14, with an engineered geomembrane cover system (Section 3 of Reference (3)). Cover systems are not needed for the temporary stockpiles (Category 2/3 and Category 4 Waste Rock Stockpiles and Ore Surge Pile). Reclamation of the temporary stockpile footprints is described in Section 7 of Reference (1).

6.0 Stockpile Analysis and Design Outcomes

6.1 Stockpile Stability

The requirements for the stockpile geotechnical modeling are based on requirements of the Minnesota Department of Natural Resources Division of Lands and Minerals and are outlined in Attachment H, which describes the requirements for geotechnical analysis. Factors of Safety typically used by Golder for stockpile design at various phases of stockpile development are presented below. For geomembrane lined stockpiles, factors of safety are dependent on the geomembrane/soil liner interface strength parameters. For this analysis an effective friction angle of 19.0 degrees was used for the soil/liner interface strength. Peak friction angles in excess of 25 degrees are commonly reported in the literature, e.g. Williams and Houlihan (Reference (5)), Koutsourais et al. (Reference (6)), Stark et al. (Reference (7)), and Bhatia and Kasturi (Reference (8)). Interface friction angle will be confirmed during a Phase II Geotechnical Evaluation to be implemented prior to the initial stockpile construction. In summary, the stockpiles are designed to achieve the following:

- minimum long-term (effective stress) operational static factor of safety for deep-seated failures (waste rock mass thickness in excess of 30 feet): 1.3
- minimum short-term (total stress) operational static factor of safety for deep-seated failures (waste rock mass thickness in excess of 30 feet): 1.1
- minimum composite slope (effective stress) pseudo static factor of safety: 1.0
- minimum composite slope static factor of safety at closure: 1.5
- minimum composite slope pseudo static factor of safety at closure: 1.1
- design earthquake peak ground acceleration (PGA) (operations and closure): 0.05g with a return period of approximately 500 years. The PGA for the NorthMet Mine Site is approximately 0.05g using the FEMA maps (Reference (9)) for the spectral accelerations with a 10% probability of exceedance in 50 years.

The PGA value, based on 10% probability of occurrence in 50 years and given the anticipated site conditions, is considered appropriate for the proposed structures assuming that failure would not represent significant risk to people or result in significant damages. The adopted PGA value of 0.05 g is likely conservative as the project is located in an area of negligible (lowest) seismic hazard for which seismic parameters are difficult to quantify. Further, the USGS reports the PGA value with the return period of approximately 2500 years (2% probability of exceedance in 50 years) to be below 0.04 g (Reference (10)).

Golder conducted global stability analyses to evaluate stockpile stability under static and pseudo-static (i.e., earthquake loading) conditions, to support the basic level engineering designs. Detailed documentation of the stability analyses are presented in Attachment I.

Design cross-sections were developed to represent the following typical conditions at different phases of stockpile development:

- Category 2/3 and Category 4 Waste Rock Stockpiles and Ore Surge Pile: initial operational configuration (single lift of waste rock placed in two stages)
- Category 2/3 and Category 4 Waste Rock Stockpiles: operational configuration at ultimate build-out
- Category 1 Waste Rock Stockpile:, initial operational configuration (a single lift of waste rock with a maximum height of 40 feet placed at the angle of repose)
- Category 1 Waste Rock Stockpile: operational configuration at ultimate buildout prior to reclamation (assume four lifts of waste rock)
- Category 1 Waste Rock Stockpile: reclaimed configuration, interbench slopes regraded to 2.5H:1V
- Category 1 Waste Rock Stockpile: reclaimed configuration, interbench slopes regraded to 3.0H:1V
- Category 1 Waste Rock Stockpile:, reclaimed configuration, interbench slopes regraded to 3.75H:1V

Stability analyses were conducted using RocScience's limit equilibrium program *SLIDE* (Reference (11)). Stability analyses assumed effective stress conditions and considered both circular and non-circular slip surfaces when searching for the critical surface with the minimum factor of safety. The stability analyses utilized the Spencer method (Reference (12)).

Assuming a liner interface (i.e., overliner material/LLDPE geomembrane liner/soil liner) friction angle of 19.0 degrees, all design sections met the minimum required factors of safety outlined above. As reported in Attachment I, computed slope stability factors of safety are equal or greater than the minimum required slope stability factors of safety for the assumed material parameters. As determined by the interface friction angle sensitivity analysis in Attachment I, interface friction angles of 15.7 degrees and greater will yield acceptable slope stability factors of safety for the conditions analyzed.

Stability analyses presented herein may change as a part of the final optimized stockpile design. Anticipated additional configurations to be analyzed during the final design include but are not limited to:

- 180 feet high stockpile with liner, and interbench slope angle of 1.4(H):1(V)
- 240 feet high stockpile without liner, and interbench slope angle of 1.4(H):1(V)

- Other configurations if needed to account for variation in stockpile foundation area topography and interim fill heights as deemed appropriate by the stockpile designer.

As presented in Attachment I, the analyses yielding the smallest computed factor of safety against slope instability are those that consider the 1.4(H):1(V) interbench stockpile slopes above a geomembrane liner system. The assumed liner interface friction, as well as the strength parameters for the considered foundation and stockpile materials, will be confirmed during the Phase II Geotechnical Investigation.

6.2 Foundation Settlement

To minimize foundation settlement and to achieve the desired performance characteristics of the stockpile drainage system, compacted waste rock and/or native soils will be used for foundation grading. Structural fill will dominantly consist of native till soils compacted to 95% of the maximum dry density as determined by the standard Proctor compaction test (ASTM D 698), or to other densities as may be specified in final construction plans and specifications. When Category 1 waste rock is used to develop the foundation grades, rock fill placement will need to occur with controlled lifts placed in accordance with a specified rock fill compaction method.

The foundation soils may exhibit moderate settlement under the high-stress design conditions. As a result, a LLDPE geomembrane, or elastic polymer geomembrane with similar biaxial deformation properties, is specified for the geomembrane barrier layer component of the basal liner system for the Category 2/3 Waste Rock Stockpile, Category 4 Waste Rock Stockpile and the Ore Surge Pile due to its ability to accommodate high strain deformations. Foundation settlement and liner strain calculations are presented in Attachment J. Estimated strains are less than 1%; well below the 30% maximum strain allowed for a LLDPE geomembrane.

6.3 Liner Survivability

For angular overliner materials, a geomembrane liner load test will be conducted during the Phase II Geotechnical Investigation to support specification of the acceptable geomembrane thickness. Survivability of the proposed 80 mil LLDPE geomembrane liner for use in stockpile construction under the anticipated loading conditions is discussed in more detail in Attachment K.

7.0 Revision History

Date	Version	Description
10/04/2011	1	Initial release
05/29/2012	2	Version 2 with Responses to Comments (ERM and MDNR, EPA, Sutton) Incorporated
11/3/2014	3	Version 3 incorporates edits for consistency with Project changes since issuance of Version 2
11/25/2014	4	Version 4 incorporates edits in Response to Comments (MDNR, Knight Piesold)
7/11/2016	5	Updated to include signed PE certification.

8.0 References

1. **Poly Met Mining Inc.** NorthMet Project Rock and Overburden Management Plan (v8). July 2016.

2. —. NorthMet Project Water Management Plan - Mine Site (v5). July 2016.

3. —. NorthMet Project Adaptive Water Management Plan (v10). July 2016.

4. **Barr Engineering Co.** Wetland Delineation and Wetland Functional Assessment Report, PolyMet NorthMet RS-14 Draft-02. November 2006.

5. *Evaluations of Interface Friction Properties Between Geosynthetics and Soils.* **Williams, N. D. and Houlihan, M. F.** New Orleans : s.n., 1987. Geosynthetics '87. pp. 616-627.

6. **Koutsourais, M. M., Sprague, C. J. and Pucetas, R. C.** Interfacial Friction Study of Cap and Liner Components for Landfill Design. *Geotextiles and Geomembranes.* s.l. : Elsevier Ltd., 1991, Vol. 10, pp. 531-548.

7. **Stark, Timothy D., Williamson, Thomas A. and Eid, Hisham T.** HDPE Geomembrane/Geotextile Interface Shear Strength. *Journal of Geotechnical Engineering.* 1998, Vol. 122, 3, pp. 197-203.

8. **Bhatia, Dr. Shobha K. and Kasturi, Gautam.** Comparison of PVC and HDPE Geomembranes - Interface Friction Performance for PVC Geomembrane Institute. Champaign, IL, USA : Department of Civil and Environmental Engineering Syracuse University, November 1996.

9. **Federal Emergency Management Agency (FEMA).** *National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures – Part 1: Provisions, FEMA document No. 368 prepared by the Building Seismic Safety Council, Washington D.C.* 2001.

10. **United States Geological Survey.** Hazard Mapping Images Data, 2008 Hazard Map (PGA, 2% in 50 years). *Earthquake Hazards Program.* [Online] 2012. http://earthquake.usgs.gov/hazards/products/graphic2pct50.pdf.

11. **RocScience.** Users Manual for Slide Version 6.017. *Rocscience.* 2012.

12. **Spencer, E.** A Method of Analysis of the Stability of Embankments Assuming Parallel Inter Slice Forces. *Geotechnique.* 1967. Vols. XVII, No. 1, pp. 11-26.

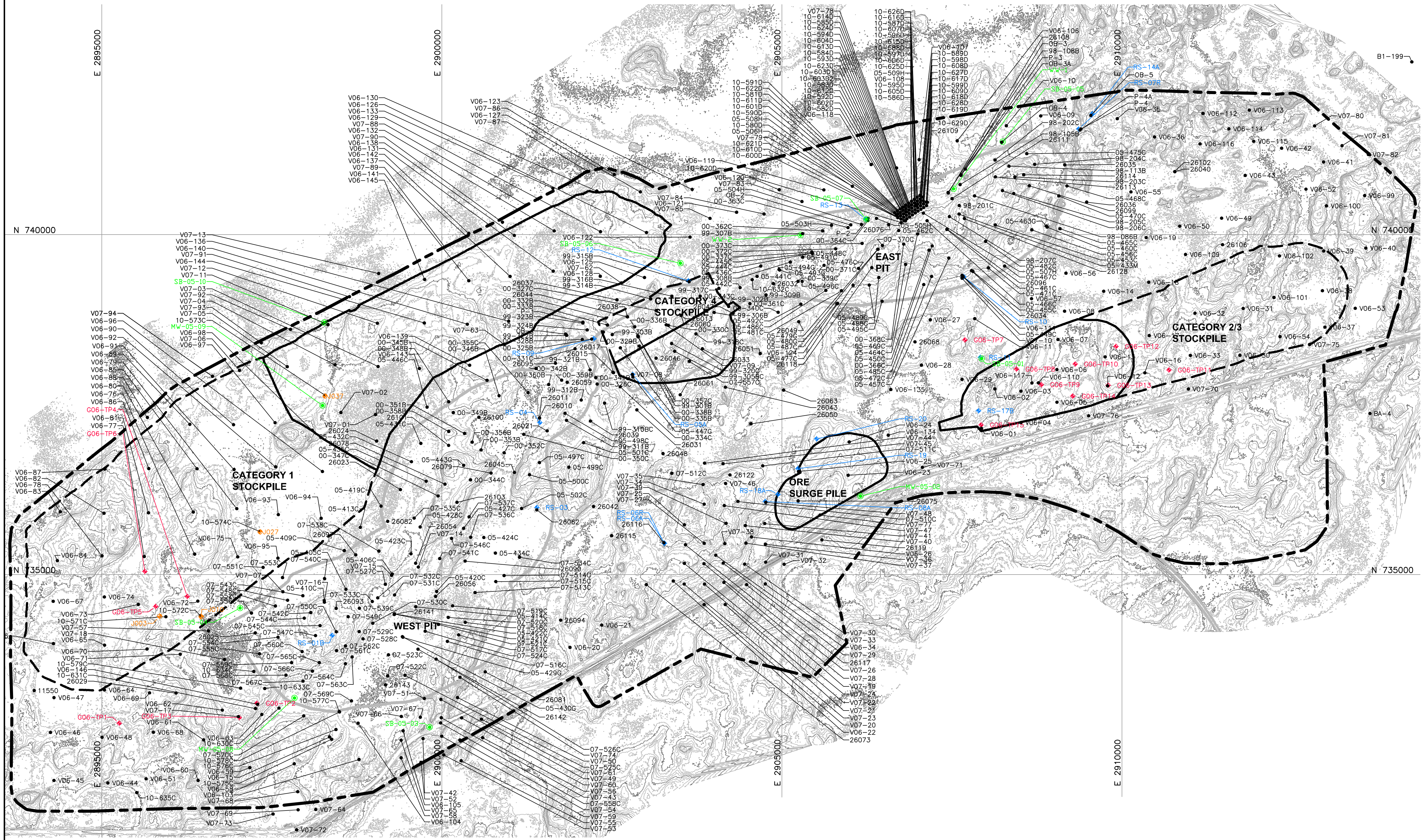
List of Tables

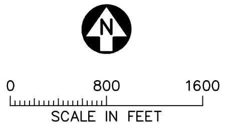
List of Attachments

Attachments

Attachment A

Exiting Conditions and Location of Field Investigations





LEGEND

▨	EXISTING GROUND TOPOGRAPHY
▬ ▬ ▬	MINE SITE BOUNDARY
─	YEAR 11 PIT BOUNDARIES (SEE NOTE 1)
─	YEAR 1 ORE, AND WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
─ ─ ─	MAXIMUM ORE, AND WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
G06-TP11 ✦	GOLDER ASSOC. TEST PIT (2006)
SB-05-01 ●	BARR ENGINEERING BOREHOLES (2005)
✦ RS-07R	BARR ENGINEERING BOREHOLES (2008)
05-444PM • 06-58	BORING OR GEOPHYSICAL SURVEY LOCATION
J003 ✦	AMERICAN ENGINEERING TESTING, INC. BOREHOLES (2010)

NOTES

1. OPEN PIT LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER.
3. SEE GENERAL NOTES AND LEGEND ON DRAWING 002.
4. SEE GEOTECHNICAL DATA PACKAGE VOLUME 3 FOR DETAILS ON TEST PITS, BOREHOLES AND GEOPHYSICAL SURVEYS.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

SITE LAYOUT AND LOCATION
OF FIELD INVESTIGATIONS

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
B	02/15/13	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
C	5/29/13	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
D	1/14/14	ISSUED FOR AGENCY REVIEW

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: MTM 09/13/11

CHECKED: GG 09/13/11

GOLDER PROJECT NO.: 113-2209

SCALE: AS SHOWN

POLYMET MINING

POLYMET MINING INC
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

Golder Associates

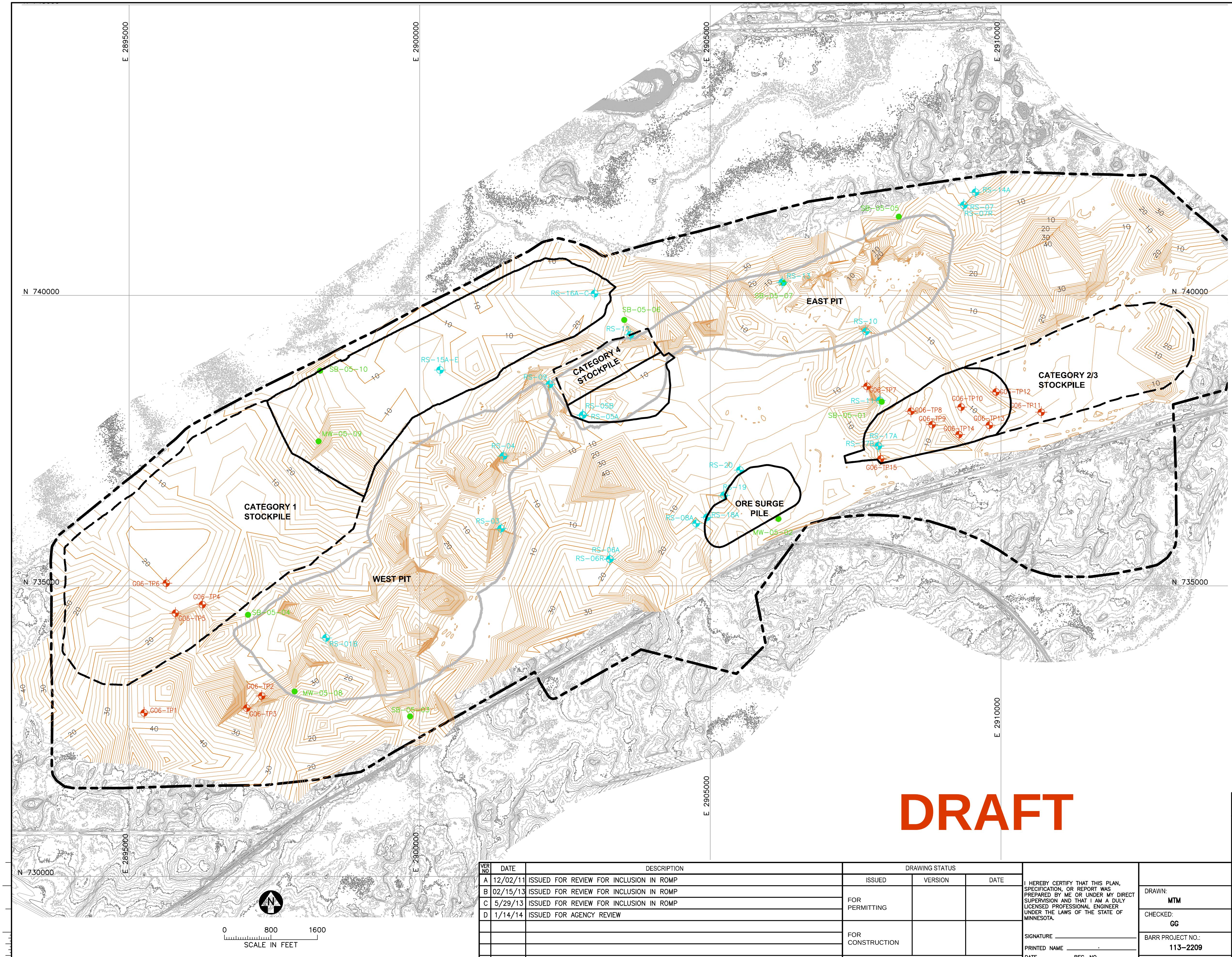
GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. SKP-008

REV D

INCHES 1 2

CADD USER: Marks, Michele FILE: C:\TAKE HOME\113-2209_H SKP FEB2013\1132209H024.DWG PLOT SCALE: 1:2 PLOT DATE: 1/11/2014 9:02 PM



LEGEND

- EXISTING GROUND TOPOGRAPHY
- MINE SITE BOUNDARY
- ESTIMATED DEPTH TO BEDROCK CONTOURS
- YEAR 11 PIT BOUNDARIES (SEE NOTE 1)
- YEAR 1 ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
- MAXIMUM ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
- G06-TP11 GOLDER ASSOC. TEST PIT (2006)
- SB-05-01 BARR ENGINEERING BOREHOLES (2005)
- RS-11 BARR ENGINEERING BOREHOLES (2008)

NOTES

1. OPEN PIT BOUNDARIES PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER.
3. SEE GENERAL NOTES AND LEGEND ON DRAWING 002.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
B	02/15/13	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
C	5/29/13	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
D	1/14/14	ISSUED FOR AGENCY REVIEW

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ______
PRINTED NAME ______
DATE ______ REG. NO. ______

DRAWN: MTM
CHECKED: GG
BARR PROJECT NO.: 113-2209
SCALE: AS SHOWN

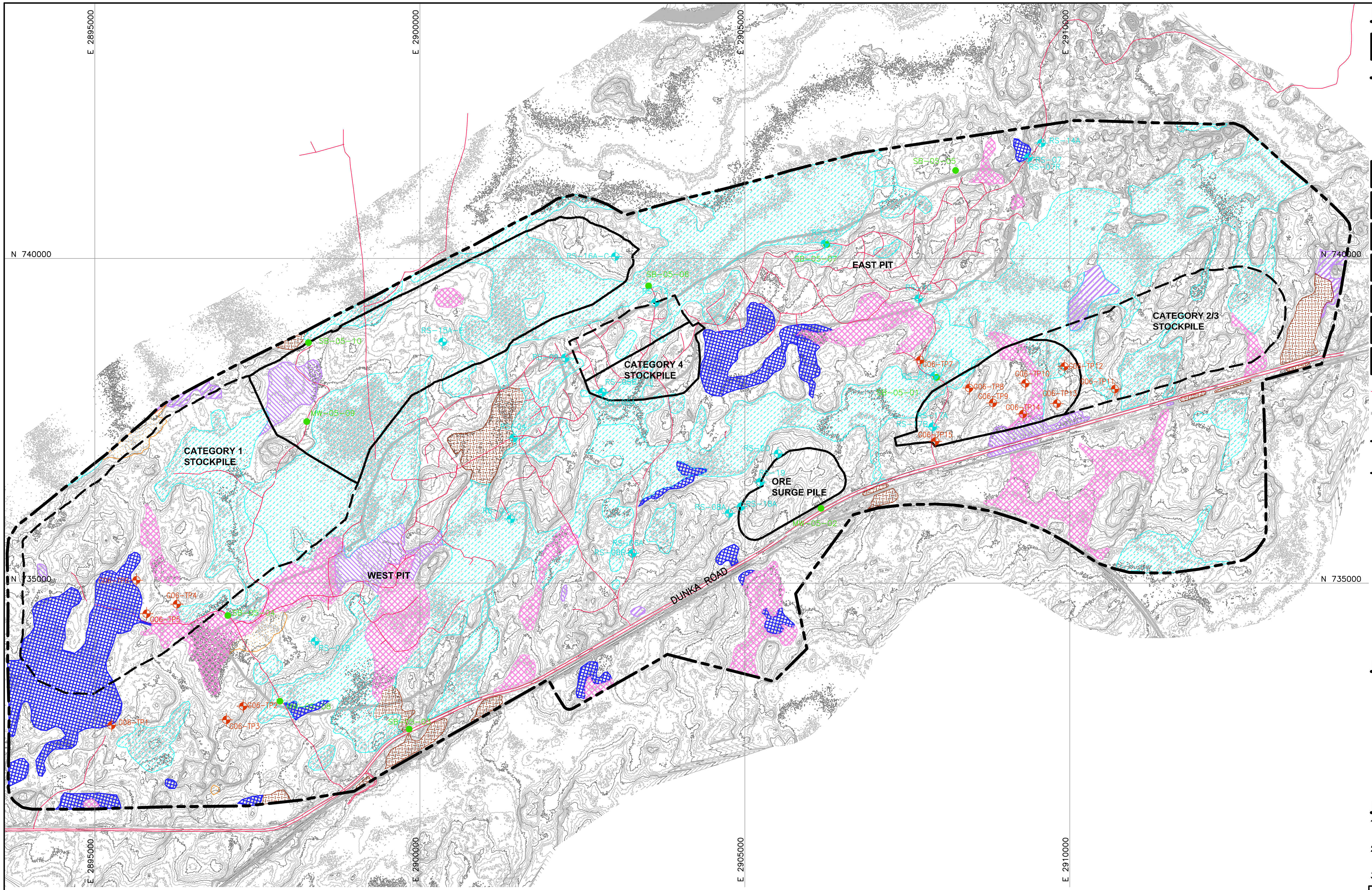
PLANT DRAWING NUMBER:

DEPTH TO BEDROCK ISOPACH MAP

POLYMET MINING INC
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. SKP-009
REV D



LEGEND

▨	EXISTING GROUND TOPOGRAPHY (SEE REFERENCE 1)
━ ━ ━	MINE SITE BOUNDARY
G06-TP11 ⌖	GOLDER ASSOC. TEST PIT (2006)
SB-05-01 ●	BARR ENGINEERING BOREHOLES (2005)
RS-11 ⌖	BARR ENGINEERING BOREHOLES (2008)
▦	SHALLOW MARSH
▩	SHRUB SWAMP
▩	CONIFEROUS SWAMP
▦	HARDWOOD SWAMP
▨	SEDGE MEADOW
▨	CONIFEROUS BOG
▨	OPEN BOG
─	EXISTING TRAIL OR ROAD
─	YEAR 11 PIT BOUNDARIES (SEE NOTE 2)
─	YEAR 1 ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 3)
─ ─	MAXIMUM ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 3)

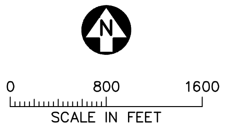
NOTES

1. WETLAND DELINEATION CHARACTERIZATION PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. OPEN PIT LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
3. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER.
4. SEE GENERAL NOTES AND LEGEND ON DRAWING 002.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH,
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

DRAFT



CADD USER: Marks, Michele FILE: C:\TAKE HOME\113-2209_H SKP FEB2013\1132209H022.DWG PLOT SCALE: 1:2 PLOT DATE: 1/11/2014 8:50 PM

INCHES 1 2

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
B	02/15/13	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
C	5/29/13	ISSUED FOR REVIEW FOR INCLUSION IN ROMP
D	1/14/14	ISSUED FOR AGENCY REVIEW

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ____________
PRINTED NAME ____________
DATE ________ REG. NO. ________

DRAWN: MTM
CHECKED: GG
GOLDER PROJECT NO.: 113-2209
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

EXISTING SITE CONDITIONS

POLYMET MINING INC
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. SKP-007
REV D

Attachment B

Well Installation Field Program - Boring Logs

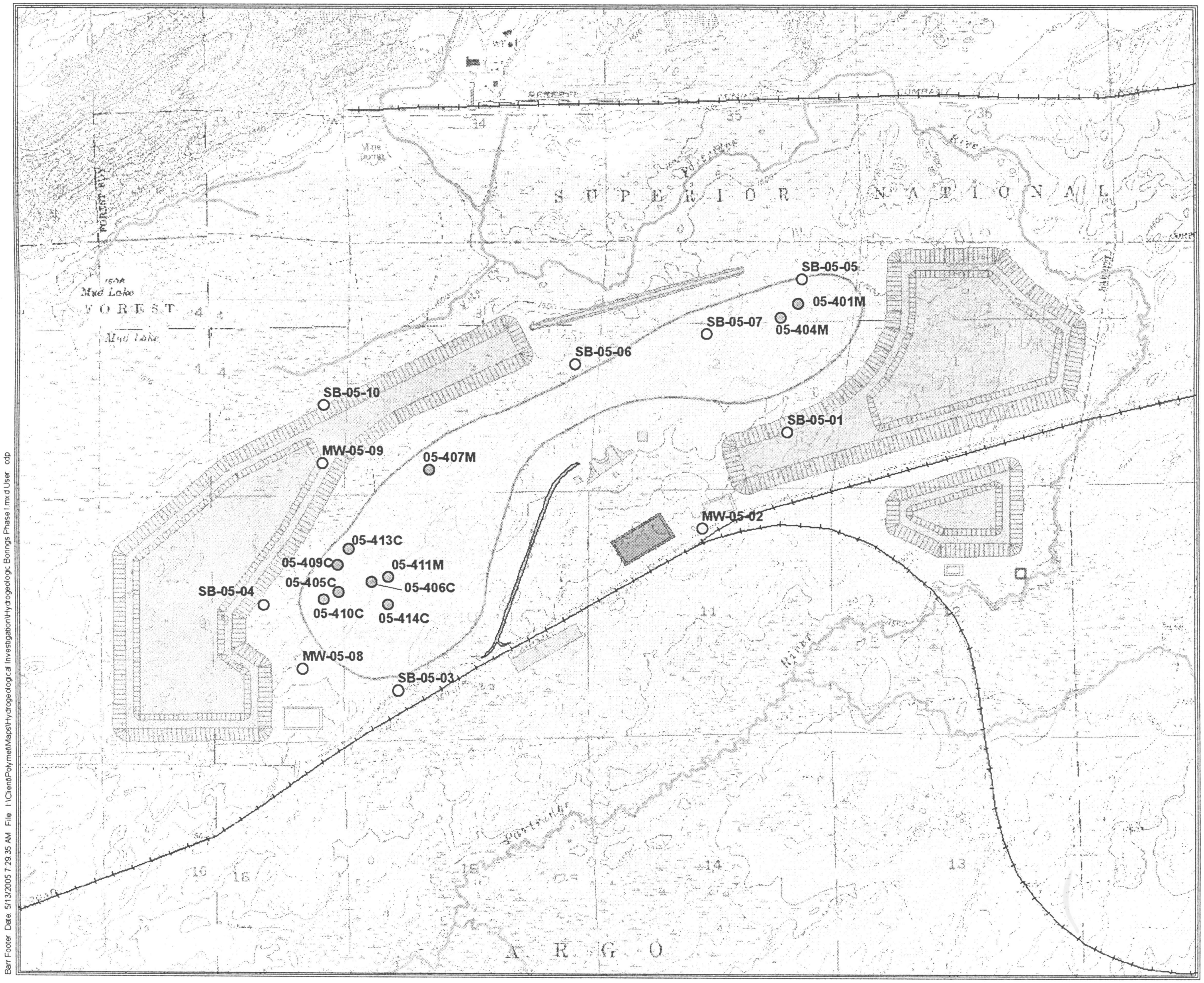


Figure 2

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

Mine Site footprint shown has been superceded and is not current

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.

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

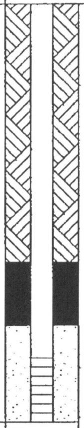
LOG OF WELL MW-05-02

DRAFT

SHEET 1 OF 1

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
0–6.5					CL	▨	Medium brown sandy clay, upper 1' wet, then moist, very moist at 5'. Chunks of black crystalline rock at 5'.		5
6.5–18							Duluth Complex gabbro.		10 15
18							End of Boring - 18 feet		



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**

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

Remarks

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
				Moist	CL	▨	Reddish-brown sandy clay with cobbles.
5				Wet	CL	▨	Dark brown to gray sandy clay.
				Moist	CL	▨	Reddish brown sandy clay with ~30% rocks/cobbles (Virginia Formation).
10				Wet	SM	⋮	Gray-brown silty sand.
				Moist	CL	▨	Gray sandy clay with ~20% rocks/pebbles.
							Boulder (no recovery).
15					CL	▨	Very dense gray clay.
20							Fine grained black rock (Virginia Formation).
							End of Boring - 20.5 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 7.5' to 12.5' 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 3/7/05 Ended 3/8/05
Logged By Mark Hagley

LOG OF Boring SB-05-04

DRAFT

SHEET 1 OF 1

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 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.

LOG OF Boring SB-05-05

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 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 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.

LOG OF Boring SB-05-06

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 3/14/05

Logged By Jere Mohr

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

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'.

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

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 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

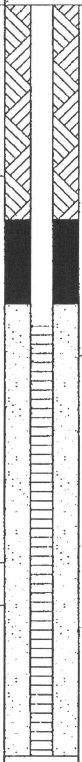
Logged By Jere Mohr

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				Wet	SP		Dark brown, well-sorted medium sand.
10				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.

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.

LOG OF WELL MW-05-09

DRAFT

SHEET 1 OF 1

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

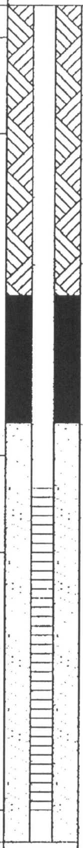
Drill Contractor WDC Exploration & Wells
Drill Method Rotasonic
Drilling Started 3/10/05 Ended 3/11/05
Logged By Mark Hagley

Elevation --
Total Depth 13.0

Moisture	ASTM	DESCRIPTION
		Topsoil.
	SP	Brown, fine-grained sand with 5-10% gravel, moist.
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.
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

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

DEPTH FEET: 5, 10, 15

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

Remarks

LOG OF Boring SB-05-10

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 3/9/05 Ended 3/10/05
Logged By Mark Hagley

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).	
							Dark gray, fine-grained crystalline rock. Argillite (Virginia Formation).	
5								5
10								10
							End of Boring - 14.5 feet	
15								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.

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

LOG OF WELL SB-05-10A

DRAFT

SHEET 1 OF 1

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

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.

Attachment C

Phase I Geotechnical 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

Golder Associates Inc.

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

August 29, 2006 Our Ref.: 053-2209.002

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

Attention: Mr. Don Hunter, C. Eng., CP

RE: PHASE I GEOTECHNICAL FIELD INVESTIGATION REPORT
POLYMET NORTHMET SITE – NEAR BABBITT, MINNESOTA

Dear Mr. Hunter:

This data report summarizes the results of the Phase I geotechnical test trench program performed for the PolyMet NorthMet Project. We trust that this report provides you with the preliminary information that you need at this time.

This report presents the results of the field investigation, referencing the early waste stockpile footprints proposed by PolyMet. Additional recommendations for the waste stockpiles, including locating and sizing of the waste stockpile footprints, are currently being developed by our staff in the Denver office based on recent information received from your design team.

We look forward to continuing to work with you on this interesting project. Please contact Brent Bronson at (303) 980-0540 with any questions regarding this report.

Sincerely,

GOLDER ASSOCIATES INC.

Amy Thorson

Amy C. Thorson, P.E.
Senior Engineer

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

ACT/BRB:dls

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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.

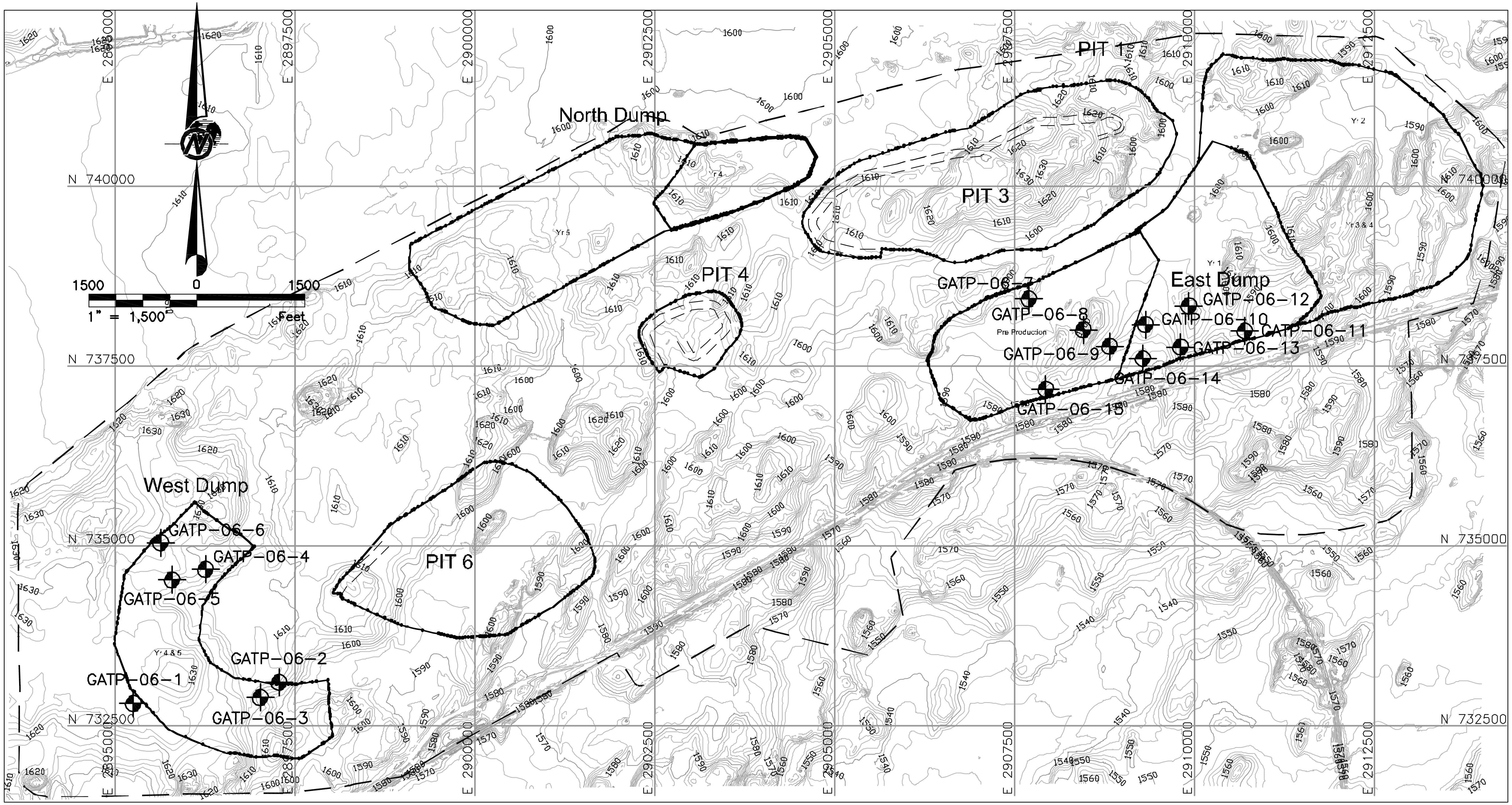
Amy Thorson

B Bronson

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

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

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

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

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

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

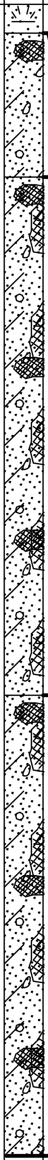
Station / Location West Area, 5272811N, 574936E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

Depth in (ft.)		
Time		
Date		
Symbol		

Method	Depth in (Feet)		Sample Data Method	Sample Data Number		Loc. Sampled	Water Level	SUBSURFACE MATERIAL
Excavaton	0 - 0.5							0.0 - 0.5 Topsoil
	0.5 - 3.0		GRAB	1				0.5 - 3.0 Moist, brown, silty SAND with little to some gravel, cobbles (SM)
	3.0 - 12.0		GRAB	2				3.0 - 12.0 Moist, light brown, silty SAND with gravel, few cobbles and boulders (SM)
	12.0 - 20.0		GRAB	3				12.0 - 20.0 Moist to wet, gray, silty SAND, little to some gravel, cobbles and boulders (SM)

Soil Graph



BOH
20 ft.

Notes:
No bedrock encountered.

CHECKED:
DATE:

Golder Associates

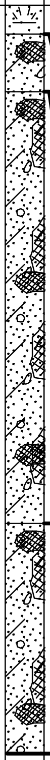
LOG OF TEST TRENCH

Test Pit Number G06-TP2
Project POLYMET
Total Depth 13 feet
Project Number 053-2209
Date Begin 4/18/06
Date End 4/18/06
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	SUBSURFACE MATERIAL
Excavation	0		GRAB	1				0.0 - 0.5 Topsoil 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.

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

Golder Associates

Sheet Number 1 of 1

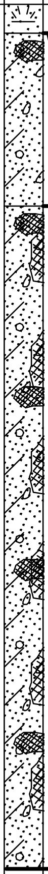
Test Pit Number G06-TP3
Total Depth 15 feet
Date Begin 4/18/06
Date End 4/18/06
Elevation Reference ---

Project POLYMET
Project Number 053-2209

Station / Location West Area, 5272836N, 575474E
Offset from Center Line
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	Sample Data Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0								0.0 - 0.5 Topsoil
	0.5		GRAB	1					0.5 - 3.5 Moist, reddish-brown, silty SAND with gravel, few cobbles (SM)
	3.5		GRAB	2					3.5 - 15.0 Moist to wet, grayish brown, silty SAND, some silt, with gravel, cobbles and boulders (SM)
	13						▼		
	15							BOH 15 ft.	Notes: Bedrock encountered at 15.0 feet.



CHECKED: DATE:

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

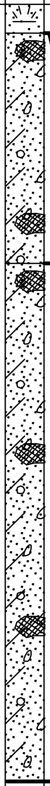
Project POLYMET
Project Number 053-2209

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		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
		Method	Number				
Excavation	0.0 - 0.5	GRAB	1				Topsoil
	0.5 - 4.5						Moist to wet, brown, silty SAND with gravel, little silt, cobbles (SM)
	4.5 - 13.5	GRAB	2				Moist, grayish-brown, silty SAND, some gravel, few cobbles, some silt (SM)



BOH
13.5 ft.

Notes:
Bedrock encountered at 13.5 feet.

CHECKED: DATE:

Golder Associates

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

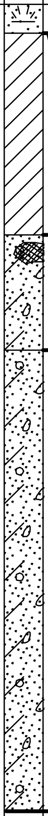
Project POLYMET
Project Number 053-2209

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	Soil Graph	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)
	14							BOH 14 ft.	



Notes:
Bedrock encountered at 14.0 feet.

CHECKED: DATE:

Golder Associates

LOG OF TEST TRENCH

Sheet Number 1 of 1

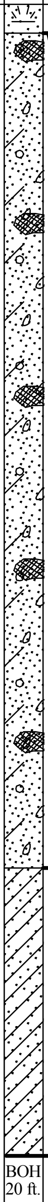
Test Pit Number G06-TP6
Total Depth 20 feet
Date Begin 4/17/06
Date End 4/17/06

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 - 0.5 Topsoil
	1		GRAB	1					0.5 - 15.0 Moist, brown, silty SAND with gravel, little to some silt, few cobbles and boulders (SM)
	15		GRAB	2			▼		15.0 - 20.0 Waterbearing, gray, sandy SILT (ML)
	20							BOH 20 ft.	Notes: No bedrock encountered
	25								

CHECKED: DATE:

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 – 0.5		GRAB	1					0.0 - 0.5 Topsoil
	0.5 – 3.5								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

Golder Associates

Sheet Number 1 of 1

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

Project POLYMET
Project Number 053-2209

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	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL	
Excavation	0		GRAB	1					0.0 - 2.0 Moist, reddish-brown, silty SAND, little gravel, little to some silt (SM)	0
	1									1
	2		GRAB	2					2.0 - 4.5 Moist, brown, medium to coarse grained SAND and GRAVEL, trace silt, (SP)	2
	3									3
	4						▼			4
	5							BOH 4.5 ft.	Notes: Bedrock encountered at 4.5 feet	5
	6									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

CHECKED: DATE:

LOG OF TEST TRENCH

Golder Associates

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	▼	

BOH
8.5 ft.

Method	Depth in (Feet)		Sample Data: Method	Sample Data: Number	Sample Data	Loc. Sampled	Water Level	SUBSURFACE MATERIAL
Excavation	0 - 4		GRAB	1				0.0 - 0.5 Topsoil 0.5 - 4.0 Moist, brown, silty SAND, little to some gravel, some silt, few cobbles and boulders (SM)
	4 - 8.5		GRAB	2			▼	4.0 - 8.5 Wet, brown, medium to coarse grained SAND and GRAVEL, little silt, few cobbles (SP-SM)

Notes:
Bedrock encountered at 8.5 feet

CHECKED: DATE:

Golder Associates

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

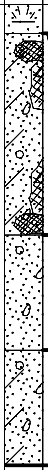
Station / Location East Area, 5274415N, 579221E
Offset from Center Line
Elevation Reference ---
Equipment Type 690 ELC
Weather
Golder Staff M. Krzewinski
Field Crew R. Radotich

Ground Water Data

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

Method	Sample Data Method	Number
Excavation	GRAB	1
	GRAB	2
	GRAB	3

Water Level: ▼ 4


BOH 8 ft.

SUBSURFACE MATERIAL

0.0 - 0.5
Topsoil

0.5 - 4.0
Moist, brown, silty SAND, little gravel, some silt, few cobbles
(SM)

4.0 - 6.0
Wet, brown, medium to coarse grained SAND and GRAVEL, trace silt
(SP)

6.0 - 8.0
Wet, brown, silty SAND with gravel, little silt, some gravel
(SP-SM)

Notes:
Bedrock encountered at 8.0 feet

CHECKED: DATE:

LOG OF TEST TRENCH

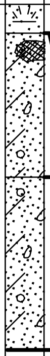
Sheet Number 1 of 1

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								0.0 - 0.5 Topsoil	0
	1		GRAB	1					0.5 - 3.0 Moist, reddish-brown, silty SAND with gravel, some silt, cobbles (SM)	1
	2									2
	3		GRAB	2					3.0 - 6.0 Moist to wet, brown, fine to coarse grained silty SAND and GRAVEL, (SM)	3
	4									4
	5									5
	6							BOH 6 ft.		6
	7								Notes: Bedrock encountered at 6.0 feet	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

CHECKED: DATE:

LOG OF TEST TRENCH

Golder Associates

Sheet Number 1 of 1

Project POLYMET
Project Number 053-2209

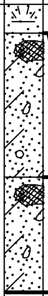
Test Pit Number G06-TP12
Total Depth 5 feet
Date Begin 4/17/06
Date End 4/17/06

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 – 0.5								0.0 - 0.5 Topsoil
	0.5 – 3		GRAB	1					0.5 - 3.0 Moist, brown, silty SAND with gravel, little to some silt, cobbles (SM)
	3 – 5		GRAB	2					3.0 - 5.0 Moist, grayish-brown, silty SAND with gravel, little to some silt, few cobbles (SM)
	5							BOH 5 ft.	



Notes:
Bedrock encountered at 5.0 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:

Golder Associates

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

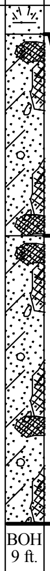
Project POLYMET
Project Number 053-2209

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	SUBSURFACE MATERIAL
Excavation	0.0 - 0.5	GRAB	1			Topsoil
	0.5 - 4.0					Moist, reddish-brown, silty SAND with gravel, little to some silt, few cobbles and boulders (SM)
	4.0 - 9.0	GRAB	2			Moist to wet, grayish-brown, silty SAND with gravel, little to some silt, few cobbles and boulders (SM)



BOH
9 ft.

Notes:
Bedrock encountered at 9.0 feet

CHECKED:
DATE:

LOG OF TEST TRENCH

Golder Associates

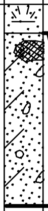
Sheet Number 1 of 1

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

Project POLYMET
Project Number 053-2209

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		

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

CHECKED: DATE:

LOG OF TEST TRENCH

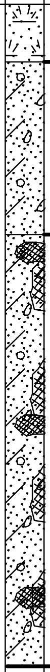
Sheet Number 1 of 1

Golder Associates

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	Number		Loc. Sampled	Water Level	Soil Graph	SUBSURFACE MATERIAL
Excavation	0								0.0 - 1.0 Topsoil
	1		GRAB	1					1.0 - 4.0 Moist, brown, silty SAND with gravel, some gravel, some silt (SM)
	4		GRAB	2			▼		4.0 - 11.5 Moist, grayish-brown, silty SAND with little gravel, little to some silt, cobbles and boulders (SM)



BOH
11.5 ft.

Notes:
Bedrock encountered at 11.5 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

CHECKED: DATE:

APPENDIX B

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

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.: 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 for
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 **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.: 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
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: 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

BRAUN
INTERTEC

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

Phone: 218.263.8869
Fax: 218.263.6700
Web: brauninterec.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.: 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

BRAUN
INTERTEC

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

Phone: 218.263.8869
Fax: 218.263.6700
Web: brauninterec.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.: 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

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: 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'

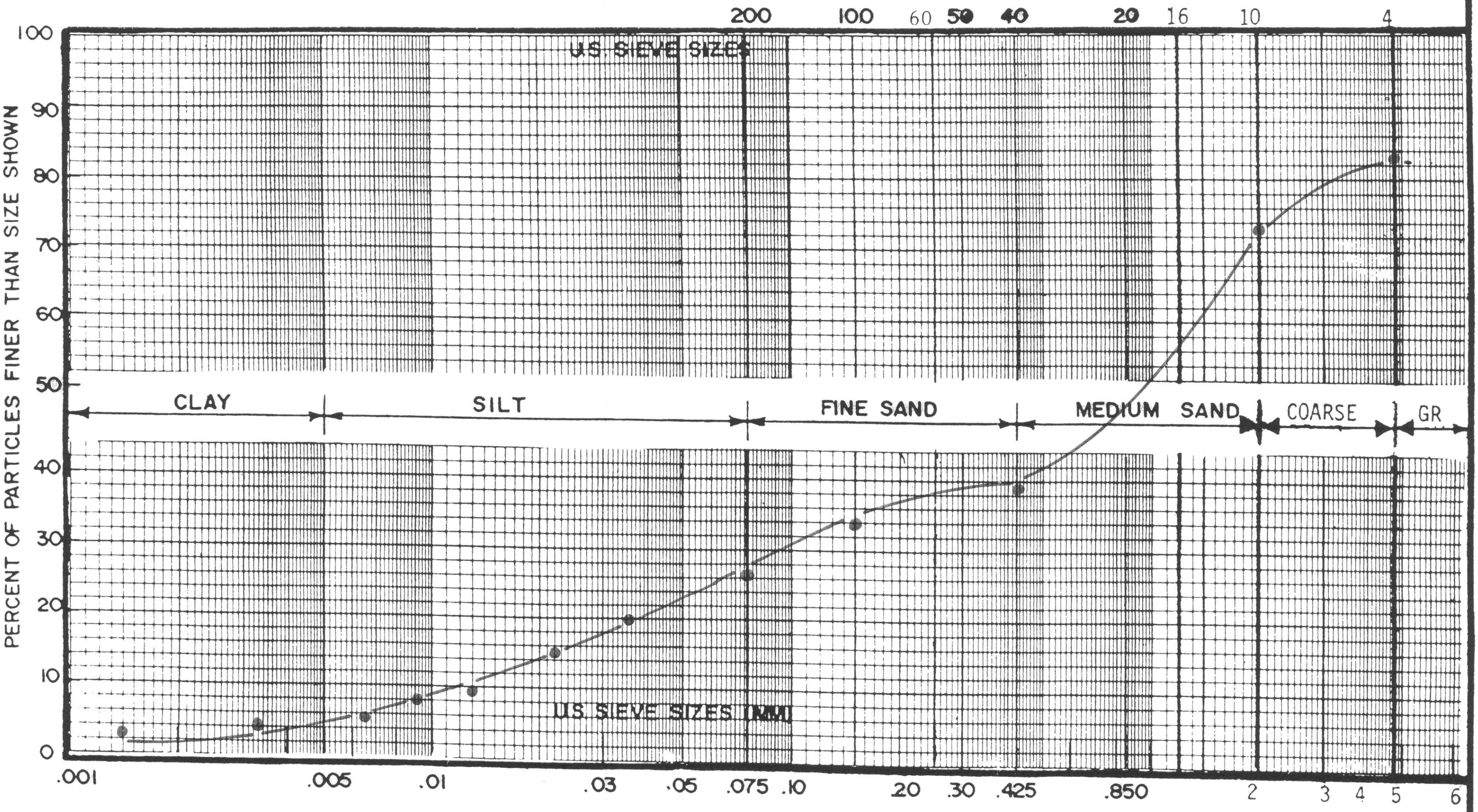
Laboratory Results:

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

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: 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
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: 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

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.: 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'

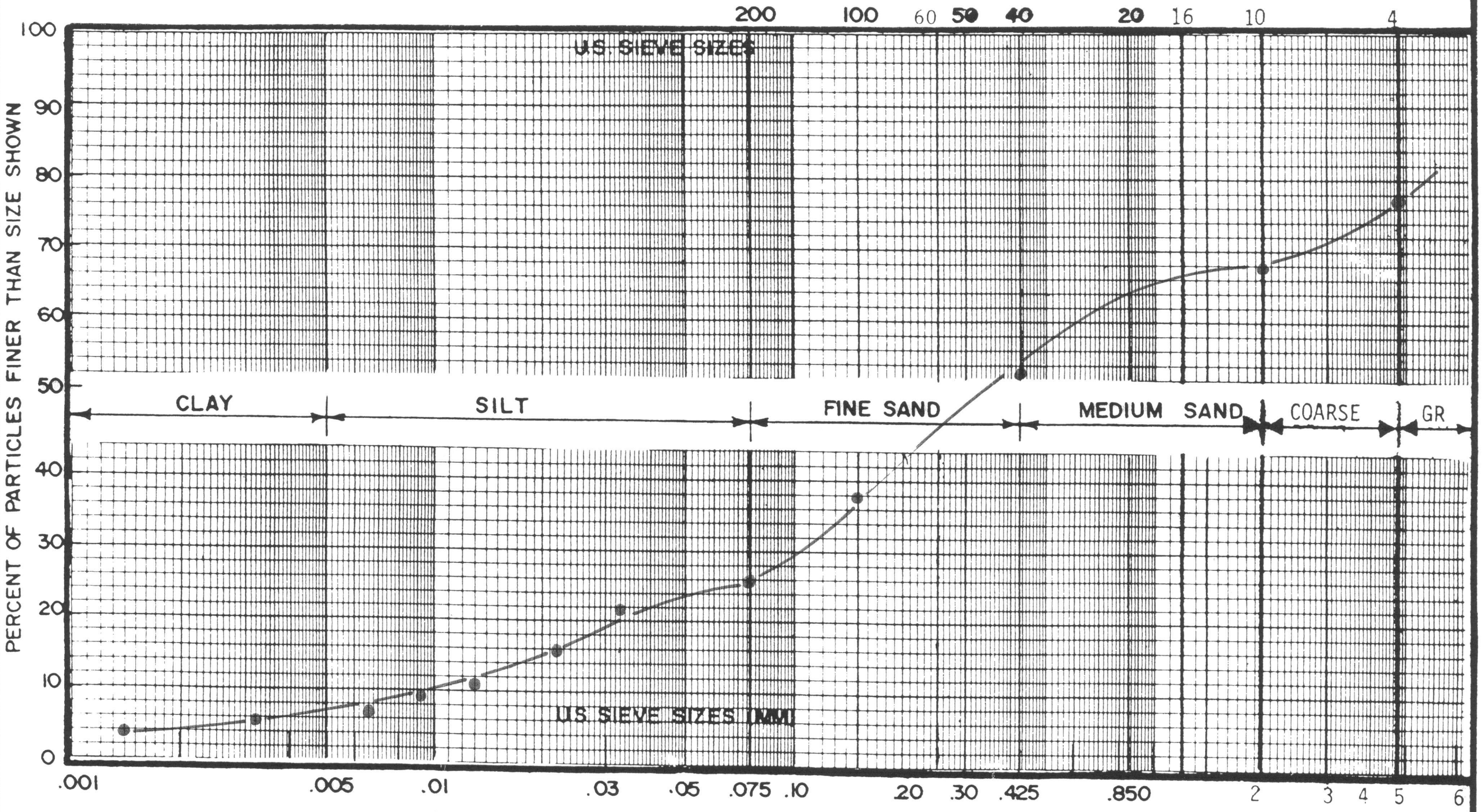
Laboratory Results:

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
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.: 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

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.: 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'

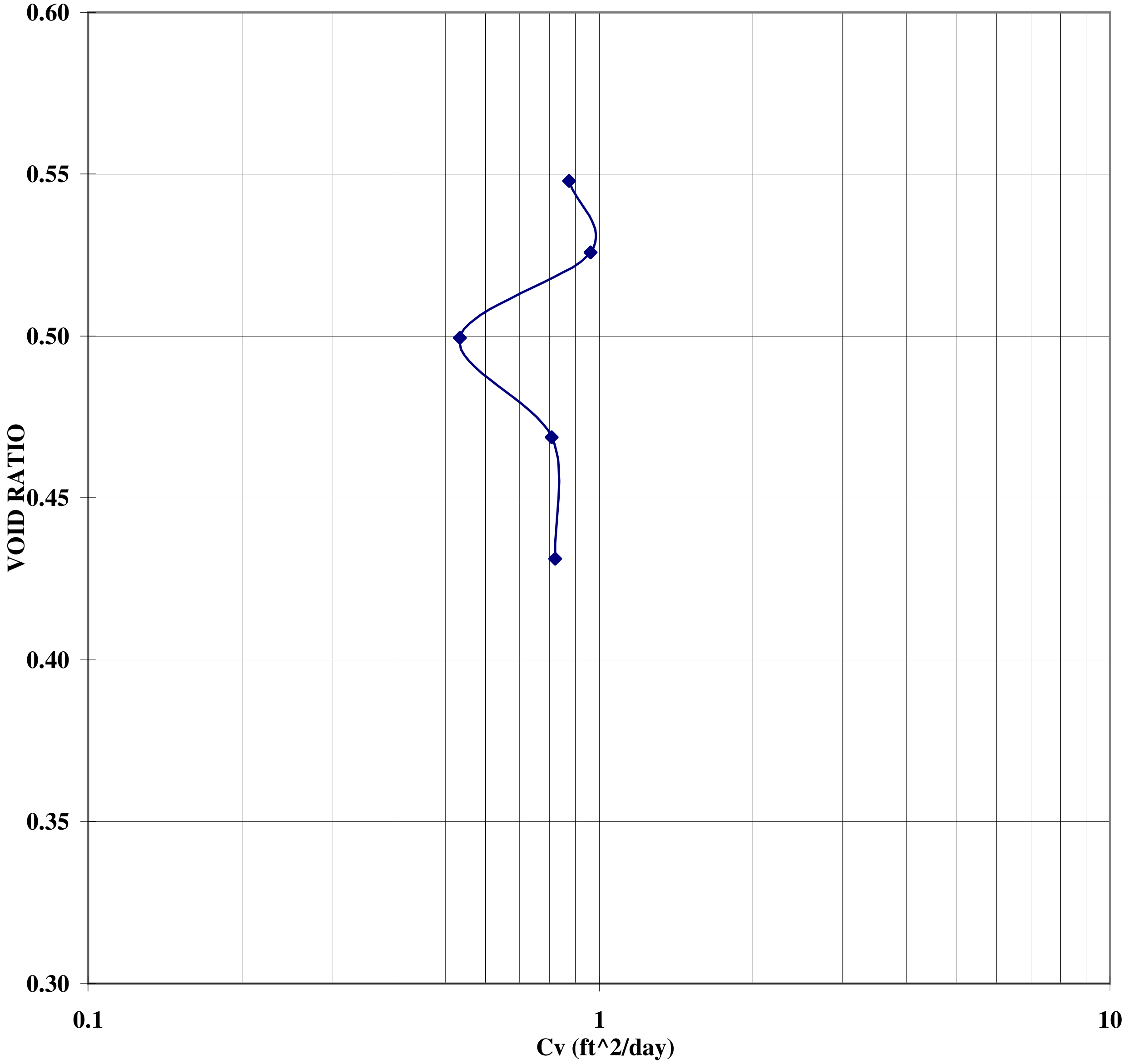
Laboratory Results:

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.

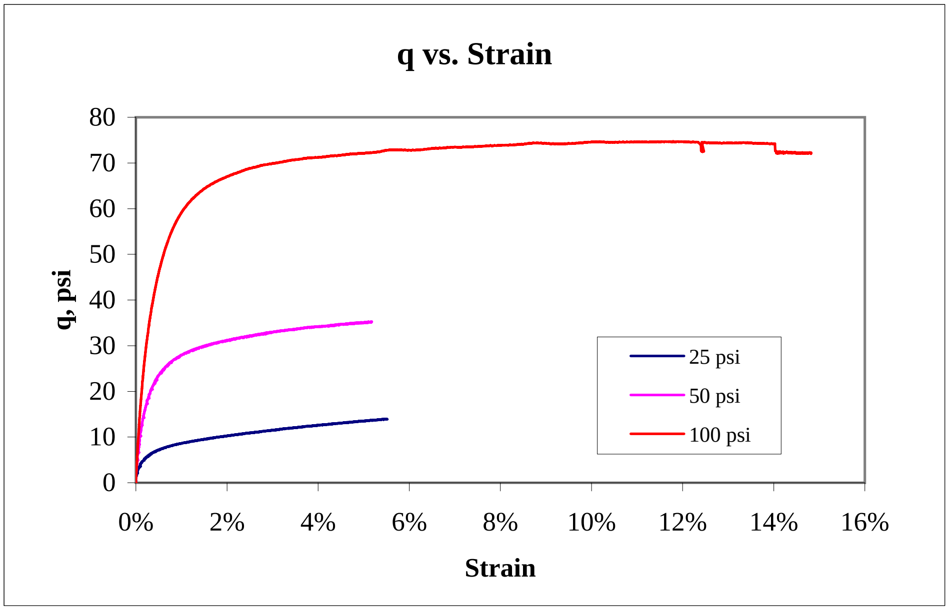
Golder Associates, Inc.
Denver, Colorado

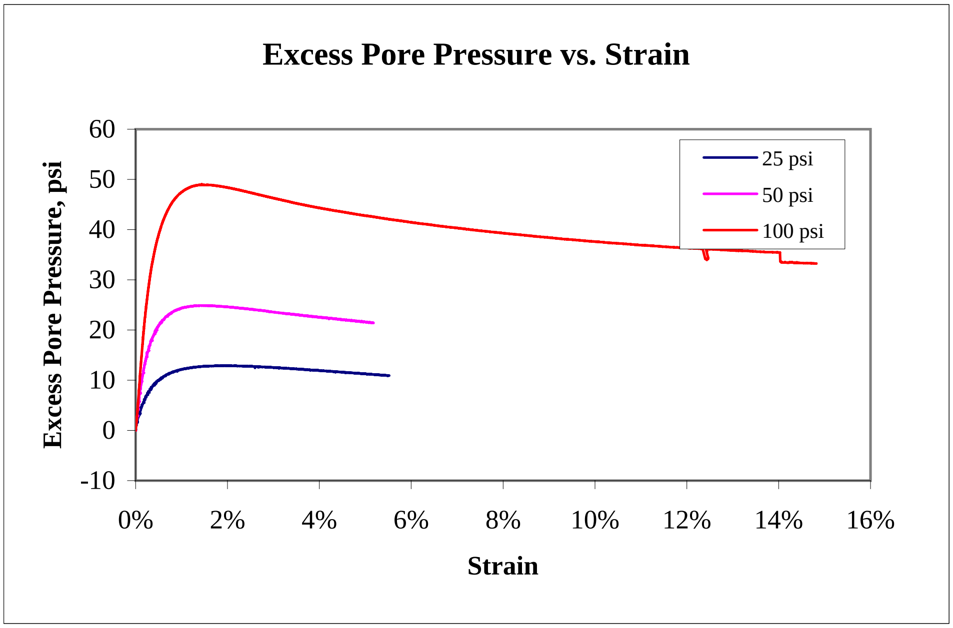
Job Short Title:
Polymet Minnesota

Title:

TRIAXIAL SHEAR TEST REPORT
SAMPLE DATA AND CALCULATIONS

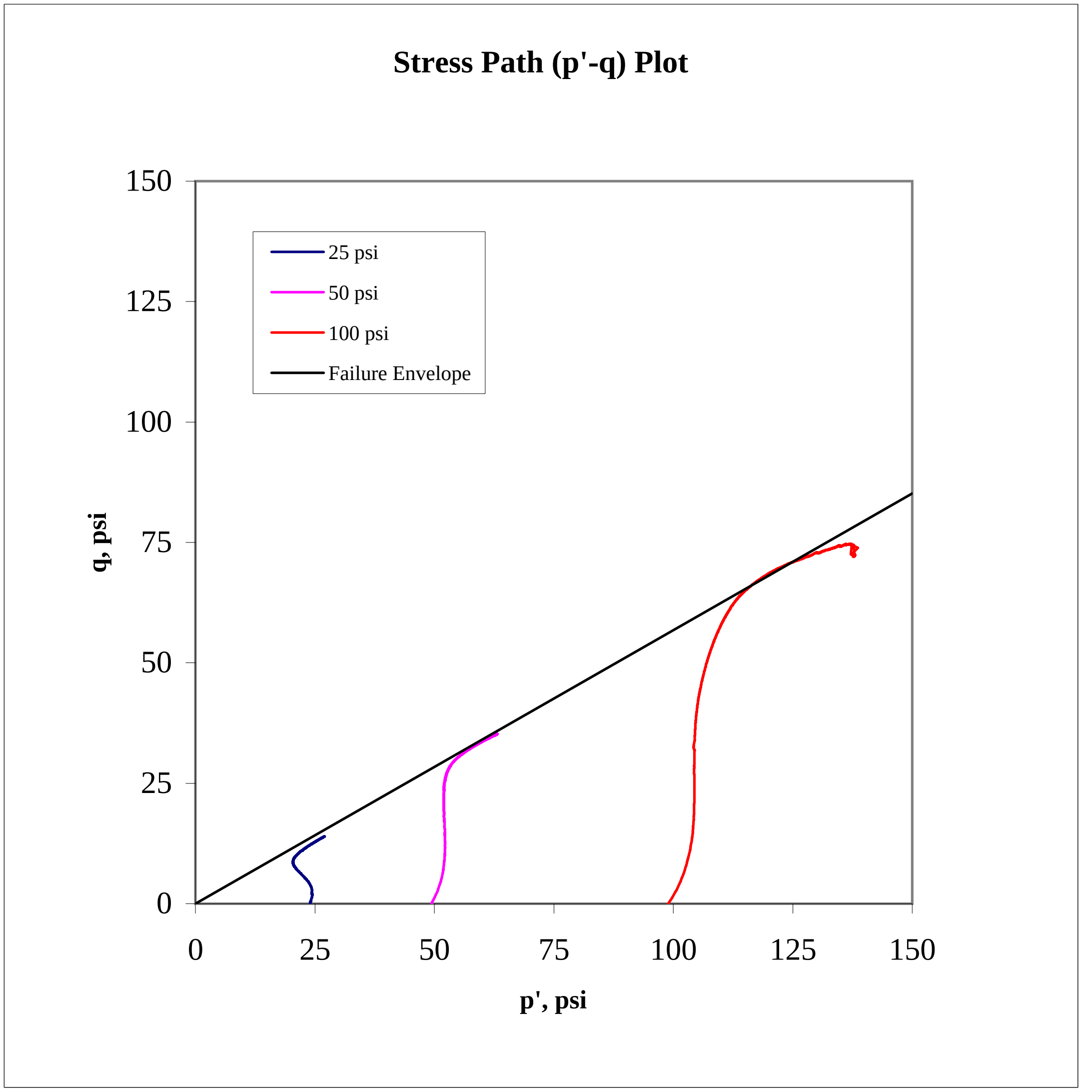
	Reviewed:	**Date:**	**Job Number:**	**Figure:**
G06 - TP5 1A 0.5 -4'	**JEO**	**5/12/2006**	**053-2209**	**1**





Golder Associates, Inc. **Denver, Colorado**	**Title:** **C-U TRIAXIAL SHEAR DATA** **q AND EXCESS PORE PRESSURE PLOTS**
Job Short Title: **Polymet Minnesota**	

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



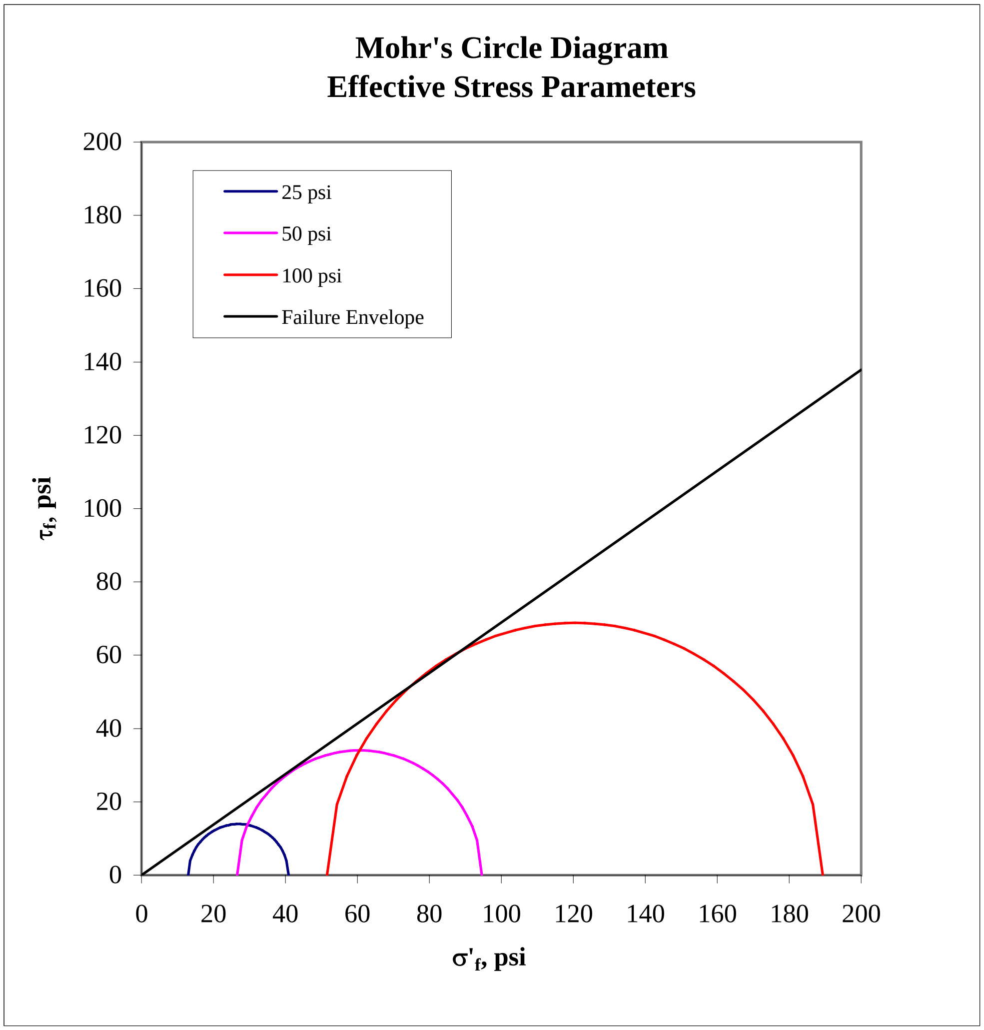
Stress Path Parameters

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

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

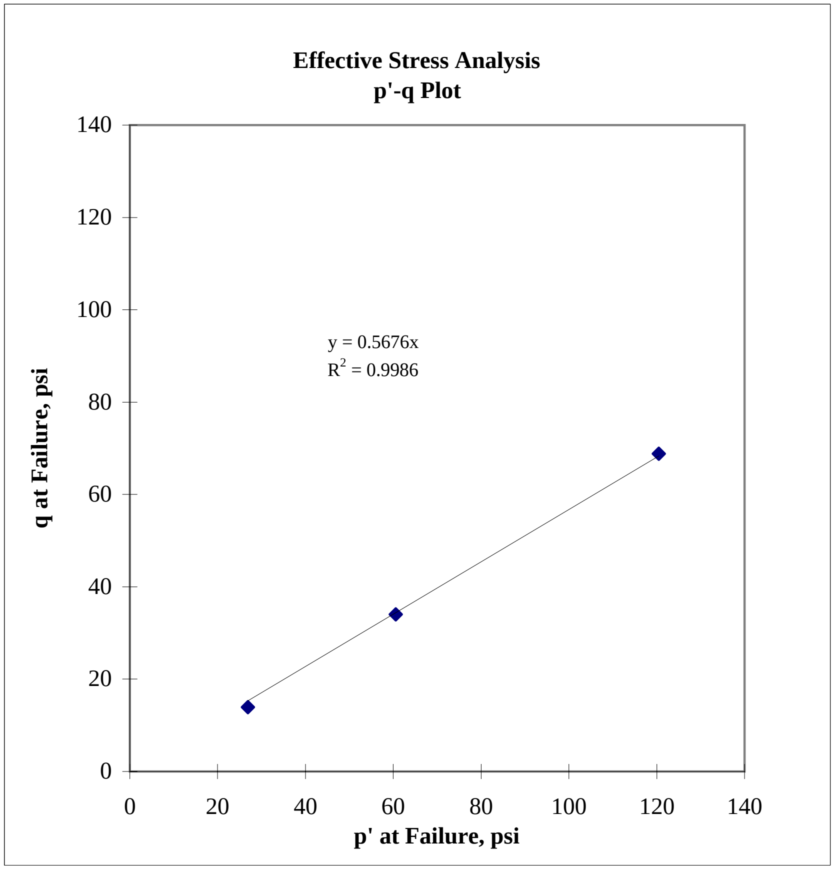
Sample Number G06 - TP5 1A 0.5 -4'

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**

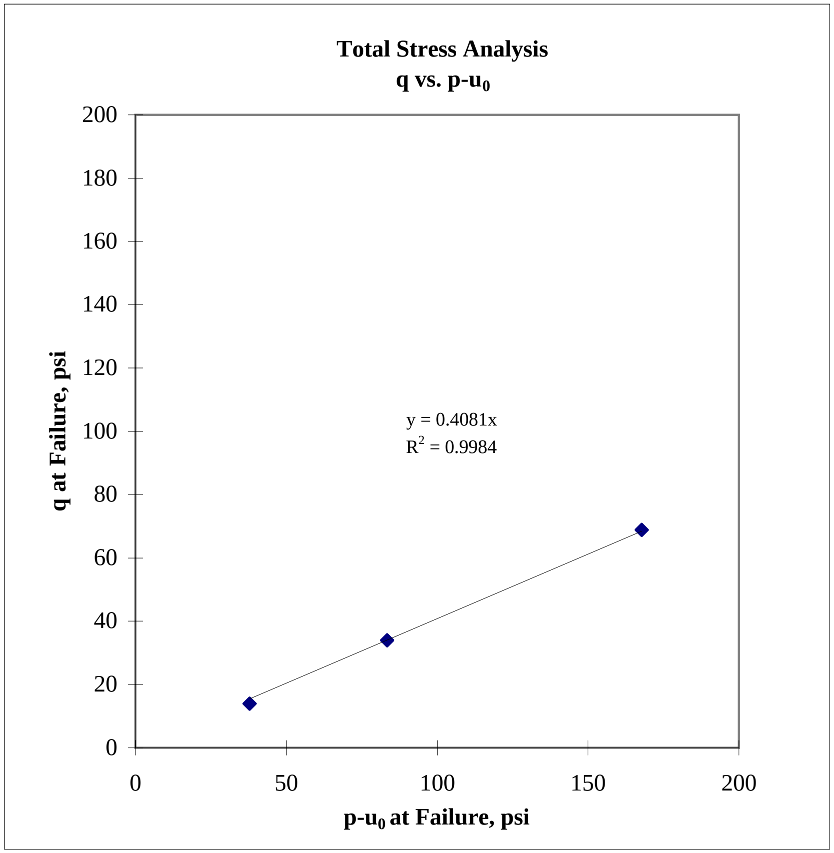
Sample Number G06 - TP5 1A 0.5 -4'

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(ψ) = **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:

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

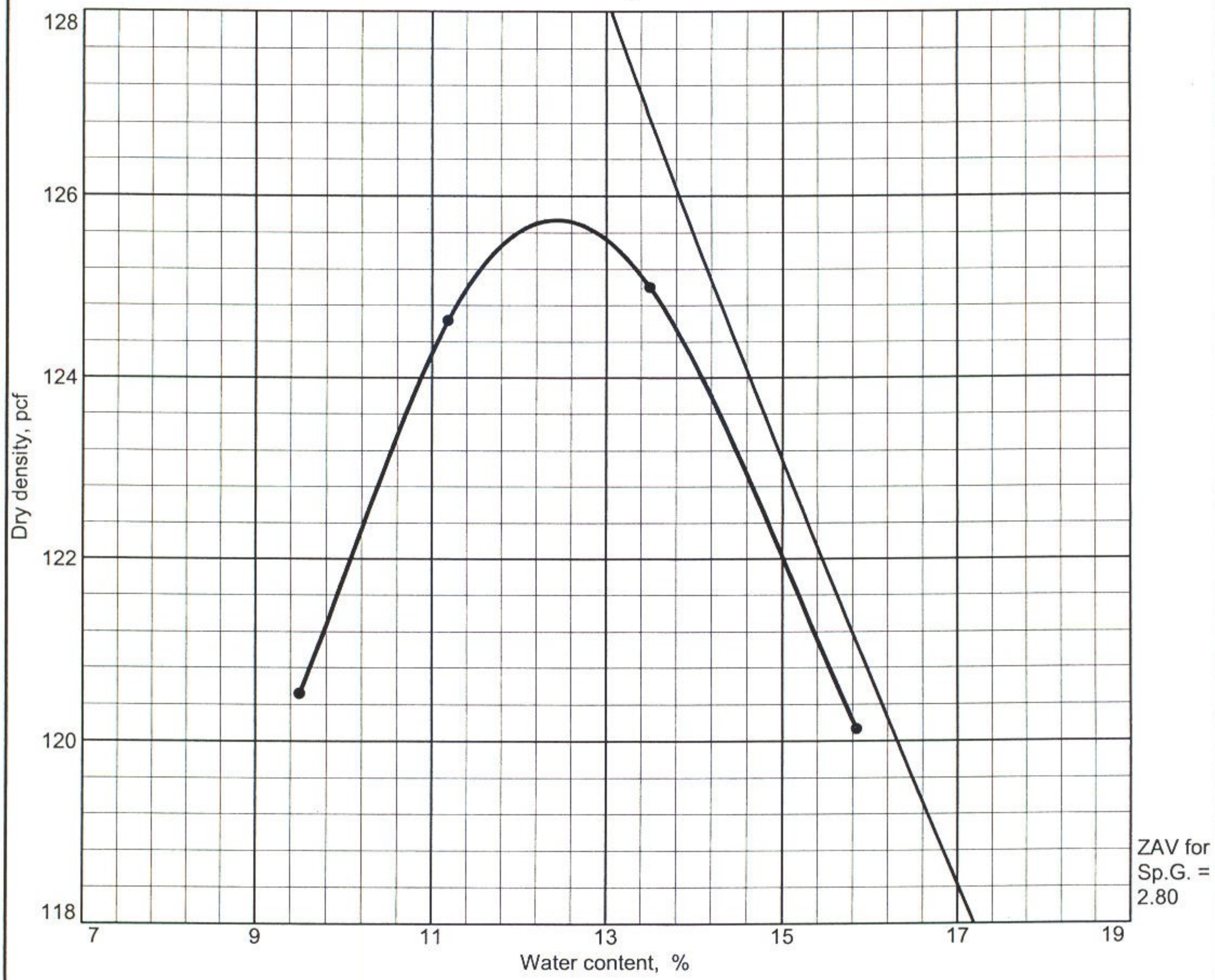
The relationships between ψ' and ϕ' and a' and c' are as follows:

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

Staged Triaxial Shear Test
Polymet/ Minnesota
053-2209

Boring Number G06-TP5
Sample Depth 0.5-4'

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)

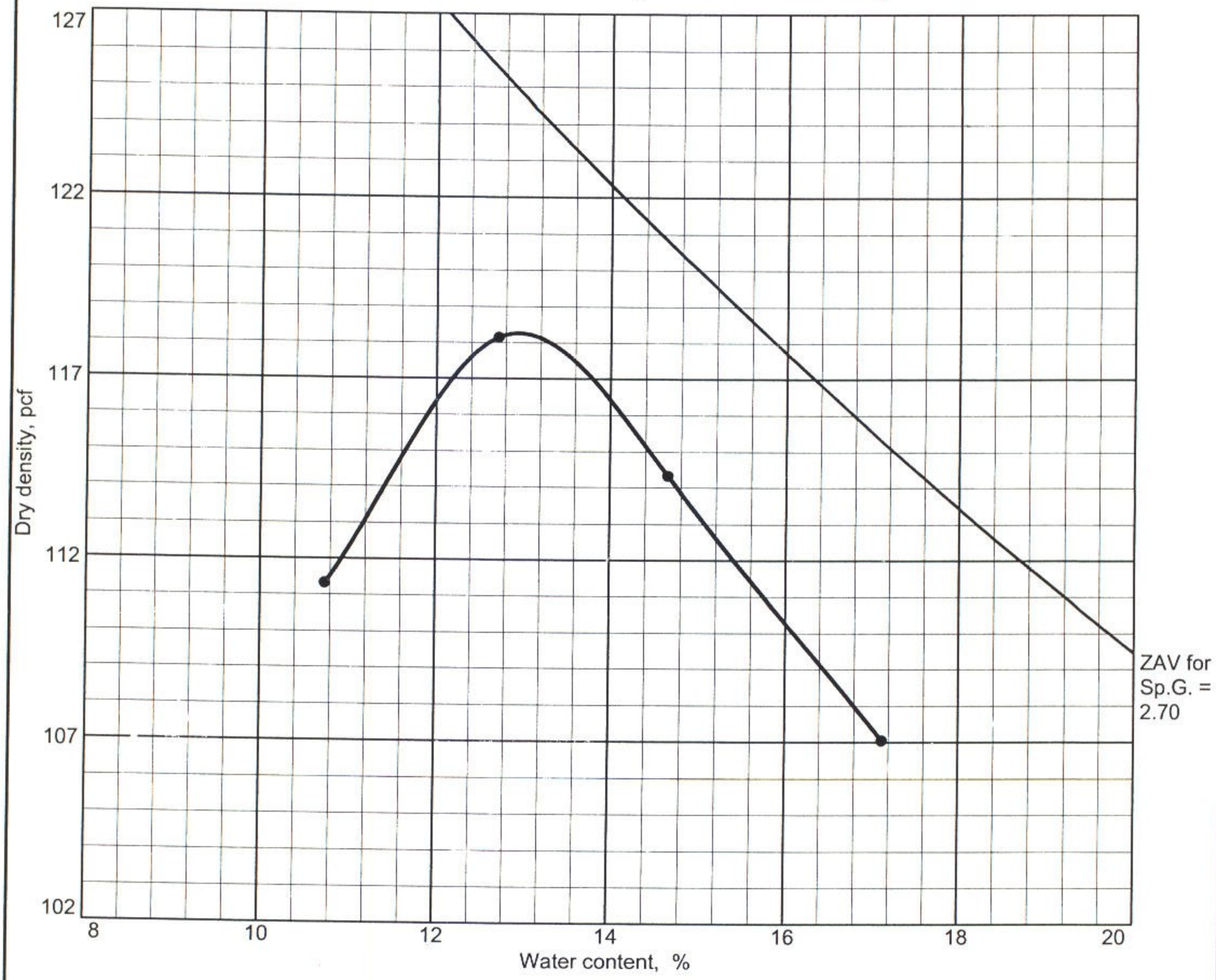
Sample Number:	3
Date Sampled:	N/A
Sample Location:	TP #4, Sample #1, 0.5-4.5'
Soil Classification:	SC-SM – Silty Clayey Sand, brown
Type of Test:	Falling Head (ASTM D 5084)
Standard Proctor: Max. Density (pcf):	125.7
Optimum Moisture (%):	12.4
Density of Sample (pcf):	119.4
Percent Compaction (%)	95
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)	1.35×10^{-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

Maximum dry density = 118.3 pcf

Optimum moisture = 12.9 %

MATERIAL DESCRIPTION

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≥4 and 1≤ Cc≤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≥6 and 1≤Cc≤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] $Cu = D_{60}/D_{10}$ $Cu = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥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 ≥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 ≥15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

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

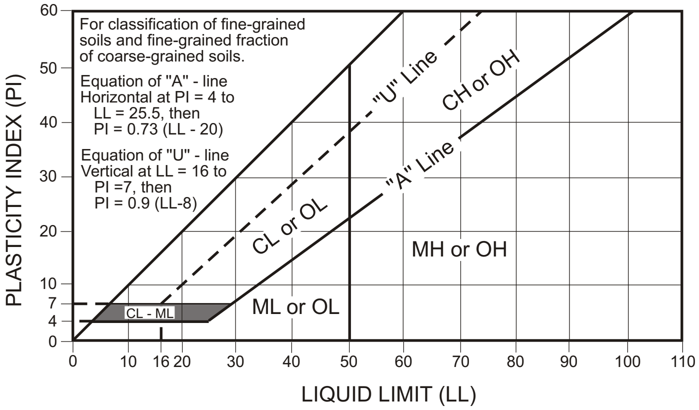
[M] If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.

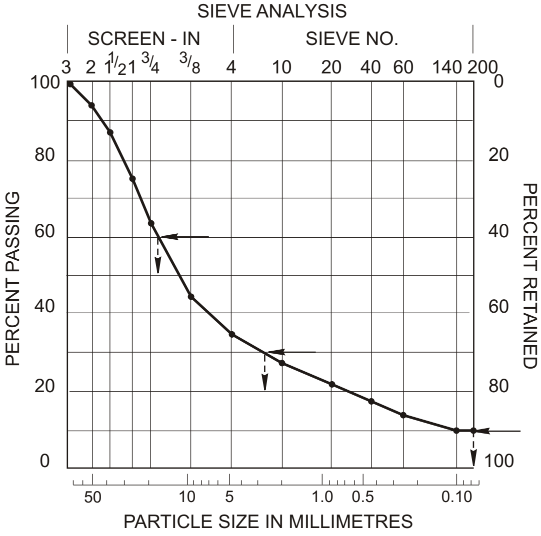
[N] PI ≥4 and plots on or above "A" line.

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

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

[Q] PI plots below "A" line.





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

REVISED: 03/02

Golder Associates

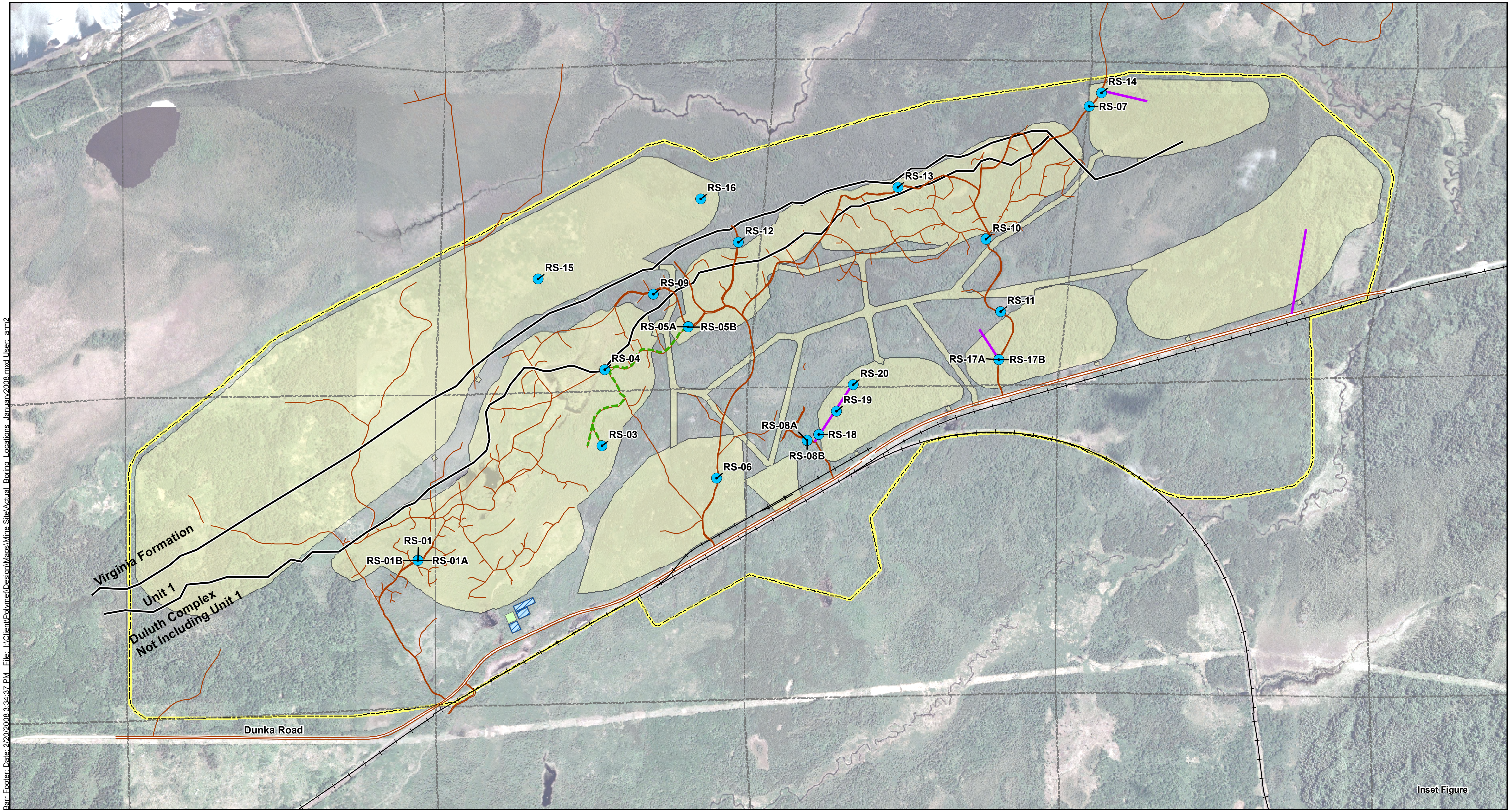
Figure C-2

ASTM D2487-93
ASTM CLASSIFICATION INDEX

FILE NAME: SOILS/ASTM_INDEX.CDR

Attachment D

Rotasonic Drilling Investigation – Boring Logs and Classification Testing



● Actual Boring Locations-January 2008
— Existing Roads
- - Tracked Vehicle Only
— Proposed Access Roads for Stockpile Geotechnical Investigation
— All Trails
▭ Project Boundary
▭ Mine Site Footprint-Year 20
▭ Sections
🟩 Wastewater Treatment Facility
▨ Equilization Ponds

0 750 1,500 3,000
Feet

Mine Site footprint shown has been superceded and is not current

BORING LOCATIONS
JANUARY 2008
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

LOG OF Boring RS-01B

SHEET 1 OF 3

DRAFT

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/15/08 Ended 1/15/08
Logged By MMB/REE

Elevation 1613.0
Total Depth 20.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%		7.05 248.1 24		Frozen	10YR 2/1 Black	PT	■	Peat	Fibrous Peat; 90-100% organic matter, mostly woody material. Up to 10% mineral soil.	
2 4		None	5.89 256.9 10	24/47/29 (Lab)	Dry to Moist	10YR 4/4 Dark Yellowish Brown	SM	⁘	Upper Till	Silty sand with gravel, homogeneous, very fine- to fine-grained, angular to subrounded, fine to coarse gravel. Sand fraction is 80% quartz, 15% lithics, and 5% feldspars. Cobbles are 80% granitic rock, 15% black fine-grained metasediment (Virginia Formation?), and 5% other (foliated gneiss).	1612 1610
6 8	100% 100%	None	6.55 268.1 10 5.97 258.0 17	15/75/10 (Visual)	Moist	10YR 3/2 Very Dark Grayish Brown	SP-SM	⁘		Sand with silt and gravel, homogeneous, medium dense, fine- to medium-grained, gravel is fine- to coarse-grained, angular to subrounded. Cobbles are 70% granitoids, 20% black fine-grained metasediment, and trace schist. Rust-colored coatings along fractures and cobble interfaces, dark red brown (7.5YR 3/4). Less than 2% dendritic or irregular mottles, fine to medium size - dark reddish brown (5YR 3/4). 9-10': 10% dark red (2.5YR 3/6) mottles associated with tiny fractures within matrix.	1608 1606 1604

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-5', 6-7', 14-15', 18-20', 20-20.5'; Geotechnical samples: 0-1', 1-5', 5-10', 10-15', 12.5-15', 15-17.5', 18-20', 20-20.5'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/15/08 Ended 1/15/08
Logged By MMB/REE

LOG OF Boring RS-01B

DRAFT

SHEET 2 OF 3

Elevation 1613.0
Total Depth 20.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
				15/65/20 (Visual)	Very Moist					Silty sand with gravel, homogeneous, medium dense, fine- to medium-grained, gravel is fine- to coarse-grained, angular to subrounded. Cobbles are 70% granitoids, 20% black fine-grained metasediment, and trace schist. Rust-colored coatings along fractures and cobble interfaces, dark red brown (7.5YR 3/4). Less than 2% dendritic or irregular mottles, fine to medium size - dark reddish brown (5YR 3/4).	1602
12		None									
	80%				Wet	2.5Y 4/3 Olive Brown					▼
											1600
14			6.37 223.7 16								
				25/60/15 (Visual)			SM		Upper Till	Abundant dark red (2.5YR 3/6) staining on coarse clasts. Brownish yellow (10YR 6/6) weathering or precipitate along fractures of black, fine-grained metasediment clasts.	1598
16											
											1596
	80%	None									
18			7.28 65.6 34								
											1594

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-5', 6-7', 14-15', 18-20', 20-20.5'; Geotechnical samples: 0-1', 1-5', 5-10', 10-15', 12.5-15', 15-17.5', 18-20', 20-20.5'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/15/08 Ended 1/15/08
Logged By MMB/REE

LOG OF Boring RS-01B

DRAFT

SHEET 3 OF 3

Elevation 1613.0
Total Depth 20.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%		8.79 -40.0 66	10/50/40 (Visual)	Moist	Gley1 3/10Y Very Dark Greenish Gray	SM	░	Lower Till	Silty sand, homogeneous, dense, very fine- to fine-grained sand. Gravel is fine- to coarse-grained, angular to subrounded. Cobbles are black, fine-grained metasediment and granitoid. Olive brown (2.5Y 4/3) color at bottom of borehole, irregular contact with above. Bedrock at 20.5'. End of Boring - 20.5 feet	

DEPTH FEET
22
24
26
28

ELEV. FEET
1592
1590
1588
1586
1584

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-5', 6-7', 14-15', 18-20', 20-20.5'; Geotechnical samples: 0-1', 1-5', 5-10', 10-15', 12.5-15', 15-17.5', 18-20', 20-20.5'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/16/08 Ended 1/16/08
Logged By REE/JAM2

LOG OF Boring RS-03

SHEET 1 OF 3

DRAFT

Elevation 1595.5
Total Depth 22.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
					Very Moist	2.5YR 2.5/1 Reddish Black				Fibrous peat; wood and other organic material. Note: Low recovery	
											1594
2	40%										
											1592
4											
					Wet	10YR 2/1 Black	PT		Peat	Fibrous and amorphous peat, composed of primarily muddy material with trace leaf and woody organic material.	
											1590
6			5.17 65 116								
	60%										1588
8											
											1586

(continued)

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-5', 5-10', 10-15', 15-20', 20-22'; Geotechnical samples: 5-10', 10-15', 15-20', 16', 19', 20-22'

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

LOG OF Boring RS-03

DRAFT

SHEET 2 OF 3

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/16/08 Ended 1/16/08
Logged By REE/JAM2

Elevation 1595.5
Total Depth 22.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
										Sandy silt with a little gravel, loose, homogeneous, up to 5% organic matter from 10-12'. Sand is fine- to medium-grained, gravel is fine-grained, subangular to subrounded. Cobbles are black, fine-grained metasediment and troctolite.	
					Wet						
											1584
12										12-15': No organic matter, increased gravel and sand, cobbles as above.	
	60%		5.46 3 36	12/33/55 (Lab)		Gley1 5/10Y Greenish Gray	ML				
					Wet						1582
14											
				15/45/40 (Visual)					Upper Till	Silty sand with gravel, homogeneous, loose, fine-grained, gravel is fine- to coarse-grained, subangular to subrounded. Cobbles are as above, also some magnetic cherty iron formation, and one pyrite-bearing rock (possibly greenstone).	
			7.4 -208.7 50								1580
16											
	80%			15/40/35 (Visual)	Wet		SM				1578
18			9.08 -27 37								
											1576

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-5', 5-10', 10-15', 15-20', 20-22'; Geotechnical samples: 5-10', 10-15', 15-20', 16', 19', 20-22'

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

LOG OF Boring RS-03

DRAFT

SHEET 3 OF 3

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/16/08 Ended 1/16/08
Logged By REE/JAM2

Elevation 1595.5
Total Depth 22.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%		9.42 -200 63	40/10/50 (Visual)	Moist	Gley1 2.5/10Y Greenish Black	ML		Lower Till	Gravelly silt, homogenous, gravel is fine- to coarse-grained, subangular to subrounded. Cobbles are magnetic cherty iron formation, granitoid.	1574
22										Bedrock at 22.0', troctolite. End of Boring - 22 feet	
											1572
24											
											1570
26											
											1568
28											
											1566

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-5', 5-10', 10-15', 15-20', 20-22'; Geotechnical samples: 5-10', 10-15', 15-20', 16', 19', 20-22'

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

LOG OF Boring RS-04

DRAFT

SHEET 1 OF 3

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/16/08 Ended 1/18/08
Logged By REE/JAM2

Elevation 1600.0
Total Depth 26.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
				95% organics	Wet	10YR 2/2 Very Dark Brown	PT		Peat	Fibrous peat, composed primarily of woody material with some fine-grained organic material.	
2	100%	None	5.71 124.3 22	30/30/40 (Visual)	Wet	2.5Y 3/3 Dark Olive Brown	SM		Soil	Silty sand with gravel, homogeneous, up to 10% organic material, sand is fine- to coarse-grained, gravel is subangular to subrounded. Matrix has dark reddish brown (2.5YR 3/4) mottles.	1598
4											1596
6							SM		Upper Till	Silty sand with gravel, homogeneous, fine- to coarse-grained. Gravel is fine- to coarse-grained. Cobbles are fine-grained black metasediment, magnetic cherty iron formation, and granitoid.	1594
8	100%	None	5.91 82 19	30/50/20 (Visual)	Wet	10YR 4/3 Brown					1592

(continued)

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-5', 5-10', 10-15', 15-20', 20-25', 25-26'; Geotechnical samples: 1-5', 5-10', 10-15', 15-20', 20-25'

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

LOG OF Boring RS-04

DRAFT

SHEET 2 OF 3

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site
Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/16/08 Ended 1/18/08
Logged By REE/JAM2
Elevation 1600.0
Total Depth 26.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
										Silty sand with gravel, homogeneous, same as the 5-10' interval.	
				19/60/21 (Lab)							
12											1588
	100%				Wet		SM				
		None	6.33 104.5 25			Transitional Mottling				13-15': Gradational change in color and texture to 15-20' interval.	
14									Upper Till		1586
										Silty sand with gravel, homogeneous, fine- to coarse-grained. Gravel is fine- to coarse-grained, subangular to subrounded. Cobbles as above.	
16		None	6.74 -90 25								1584
	100%			18/59/23 (Lab)	Wet	10YR 3/1 Very Dark Gray	SM				
18		None	6.85 -81.6 25								1582
									Lower Till	19-20': Matrix contains possible sulfide flakes or secondary mineralization.	
										20': Several troctolite cobbles with sulfide minerals.	

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-5', 5-10', 10-15', 15-20', 20-25', 25-26'; Geotechnical samples: 1-5', 5-10', 10-15', 15-20', 20-25'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/16/08 Ended 1/18/08
Logged By REE/JAM2

LOG OF Boring RS-04

DRAFT

SHEET 3 OF 3

Elevation 1600.0
Total Depth 26.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/ FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
										Silty sand with gravel, homogeneous, fine- to coarse-grained. Gravel is fine- to coarse-grained, subangular to subrounded. Matrix has possible secondary sulfide mineralization. Cobbles are sulfide-bearing troctolite, fine-grained black metasediment, magnetic cherty iron formation, and granitoid.	
22	60%	None	7.83 -87.6 17	30/50/20 (Visual)	Wet	10YR 3/1 Very Dark Gray	SM		Lower Till		1578
24		None	8.10 173.0 94	70/20/10 (Visual)	Dry	Gley1 2.5/N Black to Gley1 6/1 Greenish Gray	GP-GM			Gravel with silt and sand, fine- to coarse-grained. Cobbles are as above.	1576
	100%								Bed-rock	Bedrock at 25'. Sulfide-bearing troctolite.	
26										End of Boring - 26 feet	1574
28											1572

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-5', 5-10', 10-15', 15-20', 20-25', 25-26'; Geotechnical samples: 1-5', 5-10', 10-15', 15-20', 20-25'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/18/08 Ended 1/18/08
Logged By REE

LOG OF Boring RS-05A

SHEET 1 OF 2

DRAFT

Elevation 1605.0
Total Depth 13.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
2 4	20%	None	6.42 124.5 30		Moist	7.5YR 3/3 Dark Brown	SM			Low recovery on RS-05A for 0-5'. See R5-05B log for description.	1604 1602
6	100%	None	6.55 88.7 22	20/60/20 (Visual)	Moist	10YR 3/4 Dark Yellow Brown	SM		Upper Till	Silty sand with gravel, homogeneous, fine- to coarse-grained. Gravel is fine- to medium- grained, subangular to subrounded. Up to 1% organic matter. Cobbles are 60% granitoid, 30% black fine-grained metasediment, 5% cherty iron formation, and trace greenstone. Rust-colored staining on some clast surfaces.	1600 1598
8		None	6.49 166.6 19	40/40/20 (Visual)	Moist	2.5Y 4/2 Dark Gray Brown	SM			Silty sand with gravel, transitional color change with above. Cobbles are same lithologies as above. Note: Geotechnical laboratory homogenized 6-11.5' interval. Grain size analysis indicates 28% gravel, 46% sand, and 26% silt.	1596

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 5-10', 10-13'; Geotechnical samples: 0-1', 5-6', 6-11.5', 10-11.5', 11.5-13'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/18/08 Ended 1/18/08
Logged By REE

LOG OF Boring RS-05A

SHEET 2 OF 2

DRAFT

Elevation 1605.0
Total Depth 13.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/ FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%			64/23/13 (Lab)		2.5Y 4/2 Dark Gray Brown	GM			Silty gravel with sand, fine- to coarse-grained, subangular to subrounded. Cobbles are 60% troctolite, 30% granitoid, 5% magnetic cherty iron formation with rust-colored staining, and 5% black fine-grained metasediment with rust-colored staining.	1594
				70/20/10 (Visual)	Wet				Upper Till	As above, increased clay content, gray.	
12		None	8.9 -70 88	61/24/15 (Lab)		2.5Y 5/1 Gray	GM				
										Bedrock at 13.0', troctolite. End of Boring - 13 feet	1592
14											1590
16											1588
18											1586

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 5-10', 10-13'; Geotechnical samples: 0-1', 5-6', 6-11.5', 10-11.5', 11.5-13'

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

LOG OF Boring RS-05B

SHEET 1 OF 1

DRAFT

Client PolyMet Mining Corporation

Project Name Polymet Overburden Characterization

Number 23/69-B75 INV

Location NorthMet Mine Site

Drill Contractor Boart Longyear

Drill Method Rotasonic

Drilling Started 1/18/08 Ended 1/18/08

Logged By REE

Elevation 1605.0

Total Depth 5.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
				30/50/20 (Visual)		10YR 4/4 Dark Yellowish Brown				Silty sand with gravel, homogeneous, fine- to coarse-grained. Gravel is fine- to coarse-grained, angular to subrounded. Cobbles are 50% granitoid, 30% fine-grained, black metasediment, 20% magnetic cherty iron formation, and trace greenstone or silica rocks (possible Archean).	
											1604
2		None	6.13 179.0 21								
	100%			30/50/20 (Visual)	Moist		SM		Upper Till		
											1602
		None	6.54 187.0 26			10YR 4/2 Dark Grayish Brown				3.5-4': Lens of dark grayish brown silty sand with gravel.	
4											
		None	6.25 193.0 25			SA 1-3.5'					
										End of Boring - 5 feet	1600
6											
											1598
8											
											1596

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 1-5'; Geotechnical samples: 1-3.5', 3.5', 3.5-4'

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

LOG OF Boring RS-06A

DRAFT

SHEET 1 OF 3

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/26/08 Ended 1/26/08
Logged By MMB/MJD/REE

Elevation 1611.0
Total Depth 21.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
		None	4.45 290.3 6	10/50/40 (Visual)		10YR 4/4 Dark Yellowish Brown	SM		Soil	Silty sand, up to 20% organic matter, homogeneous, sand is fine- to coarse-grained, gravel is fine- to coarse- grained, subrounded to subangular. Matrix is magnetic. Sand fraction is 70% quartz, 10% feldspar, and 20% white fragments. Cobbles are 75% black fine-grained metasediment, 20% magnetic iron formation, and 5% granitoid.	1610
		None	4.84 313.0 5	5/65/30 (Visual)	Moist	7.5YR 3/2 Dark Brown	SM			Silty sand, up to 30-40% organic matter, homogeneous, sand is fine- to coarse-grained. Matrix has dark-brown to black organic masses and lenses. Sand fraction is 40% quartz, 50% feldspar, and 10% lithic fragments. Cobbles are 90% granitoid, 5% fine-grained black metasediment, and 5% magnetic iron formation.	
2 4	100%	None	4.99 279 11 5.03 316 8	20/65/15 (Visual)	Dry	7.5YR 3/4 Dark Brown	SM		Upper Till	Silty sand with gravel, homogeneous, sand is fine- to medium-grained, gravel is fine- to coarse grained. Matrix has less than 5% mottles, black (5YR 2.5/1) and yellowish red (5YR 4/6), and is magnetic. Sand fraction is 50% quartz, 40% feldspar, and 10% lithic fragments. Cobbles are 70% granitoid, 30% gabbroic (or possibly recrystallized metasediment) - abundant, rust staining. Large granitoid boulder from 3.5-4.5'.	1608
6		None	5.82 264 12	17/26/57 (Lab)			ML/ CL-ML			Sandy silt with gravel, firm, laminated, sand is fine- to medium-grained, gravel is fine- to medium-grained. Matrix is magnetic and has abundant mottles (30-40%), dark yellowish gray (10YR 4/6) and grayish brown (2.5YR 5/2). Sand fraction is 70% quartz, 20% feldspar, and 10% lithic fragments. Cobbles are 80% magnetic chert iron formation, 10% granitoid, and 10% fine-grained black metasediment.	1606 1604
8	100%		6.32 251 17	24/48/28 (Lab)		10YR 4/3 Brown	SM			Silty sand with gravel, dense, homogeneous, sand is fine- to coarse-grained, gravel is fine- to coarse-grained. Matrix is slightly magnetic, has less than 5% disseminated mottles, very dark gray (10YR 3/1), dark brown (7.5YR 3/4), dark yellowish brown (10YR 4/6), and black mottles associated with rootlets. Increased mottles at 10-12'. Matrix has a faint rotten egg odor below 15', increasing odor with depth. Sand fraction lithology transition from 70% quartz, 10% feldspar, and 20% lithic fragments to 15% quartz, 65% feldspar, and 20% lithic fragments at 10'. Cobbles are 70% iron formation rocks (magnetic and non-magnetic), 25% granitoid, 5% other (troctolite, gabbroic).	1602

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0.5-2', 2-4', 5-7.5', 7.5-10', 10-15', 15-19', 19-21'; Geotechnical samples: 0-1', 1-2', 2-3.5', 3.5-7.5', 7.5-10', 10-15', 15-21'; Shelby tubes: 6-7', 15-16', 16-18'

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

LOG OF Boring RS-06A

DRAFT

SHEET 2 OF 3

Client PolyMet Mining Corporation

Project Name Polymet Overburden Characterization

Number 23/69-B75 INV

Location NorthMet Mine Site

Drill Contractor Boart Longyear

Drill Method Rotasonic

Drilling Started 1/26/08 Ended 1/26/08

Logged By MMB/MJD/REE

Elevation 1611.0

Total Depth 21.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
					Moist					Silty sand with gravel, dense, homogeneous, sand is fine- to coarse-grained, gravel is fine- to coarse-grained. Matrix is slightly magnetic, has less than 5% disseminated mottles, very dark gray (10YR 3/1), dark brown (7.5YR 3/4), dark yellowish brown (10YR 4/6), and black mottles associated with rootlets. Increased mottles at 10-12'. Matrix has a faint rotten egg odor below 15', increasing odor with depth. Sand fraction lithology transition from 70% quartz, 10% feldspar, and 20% lithic fragments to 15% quartz, 65% feldspar, and 20% lithic fragments at 10'. Cobbles are 70% iron formation rocks (magnetic and non-magnetic), 25% granitoid, 5% other (troctolite, gabbroic).*(continued)*	
											1600
12											
	100%	None	6.81 235 17	21/49/30 (Lab)							
											1598
14											
					Moist to Wet	10YR 4/3 Brown	SM		Upper Till		1596
16											
	100%										▼ 1594
			6.75 38 18								
18											
											1592
	100%		7.86 18.0 20		Wet						
										(continued)	

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0.5-2', 2-4', 5-7.5', 7.5-10', 10-15', 15-19', 19-21'; Geotechnical samples: 0-1', 1-2', 2-3.5', 3.5-7.5', 7.5-10', 10-15', 15-21'; Shelby tubes: 6-7', 15-16', 16-18'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/26/08 Ended 1/26/08
Logged By MMB/MJD/REE

LOG OF Boring RS-06A

DRAFT

SHEET 3 OF 3

Elevation 1611.0
Total Depth 21.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%						SM		Upper Till		
										End of Boring - 21 feet	1590
22											
											1588
24											
											1586
26											
											1584
28											
											1582

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0.5-2', 2-4', 5-7.5', 7.5-10', 10-15', 15-19', 19-21'; Geotechnical samples: 0-1', 1-2', 2-3.5', 3.5-7.5', 7.5-10', 10-15', 15-21'; Shelby tubes: 6-7', 15-16', 16-18'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/29/08 Ended 1/29/08
Logged By MMB

LOG OF Boring RS-06R

DRAFT

SHEET 1 OF 3

Elevation 1611.0
Total Depth 21.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%						SM		Soil	See RS-06A, 0-1' for description.	
							SM			See RS-06A, 1-2' for description.	1610
2							SM		Upper Till	See RS-06A, 2-4.75' for description.	1608
4							CL			See RS-06A, 4.75-7.5' for description.	1606
6 8	100%						SM			See RS-06A, 7.5-21.0' for description.	1604 1602

(continued)

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. See RS-06A log for sampling intervals.

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/29/08 Ended 1/29/08
Logged By MMB

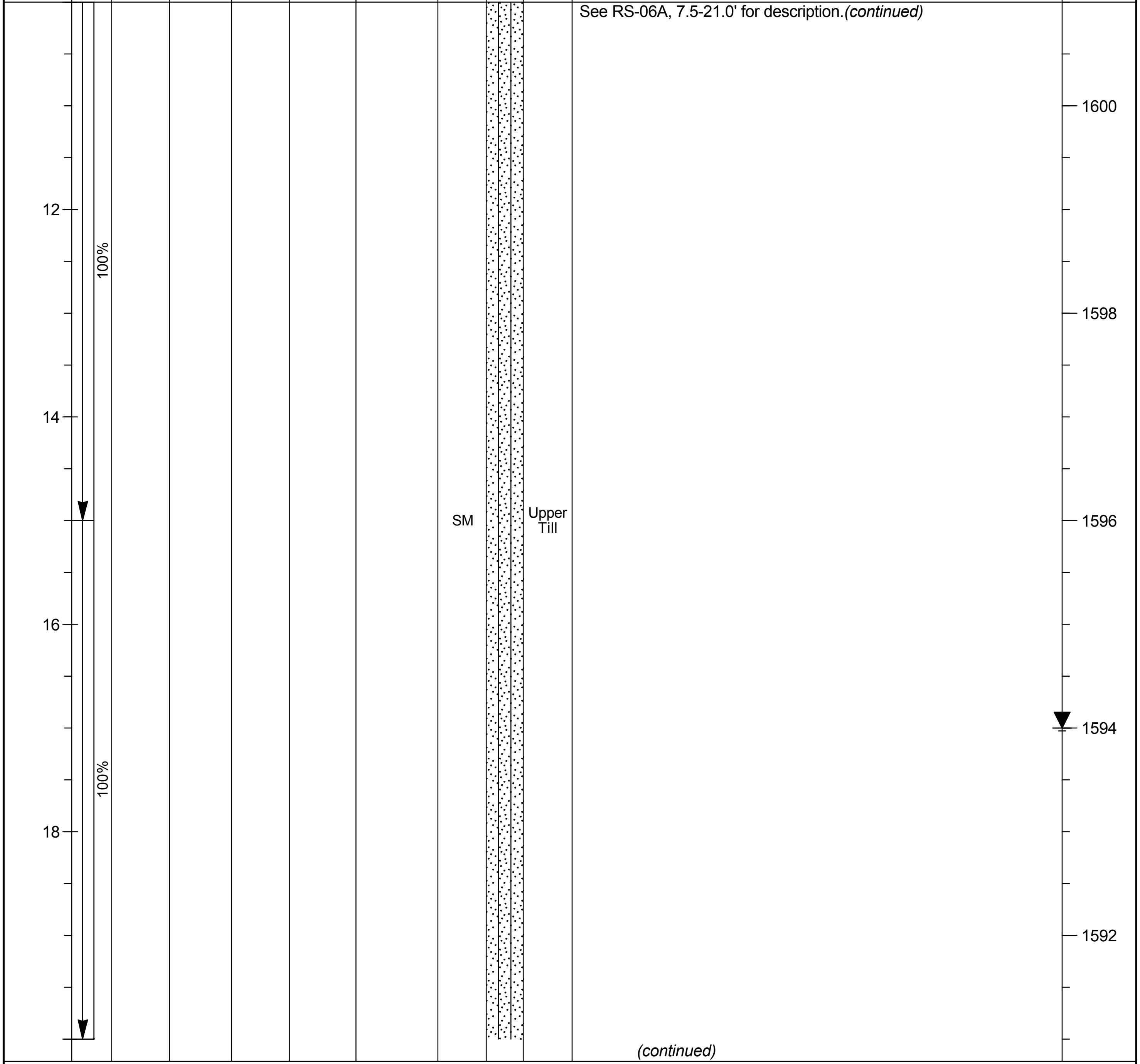
LOG OF Boring RS-06R

DRAFT

SHEET 2 OF 3

Elevation 1611.0
Total Depth 21.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100% 100%						SM		Upper Till	See RS-06A, 7.5-21.0' for description.*(continued)*	



(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. See RS-06A log for sampling intervals.

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

LOG OF Boring RS-06R

DRAFT

SHEET 3 OF 3

Client PolyMet Mining Corporation

Project Name Polymet Overburden Characterization

Number 23/69-B75 INV

Location NorthMet Mine Site

Drill Contractor Boart Longyear

Drill Method Rotasonic

Drilling Started 1/29/08 Ended 1/29/08

Logged By MMB

Elevation 1611.0

Total Depth 21.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%						SM		Upper Till	See RS-06A, 7.5-21.0' for description.*(continued)*	
									Bed-rock	Bedrock at 21.0'. Troctolite piece, 4" thick.	1590
										End of Boring - 21.5 feet	
22											
											1588
24											
											1586
26											
											1584
28											
											1582

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. See RS-06A log for sampling intervals.

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

LOG OF Boring RS-07

DRAFT

SHEET 1 OF 2

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/24/08 Ended 1/24/08
Logged By MMB/MJD/REE

Elevation 1608.0
Total Depth 11.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
					Frozen	10YR 2/2 Very Dark Brown	PT		Peat	Fibrous peat; grass, roots, twigs.	
		None	5.61 97.8 45	25/42/33 (Lab)	Wet	10YR 2/2 Very Dark Brown	OL/OH		Soil	95% organic material (roots, grass, branches). Mineral component is silty sand with gravel. Less than 5% dark brown (10YR 3/3) mottles from 1.5-2'.	
2	100%	None		40/42/18 (Lab)	Moist	2.5Y 3/3 Dark Olive Brown	SM			Gravelly silty sand, 5% organic material, sand is fine- to medium-grained. Less than 5% mottles and layers, dark brown (7.5YR 3/3).	1606
4		None	6.10 27.0 52	38/44/18 (Lab) 30/60/10 (Visual)	Moist	7.5YR 3/3 Dark Brown	SM			Gravelly silty sand, homogeneous, trace organic matter, sand is fine- to coarse-grained, gravel is fine- to coarse-grained, subrounded to subangular. Matrix is mottled: irregular, very dark brown (7.5YR 2/2) and minor strong brown (7.5YR 5/8) mottles. Sand fraction is 10% quartz, 10% feldspar, and 80% lithic fragments. Cobbles are 90% fine-grained black metasediment, 5% black cherty iron formation, and 5% granitoid.	1604
6 8	100%	None	6.40 60.0 17 6.61 38.0 24	47/39/14 (Lab)	Moist	5Y 2.5/1 Black	GM		Upper Till	Sand with silty gravel, homogeneous, sand is fine- to coarse-grained, gravel is fine- to coarse-grained, subrounded to subangular. Sandier and slightly drier toward 10'. Sand fraction and cobble lithologies are same as 3-6' interval.	1602 1600

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 1-2', 2-3', 3-5', 5-6', 6-10', 10-11'; Geotechnical samples: 0-2', 2-5', 8-10', 10-11'

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

LOG OF Boring RS-07

DRAFT

SHEET 2 OF 2

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/24/08 Ended 1/24/08
Logged By MMB/MJD/REE

Elevation 1608.0
Total Depth 11.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%	None	7.15 -23.0 19	59/30/11 (Lab)	Wet	Gley1 2.5/10Y Greenish Black	GP-GM		Lower Till	Sandy gravel with silt, homogeneous, sand is fine-grained, gravel is fine- to coarse-grained, angular to subrounded. Matrix has a rotten egg odor after HCL, and a very dark brown (10YR 2/2) layer from 10-10.25'. Sand fraction is 50% quartz, 10% feldspar, and 40% lithic fragments.	
										Bedrock at 11.0'. End of Boring - 11 feet	
12											1596
14											1594
16											1592
18											1590

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 1-2', 2-3', 3-5', 5-6', 6-10', 10-11'; Geotechnical samples: 0-2', 2-5', 8-10', 10-11'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/29/08 Ended 1/29/08
Logged By MMB

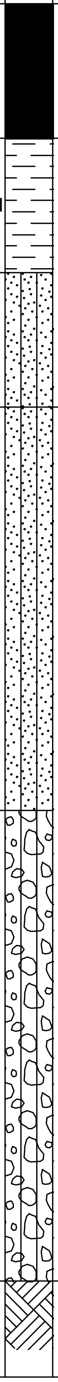
LOG OF Boring RS-07R

DRAFT

SHEET 1 OF 2

Elevation 1608.0
Total Depth 14.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/ FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%						PT		Peat	See RS-07 for description.	
							OL/OH		Soil		
2							SM				1606
4							SM				1604
6	100%						GM		Upper Till		1602
8											1600
									Lower Till		



(continued)

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 10-12', 13.5-14.5'; Geotechnical samples: 1-2', 2-3', 3-6', 6-10', 10-14.5'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/29/08 Ended 1/29/08
Logged By MMB

LOG OF Boring RS-07R

DRAFT

SHEET 2 OF 2

Elevation 1608.0
Total Depth 14.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
			6.63 -125 51						Lower Till	Possible fractured bedrock at 9.5' or boulders on bedrock. Soil in fractures. Sample is 0.5-4" thick core pieces of biotite argillite of Virginia formation. Rinse test at 14' has silver metallic sheen (floating graphite from graphite-bearing Virginia formation rocks?).*(continued)*	
12	100%										1596
									Bed-rock		
14			7.48 -152 82								1594
										End of Boring - 14.5 feet	
16											1592
18											1590

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 10-12', 13.5-14.5'; Geotechnical samples: 1-2', 2-3', 3-6', 6-10', 10-14.5'

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

LOG OF Boring RS-08A

DRAFT

SHEET 1 OF 2

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site
Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/26/08 Ended 1/26/08
Logged By MMB/MJD
Elevation 1591.0
Total Depth 11.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
		None	4.35 347.5 196	15/55/30 (Visual)	Moist	7.5YR 3/4 Dark Brown	SM		Soil	Silty sand with gravel, with up to 20% organic material, homogeneous, dense, sand is fine-grained, gravel is fine-grained, subangular to subrounded. Matrix has 2-5% dark reddish brown (2.5YR 3/4) mottles associated with disseminated rootlets and pebbles. Also less than 1% gray (5YR 5/1) mottles and layer at 1'. Sand fraction is 65% quartz, 10% feldspar, and 15% lithic fragments. Cobbles are fine-grained black metasediment, black chert/iron formation, less than 5% green-black crystalline rock with quartz veins (possibly Archean).	1590
2	100%	None	5.18 287.6 19	20/60/20 (Visual)	Wet to Moist	10YR 4/6 Dark Yellowish Brown to 2.5Y 3/3 Dark Olive Brown	SM			Silty sand with gravel, homogeneous, loose, sand is fine- to medium-grained, gravel is fine- to coarse-grained, subrounded to subangular. Occasional lenses with up to 40% clay (low plasticity). Matrix is magnetic, has mottles as above, also 30% strong brown (7.5YR 5/8) irregular to wavy mottles from 3-4'. Sand fraction is 70% quartz, 10% feldspar, and 20% lithic fragments. Cobbles are fine-grained black metasediment, fine-grained magnetic and non-magnetic cherty iron formation with rust coatings.	1588
4			5.63 262.4 16								1586
6	100%		5.78 217.4 22						Upper Till	Gravelly silty sand, homogeneous, dense, sand is fine- to coarse-grained, gravel is fine- to coarse-grained, angular to subangular. Matrix has a faint rotten egg odor after HCL, 1-2% yellowish red (5YR 4/6) mottles. Sand fraction is 75% quartz, 5% feldspar, and 20% lithic fragments. Cobbles are 40% magnetic black iron formation, 30% fine-grained black metasediment, 25% non-magnetic black iron formation, and 5% granitoid.	1584
8		None		30/43/27 (Lab)	Moist	10YR 4/2 Dark Grayish Brown	SM				1582

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0.25-1', 1-5', 5-11'; Geotechnical samples: 1-5', 5-11'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/26/08 Ended 1/26/08
Logged By MMB/MJD

LOG OF Boring RS-08A

DRAFT

SHEET 2 OF 2

Elevation 1591.0
Total Depth 11.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%		6.77 68.3 34				SM	▨	Upper Till		
										Bedrock at 11'. Troctolite, no visible sulfides. End of Boring - 11 feet	1580
12											
											1578
14											
											1576
16											
											1574
18											
											1572

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0.25-1', 1-5', 5-11'; Geotechnical samples: 1-5', 5-11'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/23/08 Ended 1/23/08
Logged By REE/MJD

LOG OF Boring RS-09

SHEET 1 OF 1

DRAFT

Elevation 1610.5
Total Depth 8.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
		None		5/15/80 (Visual)	Frozen	7.5YR 2.5/3 Very Dark Brown	OL/OH		Soil	Silt with sand, homogeneous, sand is fine-grained. Organic content decreases from 75% to 50%. Some grayish mottles and black (7.5YR 2.5/1) lenses, matrix is magnetic. Sand faction is 50% quartz, 30% feldspar, and 20% lithic fragments. Cobbles are 80% fine-grained black metasediment and 20% granitoid. Abundant rust-colored staining on clasts.	1610
2	100%									Gravelly silty sand, homogeneous, sand is fine-grained, subangular to subrounded, gravel is fine- to coarse-grained, subangular to subrounded. Color change is gradational. Matrix is magnetic. Sand fraction is 50% quartz, 25% feldspars, and 25% lithic fragments. Cobbles are 60% fine-grained black metasediment, 20% magnetic black siltstone, 5-10% medium-grained bedded/foliated metasediment, 10% granitoid, and 5% biotite argillite. One cobble has orange precipitate or oxidation along microfractures. Increased granitoid cobbles from 5 to 7'. Occasional rust colored staining on clasts.	1608
4		None	5.96 175.0 15	32/50/18 (Lab)	Dry to Moist	10YR 4/4 Dark Yellowish Brown to 2.5Y 4/4 Olive Brown	SM		Upper Till		1606
6	100%	None	6.22 116.7 13								1604
	100%		5.88 182.0 2	15/20/65 (Visual)	Wet	2.5Y 3/1 Very Dark Gray	CL		Lower Till	Sandy lean clay with gravel, homogeneous, soft, sand is fine-grained, gravel is fine-grained. Matrix is magnetic, has faint rotten egg odor after HCL. Sand fraction is 70% quartz, 10% feldspars, and 20% lithic material. Cobbles are 75% granitoid, 20% fine-grained black metasediment with rust-colored staining on some surfaces, and 5% banded red and black iron formation.	▼
8										Bedrock at 8'. Troctolite, no visible sulfides. End of Boring - 8 feet	1602

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 2-5', 5-7', 7-8'; Geotechnical samples: 0-1', 1-7', 7-8'

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

LOG OF Boring RS-10

DRAFT

SHEET 1 OF 2

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB/MJD/REE

Elevation 1602.5
Total Depth 16.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%	None			Frozen	7.5YR 2.5/2 Very Dark Brown	OL/OH		Soil	Organic soil with sand. 80% organic matter (grass, roots, branches). Mineral fraction is silty sand, laminated lenses [dark yellowish brown (10YR 3/6) and black (10YR 2/1)].	1602
		None		35/55/10 (Visual)	Moist	10YR 2/2 very Dark Grayish Brown	SP-SM		Upper Till	Sand with silt and gravel, homogeneous, fine- to medium-grained, gravel is fine- to coarse-grained, subrounded to subangular. Sand fraction is 40% quartz, 40% feldspar, and 20% lithic fragments. Cobbles are 70% granitoid, and 30% fine-grained black metasediment with rust-colored staining.	
2	100%	None	6.07 193.0 30	25/60/15 (Visual)	Moist	10YR 3/6 Dark Yellowish Brown	SM			Silty sand with gravel, homogeneous, fine- to medium-grained, gravel is fine- to coarse-grained, angular to subangular. Matrix has mottles associated with break-down of pebbles [bluish black (gley2 2.5/5PB)]. Sand fraction is 20% quartz, 60% feldspar, and 20% lithic fragments. Cobbles are 30% granitoid and 70% black fine-grained metasediment.	1600
4	100%	None	5.73 241.6 12	40/41/19 (Lab)	Moist	7.5YR 3/3 Dark Brown	GM/SM			Sandy, silty gravel, homogeneous, fine- to coarse-grained, trace angular to subangular pebbles and cobbles. Sand fraction is 40% quartz, 30% feldspar, and 30% lithic fragments. Cobbles are 95% fine-grained metasediment with possible trace pyrite or pyrrhotite, and 5% granitoid.	1598
6	100%	None	7.08 60.2 20	20/75/5 (Visual)	Dry to Moist	10YR 4/3 Brown	SP			Sand with gravel, homogeneous, fine- to coarse-grained, with 20% fine- to medium-grained gravel, angular to subangular. Matrix is mottled with irregular yellowish red (5YR 4/6) and white (5YR 8/1) mottles. White mottles have no HCL reaction, but appear to be weakly cemented. Sand fraction is 85% quartz, 5% feldspar, and 10% lithic fragments. Cobbles are 95% black fine-grained metasediment and 5% magnetic cherty iron formation.	1596
8	100%	None	6.81 152.3 30	40/40/20 (Visual)	Dry	5Y 3/1 Very Dark Gray	SM			Silty sand with gravel, homogeneous, fine- to medium-grained, gravel is fine- to coarse-grained, angular to subangular. Matrix has a faint odor after HCL. Sand fraction is 10% quartz, 20% feldspar, and 70% lithic fragments. Cobbles are 80% black fine-grained metasediment, 10% magnetic cherty iron formation, and 10% granitoid. Supernatant from 8.0' rinse test has metallic sheen/possible graphite from graphite-bearing Virginia formation rocks.	1594

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-2', 2-3', 3-5.5', 5.5-7.5', 7.5-10', 10-14'; Geotechnical samples: 2-3', 3.5-5', 5.5-7.5', 7.5-10', 10-14'

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

LOG OF Boring RS-10

DRAFT

SHEET 2 OF 2

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB/MJD/REE

Elevation 1602.5
Total Depth 16.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
										Sand with gravel, homogeneous, fine- to coarse-grained, gravel is fine- to coarse-grained, angular to subangular. Matrix has a few white lenses (precipitate?), no HCL reaction, no odor. Sand fraction is 10% quartz, 10% feldspar, and 80% lithic fragments. Cobbles are 65% black fine-grained metasediment, 20% augite troctolite with weathered brown minerals, 10% magnetic, black cherty iron formation with rust-colored staining, and 5% granitoid.	1592
12	75%	None		40/45/5 (Visual)	Moist	5Y 4/3 Olive	SP		Upper Till		
			6.50 145.3 26								1590
14										Bedrock at 14.0'. Crushed troctolite pieces.	1588
	100%								Bed-rock		
16										End of Boring - 16 feet	1586
18											1584

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1', 1-2', 2-3', 3-5.5', 5.5-7.5', 7.5-10', 10-14'; Geotechnical samples: 2-3', 3.5-5', 5.5-7.5', 7.5-10', 10-14'

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

LOG OF Boring RS-11

DRAFT

SHEET 1 OF 4

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site
Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB/MJD
Elevation 1594.0
Total Depth 33.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
					Frozen					Fibrous peat (grass, roots, root material). Up to approximately 10% mineral soil below 5'.	
2	20%										1592
4											1590
		None			Wet	5YR 2.5/1 Black	PT		Peat		
6											1588
	18%		5.89 107.1 40								
8											1586
		None		43/43/14 (Lab)	Wet	10YR 3/2 Very Dark Grayish Brown	SM		Upper Till	Gravelly silty sand. Less than 5% organic matter, sand is fine- to coarse-grained, gravel is fine- to coarse grained. Sand fraction is 30% quartz, 10% feldspar, and 60% lithic fragments. Cobbles are *(continued)*	

BARR
Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-9.5', 11.5-17', 17-25', 25-28', 28-31', 31-33'; Geotechnical samples: 9.5-10', 10-11.5', 17-25', 25-28', 28-31', 31-33'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB/MJD

LOG OF Boring RS-11

DRAFT

SHEET 2 OF 4

Elevation 1594.0
Total Depth 33.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
										90% fine-grained black metasediment, and 10% biotite argillite.	
			6.31 -26.7 67	20/65/15 (Visual)		10YR 2/2 Black				Gradational change from silty sand with gravel to silty gravel with sand, sand is fine- to coarse-grained, gravel is fine- to medium-grained. Matrix has less than 5% organic material (black), and less than 5% reddish mottles (less than 1 mm in diameter) disseminated, and a faint rotten egg odor after HCL. Sand is 30% quartz, 5% feldspar, and 65% lithic fragments. Cobbles are 80-90% fine-grained black metasediment, 5-10% granitoid, and 5-10% biotite-containing anorthosite.	
12	100%										1582
			6.47 -61.4 47	65/20/15 (Visual)	Wet	10YR 2/1 Black					
							SM to GM		Upper Till		
14											1580
		None									
			6.69 -44.1 12								
16											1578
										Gravelly sand with silt, sorted, sand is medium- to coarse-grained, gravel is fine- to coarse-grained, subrounded to subangular. Matrix has a faint rotten egg odor after HCL. Sand fraction is 60% quartz, 5% feldspar, and 35% lithic fragments. Cobbles are 80-90% fine-grained black metasediment, 5-10% granitoid, and 5-10% chert (possible Archean rocks).	
	80%										
18											1576
		None	6.56 -37.5 30	35/59/6 (Lab)	Moist to Wet	Gley1 2.5/N Black	SP-SM		Out-wash		

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-9.5', 11.5-17', 17-25', 25-28', 28-31', 31-33'; Geotechnical samples: 9.5-10', 10-11.5', 17-25', 25-28', 28-31', 31-33'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB/MJD

LOG OF Boring RS-11

SHEET 3 OF 4

DRAFT

Elevation 1594.0
Total Depth 33.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
22 24	20%	None	6.51 17.0 9		Moist to Wet	Gley1 2.5/N Black	SP-SM		Out-wash	20-25': Same as 17-20' interval. Note low recovery.	1572 1570
26	100%	None	6.33 31.3 25	0/90/10 (Visual) 30/65/5 (Visual)	Wet	10YR 2/1 Black	SW-SM to SP			Gradational change downward: sand with silt to sand with gravel. Sand is fine- to medium-grained, subrounded to subangular. Up to 2% organic matter in lower part of sample. Matrix has a faint rotten egg odor after HCL. Sand fraction is 50% quartz, 5% feldspar, and 45% lithic fragments. Cobbles are 85% fine-grained black metasediment, 10% magnetic cherty iron formation, and 5% granitoid. Note: Geotechnical laboratory homogenized unit. Grain size analysis indicates 23% gravel, 67% sand, 10% silt.	1568
28		None		34/47/19 (Lab)	Wet	Gley1 3/10Y Very Dark Greenish Gray	SM		Lower Till	Gravelly silty sand, homogeneous, sand is medium-grained, gravel is fine- to medium-grained. Matrix has a faint rotten egg odor after HCL. Sand fraction is 60% quartz, 10% feldspar, and 30% lithic fragments. Cobbles are 70% fine-grained black metasediment, 20% granitoid, and 10% other.	1566

(continued)

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-9.5', 11.5-17', 17-25', 25-28', 28-31', 31-33'; Geotechnical samples: 9.5-10', 10-11.5', 17-25', 25-28', 28-31', 31-33'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB/MJD

LOG OF Boring RS-11

DRAFT

SHEET 4 OF 4

Elevation 1594.0
Total Depth 33.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%	None	6.50 -49.7 70	39/46/15 (Lab)	Wet	Gley1 3/10Y Very Dark Greenish Gray	SM		Lower Till	Gravelly silty sand, homogeneous, sand is medium-grained, gravel is fine- to medium-grained. Matrix has a faint rotten egg odor after HCL. Sand fraction is 60% quartz, 10% feldspar, and 30% lithic fragments. Cobbles are 70% fine-grained black metasediment, 20% granitoid, and 10% other.*(continued)*	
32							SM			Gravelly silty sand, homogeneous, fine- to coarse-grained, gravel is fine- to medium-grained. Cobbles are 65% fine-grained black metasediment, 30% granitoid, and 5% gabbroic (no visible sulfides).	1562
										Bedrock at 33.0'. End of Boring - 33 feet	
34											1560
36											1558
38											1556

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-9.5', 11.5-17', 17-25', 25-28', 28-31', 31-33'; Geotechnical samples: 9.5-10', 10-11.5', 17-25', 25-28', 28-31', 31-33'

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

LOG OF Boring RS-12

DRAFT

SHEET 1 OF 3

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site
Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/23/08 Ended 1/23/08
Logged By MMB/MJD
Elevation 1610.0
Total Depth 22.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%	None		2/30/68 (Visual)	Frozen	7.5YR 2.5/2 Very Dark Brown to 7.5YR 2.5/3 Very Dark Brown	ML		Soil	Sandy silt, homogeneous, sand is fine-grained. Decreasing organic material from 0-2'. Approximately 2% medium-grained charcoal pieces in soil. Several clay coatings, very dark gray (7.5YR 3/1), approximately 2 mm thick at 1.2'. Sand fraction is 70% quartz, 20% feldspar, and 10% lithic fragments.	
2 4		Weak	6.77 114.8 8	2/95/3 (Visual)	Dry to Moist	10YR 5/4 Yellowish Brown	SP		Out-wash	Sand, sorted, fine-grained, angular to subround. Matrix has less than 5% carbonate-cemented nodules, weakly cemented, up to 2 cm in size. Several cobbles of black fine-grained metasediment, granitoid, and other lithologies.	1608 1606
6 8	80%	None	7.17 111.7 33	22/55/23 (Lab)	Moist Moist to Wet	10YR 4/4 Dark Yellowish Brown	SM		Upper Till	Silty sand with gravel, homogeneous, fine- to medium-grained, gravel is fine- to coarse-grained, subrounded to subangular. Matrix has less than 5% dark reddish brown (5YR 3/4) mottles, irregular, up to 1 cm in diameter at 7'. Sand fraction is 80% quartz, 5% feldspar, and 15% lithic fragments. Cobbles are 50% granitoid, 20% black, fine-grained metasediment, 20% magnetic cherty iron formation, 5% troctolite containing approximately 5% disseminated phyrrotite and chalcopyrite, and 5% quartzite. 8-8.5': Zone of weakly cemented carbonate layers and nodules. Occurs as masses or bridges between grains; pink (7.5YR 7/4).	1604 1602

(continued)

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 3-5', 7-9', 16-18', 17-20', 20-22'; Geotechnical samples: 0-2', 2-3', 3.5-5.5', 5.5-10', 10-15', 15-19.5', 19.5-20.5', 20.5-22'; Jar samples: 0-1', 4-5', 7-9', 20', 21'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/23/08 Ended 1/23/08
Logged By MMB/MJD

LOG OF Boring RS-12

DRAFT

SHEET 2 OF 3

Elevation 1610.0
Total Depth 22.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
										Silty sand with gravel, homogeneous, fine- to medium-grained, gravel is fine- to coarse-grained, subrounded to subangular. Matrix has less than 5% dark reddish brown (5YR 3/4) mottles, irregular, up to 1 cm in diameter at 7'. Sand fraction is 80% quartz, 5% feldspar, and 15% lithic fragments. Cobbles are 50% granitoid, 20% black, fine-grained metasediment, 20% magnetic cherty iron formation, 5% troctolite containing approximately 5% disseminated phyrrotite and chalcopyrite, and 5% quartzite.*(continued)*	
12			7.19 116.6 15								1598
	80%			26/53/21 (Lab)	Wet	2.5Y 4/3 Olive Brown	SM				
		Weak									
14											1596
									Upper Till		
										Sand with silt and gravel, homogeneous, fine- to coarse-grained sand, gravel is fine- to coarse-grained, subangular to subrounded. Tiny fractures in soil matrix have approximately 2 mm thick discoloration to dark gray (2.5Y 4/1). Sand fraction is 85% quartz, 5% feldspar, and 10% lithic fragments. Cobbles are 40% fine-grained black metasediment with common red-brown staining, 40% black cherty iron formation with yellow precipitate in some fractures and rust-colored staining on surfaces, and 20% granitoid.	
16											1594
			7.14 44 14								
	100%			20/70/10 (Visual)	Wet	2.5Y 4/3 Olive Brown	SM				
18											1592
										19-19.5': Silt, well-sorted, abrupt contacts above and below, dark grayish brown (10YR 3/2).	
				0/100/0 (Visual)	Wet	10YR 4/3 Brown	SM		Out-wash	Sand, homogeneous, fine- to coarse-grained, subangular to subrounded.	
										(continued)	

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 3-5', 7-9', 16-18', 17-20', 20-22'; Geotechnical samples: 0-2', 2-3', 3.5-5.5', 5.5-10', 10-15', 15-19.5', 19.5-20.5', 20.5-22'; Jar samples: 0-1', 4-5', 7-9', 20', 21'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/23/08 Ended 1/23/08
Logged By MMB/MJD

LOG OF Boring RS-12

DRAFT

SHEET 3 OF 3

Elevation 1610.0
Total Depth 22.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
		Weak		0/100/0 (Visual)	Wet	10YR 4/3 Brown	SM		Out-wash	Sand, homogeneous, fine- to coarse-grained, subangular to subrounded.*(continued)*	
	100%	None	7.50 68.9 26	15/70/15 (Visual)	Wet	Gley1 3/N Very Dark Gray	SM		Lower Till	Silty sand with gravel, homogeneous, dense. Sand is fine-to medium-grained, gravel is fine- to coarse-grained, subangular to subrounded. Matrix has rotten-egg odor after HCL which may be associated with yellowish brown (10YR 5/6) mottles that are 1-3 mm in diameter and disseminated throughout 1-2% the matrix. Matrix also contains 20% very dark grayish brown (2.5Y 3/2) mottles from 20.5 to 21'. Sand fraction is 50% quartz, 10% feldspar, and 40% lithic fragments. Cobbles are 40% troctolite containing trace sulfides and patches of iron staining, 30% granitoid, 15% black, fine-grained metasediment, and 5% black chert or siltstone with 2% pyrrhotite veins.	
22										Bedrock at 22'. Dark gray-black troctolite containing 2% disseminated sulfides up to 2 mm in diameter. Chalcopyrite and pyrrhotite. End of Boring - 22 feet	1588
24											1586
26											1584
28											1582

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 3-5', 7-9', 16-18', 17-20', 20-22'; Geotechnical samples: 0-2', 2-3', 3.5-5.5', 5.5-10', 10-15', 15-19.5', 19.5-20.5', 20.5-22'; Jar samples: 0-1', 4-5', 7-9', 20', 21'

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

LOG OF Boring RS-13

SHEET 1 OF 1

DRAFT

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/24/08 Ended 1/24/08
Logged By MMB/MJD

Elevation 1606.0
Total Depth 10.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%	None	6.15 62.7 42	5/85/10 (Visual)	Frozen Moist	7.5R 2.5/3 Very Dark Brown	SP-SM		Soil	Sand with silt, homogeneous, fine- to coarse-grained, subangular to subrounded. Organic matter decreases from 70% to 10% between 0-1.5'. Sand fraction is 70% quartz, 10% feldspar, and 20% lithic fragments. Several cobbles of fine-grained, black metasediment with rust-colored staining on surfaces.	
2		None		5/65/30 (Visual)	Wet	7.5R 2.5/3 Very Dark Brown and 7.5R 3/1 Very Dark Gray	SM			Silty sand, variegated, homogeneous, dense, fine- to medium-grained, subangular to subrounded, trace organic material. Several very dark gray (7.5YR 3/1) lenses. Sand fraction is same as 0-1.5' interval, cobbles are fine-grained black metasediment with rust-colored surfaces. Possible perched water at 1.5'.	1604
4	100%	None	6.07 106.6 27 6.47 72.3 22	34/41/25 (Lab)	Moist	Gley1 4/5GY Dark Greenish Gray	SM		Lower Till	Gravelly silty sand, homogeneous, dense, fine- to medium-grained. Gravel is fine- to coarse-grained, angular to well-rounded. Matrix has dark gray brown, dark red brown, and black mottles, and has a weak rotten egg odor after HCL. Sand fraction is 80% quartz and 20% lithic fragments. Cobbles are 65% black chert/siltstone iron formation containing some rust staining and yellow precipitate, 20% granitoid, 10% black, fine-grained metasediment, and 5% pink quartzite.	1602
6										Interval is too destroyed by drilling to classify.	1600
8	50%								Bed-rock	Bedrock at 8': Dark gray-black troctolite containing 5% visible sulfides (30% pyrrhotite, 50% chalcopyrite, 20% pyrite).	1598
										End of Boring - 10 feet	

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1.5', 1.5-2.5', 2.5-6', 8-10'; Geotechnical samples: 0-1.5', 1.5-2.5', 2.5-6'

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

LOG OF Boring RS-14A

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation

Project Name Polymet Overburden Characterization

Number 23/69-B75 INV

Location NorthMet Mine Site

Drill Contractor Boart Longyear

Drill Method Rotasonic

Drilling Started 1/24/08 Ended 1/24/08

Logged By REE/MJD

Elevation 1609.0

Total Depth 5.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	60%	None		40/31/29 (Lab)	Frozen	10YR 2/1 Black to 10YR 3/6 Dark Yellowish Brown	GM		Soil	Silty gravel with sand and organic fines, decreasing organic matter from 90%-70%, sand is fine- to medium-grained. Gradational color change.	1608
2		None	5.41 239.0 19	10/70/20 (Visual)	Moist	7.5YR 3/4 Dark Brown	SM		Upper Till	Silty sand, homogeneous, sand is fine- to medium-grained, gravel is fine- to coarse-grained, subangular to angular. Matrix has approximately 10% rootlets with associated very dark brown (7.5YR 2.5/2) mottles. Cobbles are 100% black fine-grained metasediment.	1606
4		None		40/36/24 (Lab)		10YR 3/4 Dark Yellowish Brown	GM			Silty gravel with sand, homogeneous, dense, sand is fine- to medium-grained, gravel is fine- to coarse-grained, subangular to subrounded. Cobbles are 90% fine-grained black metasediment, 5% black coarse-grained gabbro (no sulfides), 5% granitoid.	1604
6 8										Bedrock at 5.0'. Black biotite argillite. End of Boring - 5 feet	1602 1600

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1.5', 1.5-3', 3-5'; Geotechnical samples: 0-1.5', 1.5-3', 3-5'

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/24/08 Ended 1/24/08
Logged By REE/MJD

LOG OF Boring RS-14B

DRAFT

SHEET 1 OF 1

Elevation 1609.0
Total Depth 5.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
							GM		Soil	See RS-14A, 0-1.5' interval for description.	1608
2	100%						SM			See RS-14A, 1.5-3' interval for description.	
4							GM		Upper Till	Similar to RS-14A, 3.0-5.0' interval. Slightly fewer fines, mottled. Mottles are yellowish red (5YR 4/6) and very dark grayish brown (10YR 3/2). Rust coloring also seen on most cobbles. Cobbles are 85% black fine-grained magnetic cherty iron formation and 5% granitoid.	1606
6 8										Bedrock at 5.0'. Black biotite argillite. End of Boring - 5 feet	1604 1602 1600

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: 0-1.5', 1.5-3', 3-5'; Geotechnical samples: 0-1.5', 1.5-3', 3-5'

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

LOG OF Boring RS-15A-E

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/27/08 Ended 1/27/08
Logged By MMB/REE

Elevation 1615.5
Total Depth 0.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%		5.59 275 104	1/46/53 (Lab)	Moist	Black	OL/OH		Peat	Fibrous peat.	
						7.5YR 3/3 Dark Brown	ML		Soil	Sandy silt with organic material, homogeneous, no odor, no mottles, no visible sulfides. Hand auger refusal on rocks. End of Boring - 0.5 feet	
											1614
2											
											1612
4											
											1610
6											
											1608
8											
											1606

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: RS-15A-D 0-0.5'; Geotechnical samples: 0-0.5'

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

Client PolyMet Mining Corporation

Project Name Polymet Overburden Characterization

Number 23/69-B75 INV

Location NorthMet Mine Site

Drill Contractor Boart Longyear

Drill Method Rotasonic

Drilling Started 1/27/08 Ended 1/27/08

Logged By MMB/REE

LOG OF Boring RS-16A-C

DRAFT

SHEET 1 OF 1

Elevation 1605.0

Total Depth 2.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%		5.29 290 8	0/69/31 (Lab)	Moist	10YR 3/6 Dark Yellowish Brown	SM	▨	Soil	Silty sand, homogeneous, no odor, no mottles, no visible sulfides.	1604
2										Hand auger refusal on rocks. End of Boring - 2 feet	
											1602
4											
											1600
6											
											1598
8											
											1596

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Soil matrix and clasts were examined for visible sulfides, HCl reaction, odor, and odor after HCl. No sulfides, reaction with HCl, or unusual odors were observed, unless otherwise noted. Geochemical samples: RS-16B 0-2'; Geotechnical samples: 0-2'

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

LOG OF Boring RS-17A

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB

Elevation 1598.0
Total Depth 8.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
					Frozen	Dark Brown	OL/OH		Soil	Sandy organic soil. Abundant roots, grass, vegetative material.	
2					Dry to Moist	Brown				Gravelly silty sand. Sand is very fine- to fine-grained. Gravel is fine- to coarse-grained. Possible low-plasticity clay from 1 to 2.5'. Gravel is subangular to subrounded with various lithologies.	1596
	110%			30/37/33 (Lab)			SM				
4					Moist	Dark Brown					1594
				44/43/13 (Lab)	Moist	Dark Brown	GM		Upper Till	Silty gravel with sand. Sand is very fine- to coarse-grained. Gravel is fine-to coarse-grained with various lithologies.	
6	66.67%			20/40/40 (Lab)	Moist to Wet	Brown	SM			Silty sand with gravel, sand is very fine- to fine-grained, gravel is fine- to coarse-grained with various lithologies, subrounded to rounded.	1592
										Granitoid boulder. Refusal on boulder at 8.0'.	
8										End of Boring - 8 feet	1590

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Geotechnical samples collected: 1-2.5' plastic bag, 2.5-4.5' 5-gallon bucket, 4.5-6' 5-gallon bucket

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

LOG OF Boring RS-17B

DRAFT

SHEET 1 OF 2

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB

Elevation 1598.0
Total Depth 12.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/ FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
							OL/OH		Soil	See RS-17A, 0-1' interval for description.	
2 4	110%						SM			See RS-17A, 1-4.5' interval for description.	1596 1594
							GM		Upper Till	See RS-17A, 4.5-6' interval for description.	
6	80%						SM			See RS-17A, 6-7' interval for description.	1592 ▼
										See RS-17A, 7-8' interval for description.	
8	150%			40/50/10 (Visual)	Wet	Brown	SP-SM			Sand with silt and gravel. Sand is very fine- to medium-grained. Gravel is angular to rounded with various lithologies.	1590

(continued)

Remarks: Geotechnical samples collected: 6.0-7.0' shelby tube, 8-11' 5-gallon bucket

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

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/25/08 Ended 1/25/08
Logged By MMB

LOG OF Boring RS-17B

DRAFT

SHEET 2 OF 2

Elevation 1598.0
Total Depth 12.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%			40/50/10 (Visual)	Wet	Brown	SP-SM		Upper Till	Sand with silt and gravel. Sand is very fine- to medium-grained. Gravel is angular to rounded with various lithologies.*(continued)*	
									Bed-rock	Troctolite bedrock, 0.8' long intact core-shaped piece.	
12										End of Boring - 12 feet	1586
14											1584
16											1582
18											1580

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Geotechnical samples collected: 6.0-7.0' shelby tube, 8-11' 5-gallon bucket

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

LOG OF Boring RS-18A

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/29/08 Ended 1/29/08
Logged By MMB

Elevation 1588.5
Total Depth 10.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
				20/60/20 (Visual)	Wet	Black	SM		Soil	Silty sand with gravel, organic rich.	1588
2	100%			10/5/85 (Visual)	Moist	Yellowish Brown	ML		Upper Till	Silt with possible low plasticity clay and approximately 10% gravel, mottled.	1586
4	100%			30/50/20 (Visual)	Moist	Brown	SC			Clayey sand with gravel, sand is fine-grained. Note: Geotechnical laboratory homogenized 0-5' interval. Grain size analysis indicates 26% gravel, 44% sand, and 30% silt and clay.	1584
6	100%			32/47/21 (Lab)	Moist	Dark Gray to Black	SM		Lower Till	Gravelly silty sand.	1582
8	100%								Bed-rock	Bedrock at 8.0'. Troctolite core pieces.	1580
										End of Boring - 10 feet	

BARR

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Geotechnical samples: 0-5', 5-8'

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

LOG OF Boring RS-19A

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site
Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/31/08 Ended 1/31/08
Logged By MMB
Elevation 1600.5
Total Depth 9.5

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	80%				Dry	Gray				Boulder	1600
2	95%			13/47/40 (Lab)	Moist	10YR 4/4 Dark Yellowish Brown	SM			Silty sand with a little gravel, sand is fine- to medium-grained, with 30% irregular gray mottles in matrix.	1598
4				20/60/20 (Visual)	Moist	10YR 4/2 Dark Grayish Brown	SM		Upper Till	Silty sand with gravel, sand is fine- to medium-grained. Mottled and has less than 5% reddish mottles.	1596
6 8	100%			80/20/0 (Visual)	Dry	Various	GP			Gravel with sand, driller suspects interval is cobbles broken into gravel by drilling.	1594 1592
									Bed-rock	Bedrock at 9.0'. Troctolite plug in core barrel.	
										End of Boring - 9.5 feet	

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Geotechnical samples: 1-6'; Shelby tubes: 1.5-3.5'

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

LOG OF Boring RS-20A

DRAFT

SHEET 1 OF 1

Client PolyMet Mining Corporation
Project Name Polymet Overburden Characterization
Number 23/69-B75 INV
Location NorthMet Mine Site

Drill Contractor Boart Longyear
Drill Method Rotasonic
Drilling Started 1/31/08 Ended 1/31/08
Logged By MMB

Elevation 1602.5
Total Depth 7.0

DEPTH FEET	SAMP. LENGTH & RECOVERY	Matrix Effervescence	Soil pH-ORP-Specific Cond.	%GR/SA/FINES	Moisture	Matrix Color	ASTM	LITHOLOGY	Stratigraphic Unit	DESCRIPTION	ELEV. FEET
	100%				Frozen					Silty sand, sand is fine-grained.	1602
2	100%			10/60/30 (Visual)	Moist	2.5Y 3/3 Dark Olive Brown	SM				
4	100%			25/42/33 (Lab) 29/41/30 (Lab)	Moist	2.5Y 4/2 Dark Grayish Brown	SM		Upper Till	Silty sand with gravel, fine- to coarse-grained sand, fine- to coarse-grained gravel, boulders and cobbles. Possible low plasticity clay.	1600 1598
6	100%										
	100%				Dry				Bed-rock	Bedrock at 6.5'. Troctolite pieces.	1596
8										End of Boring - 7 feet	1594

Barr Engineering Co.
4700 W 77th St. Suite 200
Edina, MN 55435
Telephone: 952-832-2600
Fax: 952-862-2601

Remarks: Geotechnical samples: 2-4.5', 4.5-6'; Shelby tubes: 2-3'

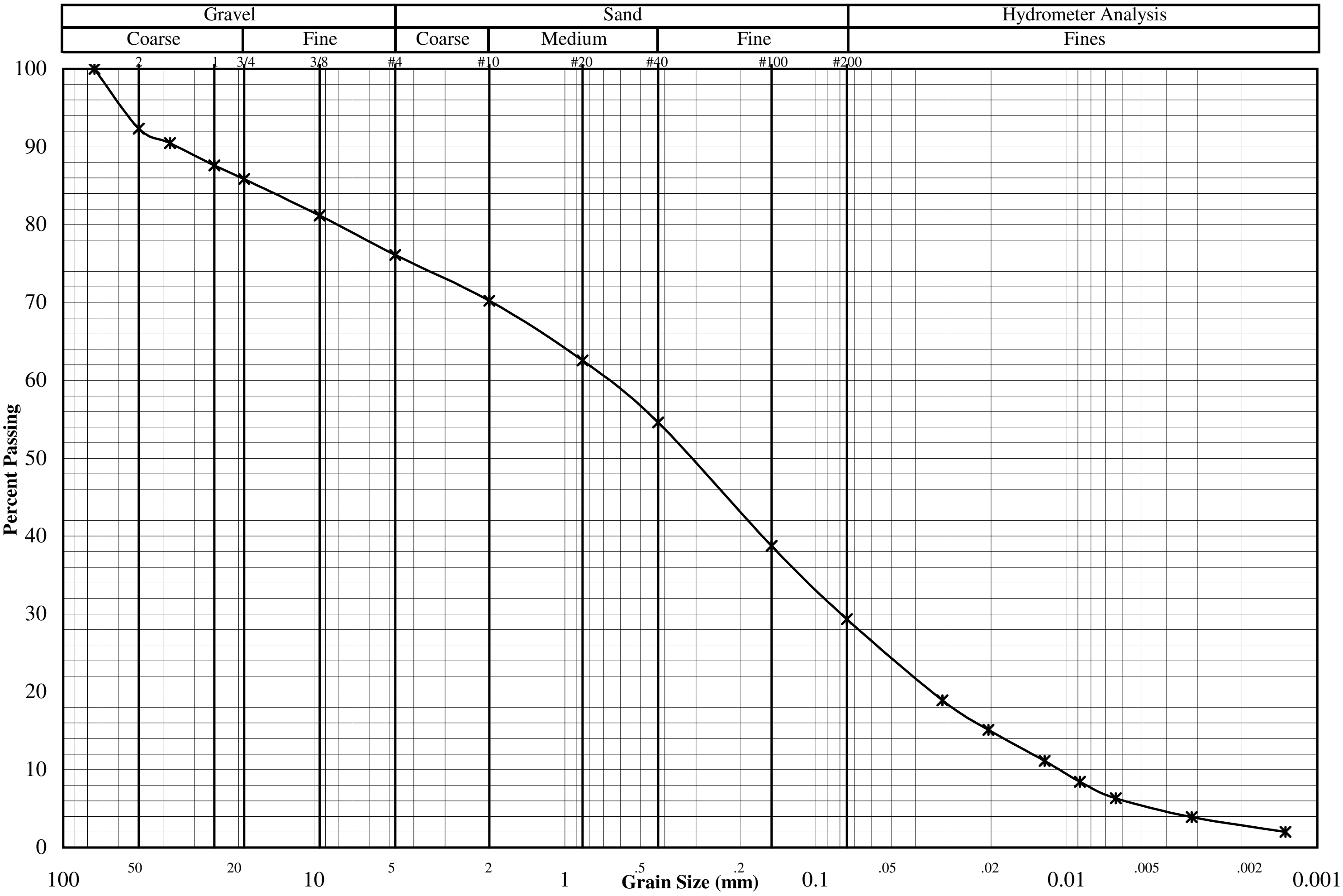
Additional data may have been collected in the field which is not included on this log.

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/5/08
Reported To:	Barr Engineering Company	Report Date:	4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-01B	07-0335	1-5	Bulk	Silty Sand w/Gravel (SM)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	NP		
Plastic Limit	NP		
Plasticity Index	NP		
Water Content	8.7		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	23986.0		
2"	92.3		
1.5"	90.5		
1"	87.6		
3/4"	85.9		
3/8"	81.2		
#4	76.1		
#10	70.2		
#20	62.6		
#40	54.6		
#100	38.7		
#200	29.3		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date: 4/5/08
Reported To:	Barr Engineering Company	Report Date: 4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-01B	07-0335	1-5	Bulk	Silty Sand w/Gravel (SM)
Spec 2					
Spec 3					

Hydrometer Data

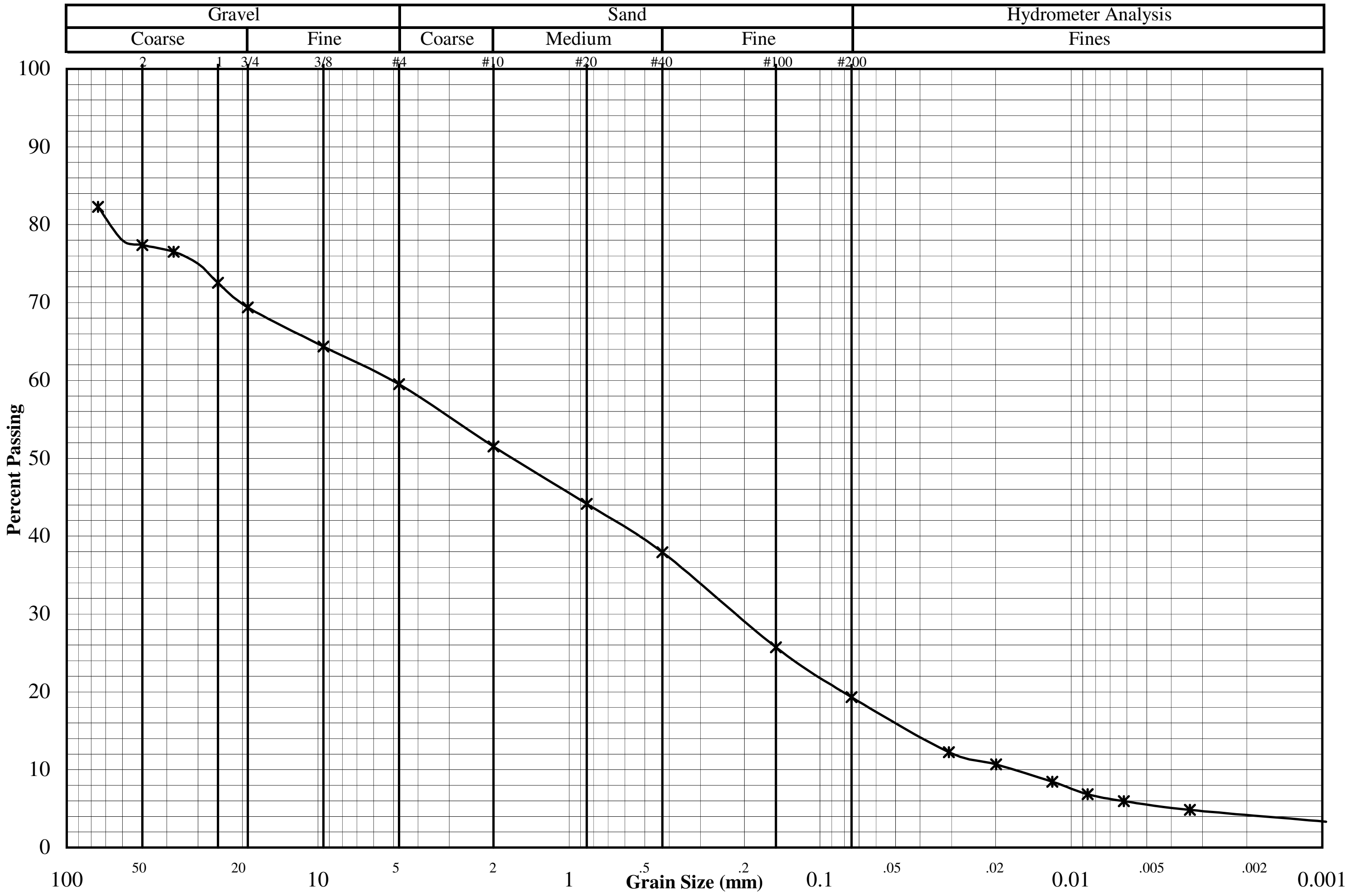
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	18.9				
0.020	15.1				
0.012	11.1				
0.009	8.5				
0.006	6.3				
0.003	3.9				
0.001	2.0				

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-10	07-0400	3.5-5	Bag	Sandy Silty Gravel (GM/SM)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	20.3		
Plastic Limit	16.0		
Plasticity Index	4.3		
Water Content	10.4		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	9484.4		
2"	77.4		
1.5"	76.5		
1"	72.5		
3/4"	69.4		
3/8"	64.3		
#4	59.5		
#10	51.5		
#20	44.1		
#40	37.9		
#100	25.7		
#200	19.3		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

All 3" gravel passed 3.5" seive

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-10	07-0400	3.5-5	Bag	Sandy Silty Gravel (GM/SM)
Spec 2					
Spec 3					

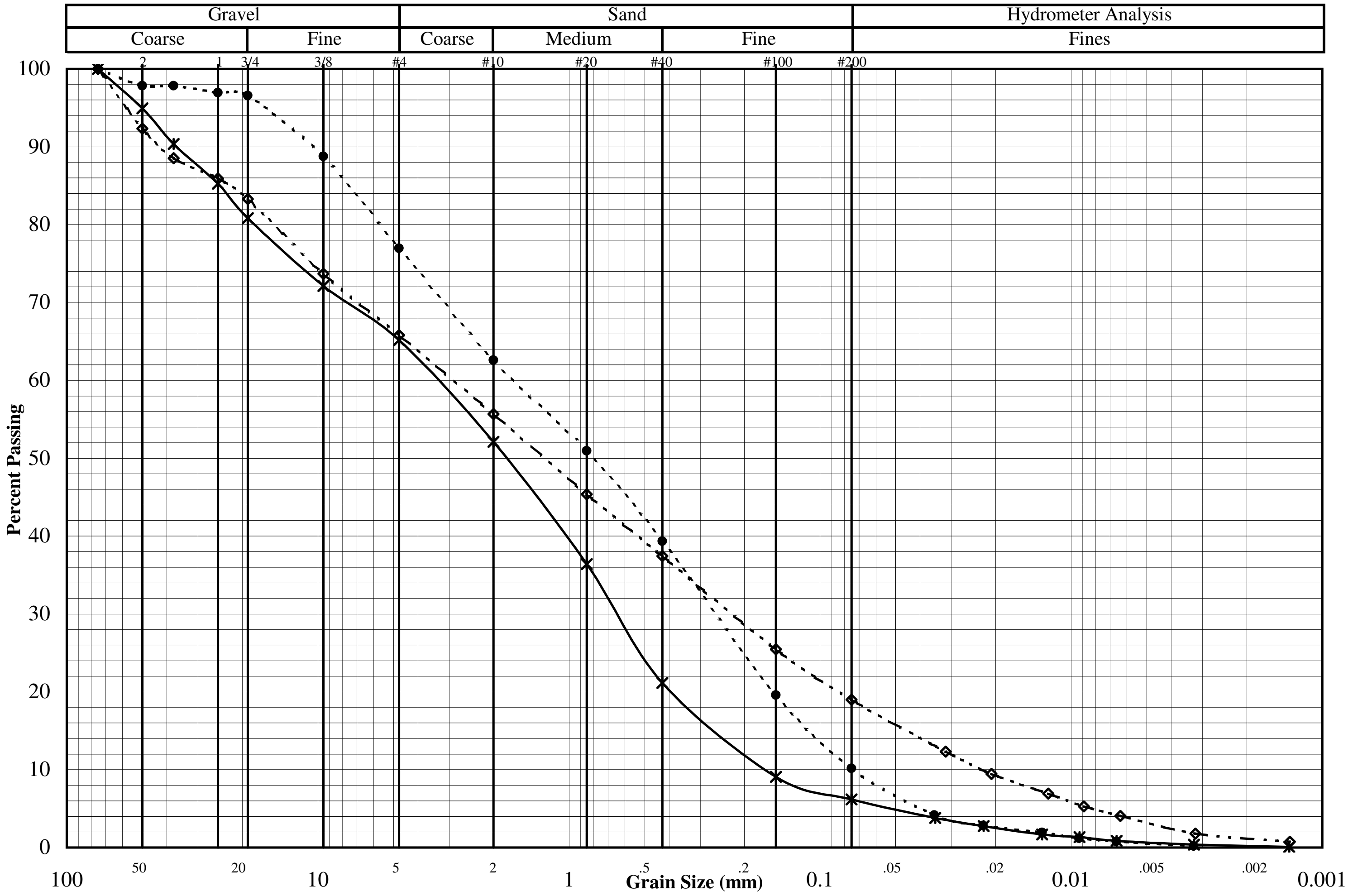
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	12.2				
0.020	10.7				
0.012	8.4				
0.009	6.9				
0.006	6.0				
0.003	4.8				
0.001	3.3				

Grain Size Distribution ASTM D422

Project:	Polymet	Job No. :	**6428**
		Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-11	07-0244	17-25	Bag	Gravelly Sand w/Silt, medium to coarse grained (SP-SM)
●	RS-11	07-0228	25-28	Bag	Sand w/Silt and Gravel, fine to medium grained (SP-SM)
◇	RS-11	07-0236	28-31	Bag	Gravelly Silty Sand (SM)



	Other Tests		
	*	●	◇
Liquid Limit	NP	NP	NP
Plastic Limit	NP	NP	NP
Plasticity Index	NP	NP	NP
Water Content	9.9	13.7	7.1
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	2.66*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

	Percent Passing		
	*	●	◇
Mass (g)	16585.9	12883.5	13443.7
2"	95.0	97.8	92.3
1.5"	90.3	97.8	88.5
1"	85.3	96.9	85.9
3/4"	80.8	96.6	83.3
3/8"	72.1	88.8	73.7
#4	65.2	77.0	65.8
#10	52.1	62.6	55.7
#20	36.4	51.0	45.4
#40	21.1	39.3	37.4
#100	9.1	19.6	25.5
#200	6.2	10.2	19.0

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

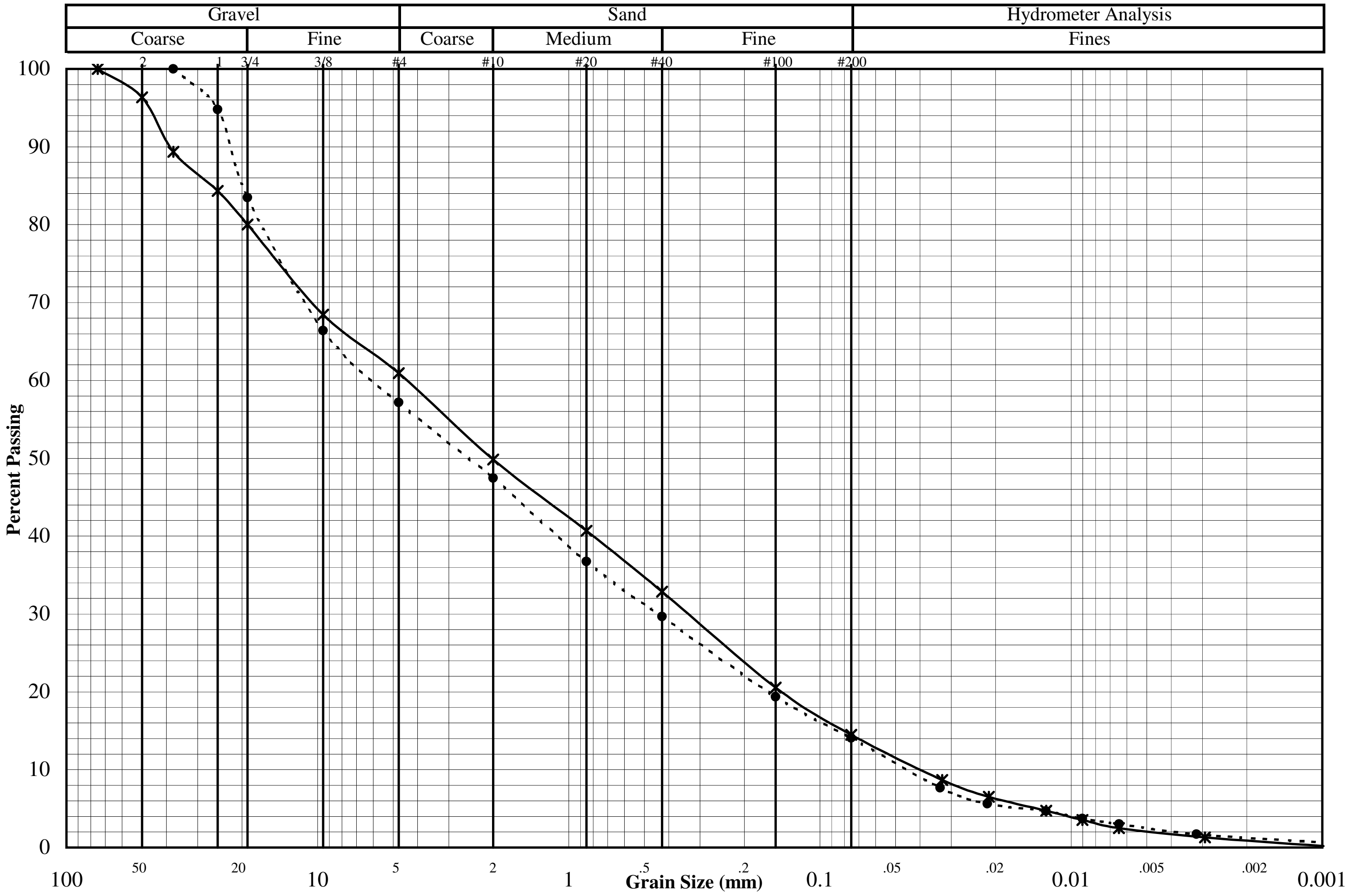
Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-11	07-0385	31-33	Bag	Gravelly Silty Sand (SM)
●	RS-11	07-0370	9.5-10	Jar	Gravelly Silty Sand (SM)
◇					



Other Tests

	*	●	◇
Liquid Limit	NP	NP	
Plastic Limit	NP	NP	
Plasticity Index	NP	NP	
Water Content	15.4	3.7	
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	16975.9	410.9	
2"	96.3		
1.5"	89.3	100.0	
1"	84.3	94.8	
3/4"	80.0	83.5	
3/8"	68.4	66.4	
#4	60.9	57.2	
#10	49.8	47.4	
#20	40.7	36.7	
#40	32.8	29.7	
#100	20.6	19.4	
#200	14.5	14.1	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project: Polymet

Test Date: 4/10/08

Reported To: Barr Engineering Company

Report Date: 4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-11	07-0244	17-25	Bag	Gravelly Sand w/Silt, medium to coarse grained (SP-SM)
Spec 2	RS-11	07-0228	25-28	Bag	Sand w/Silt and Gravel, fine to medium grained (SP-SM)
Spec 3	RS-11	07-0236	28-31	Bag	Gravelly Silty Sand (SM)

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.035	3.8	0.035	4.2	0.032	12.3
0.022	2.8	0.022	2.8	0.021	9.5
0.013	1.7	0.013	2.0	0.012	6.9
0.009	1.3	0.009	1.2	0.009	5.3
0.007	0.9	0.007	0.8	0.006	4.1
0.003	0.4	0.003	0.2	0.003	1.8
0.001	0.1	0.001	-0.1	0.001	0.7

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-11	07-0385	31-33	Bag	Gravelly Silty Sand (SM)
Spec 2	RS-11	07-0370	9.5-10	Jar	Gravelly Silty Sand (SM)
Spec 3					

Hydrometer Data

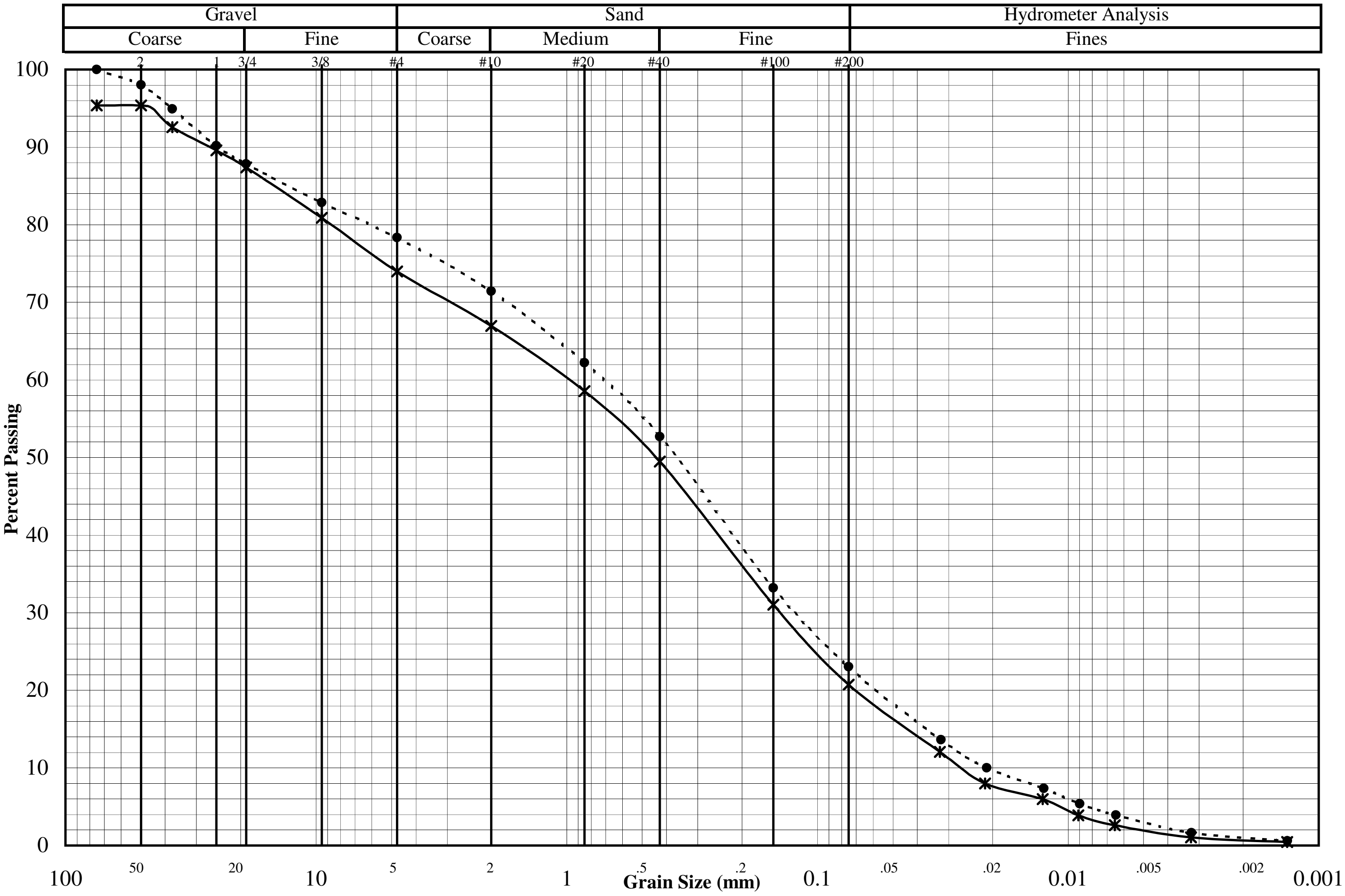
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.033	8.7	0.033	7.7		
0.021	6.5	0.022	5.6		
0.013	4.7	0.013	4.7		
0.009	3.5	0.009	3.7		
0.006	2.5	0.006	3.0		
0.003	1.3	0.003	1.7		
0.001	0.2	0.001	0.6		

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	**Test Date:**	4/10/08
Reported To:	Barr Engineering Company	**Report Date:**	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-12	07-0372	10-15	Bulk	Silty Sand w/Gravel (SM)
●	RS-12	07-0378	5.5-10	Bulk	Silty Sand w/Gravel (SM)
◇					



Other Tests

	*	●	◇
Liquid Limit	NP	NP	
Plastic Limit	NP	NP	
Plasticity Index	NP	NP	
Water Content	3.7	5.4	
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	27040.9	21277.9	
2"	95.4	98.0	
1.5"	92.6	94.9	
1"	89.6	90.2	
3/4"	87.4	87.8	
3/8"	80.9	82.9	
#4	74.0	78.3	
#10	67.0	71.4	
#20	58.5	62.2	
#40	49.5	52.7	
#100	31.0	33.2	
#200	20.7	23.0	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

All 3" gravel passed 3.5" seive

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-12	07-0372	10-15	Bulk	Silty Sand w/Gravel (SM)
Spec 2	RS-12	07-0378	5.5-10	Bulk	Silty Sand w/Gravel (SM)
Spec 3					

Hydrometer Data

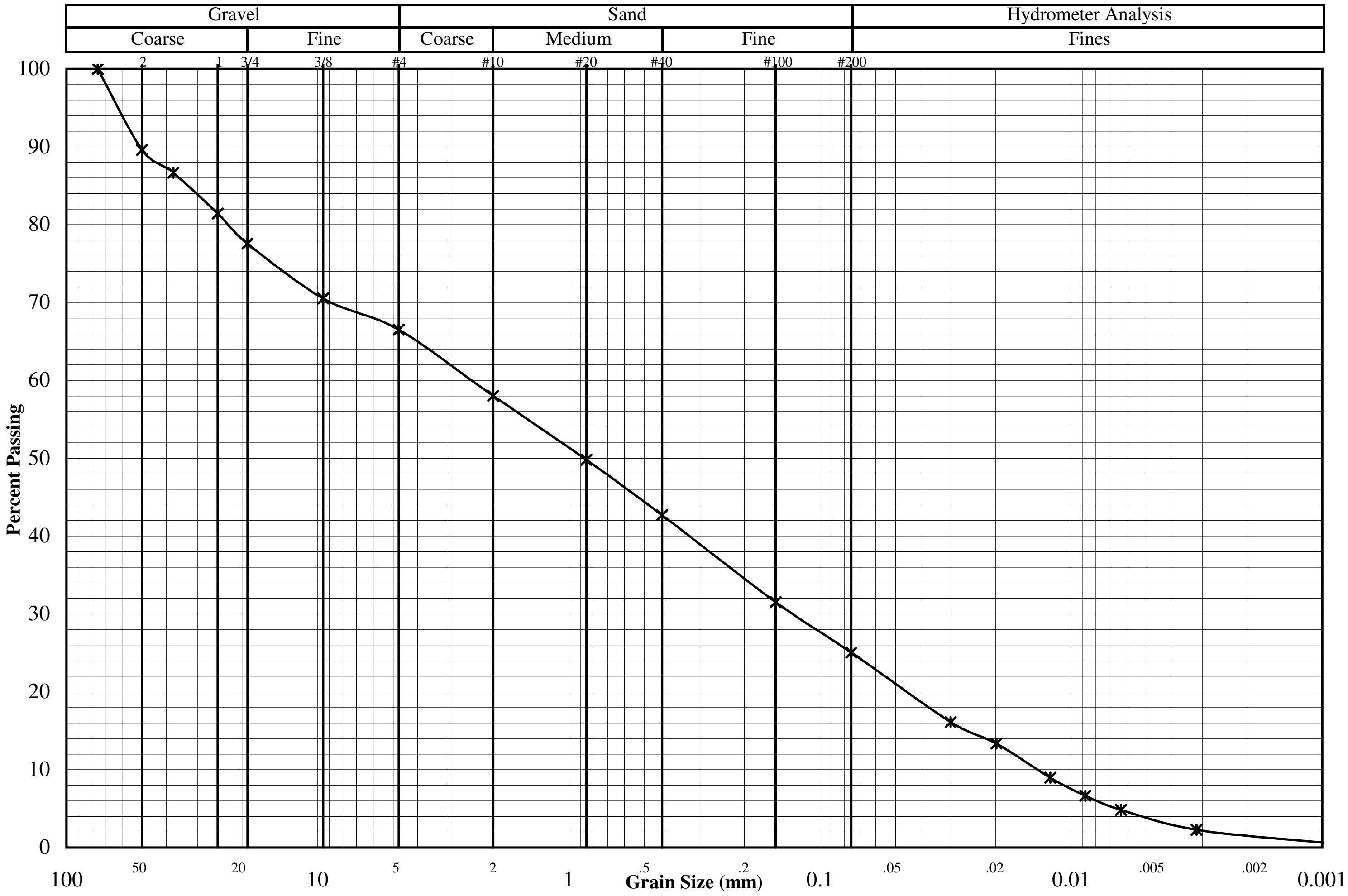
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.032	12.1	0.032	13.6		
0.021	8.0	0.021	10.0		
0.013	6.0	0.012	7.4		
0.009	3.9	0.009	5.4		
0.007	2.6	0.006	3.9		
0.003	1.1	0.003	1.6		
0.001	0.4	0.001	0.6		

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-13	07-0394	2.5-6	Bag	Gravelly Silty Sand (SM)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	NP		
Plastic Limit	NP		
Plasticity Index	NP		
Water Content	11.5		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	10618.6		
2"	89.6		
1.5"	86.7		
1"	81.4		
3/4"	77.6		
3/8"	70.5		
#4	66.5		
#10	58.0		
#20	49.8		
#40	42.7		
#100	31.5		
#200	25.0		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-13	07-0394	2.5-6	Bag	Gravelly Silty Sand (SM)
Spec 2					
Spec 3					

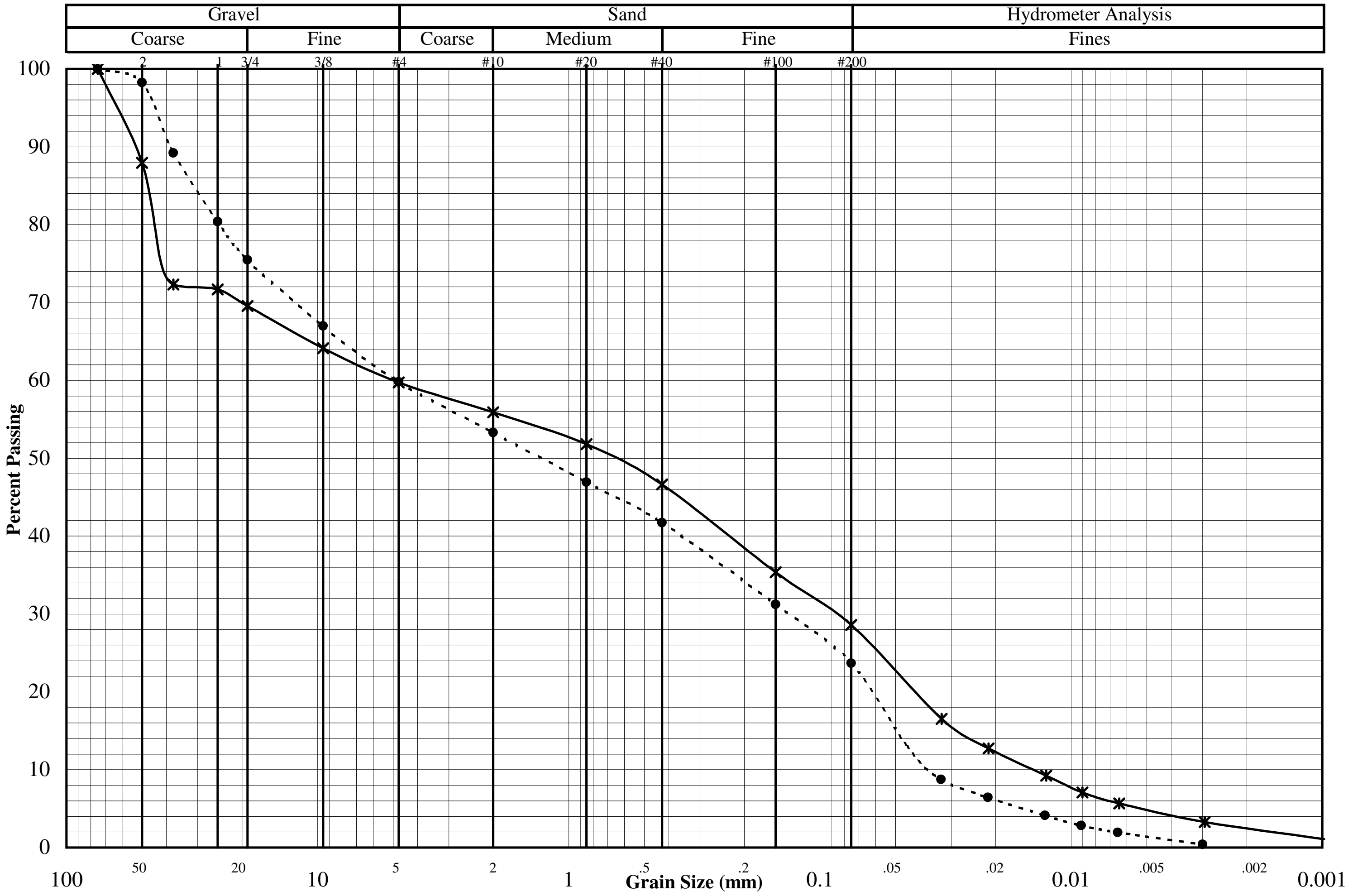
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	16.1				
0.020	13.4				
0.012	9.0				
0.009	6.7				
0.006	4.8				
0.003	2.3				
0.001	0.6				

Grain Size Distribution ASTM D422

Project:	Polymet	Job No. :	**6428**
		Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-14A/RS-14R	07-0240	0-1.5	Bag	Silty Gravel w/Sand and Organic fines (GM)
●	RS-14A/RS-14R	07-0232	3-5	Bag	Silty Gravel w/Sand (GM)
◇					



Other Tests

	*	●	◇
Liquid Limit	45.2	NP	
Plastic Limit	43.0	NP	
Plasticity Index	2.2	NP	
Water Content	68.8	11.7	
Dry Density (pcf)			
Specific Gravity	2.55*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	2392.0	12931.6	
2"	88.0	98.2	
1.5"	72.3	89.2	
1"	71.7	80.4	
3/4"	69.6	75.5	
3/8"	64.1	67.0	
#4	59.7	59.8	
#10	55.9	53.3	
#20	51.8	46.9	
#40	46.6	41.7	
#100	35.4	31.2	
#200	28.6	23.7	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-14A/RS-14R	07-0240	0-1.5	Bag	Silty Gravel w/Sand and Organic fines (GM)
Spec 2	RS-14A/RS-14R	07-0232	3-5	Bag	Silty Gravel w/Sand (GM)
Spec 3					

Hydrometer Data

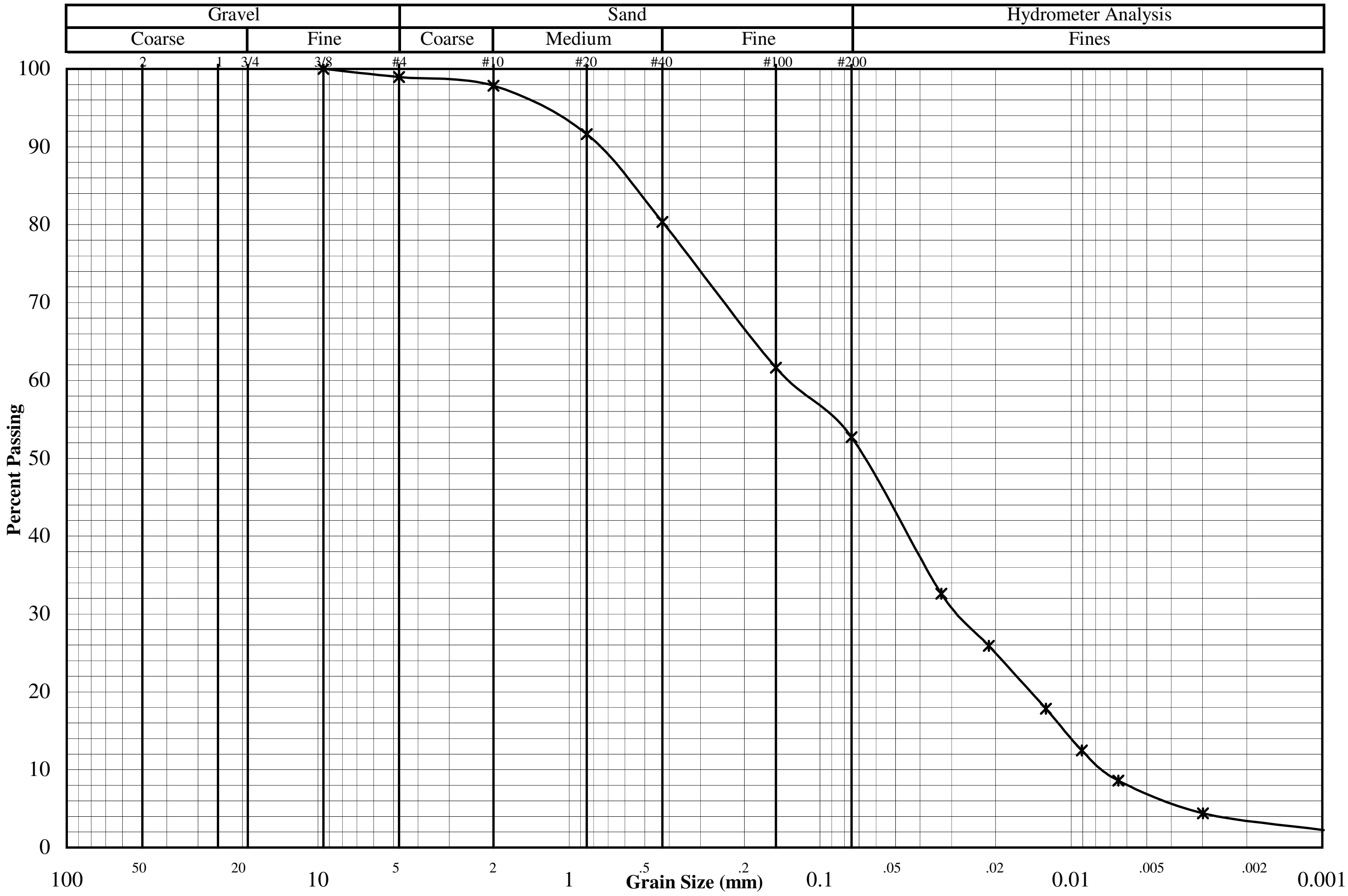
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.033	16.5	0.033	8.8		
0.021	12.7	0.021	6.4		
0.013	9.2	0.013	4.1		
0.009	7.1	0.009	2.8		
0.006	5.7	0.007	2.0		
0.003	3.3	0.003	0.4		
0.001	1.1	0.001	-0.2		

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-15	07-0355	0-0.5	Jar	Sandy Silt w/organic material (ML)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	NP		
Plastic Limit	NP		
Plasticity Index	NP		
Water Content	69.7		
Dry Density (pcf)			
Specific Gravity	2.55*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	104.4		
2"			
1.5"			
1"			
3/4"			
3/8"	100.0		
#4	99.0		
#10	97.8		
#20	91.6		
#40	80.3		
#100	61.6		
#200	52.7		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-15	07-0355	0-0.5	Jar	Sandy Silt w/organic material (ML)
Spec 2					
Spec 3					

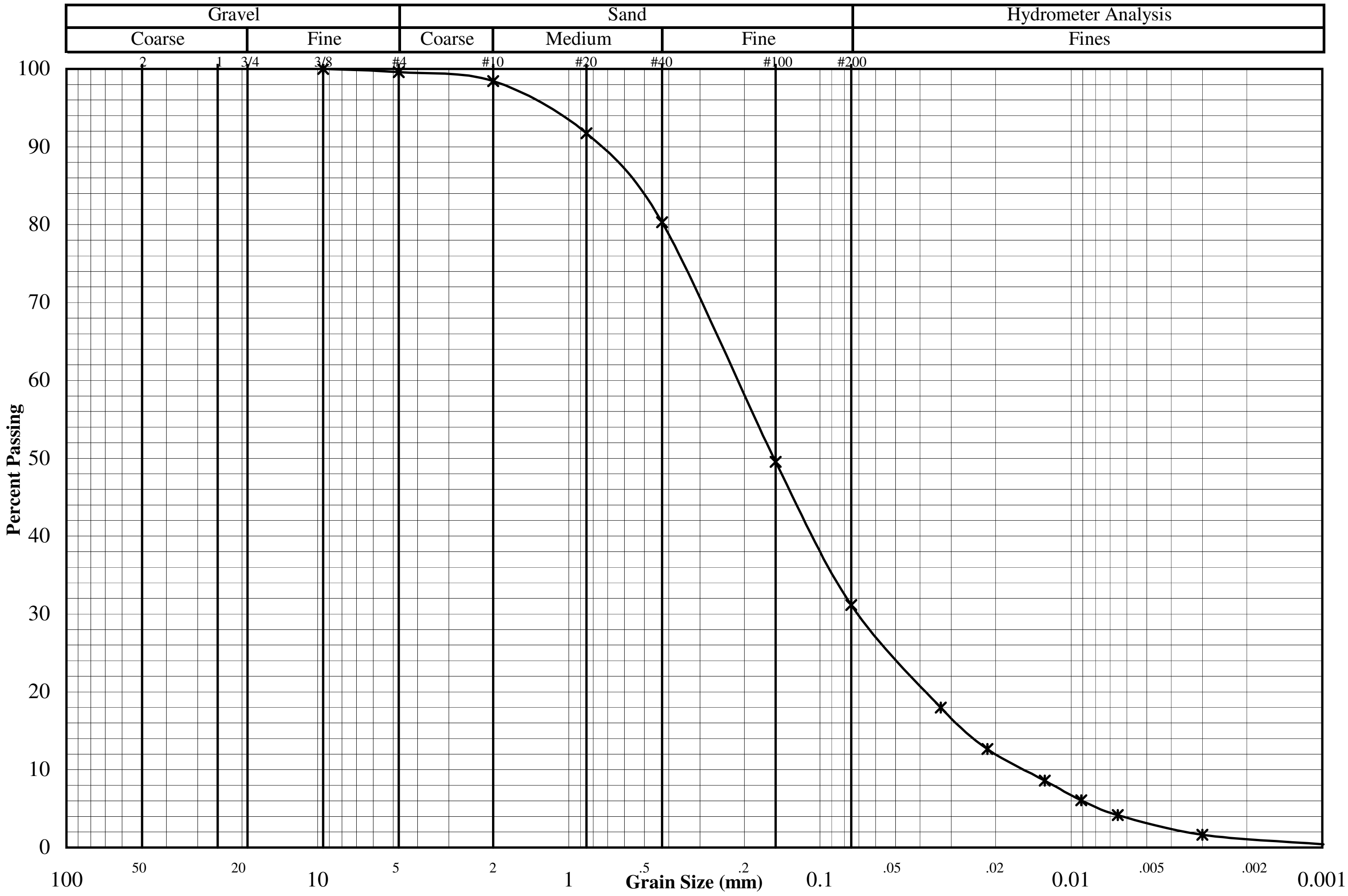
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.033	32.6				
0.021	25.9				
0.013	17.8				
0.009	12.5				
0.006	8.6				
0.003	4.4				
0.001	2.2				

Grain Size Distribution ASTM D422

		Job No. :	**6428**
Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-16	07-0357	0-2	Jar	Silty Sand (SM)
●					
◇					



Other Tests	*	●	◇
Liquid Limit	NP		
Plastic Limit	NP		
Plasticity Index	NP		
Water Content	22.3		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing	*	●	◇
Mass (g)	240.2		
2"			
1.5"			
1"			
3/4"			
3/8"	100.0		
#4	99.6		
#10	98.4		
#20	91.7		
#40	80.3		
#100	49.5		
#200	31.2		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-16	07-0357	0-2	Jar	Silty Sand (SM)
Spec 2					
Spec 3					

Hydrometer Data

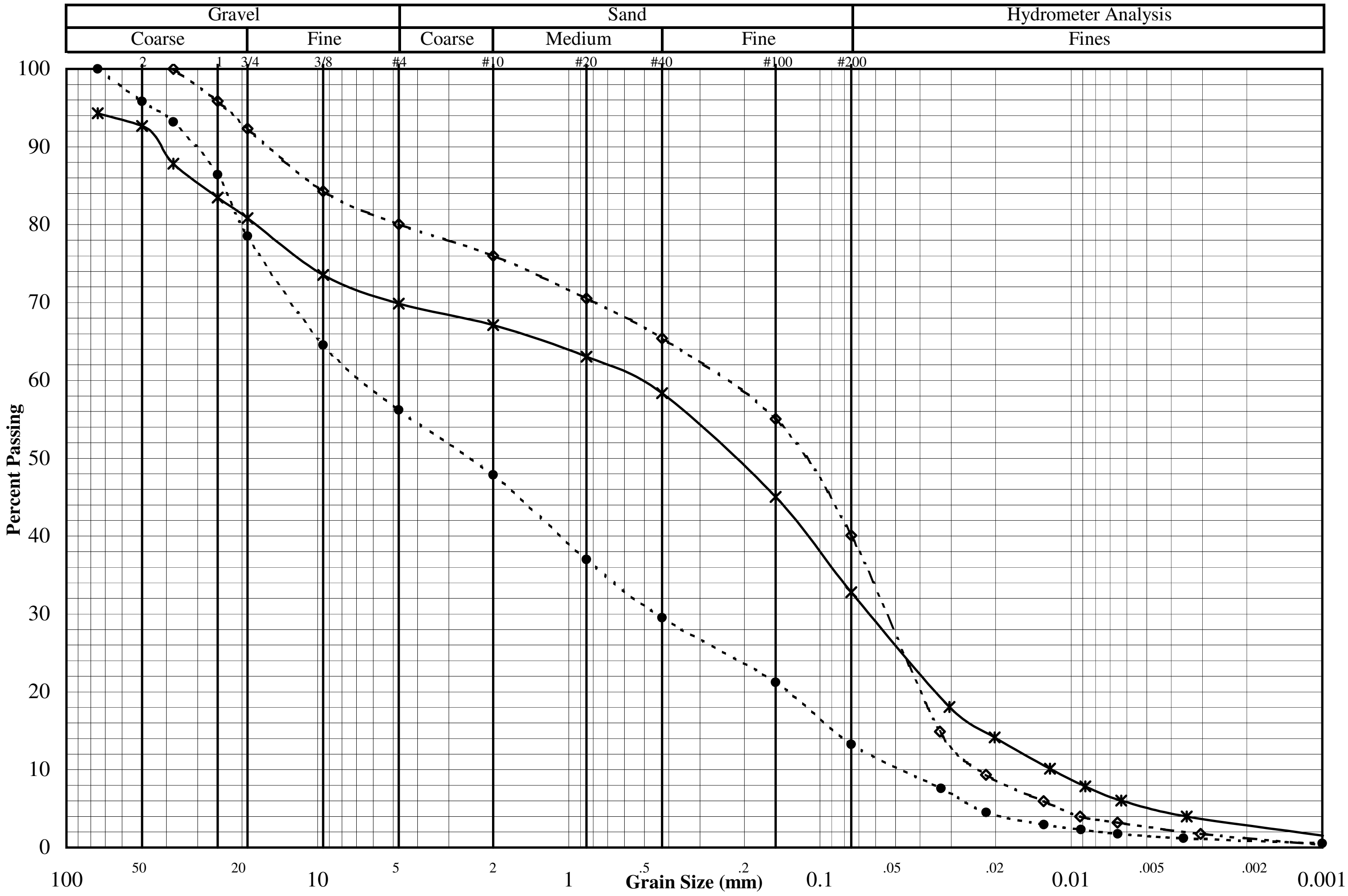
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.033	18.0				
0.022	12.7				
0.013	8.6				
0.009	6.1				
0.007	4.2				
0.003	1.6				
0.001	0.4				

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-17B	07-0214	2.5-4.5	Bulk	Gravelly Silty Sand (SM)
●	RS-17B	07-0205	4.5-6	Bulk	Silty Gravel w/Sand (GM)
◇	RS-17C	07-0346	6-7	TWT	Silty Sand w/Gravel (SM)



Other Tests	*	●	◇
Liquid Limit	16.2	NP	NP
Plastic Limit	15.5	NP	NP
Plasticity Index	0.7	NP	NP
Water Content	13.4	10.2	17.3
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	2.66*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing	*	●	◇
Mass (g)	20077.4	15415.3	2836.4
2"	92.7	95.8	
1.5"	87.8	93.2	100.0
1"	83.5	86.4	95.9
3/4"	80.8	78.5	92.3
3/8"	73.5	64.5	84.3
#4	69.8	56.2	80.1
#10	67.1	47.9	76.0
#20	63.1	37.0	70.5
#40	58.4	29.5	65.4
#100	45.0	21.2	55.0
#200	32.8	13.2	40.1

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

All 3" gravel passed 3.5" seive

Grain Size Distribution ASTM D422

Job No. : **6428**

Project: Polymet

Test Date: 4/10/08

Reported To: Barr Engineering Company

Report Date: 4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-17B	07-0214	2.5-4.5	Bulk	Gravelly Silty Sand (SM)
Spec 2	RS-17B	07-0205	4.5-6	Bulk	Silty Gravel w/Sand (GM)
Spec 3	RS-17C	07-0346	6-7	TWT	Silty Sand w/Gravel (SM)

Hydrometer Data

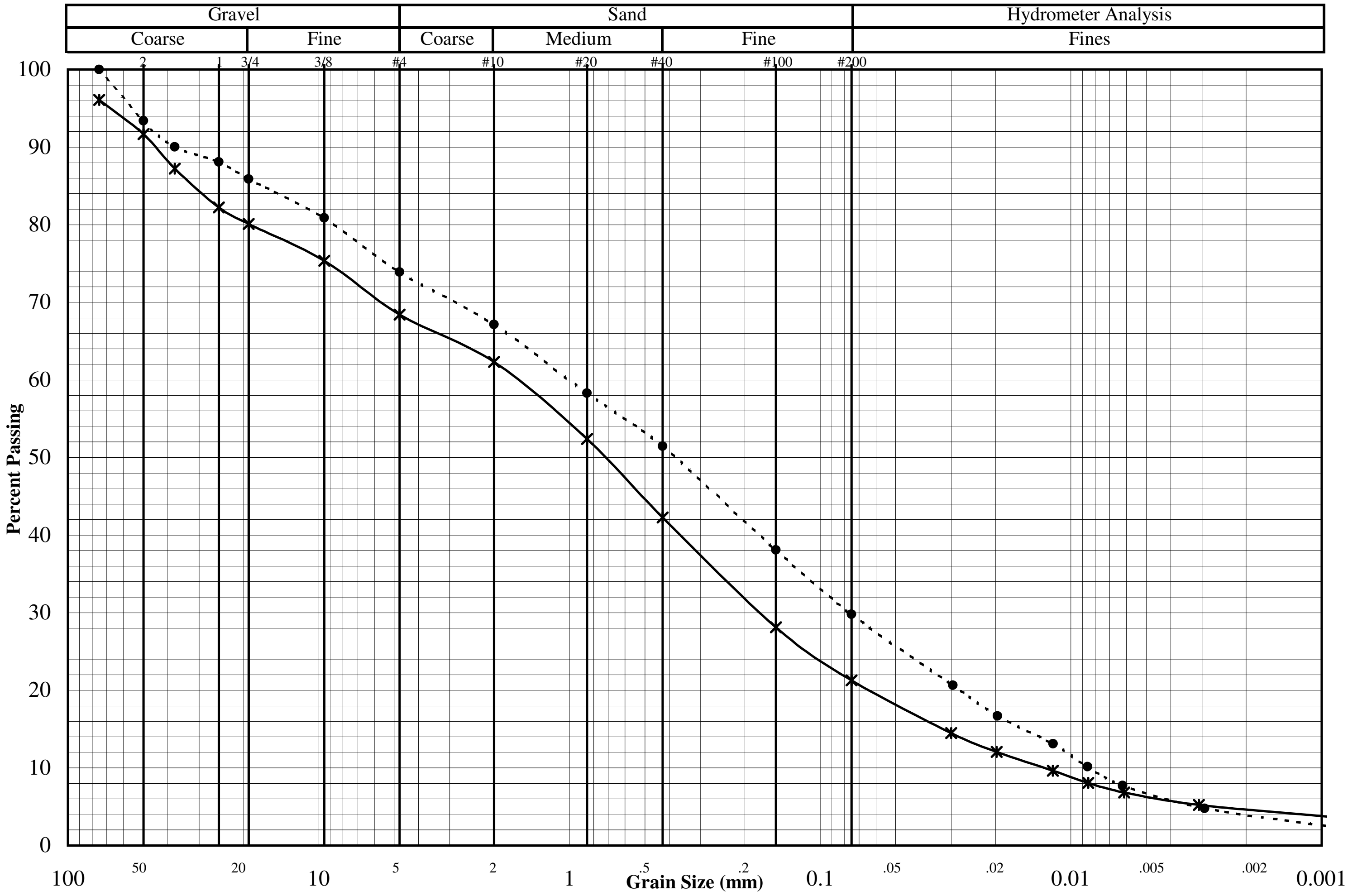
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	18.1	0.033	7.6	0.033	14.9
0.020	14.2	0.022	4.5	0.022	9.3
0.012	10.1	0.013	3.0	0.013	5.9
0.009	7.9	0.009	2.3	0.009	4.0
0.006	6.0	0.007	1.8	0.007	3.2
0.003	4.0	0.004	1.2	0.003	1.8
0.001	1.5	0.001	0.5	0.001	0.4

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-18		5-8	Bulk	Gravelly Silty Sand (SM)
●	RS-18		0-5	Bulk	Silty Clayey Sand w/Gravel (SC-SM)
◇					



Other Tests

	*	●	◇
Liquid Limit	NP	23.1	
Plastic Limit	NP	17.1	
Plasticity Index	NP	6.0	
Water Content	21.5	25.4	
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	27086.5	19537.0	
2"	91.7	93.4	
1.5"	87.2	90.0	
1"	82.2	88.1	
3/4"	80.1	85.9	
3/8"	75.4	80.9	
#4	68.4	73.9	
#10	62.3	67.1	
#20	52.4	58.3	
#40	42.3	51.5	
#100	28.1	38.1	
#200	21.3	29.8	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

All 3" gravel passed 3.5" seive

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet			Test Date:	4/10/08
Reported To:	Barr Engineering Company			Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-18		5-8	Bulk	Gravelly Silty Sand (SM)
Spec 2	RS-18		0-5	Bulk	Silty Clayey Sand w/Gravel (SC-SM)
Spec 3					

Hydrometer Data

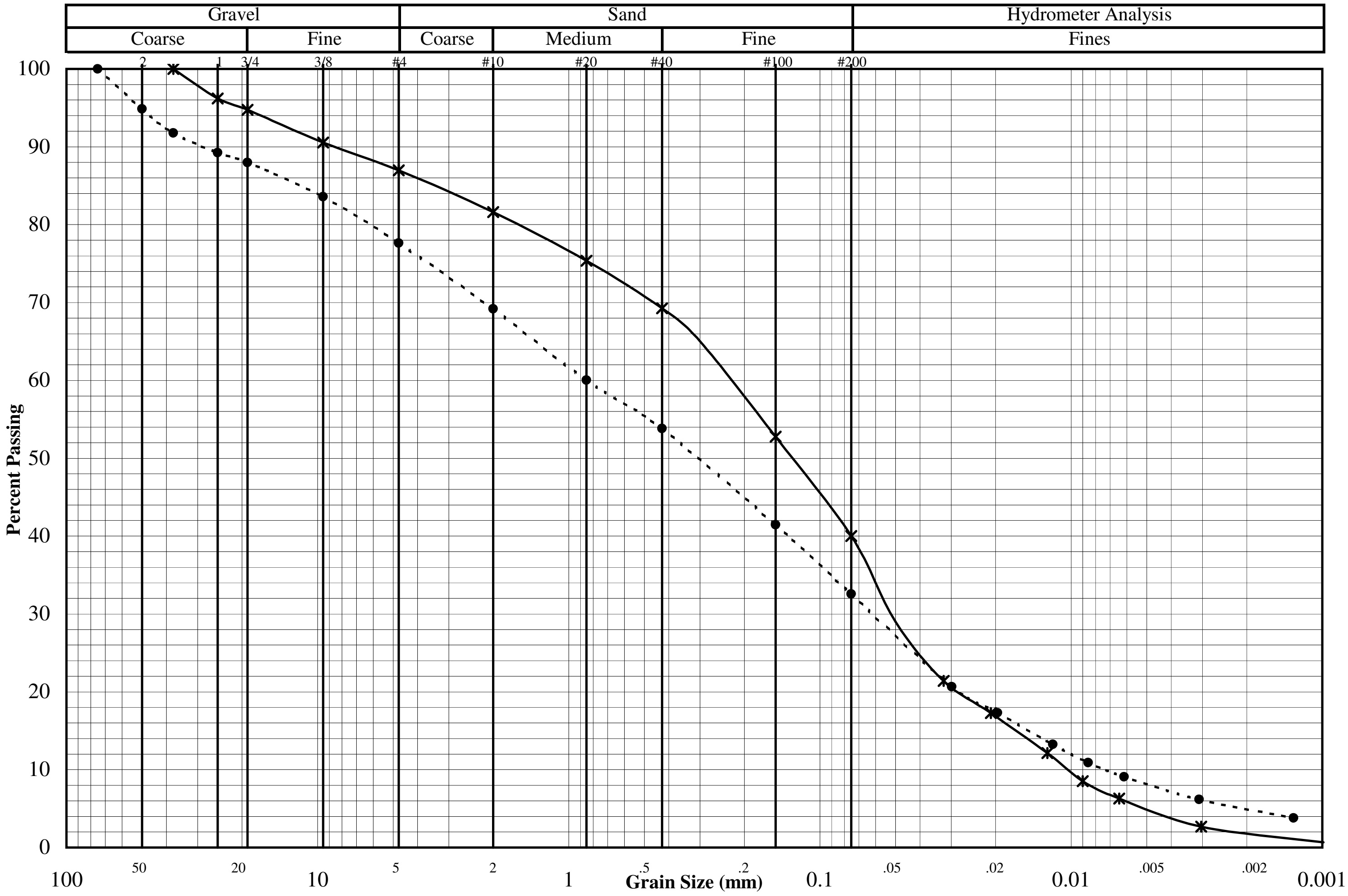
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	14.5	0.030	20.6		
0.020	12.0	0.020	16.7		
0.012	9.6	0.012	13.1		
0.009	8.1	0.009	10.2		
0.006	6.8	0.006	7.7		
0.003	5.2	0.003	4.8		
0.001	3.7	0.001	2.5		

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-19	07-0342	1.5-3.5	TWT	Silty Sand w/a little gravel (SM)
●	RS-19	07-0382	1-6	Bulk	Silty Sand w/Gravel (SM/SC-SM)
◇					



Other Tests

	*	●	◇
Liquid Limit	19.1	19.7	
Plastic Limit	17.8	16.1	
Plasticity Index	1.3	3.6	
Water Content	7.6	3.9	
Dry Density (pcf)			
Specific Gravity	2.66*	2.67*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	4861.0	22002.7	
2"		94.9	
1.5"	100.0	91.8	
1"	96.2	89.2	
3/4"	94.7	88.0	
3/8"	90.5	83.6	
#4	87.0	77.6	
#10	81.6	69.2	
#20	75.4	60.0	
#40	69.2	53.8	
#100	52.8	41.5	
#200	40.0	32.6	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-19	07-0342	1.5-3.5	TWT	Silty Sand w/a little gravel (SM)
Spec 2	RS-19	07-0382	1-6	Bulk	Silty Sand w/Gravel (SM/SC-SM)
Spec 3					

Hydrometer Data

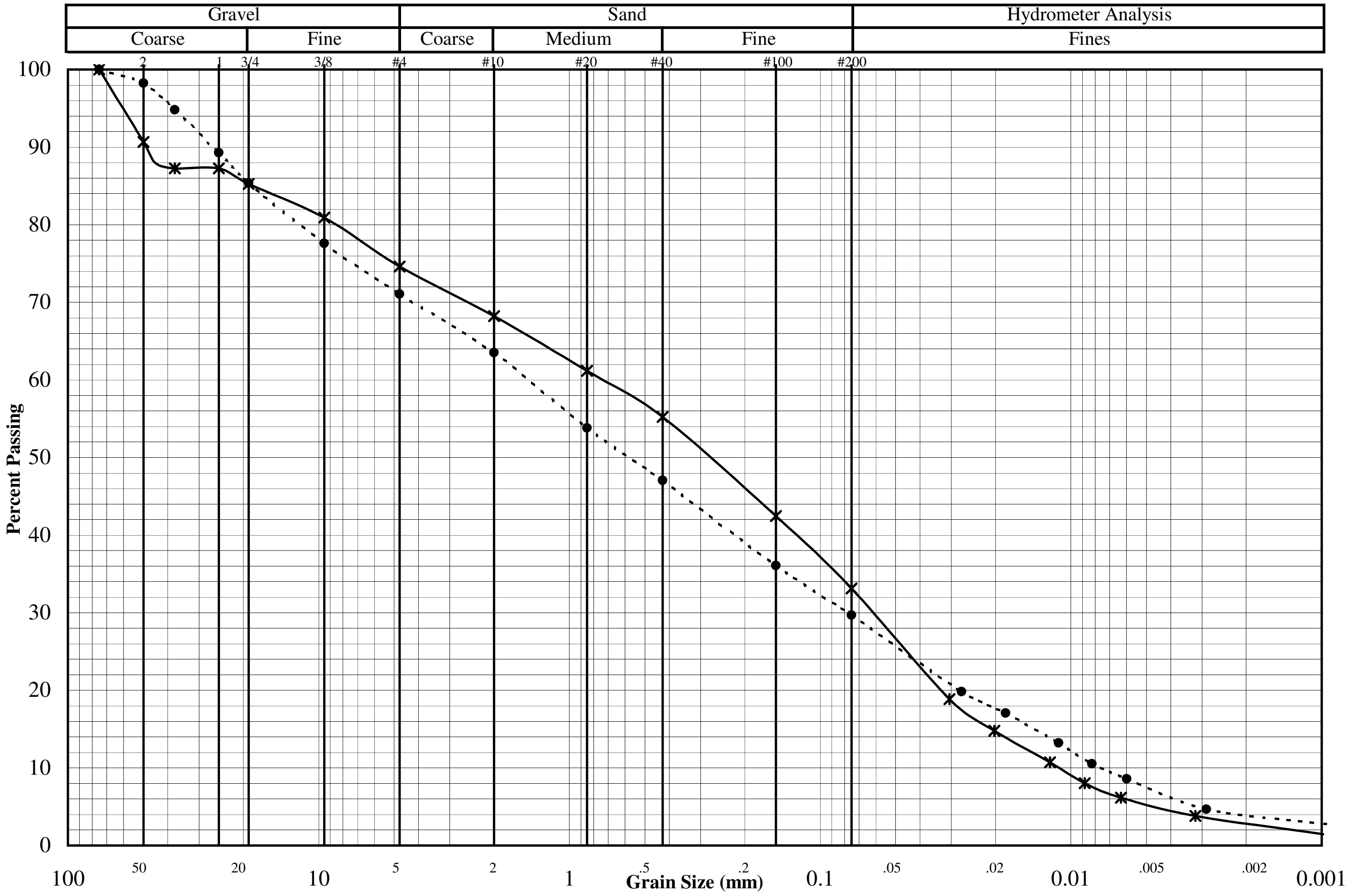
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.032	21.4	0.030	20.7		
0.021	17.3	0.020	17.3		
0.012	12.1	0.012	13.3		
0.009	8.5	0.009	10.9		
0.006	6.3	0.006	9.1		
0.003	2.7	0.003	6.2		
0.001	0.7	0.001	3.8		

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-20	07-0345	2-3	TWT	Silty Sand w/gravel (SM)
●	RS-20	07-0377	2-4.5	Bulk	Silty Sand w/gravel (SM)
◇					



Other Tests

	*	●	◇
Liquid Limit	NP	15.5	
Plastic Limit	NP	15.4	
Plasticity Index	NP	0.1	
Water Content	3.7	10.4	
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	3120.4	18390.9	
2"	90.6	98.2	
1.5"	87.3	94.8	
1"	87.3	89.3	
3/4"	85.2	85.4	
3/8"	80.9	77.6	
#4	74.6	71.1	
#10	68.2	63.5	
#20	61.2	53.8	
#40	55.2	47.1	
#100	42.5	36.1	
#200	33.1	29.7	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet			Test Date:	4/10/08
Reported To:	Barr Engineering Company			Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-20	07-0345	2-3	TWT	Silty Sand w/gravel (SM)
Spec 2	RS-20	07-0377	2-4.5	Bulk	Silty Sand w/gravel (SM)
Spec 3					

Hydrometer Data

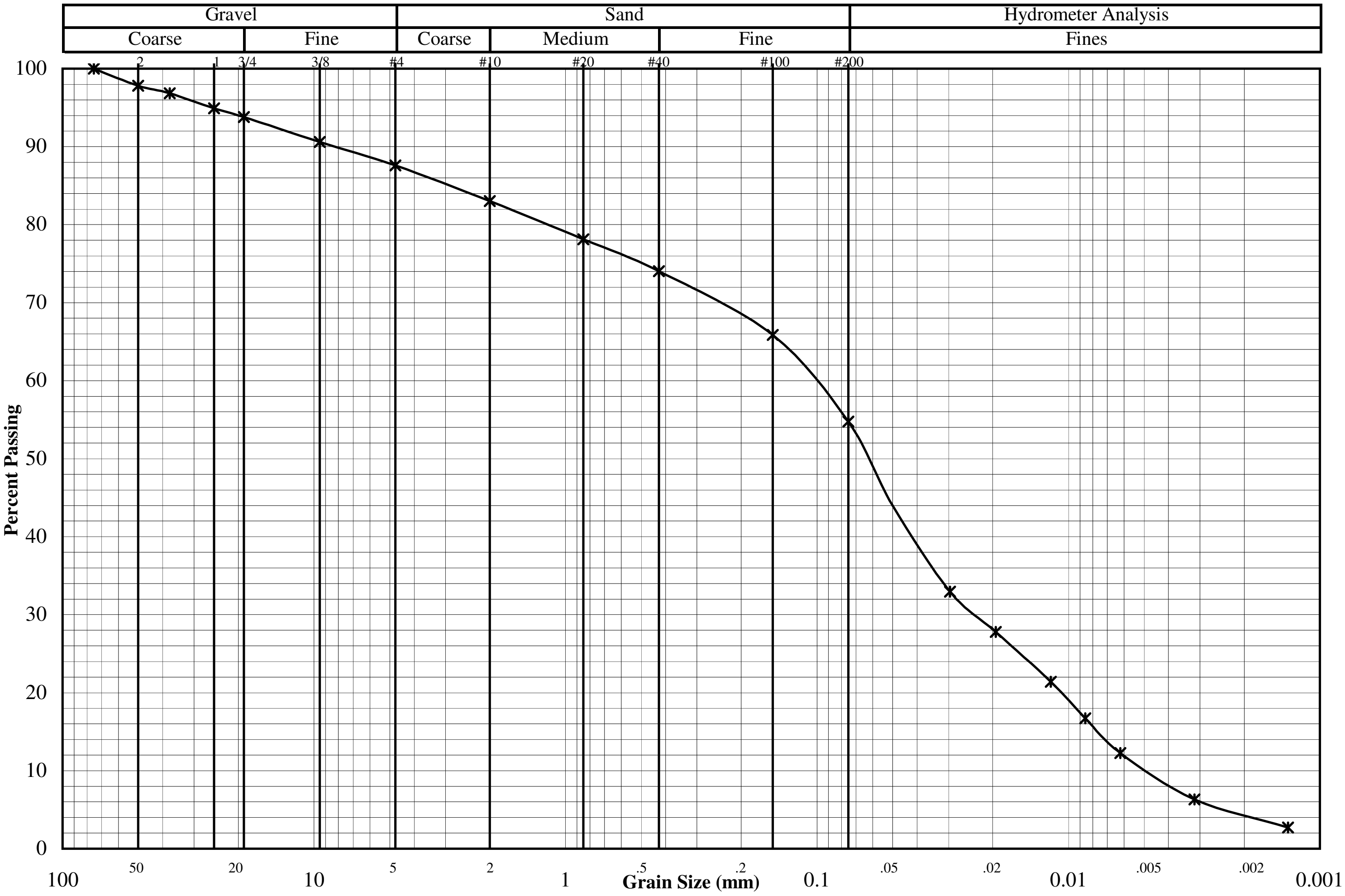
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	18.9	0.027	19.8		
0.020	14.8	0.018	17.1		
0.012	10.7	0.011	13.2		
0.009	8.0	0.008	10.5		
0.006	6.2	0.006	8.6		
0.003	3.8	0.003	4.7		
0.001	1.5	0.001	2.8		

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/5/08
Reported To:	Barr Engineering Company	Report Date:	4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-03	07-0336	10-15	Bulk	Sandy Silt w/a little gravel (ML)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	16.9		
Plastic Limit	14.3		
Plasticity Index	2.6		
Water Content	11.3		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	24964.0		
2"	97.8		
1.5"	96.8		
1"	94.9		
3/4"	93.8		
3/8"	90.6		
#4	87.6		
#10	83.0		
#20	78.1		
#40	74.0		
#100	65.9		
#200	54.8		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

9301 Bryant Ave. South, Suite 107

SOIL
ENGINEERING
TESTING, INC.

Bloomington, Minnesota 55420-3436

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date: 4/5/08
Reported To:	Barr Engineering Company	Report Date: 4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-03	07-0336	10-15	Bulk	Sandy Silt w/a little gravel (ML)
Spec 2					
Spec 3					

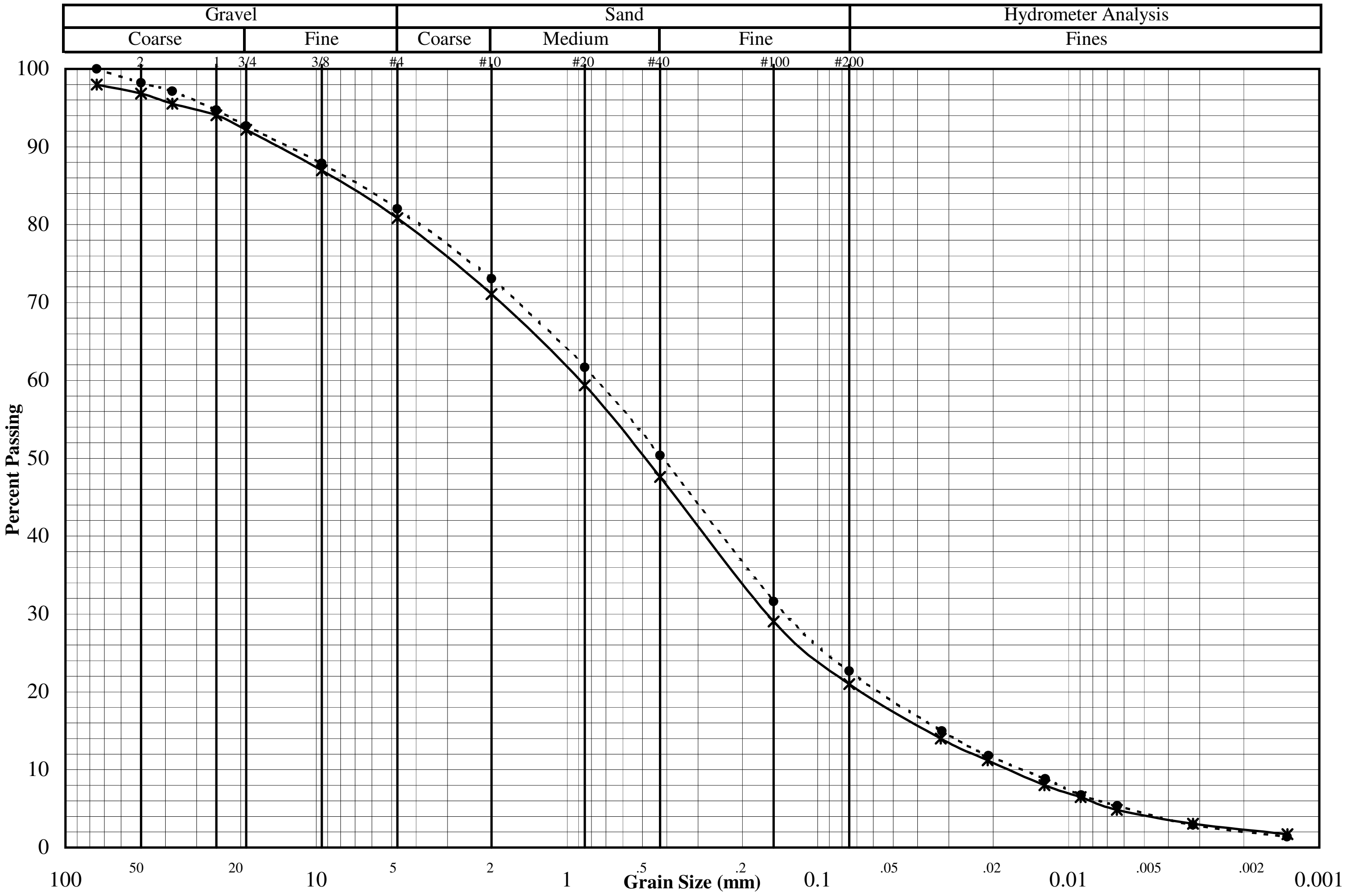
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	33.0				
0.019	27.8				
0.012	21.4				
0.009	16.7				
0.006	12.3				
0.003	6.3				
0.001	2.7				

Grain Size Distribution ASTM D422

Project:	Polymet	Job No. :	6428
		Test Date:	4/5/08
Reported To:	Barr Engineering Company	Report Date:	4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-04	07-0209	10-15	Bulk	Silty Sand w/Gravel (SM)
●	RS-04	07-0203	15-20	Bulk	Silty Sand w/Gravel (SM)
◇					



Other Tests

	*	●	◇
Liquid Limit	NP	NP	
Plastic Limit	NP	NP	
Plasticity Index	NP	NP	
Water Content	10.9	13.5	
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	32700.0	30183.0	
2"	96.8	98.2	
1.5"	95.6	97.1	
1"	94.1	94.7	
3/4"	92.2	92.7	
3/8"	87.0	87.9	
#4	80.8	82.0	
#10	71.1	73.0	
#20	59.4	61.7	
#40	47.6	50.3	
#100	29.0	31.6	
#200	21.0	22.7	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

All 3" gravel passed 3.5" seive

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/5/08
Reported To:	Barr Engineering Company	Report Date:	4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-04	07-0209	10-15	Bulk	Silty Sand w/Gravel (SM)
Spec 2	RS-04	07-0203	15-20	Bulk	Silty Sand w/Gravel (SM)
Spec 3					

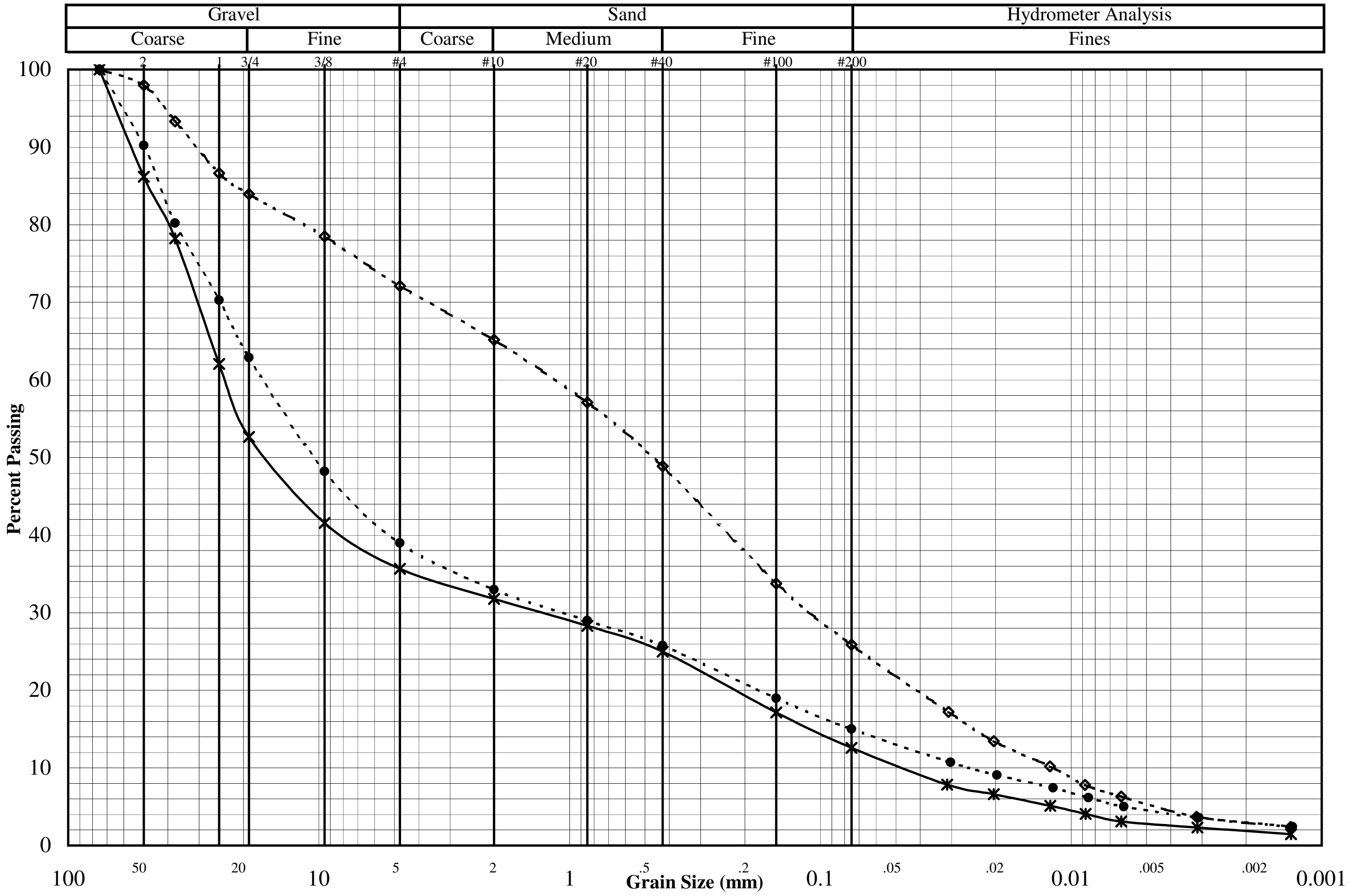
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.032	14.0	0.032	14.9		
0.021	11.2	0.021	11.8		
0.012	8.0	0.012	8.8		
0.009	6.5	0.009	6.7		
0.006	4.8	0.006	5.3		
0.003	3.0	0.003	2.9		
0.001	1.7	0.001	1.4		

Grain Size Distribution ASTM D422

Project:	Polymet	Job No. :	**6428**
		Test Date:	4/5/08
Reported To:	Barr Engineering Company	Report Date:	4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-05A	07-0231	10-11.5	Bag	Silty Gravel w/sand (GM)
●	RS-05A	07-0246	11.5-13	Bag	Silty Gravel w/sand (GM)
◇	RS-05A	07-0215	6-11.5	Bulk	Silty Sand w/Gravel (SM)



Other Tests

	*	●	◇
Liquid Limit	NP	14.3	NP
Plastic Limit	NP	13.1	NP
Plasticity Index	NP	1.2	NP
Water Content	7.2	6.6	12.0
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	2.66*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	13128.0	8983.6	25133.5
2"	86.2	90.2	98.0
1.5"	78.2	80.2	93.3
1"	62.1	70.3	86.6
3/4"	52.6	62.9	83.9
3/8"	41.5	48.2	78.5
#4	35.7	39.0	72.1
#10	31.8	33.0	65.2
#20	28.3	29.0	57.1
#40	25.0	25.8	48.9
#100	17.1	19.0	33.8
#200	12.6	15.0	25.9

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/5/08
Reported To:	Barr Engineering Company	Report Date:	4/6/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-05A	07-0231	10-11.5	Bag	Silty Gravel w/sand (GM)
Spec 2	RS-05A	07-0246	11.5-13	Bag	Silty Gravel w/sand (GM)
Spec 3	RS-05A	07-0215	6-11.5	Bulk	Silty Sand w/Gravel (SM)

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	7.9	0.030	10.7	0.031	17.2
0.020	6.6	0.020	9.1	0.020	13.5
0.012	5.1	0.012	7.4	0.012	10.2
0.009	4.1	0.009	6.2	0.009	7.8
0.006	3.1	0.006	5.0	0.006	6.3
0.003	2.3	0.003	3.6	0.003	3.7
0.001	1.5	0.001	2.4	0.001	2.4

Grain Size Distribution ASTM D422

Job No. : **6428**

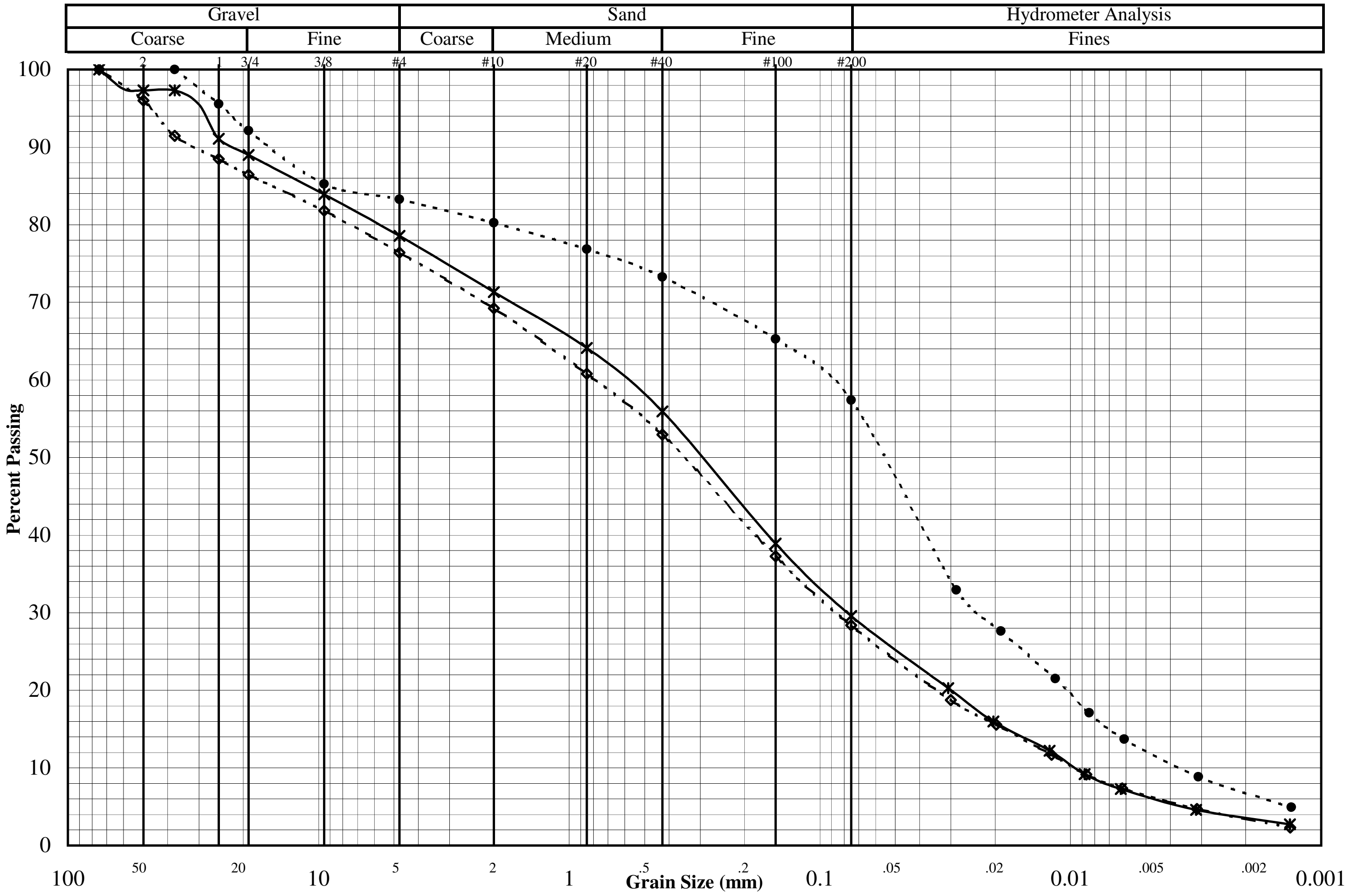
Project: Polymet

Test Date: 4/8/08

Reported To: Barr Engineering Company

Report Date: 4/9/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-06A/RS-06R	07-0223	10-15	Bag	Silty Sand w/Gravel (SM)
●	RS-06A/RS-06R	07-0339	3.5-7.5	Bulk	Sandy Silt w/Gravel (ML/CL-ML)
◇	RS-06A/RS-06R	07-0333	7.5-10	Bulk	Silty Sand w/gravel (SM)



Other Tests

	*	●	◇
Liquid Limit	NP	17.8	14.6
Plastic Limit	NP	14.7	13.9
Plasticity Index	NP	3.1	0.7
Water Content	6.8	13.9	8.2
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	2.66*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	8572.8	19468.0	28067.2
2"	97.3		96.0
1.5"	97.3	100.0	91.5
1"	91.1	95.6	88.5
3/4"	89.0	92.1	86.4
3/8"	83.9	85.2	81.8
#4	78.6	83.3	76.4
#10	71.3	80.3	69.2
#20	64.1	76.8	60.8
#40	55.9	73.3	52.9
#100	38.9	65.3	37.3
#200	29.6	57.4	28.4

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project: Polymet

Test Date: 4/8/08

Reported To: Barr Engineering Company

Report Date: 4/9/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-06A/RS-06R	07-0223	10-15	Bag	Silty Sand w/Gravel (SM)
Spec 2	RS-06A/RS-06R	07-0339	3.5-7.5	Bulk	Sandy Silt w/Gravel (ML/CL-ML)
Spec 3	RS-06A/RS-06R	07-0333	7.5-10	Bulk	Silty Sand w/gravel (SM)

Hydrometer Data

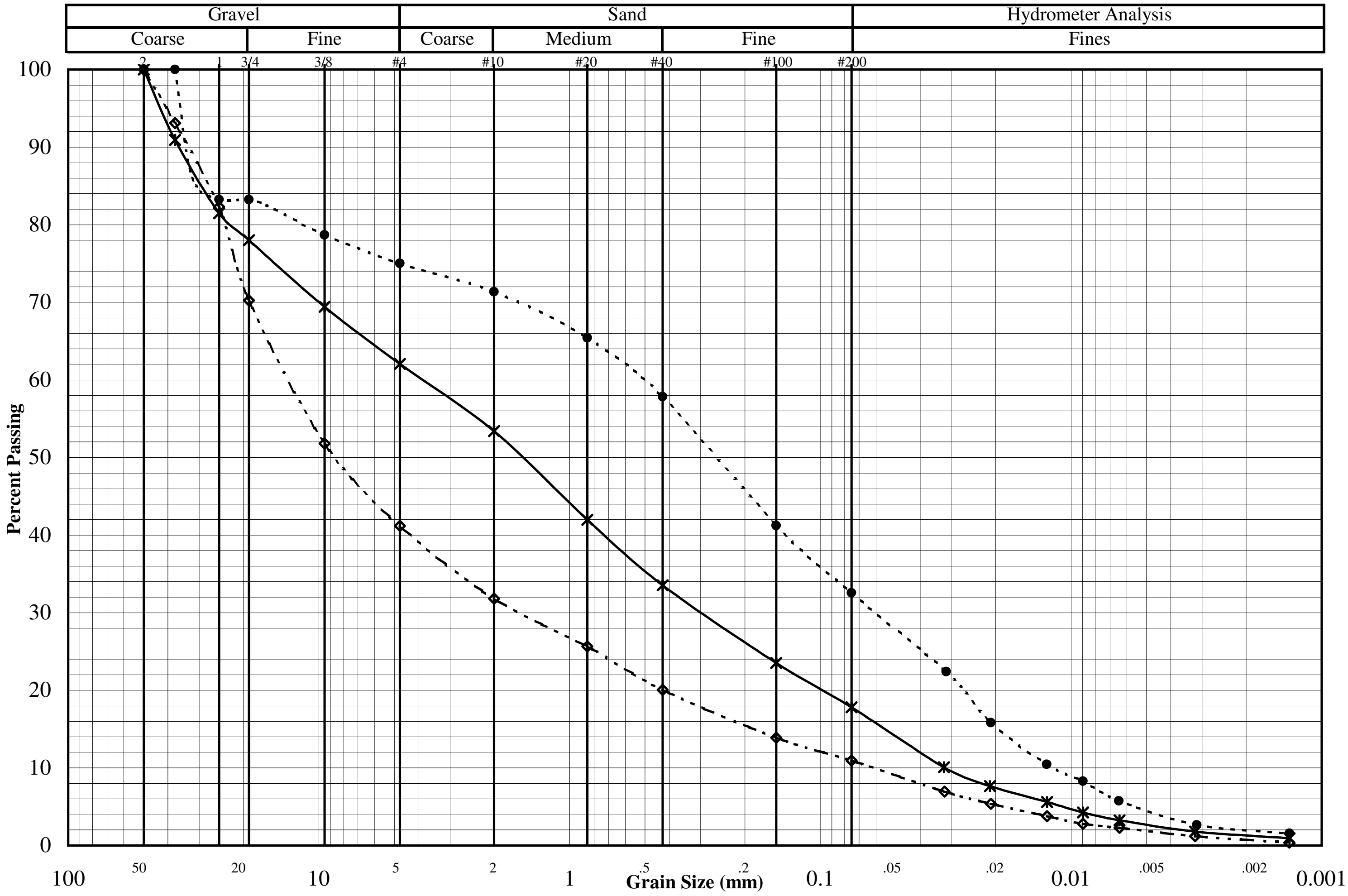
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.031	20.3	0.029	33.0	0.030	18.7
0.020	16.0	0.019	27.6	0.020	15.6
0.012	12.2	0.012	21.5	0.012	11.7
0.009	9.2	0.008	17.1	0.009	9.1
0.006	7.3	0.006	13.7	0.006	7.4
0.003	4.6	0.003	8.9	0.003	4.7
0.001	2.7	0.001	4.9	0.001	2.3

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/8/08
Reported To:	Barr Engineering Company	Report Date:	4/10/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-07	07-0235	2-5	Bag	Gravelly Silty Sand (SM)
●	RS-07	07-0233	0-2	Bag	Silty Sand w/Gravel (SM)
◇	RS-07	07-0245	10-11	Bag	Sandy Gravel w/Silt (GP-GM)



Other Tests

	*	●	◇
Liquid Limit	NP	NP	NP
Plastic Limit	NP	NP	NP
Plasticity Index	NP	NP	NP
Water Content	19.8		9.5
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	2.66*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	2436.9	1080.4	2410.2
2"	100.0		100.0
1.5"	90.9	100.0	93.1
1"	81.5	83.2	82.3
3/4"	78.0	83.2	70.2
3/8"	69.4	78.7	51.8
#4	62.1	75.0	41.2
#10	53.4	71.3	31.8
#20	42.0	65.4	25.7
#40	33.5	57.8	20.0
#100	23.5	41.2	13.9
#200	17.8	32.6	10.9

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/8/08
Reported To:	Barr Engineering Company	Report Date:	4/10/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-07	07-0235	2-5	Bag	Gravelly Silty Sand (SM)
Spec 2	RS-07	07-0233	0-2	Bag	Silty Sand w/Gravel (SM)
Spec 3	RS-07	07-0245	10-11	Bag	Sandy Gravel w/Silt (GP-GM)

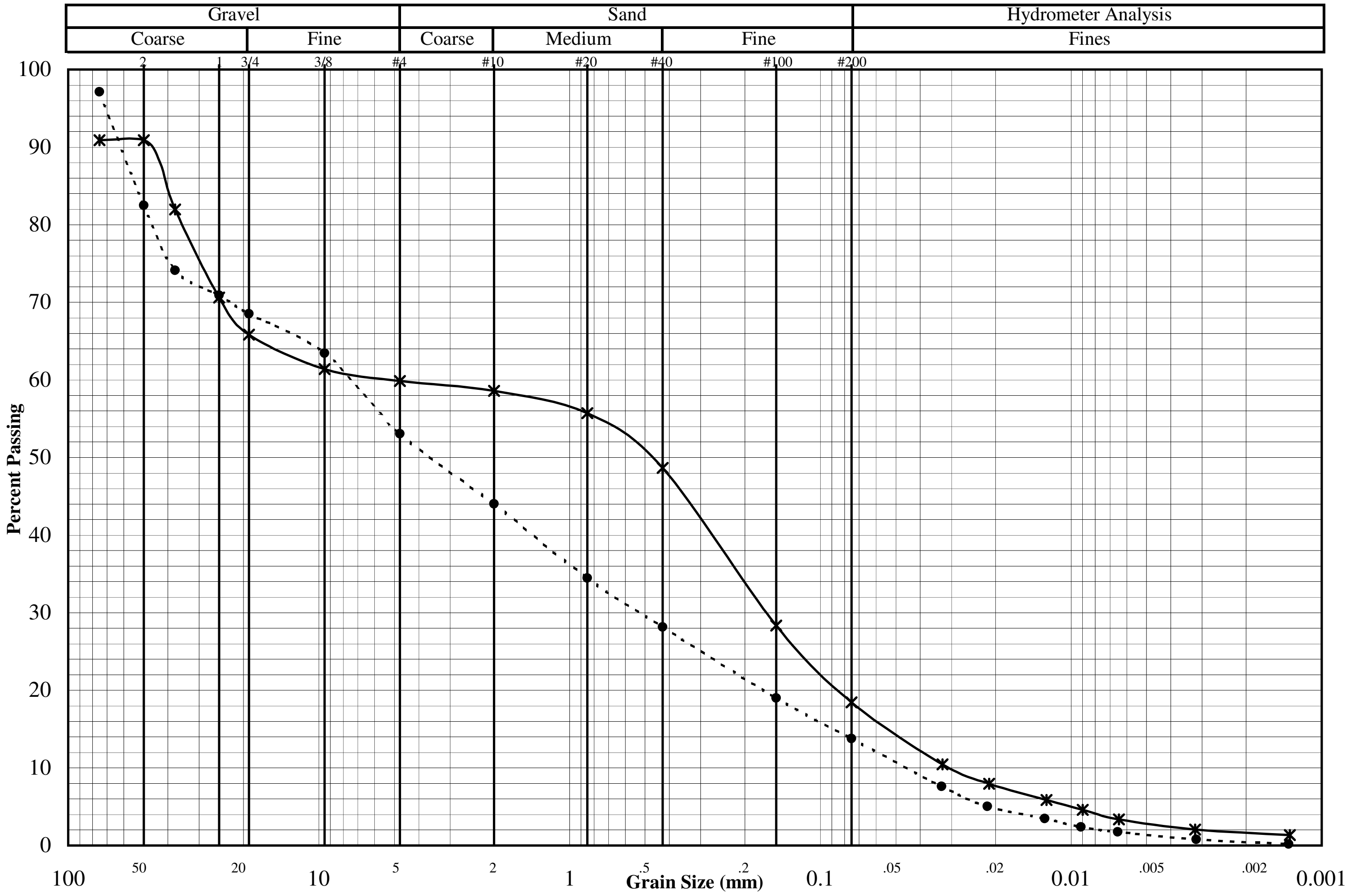
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.032	10.1	0.031	22.4	0.032	7.0
0.021	7.7	0.021	15.8	0.021	5.4
0.012	5.6	0.013	10.5	0.012	3.8
0.009	4.2	0.009	8.3	0.009	2.8
0.006	3.3	0.006	5.7	0.006	2.3
0.003	1.8	0.003	2.6	0.003	1.2
0.001	0.9	0.001	1.6	0.001	0.4

Grain Size Distribution ASTM D422

		Job No. :	**6428**
Project:	Polymet	Test Date:	4/8/08
Reported To:	Barr Engineering Company	Report Date:	4/10/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-07/RS-07R	07-0397	2-3	Bag	Gravelly Silty Sand (SM)
●	RS-07/RS-07R	07-0381	6-10	Bulk	Sandy Silty Gravel (GM)
◇					



Other Tests

	*	●	◇
Liquid Limit	NP	NP	
Plastic Limit	NP	NP	
Plasticity Index	NP	NP	
Water Content	24.8	8.7	
Dry Density (pcf)			
Specific Gravity	2.66*	2.66*	
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	7005.2	27047.0	
2"	90.9	82.5	
1.5"	82.0	74.1	
1"	70.6	70.9	
3/4"	65.8	68.5	
3/8"	61.4	63.4	
#4	59.9	53.0	
#10	58.6	44.0	
#20	55.7	34.5	
#40	48.6	28.1	
#100	28.4	19.0	
#200	18.4	13.8	

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

All 3" gravel passed 3.5" seive

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/8/08
Reported To:	Barr Engineering Company	Report Date:	4/10/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-07/RS-07R	07-0397	2-3	Bag	Gravelly Silty Sand (SM)
Spec 2	RS-07/RS-07R	07-0381	6-10	Bulk	Sandy Silty Gravel (GM)
Spec 3					

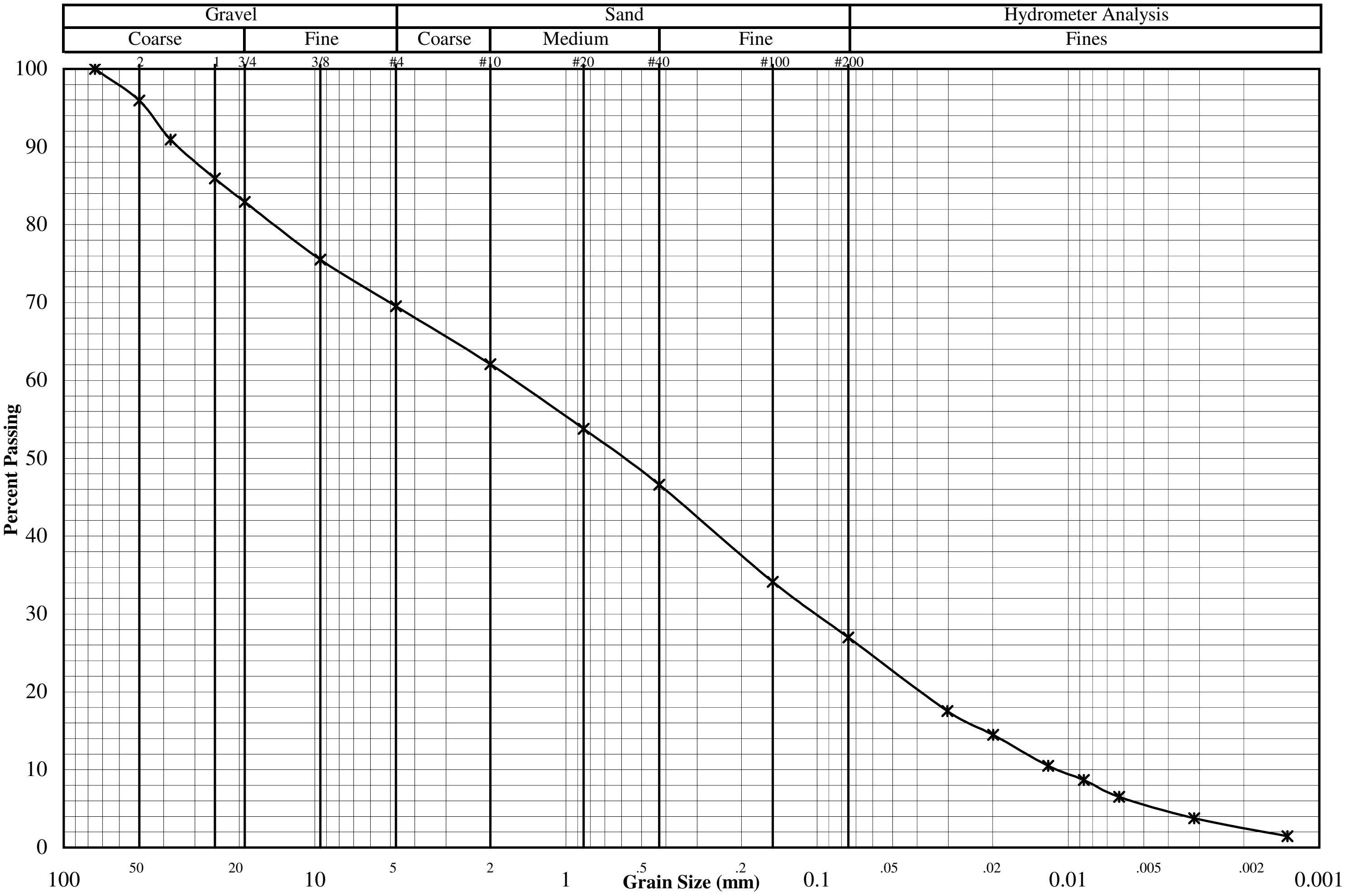
Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.033	10.5	0.033	7.6		
0.021	7.9	0.022	5.0		
0.013	5.9	0.013	3.5		
0.009	4.6	0.009	2.4		
0.006	3.3	0.007	1.8		
0.003	2.1	0.003	0.8		
0.001	1.3	0.001	0.2		

Grain Size Distribution ASTM D422

		Job No. :	**6428**
Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/11/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-08A	07-0384	5-11	Bulk	Gravelly Silty Sand (SM)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	NP		
Plastic Limit	NP		
Plasticity Index	NP		
Water Content	9.7		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	29052.2		
2"	95.9		
1.5"	90.9		
1"	85.9		
3/4"	82.9		
3/8"	75.5		
#4	69.5		
#10	62.1		
#20	53.8		
#40	46.6		
#100	34.1		
#200	27.0		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Project:	Polymet	Test Date:	4/10/08
Reported To:	Barr Engineering Company	Report Date:	4/11/08

Job No. : **6428**

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-08A	07-0384	5-11	Bulk	Gravelly Silty Sand (SM)
Spec 2					
Spec 3					

Hydrometer Data

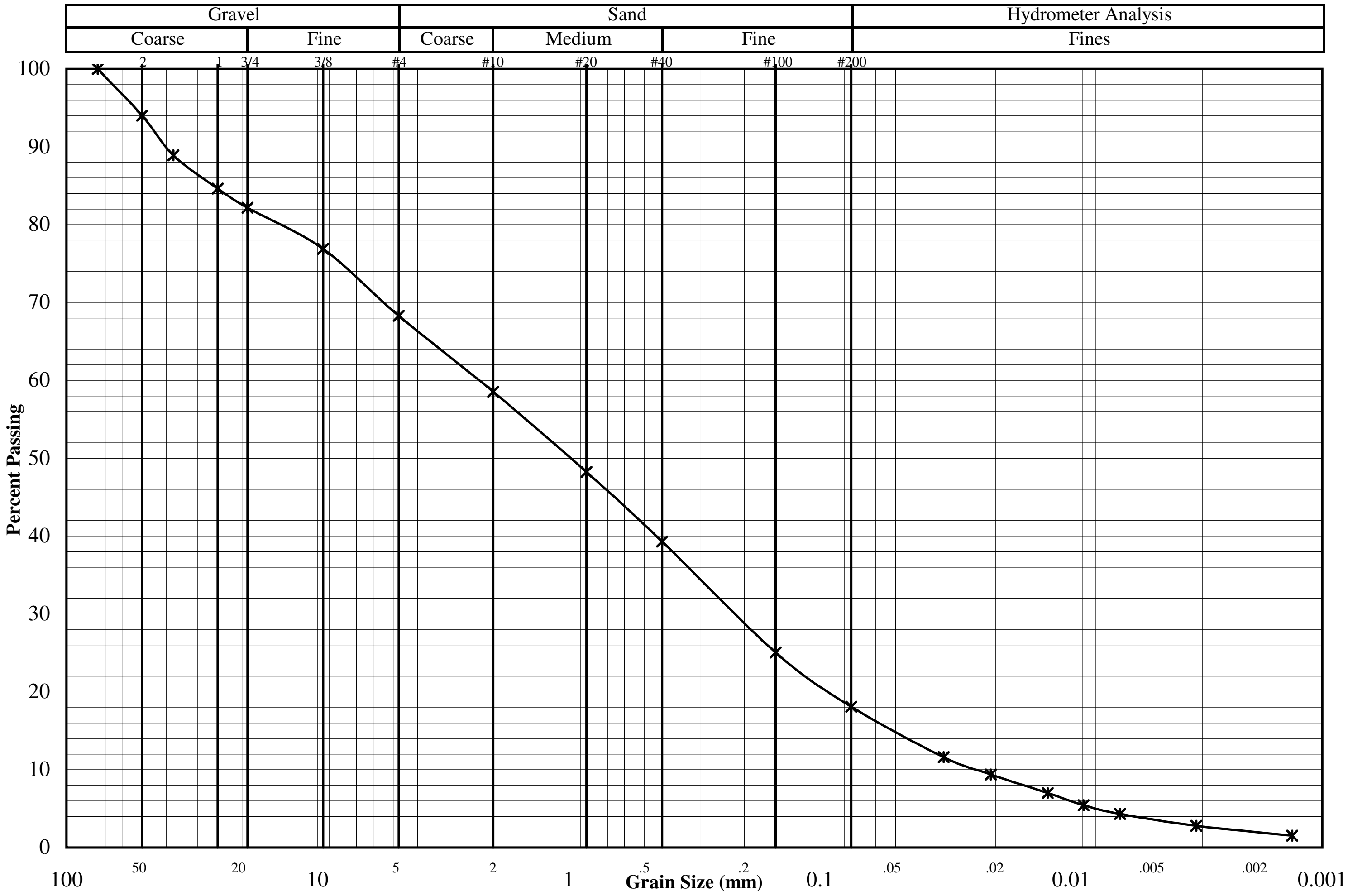
Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	17.5				
0.020	14.5				
0.012	10.5				
0.009	8.7				
0.006	6.5				
0.003	3.8				
0.001	1.5				

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/9/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	RS-09	07-0210	1-7	Bulk	Gravelly Silty Sand (SM)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	NP		
Plastic Limit	NP		
Plasticity Index	NP		
Water Content	6.1		
Dry Density (pcf)			
Specific Gravity	2.66*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	20618.8		
2"	94.0		
1.5"	88.9		
1"	84.6		
3/4"	82.2		
3/8"	76.9		
#4	68.3		
#10	58.5		
#20	48.2		
#40	39.3		
#100	25.1		
#200	18.1		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **6428**

Project:	Polymet	Test Date:	4/9/08
Reported To:	Barr Engineering Company	Report Date:	4/14/08

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	RS-09	07-0210	1-7	Bulk	Gravelly Silty Sand (SM)
Spec 2					
Spec 3					

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.032	11.6				
0.021	9.4				
0.012	7.0				
0.009	5.4				
0.006	4.3				
0.003	2.8				
0.001	1.5				

Attachment E

Overburden Geotechnical Investigation - Boring Logs and Material Testing Data Sheets

Barr Engineering Company
4700 West 77th Street • Minneapolis, MN 55435-4803
Phone: 952-832-2600 • Fax: 952-832-2601 • www.barr.com *An EEO Employer*

Minneapolis, MN • Hibbing, MN • Duluth, MN • Ann Arbor, MI • Jefferson City, MO • Bismarck, ND

Technical Memorandum

To: James Tieberg and Rich Patelke, PolyMet Mining
From: Vicki Hagberg, EIT
Tom Radue, PE
Nancy Dent, PE
Subject: 2010 Polymet Geotechnical Investigation
Date: August 16, 2010
Project: 23/69-0C29.09

This document summarizes the work completed during the 2010 geotechnical investigation and overburden characterization within the overburden and Category 1 (CAT 1) waste rock stockpile area at the proposed Polymet NorthMet mine site near Hoyt Lakes, Minnesota. The purpose of the work was to further characterize the soil stratigraphy and strength characteristics within the proposed CAT 1 stockpile area.

Exploratory borings with standard penetration testing (SPT) were completed by American Engineering Testing (AET) at each of four drilling sites: J003, J010, J027, and J037. Boring locations are shown on the Boring Locations diagram included in the appendix to this memorandum. Using the information from the SPT borings, thinwall samples were collected from new offset boreholes at J003, J010, and J027. Pressuremeter tests were then also completed in new offset boreholes. Thinwall sample collection and pressuremeter testing were not completed at J037 because of the shallow depth to auger refusal. Drilling was completed between February 16 and February 26, 2010. In-laboratory geotechnical testing was completed on the soil samples at Soil Engineering Testing (SET) in April and May, 2010. Drilling observation and test data analysis was completed by Barr Engineering (Barr) and is summarized in the balance of this memorandum.

Soil Characteristics

SPT borings were completed at four locations to investigate the soil stratigraphy within the overburden and CAT 1 waste rock stockpile area. The borings were completed to auger refusal which correlated to the expected depth to bedrock as provided by PolyMet. Two-foot SPT samples were driven every 2.5 feet, and samples were logged using the USCS soil classification system and saved in jars for testing.

Index and strength testing were completed on the soils encountered. The boring logs and test results are included in the appendix. SPT sampling and the laboratory testing indicated that there are three general soil types at the CAT 1 stockpile area: peat, silt, and silty sand with clay and gravel (silty sand). The silt and silty sand are glacial till materials with varying amounts of clay, silt, sand, and gravel. In addition, a small quantity of topsoil and fill material were encountered on site but are considered to be minor components of the site geology. The characteristics of the three soil types are described in the sections below. However, based on the small number of borings completed within the CAT 1 stockpile area, it should not be assumed that these borings fully describe the soil conditions between borings. It is quite likely that the stratigraphy is variable and that additional soil types may occur on site. A summary of the soil test results is provided in the following table.

Soil Parameters Summary Table

Material	Sat. Unit Weight [pcf]	Moist Unit Weight [pcf]	Dry Unit Weight [pcf]	Permeability [ft/s]	Permeability [cm/s]	Soil Shear Strength			
						ESSA (drained)		USSA (undrained)	
						Cohesion [psf]	Friction Angle [deg.]	Cohesion [psf]	Friction Angle [deg.]
Peat	75[1]	66[2]	15[3]	1.18E-08[4]	3.60E-07[4]	500[1]	0[1]	280[5]	0[5]
Silt	126[7]	126[2]	101[3]	3.28E-09[1]	1.00E-07[1]	580[8]	0[8]	580[5]	0[5]
Silty Sand	155[1]	150[2]	139[3]	1.69E-08[4]	5.15E-07[4]	0[6]	38.5[6]	0[6]	35.3[6]

Notes:
1. Assumed value
2. Calculated as (1+[average moisture content % of soil type])*[dry unit weight of soil type]
3. Average dry unit weight value from test data
4. Geometric mean of permeability test values
5. Calculated as 0.5*(unconfined compressive strength) from test data
6. Minimum of consolidated undrained triaxial (CIU) with pore pressure measurements test failure envelopes.
7. Calculated as (1+[average moisture content % of soil type])*[dry unit weight of soil type]. Assumes soil is saturated as tested.
8. Drained case assumed to be the same as the undrained case.

As indicated in the table above, two types of Soil Shear Strength are reported, corresponding to the two types of stability analyses typically performed for stockpiles of this type: the Undrained Strength Stability Analysis (USSA) and the Effective Stress Stability Analysis (ESSA). The USSA is performed to analyze the case in which loading or unloading is applied rapidly and excess porewater pressures do not have sufficient time to dissipate during shearing. This scenario typically applies to loading from, for example, stockpile construction where the loading takes place quickly. It is often referred to as the "end-of-construction" case. The ESSA is performed to account for much slower loading or unloading, or no external loading, in which the drained shear strength of the materials is mobilized and no shear-induced porewater pressures are developed. For example, a stockpile after porewater pressures have dissipated from construction is best analyzed using the ESSA method. For this reason, the ESSA is often referred to as the "long term" case. Testing was completed to analyze the soil strength under both of these conditions. In addition, consolidation and soil elasticity parameters were also evaluated by lab and pressuremeter testing of the soils. Soil test results are described in greater detail in the following paragraphs.

Peat

Peat was encountered at the surface of borings J003 and J027. The peat layer at J003 was one foot thick and was frozen at the time of drilling, so testing was not completed on peat samples from boring J003. The peat layer at J027 was approximately 7 feet thick and was generally sapric (highly decomposed) as classified in the boring logs provided by AET. The peat layer was characterized by N-values[1] ranging from 1 to 2 indicating the layer is very soft and loose. The organic content of the peat ranged from 40.6% to 52.8% and the moisture content ranged from 287.3% to 404.6% as tested by SET. The dry density of the peat ranged from 12.8 to 16.9 pounds per cubic foot.

In addition to the SPT information and index testing, strength, consolidation, and permeability testing was also completed on peat samples. Unconfined strength testing (ASTM D2166) resulted in an unconfined compressive strength of the peat of 560 psf and corresponding undrained shear strength[2] of 280 psf. Permeability testing on the peat resulted in saturated hydraulic conductivity at 1.18x10^{-8} ft/s (3.60 x10^{-7} cm/s).

Consolidation testing on the peat at boring J027 resulted in the following parameters: preconsolidation pressure (Pc) = 500 psf, compression index (Cc) = 2.82, and recompression index (Cr) = 0.50. During consolidation testing, the maximum displacement limit was reached during the 8000 psf loading sequence. The consolidation parameters and the results of the test indicate that the peat would

---

[1] N-value is used to correlate to undrained strength of a soil. N-values are the sum of the 6-12" and 12-18" blow counts. The 0-6" and 18-24" blow counts are not included in the N-value.

[2] Cohesion is the same as undrained shear strength in the mohr-coulomb soil model used to describe the failure envelopes of the soil encountered. The terms "shear strength" and "cohesion" are used interchangeably. This is an undrained strength value, not a drained strength value.

consolidate/settle significantly under the load of a large stockpile. If the peat layer is left unexcavated beneath the stockpile, consolidation would likely be of large magnitude and continue over a long period of time. The amount of consolidation would also be dependent on the depth of the peat formation beneath the stockpile area. Detailed consolidation modeling would be necessary to further evaluate the extent of the consolidation of a peat layer beneath the CAT 1 stockpile. The in-laboratory test results and boring logs for the peat and other soils encountered during the exploration are included in the appendix of this report.

Silt

Silt was encountered beneath the peat at borings J003 and J027 and beneath the fill material at boring J010. The silt layer was generally less than one foot thick and contained some organic material, although less than the peat. The silt also contained some sand and clay. The N-values in the silt layer ranged from 5 to 8 indicating that the layer is soft. The silt layer at J027 was too thin to provide valuable testing results. The moisture content ranged from 21.8% to 27.6% and 67.4% of the soil passed the #200 sieve in the grain size distribution test by SET. The dry density of the silt ranged from 97 to 105.2 pounds per cubic foot.

In addition to the SPT information and index testing, strength, consolidation, and permeability testing was also completed on the silt samples. Unconfined strength testing (ASTM D2166) resulted in an unconfined compressive strength of the peat of 1,160 psf and corresponding undrained shear strength of 580 psf. Permeability testing was not completed on the silt because of the small amount of material encountered while drilling.

Consolidation testing on the silt at boring J003 resulted in the following parameters: preconsolidation pressure (Pc) = 3200 psf, compression index (Cc) = 0.155, and recompression index (Cr) = 0.02. These results indicate that the silt will consolidate much less than the peat under the same loading, however, some consolidation would be expected to occur. Consolidation of the silt layer would also be limited by the thin thickness of the soil layer as encountered while drilling. Detailed consolidation modeling would be necessary to further evaluate the extent of the consolidation of a silt layer beneath the CAT 1 stockpile. Laboratory test results and boring logs are included in the appendix of this report.

Silty Sand

Silty sand was encountered at all borings conducted during the 2010 geotechnical exploration. The silty sand layer made up the bulk of the soil found on the site and extended from the bottom of the silt layer to bedrock. The silty sand is a well graded material which also contained clay, gravel and cobbles. Gravel and cobbles were encountered during drilling at all boring locations. The N-values in the silty sand layer ranged from 14 blows to hammer refusal with an average of 42 blows indicating that the layer is generally very stiff and dense. The moisture content ranged from 6.3% to 9.8% with an average of 7.7%; however these values are likely lower than insitu moisture contents because of the sandy nature of the soil and related moisture losses while sampling. A saturated unit weight of 155 pcf was assumed for the silty sand which corresponds to an insitu moisture content of 11%. This saturated moisture content was considered reasonable given the dense nature of the silty sand and the results of the completed moisture content tests. The dry density of the silty sand ranged from 133.8 to 143.3 pounds per cubic foot. Seven grain size distributions were completed on this soil type with 21.1% to 34.9% of the soil passing the #200 sieve.

In addition to the SPT information and index testing, strength, consolidation, compaction, and permeability testing was also completed on the silty sand samples. Consolidated undrained triaxial tests with porepressure measurements (ASTM D4767) were completed to evaluate shear strength of the silty sand samples in both drained (ESSA) and undrained (USSA) conditions. The effective friction angle of the silty sand ranged from 38.5° to 42.4°. A friction angle of 38.5° indicates a relatively strong soil. The undrained friction angle ranged from 35.3° to 42.2° which correlates well with undrained shear strength and blow count correlations in the silty sand zone (Kulhawy and Mayne, 1990), which ranged from 33.4° to 46.1°. An undrained friction angle of 35.3° indicates a relatively strong soil. It is assumed that the silty sand will not have a significant cohesive strength in either the drained or undrained case because of the relatively low amount of clay encountered in the soil samples.

Permeability testing on the silty sand resulted in saturated hydraulic conductivity ranging from $1.02x10^{-8}$ ft/s to $3.08x10^{-8}$ ft/s ($3.11x10^{-7}$ to $9.39x10^{-7}$ cm/s) with a geometric mean of $1.69x10^{-8}$ ft/s ($5.15x10^{-7}$ cm/s). In addition to the permeability testing, a standard proctor test was completed on a composite sample of silty sand from borings J003, J010 and J027 since a bulk sample was not available to complete the proctor test. The resulting optimum moisture was 6.7% and the maximum density was 138.7 pcf after corrections for gravel in the samples.

Pressuremeter testing (ASTM 4719) was conducted in the silty sand zone to determine the elastic behavior of the soil under load. Pressuremeter testing requires good preparation of the borehole, so testing in soil with gravel and cobbles is difficult because of the difficulty in maintaining a clean and stable borehole. Fourteen tests were attempted with six having marginal or good data, as interpreted by AET. Good tests were completed to full yield and the borehole preparation was considered of the best quality. Marginal tests may have reached yield but did not reach soil failure or the soil may have been slightly disturbed. Poor tests occurred at locations with poor borehole quality and are not included in this report. The elastic modulus of the soil (E_0) generally increases with depth. The results of the pressuremeter testing are summarized in the table below and are included in the report appendix.

Pressuremeter Test Results

Boring	Top Depth [ft]	Bottom Depth [ft]	Test Quality	E_0 [psf]
J003	3.1	4.6	Marginal	26,000
J003	6.1	7.6	Marginal	102,000
J003	6.6	8.4	Good	278,000
J003	21.6	23.4	Good	528,000
J003	13.8	15.3	Marginal	152,000
J003	16.9	18.7	Good	458,000

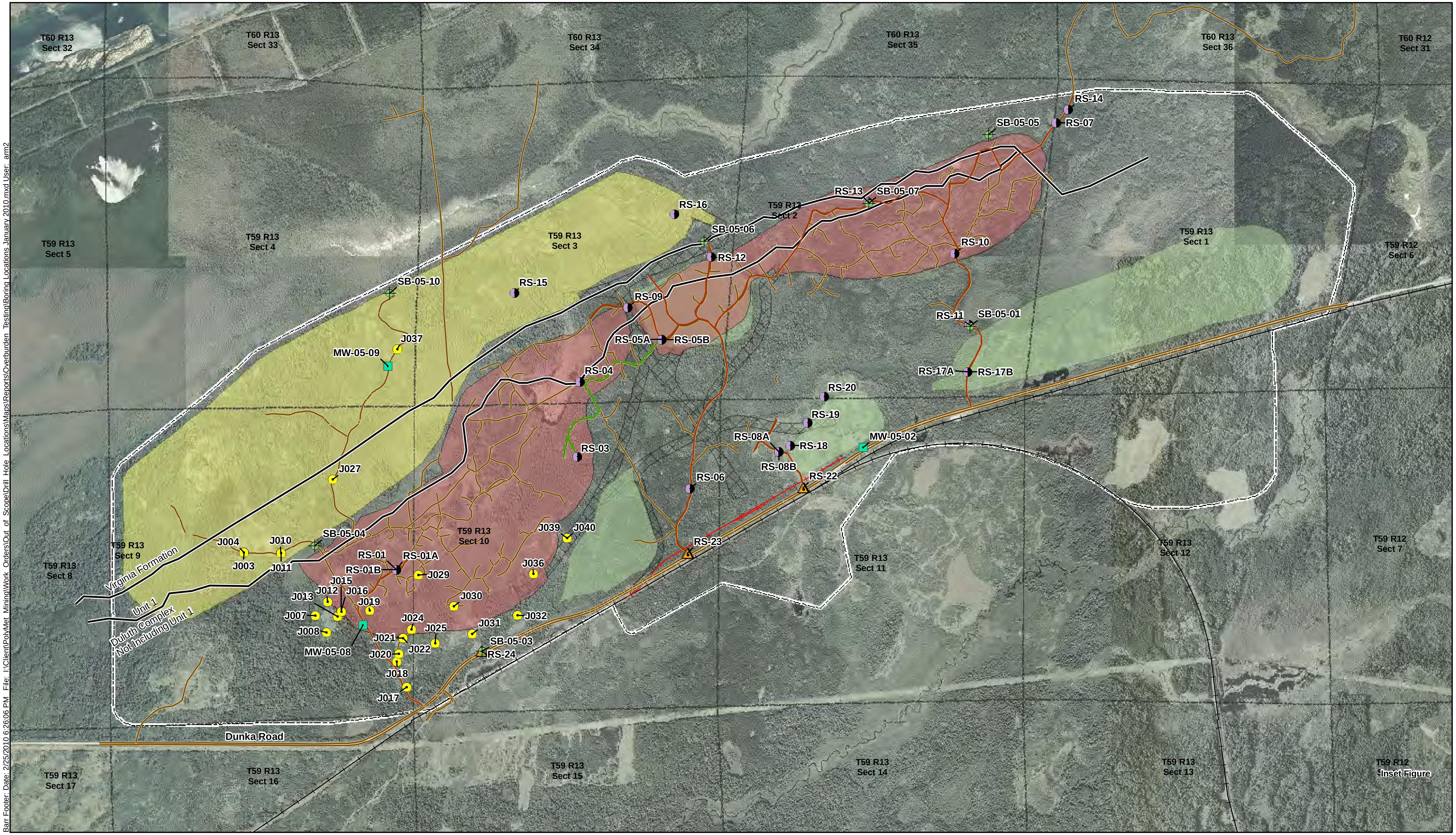
Laboratory test results and boring logs are included in the appendix of this report.

Conclusion

The 2010 geotechnical investigation at the Polymet overburden and Category 1 (CAT 1) waste rock stockpile was completed in February, 2010. Exploratory borings with Standard Penetration Testing were completed at four locations in the CAT 1 stockpile area. Thinwall sample collection and pressuremeter testing were completed in offset borings at three of the four locations. Boring logs and pressuremeter testing were completed by AET and are attached to the appendix of this report.

Laboratory testing and analysis was conducted from April through June, 2010, and the results are summarized in this document. Laboratory testing included moisture testing, organic content, grain size distribution, consolidation testing, unconfined compressive strength testing, triaxial testing, permeability testing, and standard proctor testing, and the results are included in the appendix of this document.

Peat, silt, and silty sand were the three general soil types encountered while drilling at the CAT 1 stockpile. The peat is very soft and loose and has low shear strength. The peat is also expected to consolidate greatly under stockpile loading. A thin layer of silt underlies the peat layer. The silt is soft with relatively low shear strength and a moderate capacity to consolidate limited by the thin layer thickness. The silty sand makes up the bulk of the soil encountered on site and also includes some clay, gravel and cobbles. The silty sand is generally very stiff and has high shear strength. The silty sand is unlikely to consolidate substantially.



- ● Drill Holes - 2010
- ▲ Sorption Sampling Locations - 2009
- ◐ Rotasonic Drilling Locations - 2008
- ■ Monitoring Wells - 2005
- ⊕ Soil Borings - 2005

- All Trails
- Tracked Vehicle Only
- Existing Roads
- Future Railroad
- Existing Railroad
- Project Boundary

2010 Mine Site Alternative (Year 20)
- 🟥 Mine Pits
- 🟨 Permanent Stockpile
- 🟩 Reclaimed Stockpile
- ☒ Haul Roads

N

1,500 750 0 1,500

Feet

BORING LOCATIONS
JANUARY 2010
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

AMERICAN
ENGINEERING
TESTING, INC.

CONSULTANTS
· ENVIRONMENTAL
· GEOTECHNICAL
· MATERIALS
· FORENSICS

June 14, 2010

PolyMet Mining Corporation
c/o Ms. Vicki Hagberg, EIT
Barr Engineering
3128 14th Avenue East
Hibbing, MN 55746

Re: Geotechnical Exploration Summary
PolyMet Northmet
Overburden Geotechnical Investigation
Hoyt Lakes, Minnesota
AET Project #07-04509
Barr Project # 23/69-0C29.07 WA1A

Introduction

We understand Barr Engineering (Barr) is providing project management and design services for the PolyMet Mining Corporation (PolyMet) Northmet mine near Hoyt Lakes, Minnesota. On behalf of PolyMet, Barr authorized American Engineering Testing, Inc. (AET) to provide geotechnical exploration services to aid in site planning.

AET recently completed a subsurface exploration program at the PolyMet Northmet mine site. The exploration consisted of advancing four standard penetration test borings, collecting Pitcher tube samples, collecting thinwall tube samples, and performing pressuremeter testing in offset borings. This report presents the results of the subsurface exploration.

Scope of Services

Our scope of services, as authorized by Barr, consisted of:

- Arranging for the location of existing public underground utilities through the Gopher State One-Call Service;
- Performing four standard penetration test (SPT) borings at locations denoted in the field by Barr;
- Performing Pitcher tube and thinwall tube sampling in offset borings at each of the four SPT boring locations;
- Performing eleven pressuremeter tests in offset borings at each of the four SPT boring locations (fourteen attempts were made at performing pressuremeter tests due to difficult soil conditions); and,

- Providing a data report that includes logs of the test borings, pressuremeter test results and a summary of subsurface conditions encountered in the test borings.

Test Boring and Sampling Methods

SPT borings and offset borings for pressuremeter testing were advanced in unconsolidated material using 3.25” inner diameter hollow stem augers (HSA). Offset borings for Pitcher tube and thinwall tube sampling were performed using 6.625” inner diameter HSA. Soil samples were obtained from the SPT borings using a standard split spoon sampler in general accordance with ASTM designation D1586. Pitcher tube and thinwall tube samples were collected in general accordance with ASTM D1587.

Pressuremeter testing was performed in general accordance with ASTM 4719. The borehole was prepared using a clean-out tube (COT) consisting of one or more of the following: a standard split-spoon sampler, a California sampler, and a slotted casing.

Boreholes were abandoned per Minnesota Department of Heath regulations. Soil classifications were performed on recovered samples in general accordance with ASTM designation D2488.

Barr provided the test boring GPS coordinates and elevations for the SPT borings to AET, which are shown on the SPT boring logs. The GPS coordinates reference Minnesota State Plane North, NAD83. Elevations reference mean sea level.

Results

Geologic Conditions

Logs of the test borings are attached to this letter for your review. Please refer to the logs for information concerning soil layering, soil classification, geologic description, and moisture. Relative density or consistency based on the standard penetration resistance (N-value) recorded while using with the standard split spoon sampler is also noted on the SPT and pressuremeter testing logs.

In general, the SPT borings indicate swamp deposits, existing fill, or topsoil overlying till. Swamp deposits were encountered in test borings J003 and J027, and extend to depths of approximately 2½ and 7½ feet, respectively. The swamp deposits consist of peat and organic silt. The existing fill encountered in test boring J010 consists of mixtures of silty sand, gravel, organic sandy silt and/or organic silty sand. The silty sand encountered between the depths of approximately 2½ and 5 feet in test boring J003 may be existing fill (tailings). Approximately 6 inches of topsoil was encountered in J037, and is composed of organic silt.

Till was encountered in all of the test borings. The till is comprised of sandy silt, silty sand, silty sand with gravel, and gravelly silty sand. The recorded N-values indicate the till is mainly medium dense to dense. Apparent cobbles were encountered in the till in test boring J027 and J037.

Auger refusal was encountered in each of the SPT borings at depths between 18.7 and 24.5 feet. Pitcher sampler refusal was also encountered in offset test boring J027-T at a depth of 15.1 feet. Refusal may have been caused by cobbles, boulders, or bedrock. Rock coring would need to be performed to document the cause of auger refusal.

Water Levels

Groundwater was encountered in test borings J003, J010, J027, J003-P, J010-P, and J010-T at depths between 3 and 11 feet below the existing ground surface. Groundwater levels representing static conditions cannot be reliably measured unless measurements are taken from piezometers installed at the site.

Pressuremeter Tests

A total of 14 pressuremeter tests were attempted. The pressuremeter test data from three tests is considered complete, while the data is considered marginal for three tests, and the data from the remaining eight tests is considered poor. The poor tests are mainly the result of an enlarged and irregular borehole caused by the sloughing of cobbles and dense sandy soils encountered in the borings. The enlarged borehole prevented the pressuremeter probe from making suitable contact with the borehole during the application of a test. The results of the completed and marginal tests are attached to this report.

Laboratory Tests

Laboratory testing was performed by others on SPT, Pitcher, and thinwall samples selected by Barr. The laboratory test results were provided to AET, and are attached to this report. Results that could be included in the logs are shown in the respective columns on the right side of the logs.

Limitations

The data derived through the exploration program have been used to develop our opinions about the subsurface conditions at your site. However, because no exploration program can reveal totally what is in the subsurface, conditions between borings and between samples and at other times, may differ from conditions described in this report. The exploration we conducted identified subsurface conditions only at those points where we took samples or observed ground water conditions. Depending on the sampling methods and sampling frequency, every soil layer may not be observed, and some materials or layers which are present in the ground may not be noted on the boring logs.

If conditions encountered during construction differ from those indicated by our borings, it may be necessary to alter our conclusions and recommendations, or to modify construction procedures, and the cost of construction may be affected.

The extent and detail of information about the subsurface condition are directly related to the scope of the exploration. It should be understood, therefore, that more detailed information can be obtained by means of additional exploration.

Standard of Care

Our services for your project have been conducted to those standards considered normal for services of this type at this time and location. Other than this, no warranty, either expressed or implied, is intended.

Closing

We trust that this letter report provides you with the information that you need at this time. If you should have any questions, or if you require additional information, please contact AET at 628-1518.

Reported by:
American Engineering Testing, Inc.
Sa
Sara L. Leow, PE
Geotechnical Engineer
sleow@amengtest.com

Reviewed by:
American Engineering Testing, Inc.
Robert J Wahlstrom
Robert J. Wahlstrom, PE, PG
Senior Geotechnical Engineer
rwahlstrom@amengtest.com

Attachments:
- Test Boring Logs (9 pages)
- Boring Log Notes (1 page)
- Unified Soil Classification System (1 page)
- Geologic Terminology (1 page)
- Pressuremeter Test Results (6 pages)
- Laboratory Testing Results Provided by Barr (25 pages)

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

Northing: 734386 **Easting: 2895852** **BARR JOB NO: 23/69-0C29.07 WA1A**

AET JOB NO: **07-04509**

LOG OF BORING NO. **J003 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

SURFACE ELEVATION: **1617.0**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% ORG	LL	PL	%-#200
1	PEAT, fibric with wood, black, frozen above about 12" (PT)	SWAMP DEPOSIT		F/M	SU		329	40.6			
2	ORGANIC SILT, dark brown (OL)										
3	SILTY SAND, fine grained, brown (SM) (may be tailings)	COARSE ALLUVIUM OR TAILINGS	5	M	SS	11					
4–5	SILTY SAND, dark gray, moist (SM) (may be tailings)		8	M/W	SS	11	25				67
6–7	SANDY SILT, dark gray, moist with wet lenses (ML) (may be tailings)										
8	SILTY SAND WITH GRAVEL, gray, loose, moist with wet lenses (SM)		8	M/W	SS	7					
9–10	SILTY SAND, a little gravel, dark gray, moist with wet lenses, medium dense (SM)		14	▼	SS	8					
13			15	M	SS	10					
14–15	SILTY SAND WITH GRAVEL, dark gray, medium dense, moist with wet lenses, lens of wet fine to coarse grained sand with gravel from about 24.9-25.1' (SM)		23	M	SS	10					
16		TILL									
18			32	M	SS	7					
20			36	M	SS	11	8				35
23			25	M	SS	10					
25			30	W	SS	13					
27			50/0.1'	W	SS	1					

AUGER REFUSAL AT 27.0 FEET
SAMPLER REFUSAL AT 27.1 FEET
Borehole backfilled with neat cement grout

Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.

DEPTH:	DRILLING METHOD
0-27'	**3.25" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/16/10	**13:47**	**27.1**	**27.0**	**25.5**	**---**	**10.7**

BORING COMPLETED: **2/16/10**

DR: **LA** LG: **TDD** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J003-P (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	%-#200
	See boring J003 for material description										
1											
2											
3			5	▼							
4	Marginal pressure meter test performed between 3.1 and 4.6 feet				COT						
5											
6			38								
7	Marginal pressure meter test performed between 6.1 and 7.6 feet		28		COT						
8											
9											
10											
11	Poor pressure meter test performed between 10.8 and 12.3 feet		32		COT						
12			32								
13											
14	Poor pressure meter test performed between 13.6 and 15.1 feet		38		COT						
15			24								
16											
17											
18	Poor pressure meter test performed between 17.6 and 19.1 feet		27		COT						
19			39								
20	**END OF BORING AT 20.0 FEET** Borehole backfilled with neat cement grout *Offset 4' southeast of boring J003-T* *See borings J003-P2 and J003-P3*										

DEPTH:	DRILLING METHOD
0-17'	**3.25" HSA**

BORING COMPLETED: **2/24/10**

DR: **LA** LG: **TDD** Rig: **27C**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/24/10	**8:45**	**16.0**	**None**	**13.0**	**---**	**3.0**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J003-P2 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
	See boring J003 for material description										
1											
2											
3											
4											
5											
6											
7	Good pressure meter test performed between 6.6 and 8.4 feet				COT						
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20			20								
21											
22	Good pressure meter test performed between 21.6 and 23.4 feet		31		COT						
23											
24											
25	**END OF BORING AT 25.0 FEET** Borehole backfilled with neat cement grout *Offset 4' east of boring J003-P* *See borings J003-P and J003-P3*										

DEPTH: DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-19½' 3.25" HSA							
BORING COMPLETED: **2/24/10**							
DR: **LA** LG: **TDD** Rig: **27C**							

WATER LEVEL MEASUREMENTS

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J003-P3 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	%-#200
	See boring J003 for material description										
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11	Poor pressure meter test performed between 10.8 and 12.3 feet				COT						
12											
13											
14	Marginal pressure meter test performed between 13.8 and 15.3 feet				COT						
15											
16											
17	Good pressure meter test performed between 16.9 and 18.7 feet										
18					COT						
19			52								
20											
	END OF BORING AT 20.3 FEET Borehole backfilled with neat cement grout *Offset 4.5' north of J003-P* *See borings J003-P and J003-P2*										

DEPTH: DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-14½' 4.25" HSA							
BORING COMPLETED: **2/26/10**							
DR: **LA** LG: **TDD** Rig: **51**							

WATER LEVEL MEASUREMENTS

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J003-T (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: ________ MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	q_u (psf)
1											
2											
3	3 Inch thinwall sample from 1.5 to 3.5 feet.			M	TW	21.5					
4											
5											
6	3 Inch thinwall sample from 5.0 to 7.0 feet.			M/W	TW	20.5	22	105			1160
7											
8											
9											
10											
11											
12	Pitcher sampler from 10.0 to 13.0 feet.			M	TW	26.5	7	142			
13											
14											
15											
16							8	140			
17	Pitcher sampler from 15.0 to 18.0 feet.			M	TW	19	8	136			
18											
19											
20											
21											
22	Pitcher sampler from 20.0 to 23.0 feet.			M	TW	10.5					
23	**END OF BORING AT 23.0 FEET** Borehole backfilled with neat cement grout *Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.*										

DEPTH:	DRILLING METHOD	WATER LEVEL MEASUREMENTS DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-20'	6 5/8" HSA							
BORING COMPLETED: 2/23/10								
DR: LA LG: TDD Rig: 27C								

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

SUBSURFACE TEST BORING LOG

Northing: 734378 **Easting: 2896460** **BARR JOB NO: 23/69-0C29.07 WA1A**

AET JOB NO: **07-04509** LOG OF BORING NO. **J010 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

SURFACE ELEVATION: **1611.1**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	%-#200
1	FILL, a mixture of silty sand with gravel and cobbles, and organic sandy silt with trace roots, brown and dark brown, frozen above about 12"	FILL		F/M	SU						
2–3	FILL, a mixture of silty sand, a little gravel, and slightly organic silty sand, dark brown and dark gray		5	M	SS	7					
4–5	SILTY SAND WITH GRAVEL, brown, moist (SM)	TILL	79	M	SS	10	8				31
8			43	M	SS	2					
9–10	SILTY SAND, a little gravel, dark gray, moist, dense (SM)		33	M	SS	8					32
12–13	SILTY SAND WITH GRAVEL, dark gray, moist, very dense (SM)		64	M	SS	15					
15			47/0.5' 50/0.3'	M	SS	7					
17–18			9/0.5' 23/0.5' 50/0.2'	W	SS	10					
18.7	Obstruction - possible bedrock	BEDROCK									

AUGER REFUSAL AT 18.7 FEET
Borehole backfilled with neat cement grout

Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.

DEPTH: DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-18.7' 3.25" HSA							
	2/16/10	**9:45**	**18.2**	**18.7**	**15.0**	**---**	**3.8**
	2/16/10	**10:35**	**18.2**	**18.7**	**15.0**	**---**	**4.4**
BORING COMPLETED: **2/16/10**							
DR: **LA** LG: **TDD** Rig: **27C**							

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J010-P (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	% #4	LL	PL	%-#200
	See boring J010 for material description										
1											
2											
3											
4											
5											
6	Poor pressure meter test performed between 5.8 and 7.3 feet		50		COT						
7			46	▼							
8			13/0.5' 13/0.5' 50/0.2'		COT						
9											
10											
11			42		COT						
12											
13											
14			117		COT						
15											
16	**END OF BORING AT 16.0 FEET** Borehole backfilled with neat cement grout										

DEPTH: DRILLING METHOD	WATER LEVEL MEASUREMENTS						
	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
	2/25/10	**13:00**	**8.0**	**5.0**	**8.0**	**---**	**7.0**
BORING COMPLETED: **2/25/10**							
DR: **LA** LG: **TDD** Rig: **27C**							

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J010-T (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	%-#200
1											
2											
3	3 inch thinwall sample from 2.0 to 4.0 feet.			▼	TW	20					
4											
5											
6											
7	Pitcher sampler from 5.5 to 8.0 feet			M	TW	23	9 10 14	127 134 123			
8											
9	Pitcher sampler from 8.0 to 10.5 feet			M	TW	14					
10											
11											
12											
13											
14											
15	Pitcher sampler from 14.0 to 16.5 feet			M	TW	23					
16											
	END OF BORING AT 16.5 FEET Borehole backfilled with neat cement grout *Offset 5.5' south-southwest of boring J010* *Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.*										

DEPTH: DRILLING METHOD	WATER LEVEL MEASUREMENTS DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-14' 6 5/8" HSA	**2/22/10**	**10:25**	**10.5**	**5.5**	**8.0**	**---**	**3.5**
BORING COMPLETED: **2/22/10**							
DR: **LA** LG: **TDD** Rig: **27C**							

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

Northing: 735628 **Easting: 2897327** **BARR JOB NO: 23/69-0C29.07 WA1A**

AET JOB NO: **07-04509** LOG OF BORING NO. **J027 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: 1607.6 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	% ORG	LL	PL	%-#200
1	PEAT, sapric, dark brown, frozen above about 12" (PT)			F/M	SU						
2											
3			2	M	SS	2					
4		SWAMP DEPOSIT									
5			<1	M	SS	8	287	52.8			
6											
7	ORGANIC SILT, brown (OL)										
8	SILTY SAND, a little gravel, dark gray, wet (SM)		6	M/W	SS	9					
9	SILTY SAND WITH GRAVEL, dark gray, moist with wet lenses, medium dense (SM)										
10			20	M/W	SS	1					
11				▼							
12											
13	GRAVELLY SILTY SAND, apparent cobbles, dark gray, moist, medium dense to very dense (SM)		24	M/W	SS	8	7				21
14				▽							
15			30	M	SS	3					
16		TILL									
17											
18			53	M	SS	16					
19											
20	SILTY SAND WITH GRAVEL, apparent cobbles, gray, moist to wet (SM)		48	M	SS	8					
21											
22											
23			15	W	SS	18	7				31
24											
	AUGER REFUSAL AT 24.5 FEET **SAMPLER REFUSAL AT 24.6 FEET** Borehole backfilled with neat cement grout *Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.*		70/0.1'	W	SS	1					

DEPTH:	DRILLING METHOD	WATER LEVEL MEASUREMENTS						
		DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-24½'	**3.25" HSA**							
		2/17/10	**11:18**	**24.6**	**24.5**	**17.8**	**---**	**14.0**
		2/17/10	**11:36**	**24.6**	**24.5**	**17.7**	**---**	**11.7**

BORING COMPLETED: **2/17/10**

DR: **LA** LG: **TDD** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J027-P (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	% #4	LL	PL	%-#200
	See boring J027 for material description										
1											
2											
3											
4											
5											
6					COT						
7											
8					COT						
9											
10											
11	Poor pressure meter test performed between 10.2 and 11.7 feet				COT						
12											
13	Poor pressure meter test performed between 12.6 and 14.1 feet				COT						
14											
15	**END OF BORING AT 15.0 FEET** Borehole backfilled with neat cement grout *See boring J027-P2*										

DEPTH:	DRILLING METHOD	WATER LEVEL MEASUREMENTS						
		DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
BORING COMPLETED: **2/25/10**								
DR: **LA** LG: **TDD** Rig: **27C**								

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J027-P2 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: ________ MATERIAL DESCRIPTION		GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	%-#200
	See boring J027 for material description											
1												
2												
3												
4												
5												
6												
7												
8						COT						
9												
10	Poor pressure meter test performed between 9.1 and 10.9 feet											
11												
12												
	END OF BORING AT 12.5 FEET Borehole backfilled with auger cuttings *Offset 5' southeast of boring J027-P* *See boring J027-P*											

DEPTH: DRILLING METHOD	WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
0-4½' 3.25" HSA	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
BORING COMPLETED: **2/25/10**								
DR: **LA** LG: **TDD** Rig: **51**								

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509**

LOG OF BORING NO. **J027-T (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	% #4	LL	PL	q_u (psf)
1				M							
2											
3	3 inch thinwall sample from 1.5 to 3.5 feet.			M	TW	1					
4											
5											
6	3 inch thinwall sample from 4.5 to 6.5 feet.			M	TW	14.5	310	17			560
7											
8											
9											
10											
11	Pitcher sampler from 10.0 to 12.5 feet			M	TW	22	9 8 8	140 141 140			
12											
13											
14											
15	Pitcher sampler from 15.0 to 15.1 feet				TW	0					
	PITCHER SAMPLER REFUSAL AT 15.1 FEET Borehole backfilled with neat cement grout *Offset 8' northeast of boring J027* *Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.*										

DEPTH:	DRILLING METHOD
0-15'	**6 5/8" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

BORING COMPLETED: **2/19/10**

DR: **LA** LG: **TDD** Rig: **27C**

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR JOB NO: 23/69-0C29.07 WA1A

AET JOB NO: **07-04509** LOG OF BORING NO. **J027-T2 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: ______ MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS				
							WC	% #4	LL	PL	%-#200
1											
2											
	3 inch thinwall sample from 1.5 to 3.5 feet.			W/M	TW	13	405	13			
3											
4											
5											
6											
7											
8											
9											
10											
11											
	Pitcher sampler from 10 to 13 feet				TW	0					
12											
13	**END OF BORING AT 13.0 FEET** Borehole backfilled with neat cement grout and auger cuttings *Offset 7' north-northeast of boring J027-T* *Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.*										

DEPTH: DRILLING METHOD	WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
0-10' 6 5/8" HSA	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
BORING COMPLETED: **2/19/10**								
DR: **LA** LG: **TDD** Rig: **27C**								

06/06

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

Northing: 737624 **Easting: 2898282** **BARR JOB NO: 23/69-0C29.07 WA1A**

AET JOB NO: **07-04509** LOG OF BORING NO. **J037 (p. 1 of 1)**

PROJECT: **PolyMet Northmet Mine; Hoyt Lakes, MN**

SURFACE ELEVATION: **1609.8**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
1	ORGANIC SILT WITH ROOTS, dark brown, frozen (OL)	TOPSOIL		F/M	SU						
2	SANDY SILT, trace roots, apparent boulders, brown, frozen above about 10" (ML)										
3	SILTY SAND, a little gravel, apparent cobbles, trace roots, brown and orangish brown mottled, moist (SM)		14	M	SS	11					
4											
5	SILTY SAND WITH GRAVEL, grayish brown, moist (SM)		50/0.5' 50/0.4'		SS	0					
6		TILL									
7	SILTY SAND, a little gravel, apparent cobbles, grayish brown, moist, medium dense (SM)		25/0.5' 50/0.1'	M	SS	4					
8											
9											
10			25	M	SS	10	8				33
11											
12			25/0.5' 50/0.2'	M	SS	6					
	Obstruction - possible weathered rock	WEATHERED ROCK									

AUGER REFUSAL AT 12.9 FEET
Borehole backfilled with neat cement grout

Laboratory test results on this log were provided by Barr; laboratory tests were performed by Soil Engineering Testing, Inc.

DEPTH:	DRILLING METHOD
0-12.9'	**3.25" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/17/10	**14:25**	**12.7**	**12.0**	**12.0**	**---**	**None**

BORING COMPLETED: **2/17/10**

DR: **LA** LG: **TDD** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

BORING LOG NOTES

DRILLING AND SAMPLING SYMBOLS

Symbol	Definition
B,H,N:	Size of flush-joint casing
CA:	Crew Assistant (initials)
CAS:	Pipe casing, number indicates nominal diameter in inches
CC:	Crew Chief (initials)
COT:	Clean-out tube
DC:	Drive casing; number indicates diameter in inches
DM:	Drilling mud or bentonite slurry
DR:	Driller (initials)
DS:	Disturbed sample from auger flights
FA:	Flight auger; number indicates outside diameter in inches
HA:	Hand auger; number indicates outside diameter
HSA:	Hollow stem auger; number indicates inside diameter in inches
LG:	Field logger (initials)
MC:	Column used to describe moisture condition of samples and for the ground water level symbols
N (BPF):	Standard penetration resistance (N-value) in blows per foot (see notes)
NQ:	NQ wireline core barrel
PQ:	PQ wireline core barrel
RD:	Rotary drilling with fluid and roller or drag bit
REC:	In split-spoon (see notes) and thin-walled tube sampling, the recovered length (in inches) of sample. In rock coring, the length of core recovered (expressed as percent of the total core run). Zero indicates no sample recovered.
REV:	Revert drilling fluid
SS:	Standard split-spoon sampler (steel; 1⅜" is inside diameter; 2" outside diameter); unless indicated otherwise
SU	Spin-up sample from hollow stem auger
TW:	Thin-walled tube; number indicates inside diameter in inches
WASH:	Sample of material obtained by screening returning rotary drilling fluid or by which has collected inside the borehole after "falling" through drilling fluid
WH:	Sampler advanced by static weight of drill rod and 140-pound hammer
WR:	Sampler advanced by static weight of drill rod
94mm:	94 millimeter wireline core barrel
▼:	Water level measured in borehole prior to abandonment
▽:	Interim water level measurement or estimated water level based on sample appearance

TEST SYMBOLS

Symbol	Definition
CONS:	One-dimensional consolidation test
DEN:	Dry density, pcf
DST:	Direct shear test
E:	Pressuremeter Modulus, tsf
HYD:	Hydrometer analysis
LL:	Liquid Limit, %
LP:	Pressuremeter Limit Pressure, tsf
OC:	Organic Content, %
PERM:	Coefficient of permeability (K) test; F - Field; L - Laboratory
PL:	Plastic Limit, %
q_p:	Pocket Penetrometer strength, tsf (approximate)
q_c:	Static cone bearing pressure, tsf
q_u:	Unconfined compressive strength, psf
R:	Electrical Resistivity, ohm-cms
RQD:	Rock Quality Designation of Rock Core, in percent (aggregate length of core pieces 4" or more in length as a percent of total core run)
SA:	Sieve analysis
TRX:	Triaxial compression test
VSR:	Vane shear strength, remoulded (field), psf
VSU:	Vane shear strength, undisturbed (field), psf
WC:	Water content, as percent of dry weight
%-200:	Percent of material finer than #200 sieve

STANDARD PENETRATION TEST NOTES

The standard penetration test consists of driving the sampler with a 140 pound hammer and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), permitted in ASTM:D1586, the blows for each complete 6" increment and for each partial increment is on the boring log. For partial increments, the number of blows is shown to the nearest 0.1' below the slash.

The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM:D1586 is encountered) whereas the length of sample recovered is for the entire sampler drive (which may even extend more than 18").

UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

AMERICAN ENGINEERING TESTING, INC.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% 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 $1 > Cc > 3$[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 (see Plasticity Chart below)	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 soil			Primarily organic matter, dark in color, and organic in odor	PT	Peat[R]

Notes

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

[F] If soil contains ≥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 ≥15% gravel, add "with gravel" to group name.

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

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

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

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

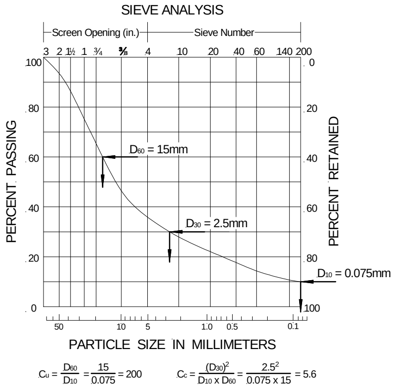
[N] PI≥4 and plots on or above "A" line.

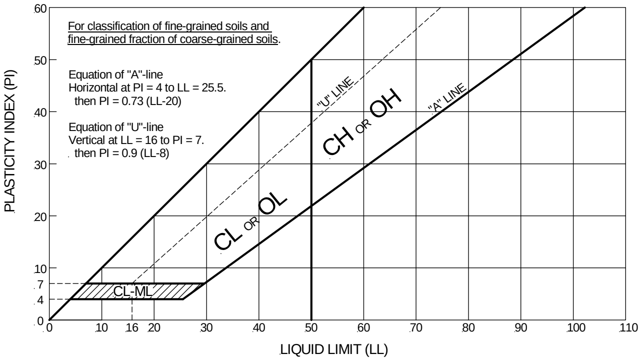
[O] PI<4 or plots below "A" line.

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

[Q] PI plots below "A" line.

[R] Fiber Content description shown below.





Plasticity Chart

ADDITIONAL TERMINOLOGY NOTES USED BY AET FOR SOIL IDENTIFICATION AND DESCRIPTION

Grain Size

Term	Particle Size
Boulders	Over 12"
Cobbles	3" to 12"
Gravel	#4 sieve to 3"
Sand	#200 to #4 sieve
Fines (silt & clay)	Pass #200 sieve

Gravel Percentages

Term	Percent
A Little Gravel	3% - 14%
With Gravel	15% - 29%
Gravelly	30% - 50%

Consistency of Plastic Soils

Term	N-Value, BPF
Very Soft	less than 2
Soft	2 - 4
Firm	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	Greater than 30

Relative Density of Non-Plastic Soils

Term	N-Value, BPF
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	Greater than 50

Moisture/Frost Condition

(MC Column)

D (Dry): Absence of moisture, dusty, dry to touch.

M (Moist): Damp, although free water not visible. Soil may still have a high water content (over "optimum").

W (Wet/ Waterbearing): Free water visible intended to describe non-plastic soils. Waterbearing usually relates to sands and sand with silt.

F (Frozen): Soil frozen

Layering Notes

Laminations: Layers less than ½" thick of differing material or color.

Lenses: Pockets or layers greater than ½" thick of differing material or color.

Fiber Content of Peat

Term	Fiber Content (Visual Estimate)
Fibric Peat:	Greater than 67%
Hemic Peat:	33 – 67%
Sapric Peat:	Less than 33%

Organic/Roots Description (if no lab tests)

Soils are described as *organic*, if soil is not peat and is judged to have sufficient organic fines content to influence the soil properties. *Slightly organic* used for borderline cases.

With roots: Judged to have sufficient quantity of roots to influence the soil properties.

Trace roots: Small roots present, but not judged to be in sufficient quantity to significantly affect soil properties.

GEOLOGIC TERMINOLOGY (SOILS)

General categories of geologic deposits used, descriptive information and common soil types is as follows:

FILL (F): Soils, rock and/or waste products placed or disturbed by man rather than through geologic processes. Mixed soils are usually easy to identify. Uniform material is more difficult, and signs such as small inclusions, underlying topsoil, topography or knowledge of below grade improvements (e.g., basement backfill, utility trenches, etc.) may be needed to properly judge. When mixed condition is stratified horizontally, the soil may be a weathered natural soil rather than fill.

TOPSOIL (TS): Upper darker colored layer formed by weathering of inorganic soil and accumulation of organic material. Usually black, dark brown, dark gray or dark grayish brown. Often transitions from darker to lighter color.

SLOPEWASH (SW): Organic and/or inorganic materials (sometimes interlayered) washed from slopes and redeposited. Usually stratified. Will be located in depressed areas where they can be washed in from slopes. When topsoil layers are thick in depressed areas, there is a good chance the soil is slopewash.

SWAMP DEPOSITS (SD): Highly organic material (peats and organic clays) which are formed through accumulation of organic material under water. **Peat, Organic clay**

COARSE ALLUVIUM (CA): Sandy (and gravelly). Stratified. Deposited from fast moving waters in streams and rivers. Includes glacial outwash. **Sand, Sand with silt, Silty sand, Gravels**

FINE ALLUVIUM (FA): Clayey and/or silty. Stratified. Deposited from slow moving waters in streams, rivers, lakes and ponds. Includes glacial outwash. **Lean clay, Fat clay, Silty clay, Silt, Sandy silt**

MIXED ALLUVIUM (MA): Combination of Fine and Coarse Alluvium. **Clayey sand, Sandy lean clay,** interlayered **CA/FA**

LACUSTRINE (LAC): Fine grained lake bed deposits (lakes may or may not still be in existence). Usually in very flat topography. **Fat clay, Lean clay, Silty clay, Silt**

LOESS (LOESS): Uniform, non-stratified, silty material (or very fine sand) which is deposited by wind. Can include significant clay content, and grain contacts may be cemented by clay or calcareous (limestone/chalky) material. **Silt, Sandy silt, Silty clay, Lean clay**

TILL (T): Normally contains a wide range of grain sizes, from boulders through clay. Usually non-stratified (not sorted through water action). Deposited directly from glaciers. **Silty sand, Clayey sand, Sandy lean clay,** usually contains **gravel**

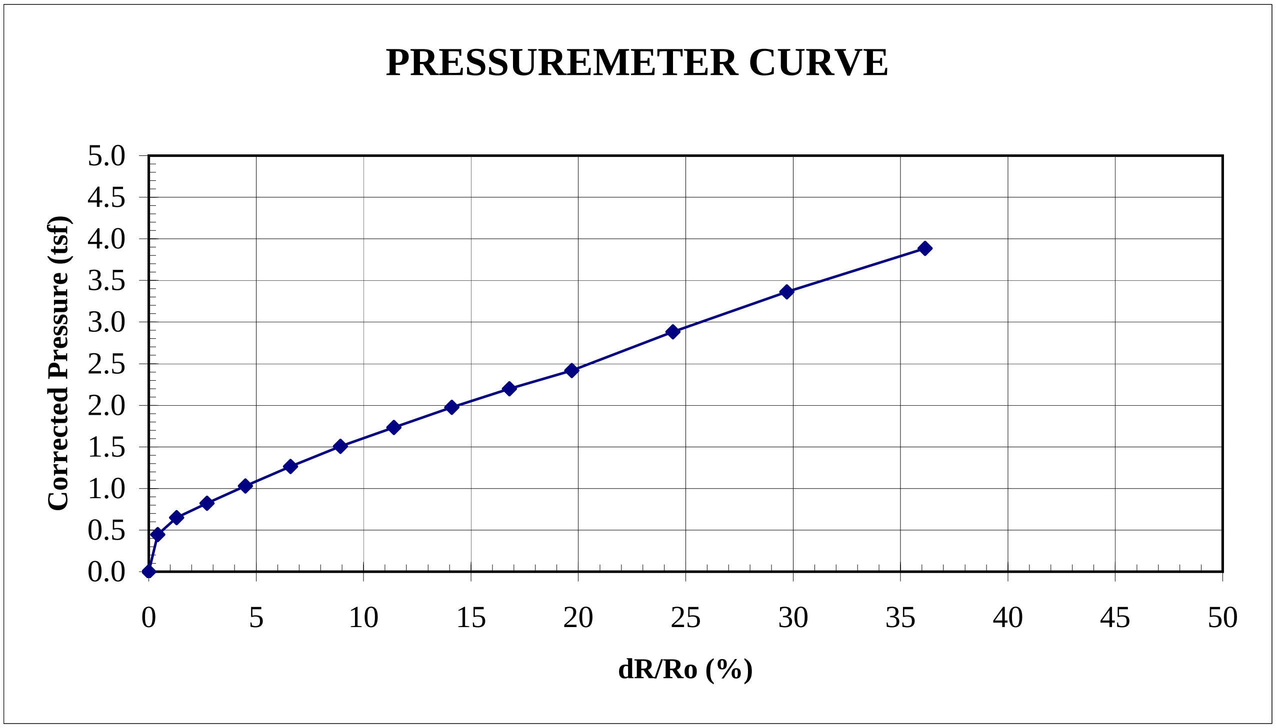
WEATHERED TILL (WT): Tills which have been altered by exposure to the action of frost, water, or chemicals. Often softer than underlying soils. May be stratified with varying colors/soil types due to filling in or other changes in frost lensed zones.

COLLUVIUM (COL): Dominantly gravel, boulders and rock slabs, sometimes intermixed or layered with soils. Deposited from gravity flow down hills or cliffs.

PRESSUREMETER TEST RESULTS

PolyMet

AET No. 07-04509; Barr No. 23/69-0C29.07 WA1A

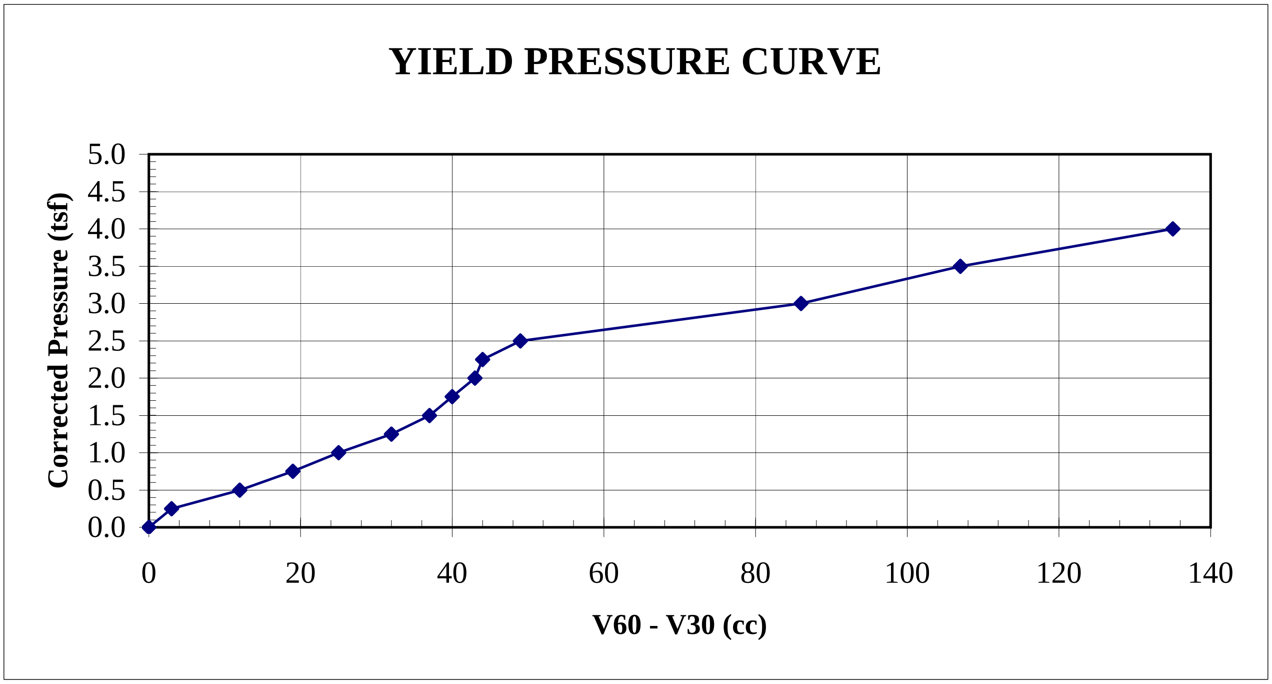


Boring No. : J003
Depth (ft) : 3.1-4.6
Probe : N1

P_L(tsf) = 4.0
P_o(tsf) = 0.2
P_L*(tsf) = 3.8

E_o(tsf) = 13
N_{ave} (bpf) = 5
P_y(tsf) = 2.3

E_o / P_l* = 3.4
E_o / N = 2.6
P_y / P_l* = 0.59



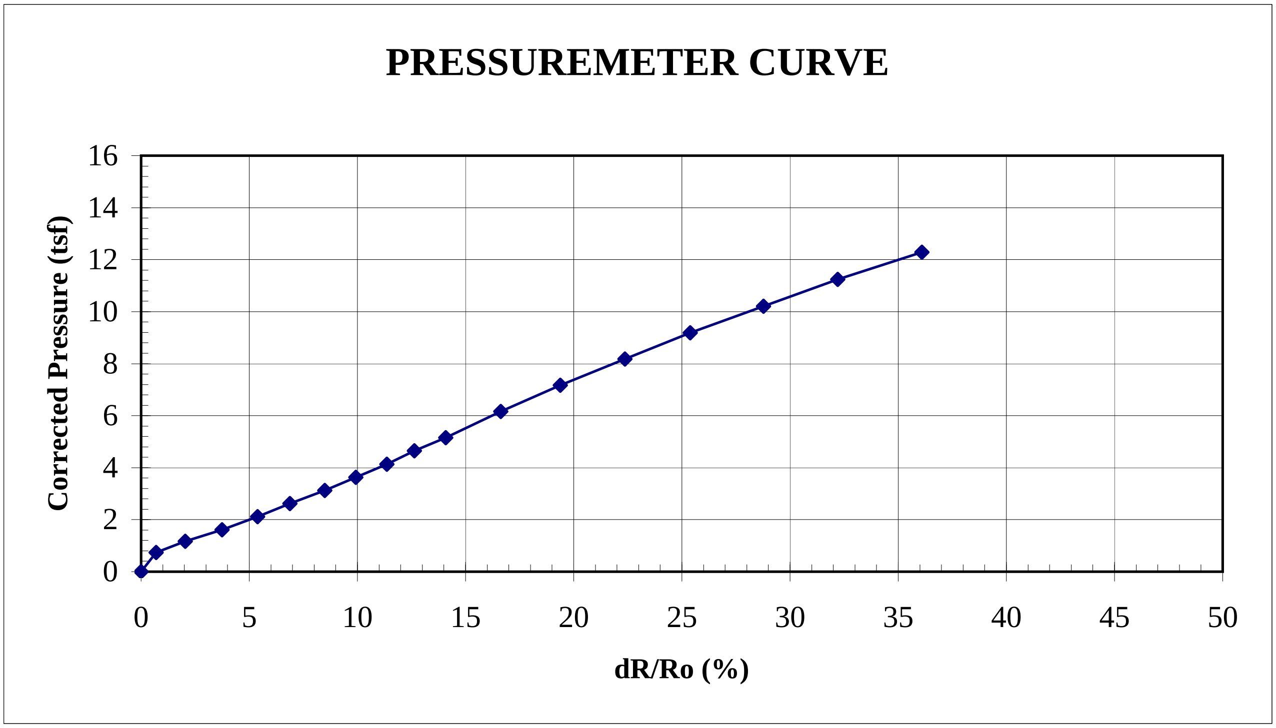
NOTES: Points Used for E_o Calculation: 6 to 10

Marginal test; disturbed soil.

PRESSUREMETER TEST RESULTS

PolyMet

AET No. 07-04509; Barr No. 23/69-0C29.07 WA1A

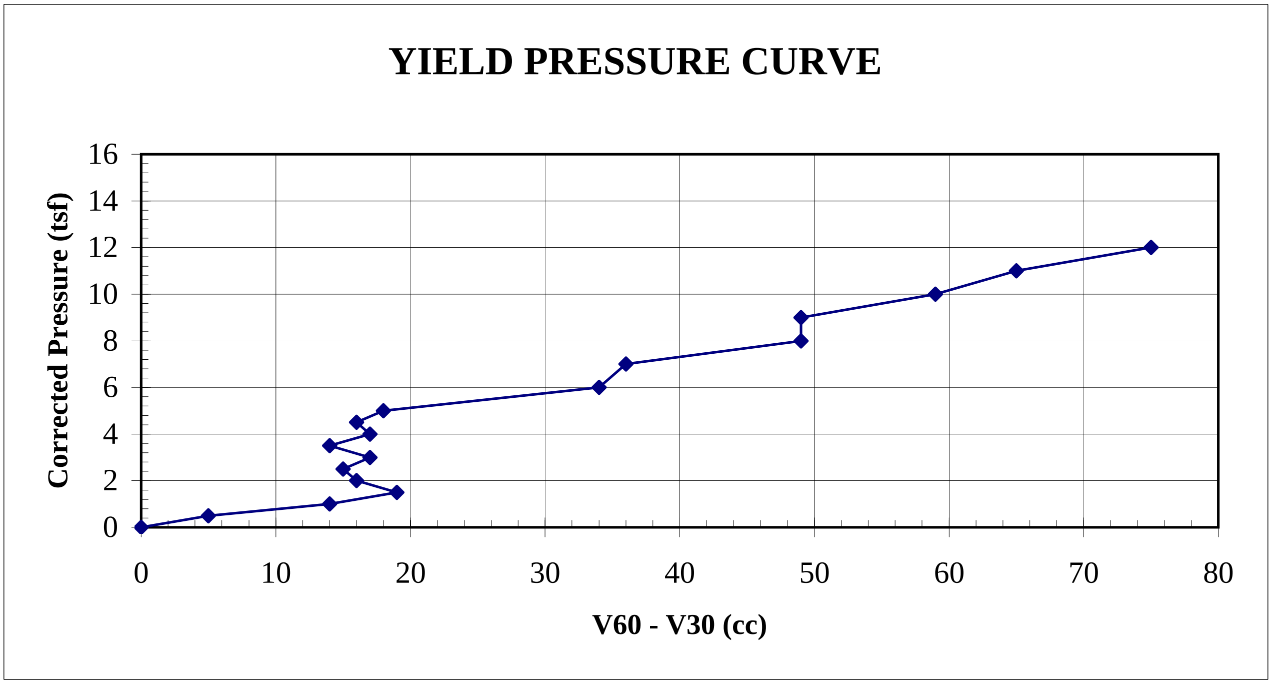


Boring No. : J003
Depth (ft) : 6.1-7.6
Probe : N1

P_L(tsf) = 12.0
P_o(tsf) = 0.5
P_L*(tsf) = 11.5

E_o(tsf) = 51
N_{ave} (bpf) = 33
P_y(tsf) = 5.0

E_o / P_l* = 4.4
E_o / N = 1.5
P_y / P_l* = 0.43

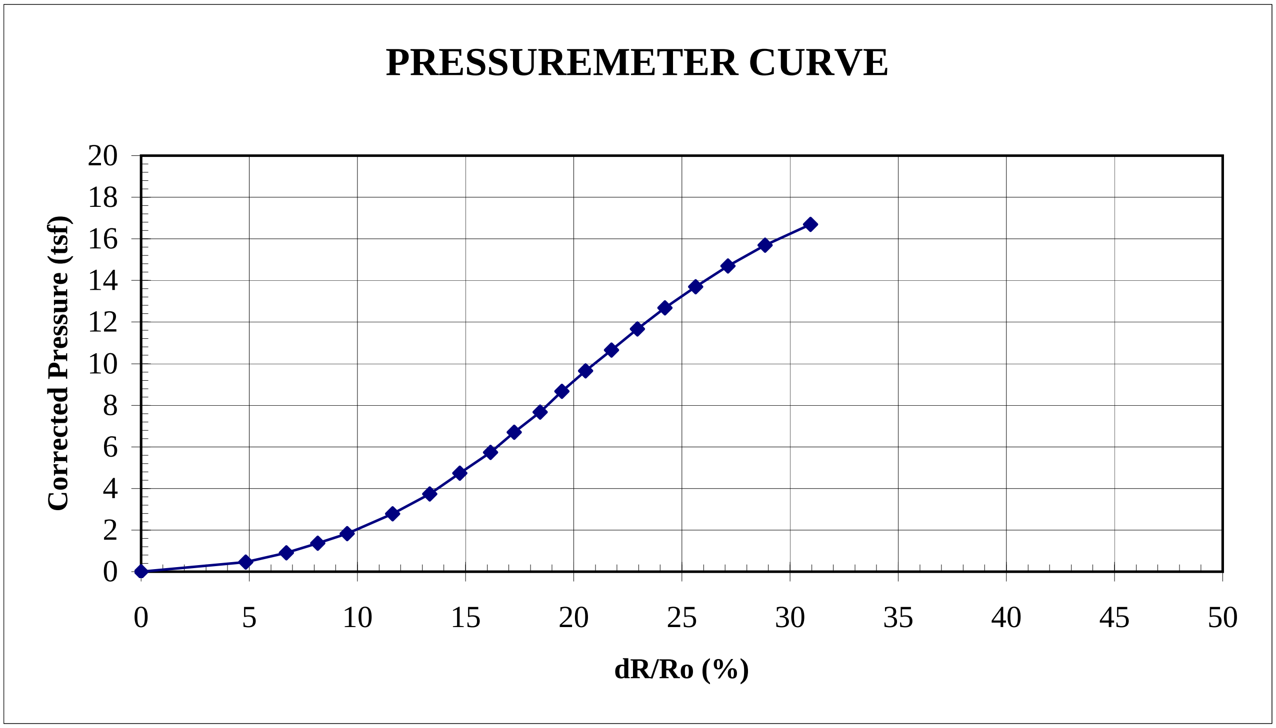


NOTES: Points Used for E_o Calculation: 5 to 11

Marginal test; disturbed soil.

PRESSUREMETER TEST RESULTS

PolyMet
AET No. 07-04509; Barr No. 23/69-0C29.07 WA1A

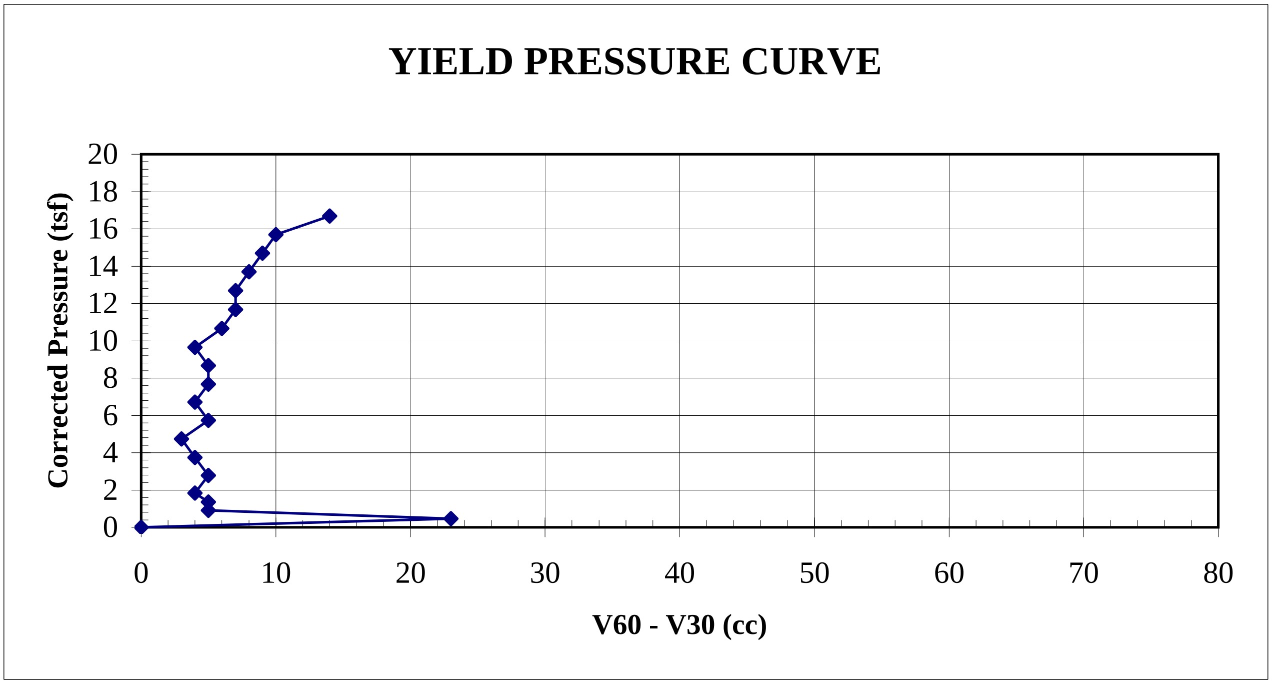


Boring No. : J003
Depth (ft) : 6.6-8.4
Probe : A1

P_L(tsf) > 17.0
P_o(tsf) = 0.5
P_L*(tsf) > 16.5

E_o(tsf) = 139
N_{ave} (bpf) = 33
P_y(tsf) = 13.0

E_o / P_l* = 8.4
E_o / N = 4.2
P_y / P_l* = 0.79



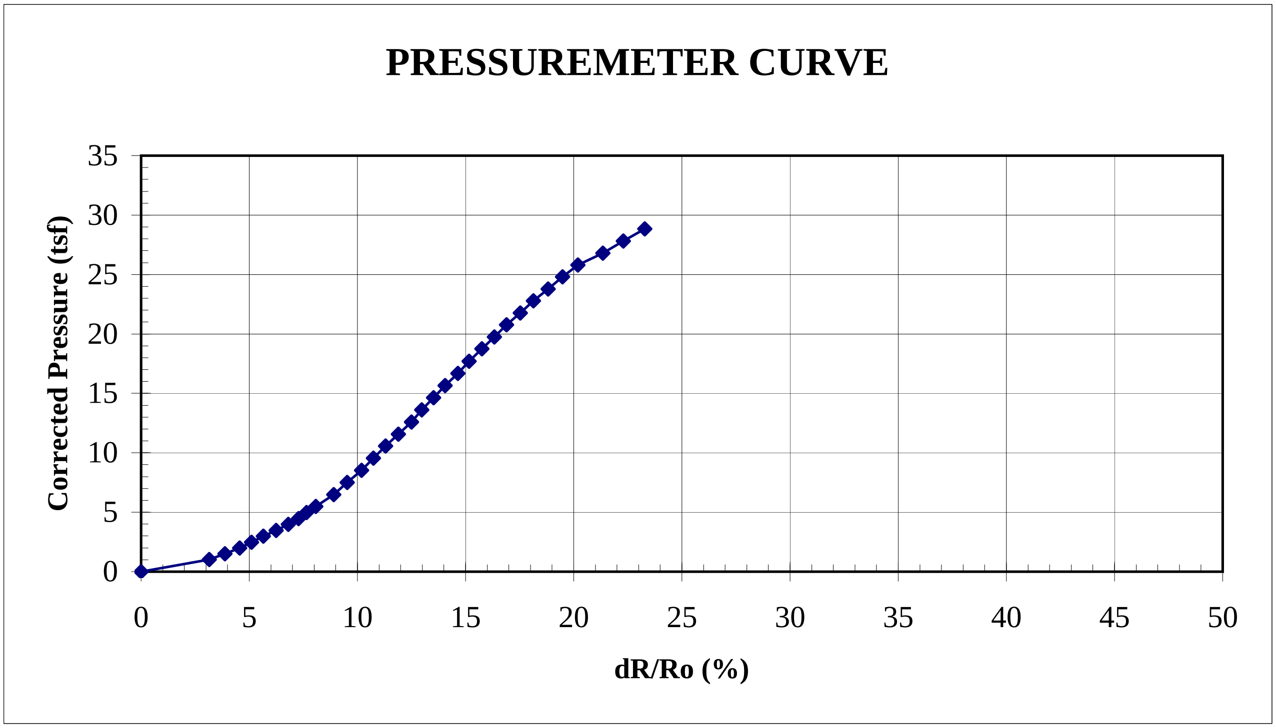
NOTES: Points Used for E_o Calculation: 9 to 16

Good test; reached yield but not failure.

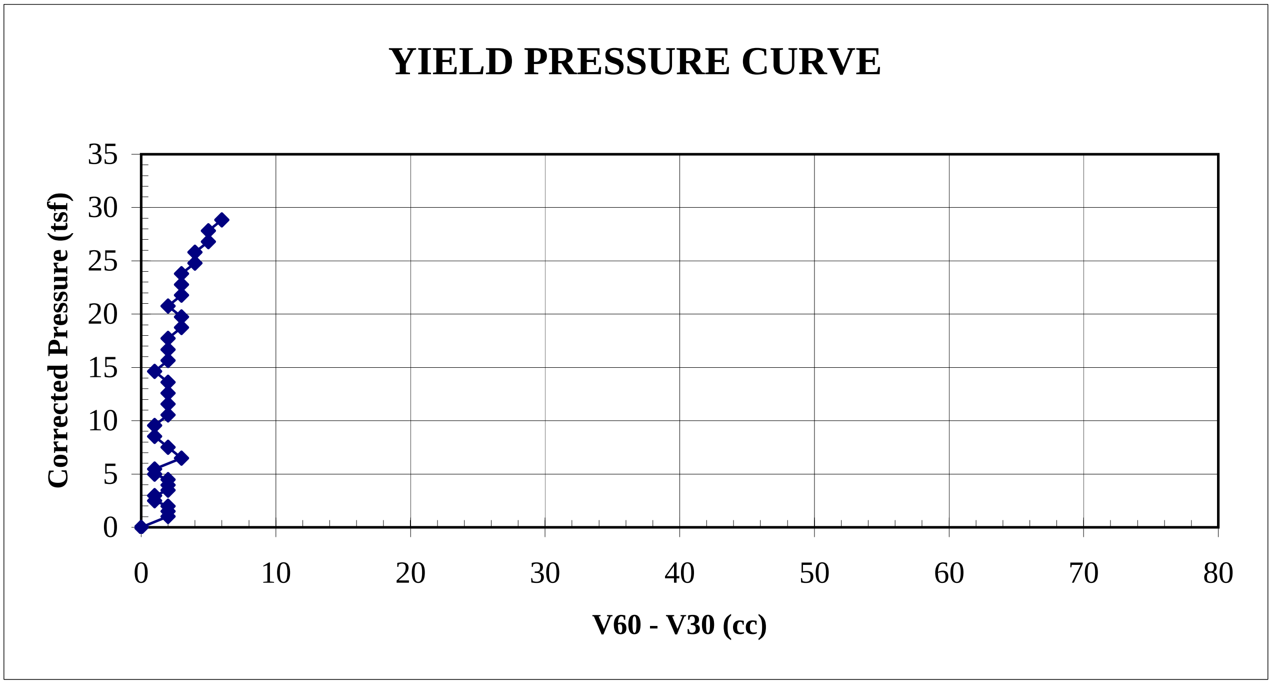
PRESSUREMETER TEST RESULTS

PolyMet

AET No. 07-04509; Barr No. 23/69-0C29.07 WA1A



Boring No. : J003	**P_L(tsf) > 30.0**	**E_o(tsf) = 264**	**E_o / P_l* = 9.3**
Depth (ft) : 21.6-23.4	**P_o(tsf) = 1.5**	**N_{ave} (bpf) = 26**	**E_o / N = 10.4**
Probe : A1	**P_L*(tsf) > 28.5**	**P_y(tsf) = 23.0**	**P_y / P_l* = 0.81**

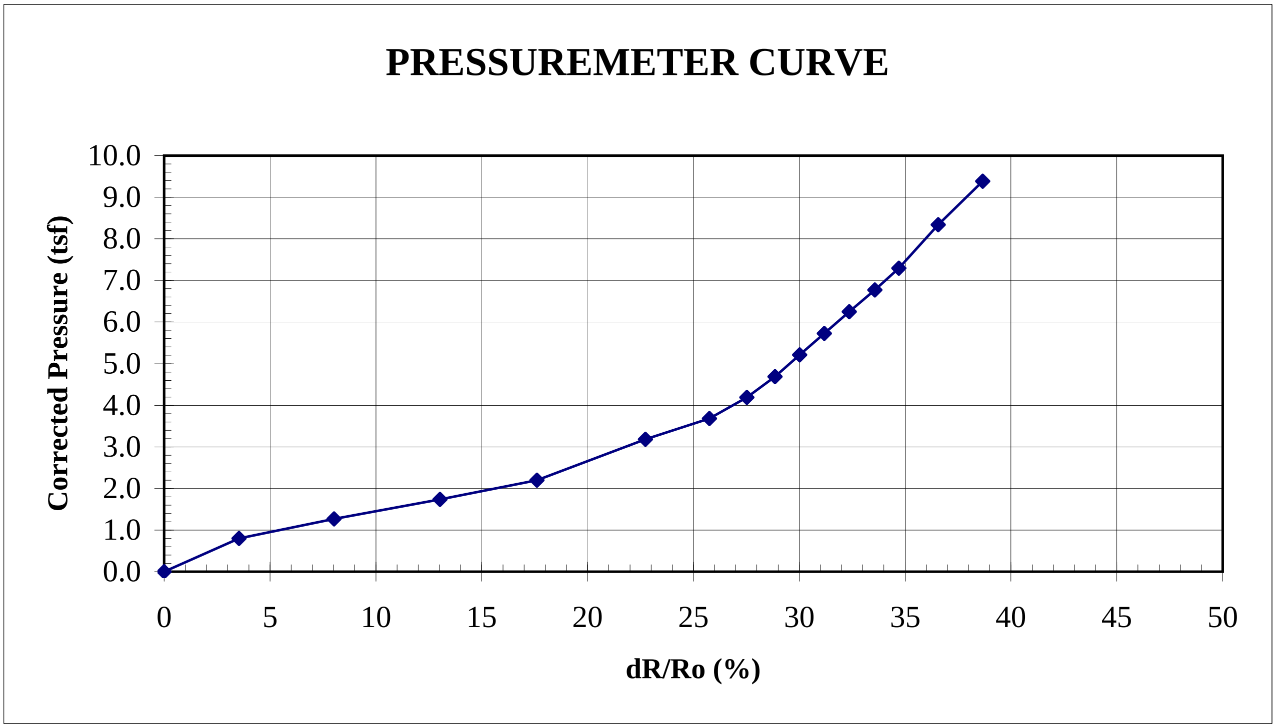


NOTES: Points Used for E_o Calculation: 14 to 28 Good test; reached yield but not failure.

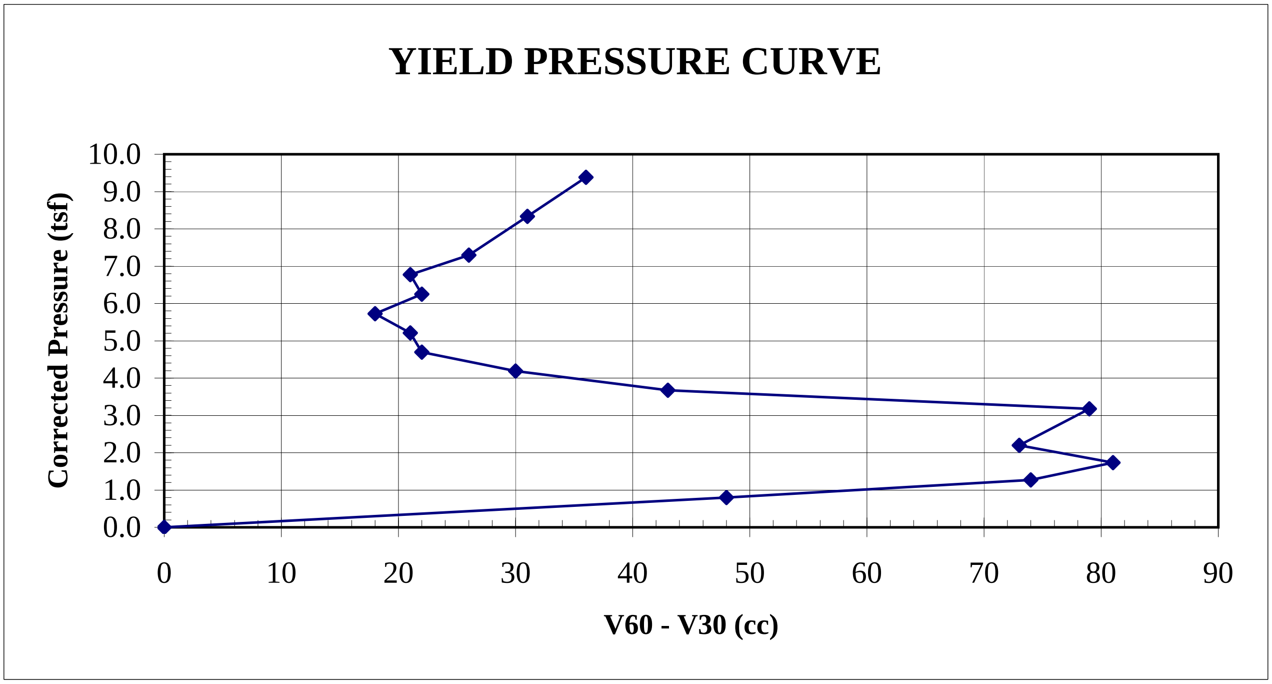
PRESSUREMETER TEST RESULTS

PolyMet

AET No. 07-04509; Barr No. 23/69-0C29.07 WA1A



Boring No. : J003	**P_L(tsf) > 10.0**	**E_o(tsf) = 76**	**E_o / P_l* = 8.4**
Depth (ft) : 13.8-15.3	**P_o(tsf) = 1.0**	**N_{ave} (bpf) = 23**	**E_o / N = 3.3**
Probe : N1	**P_L*(tsf) > 9.0**	**P_y(tsf) = 7.0**	**P_y / P_l* = 0.78**

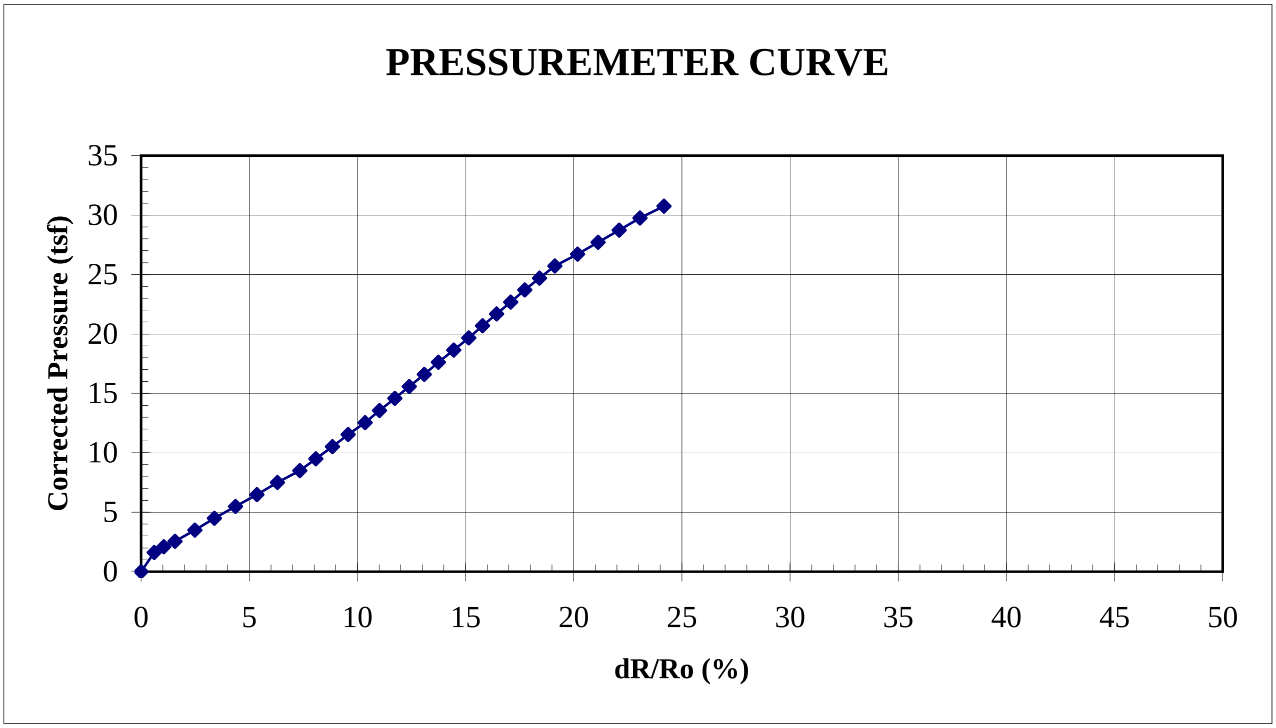


NOTES: Points Used for E_o Calculation: 9 to 13   Marginal test: may have reached yield; did not reach failure.

PRESSUREMETER TEST RESULTS

PolyMet

AET No. 07-04509; Barr No. 23/69-0C29.07 WA1A

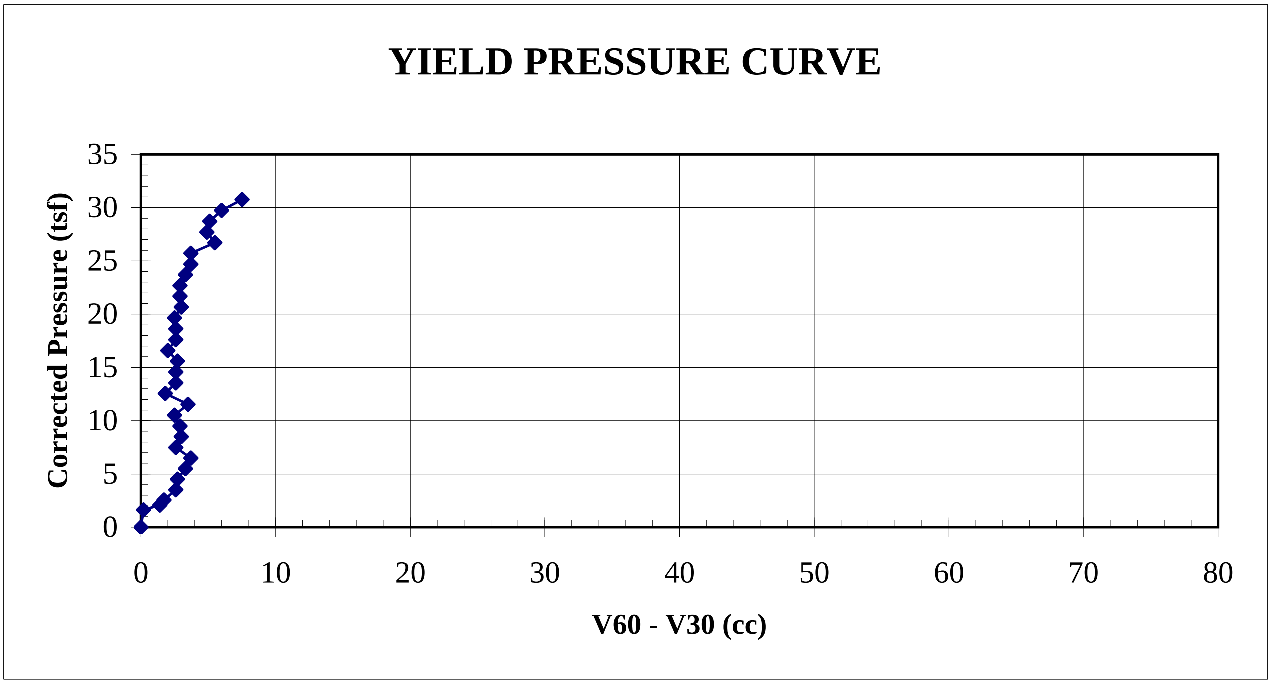


Boring No. : J003
Depth (ft) : 16.9-18.7
Probe : A1

P_L(tsf) > 31.0
P_o(tsf) = 1.0
P_L*(tsf) > 30.0

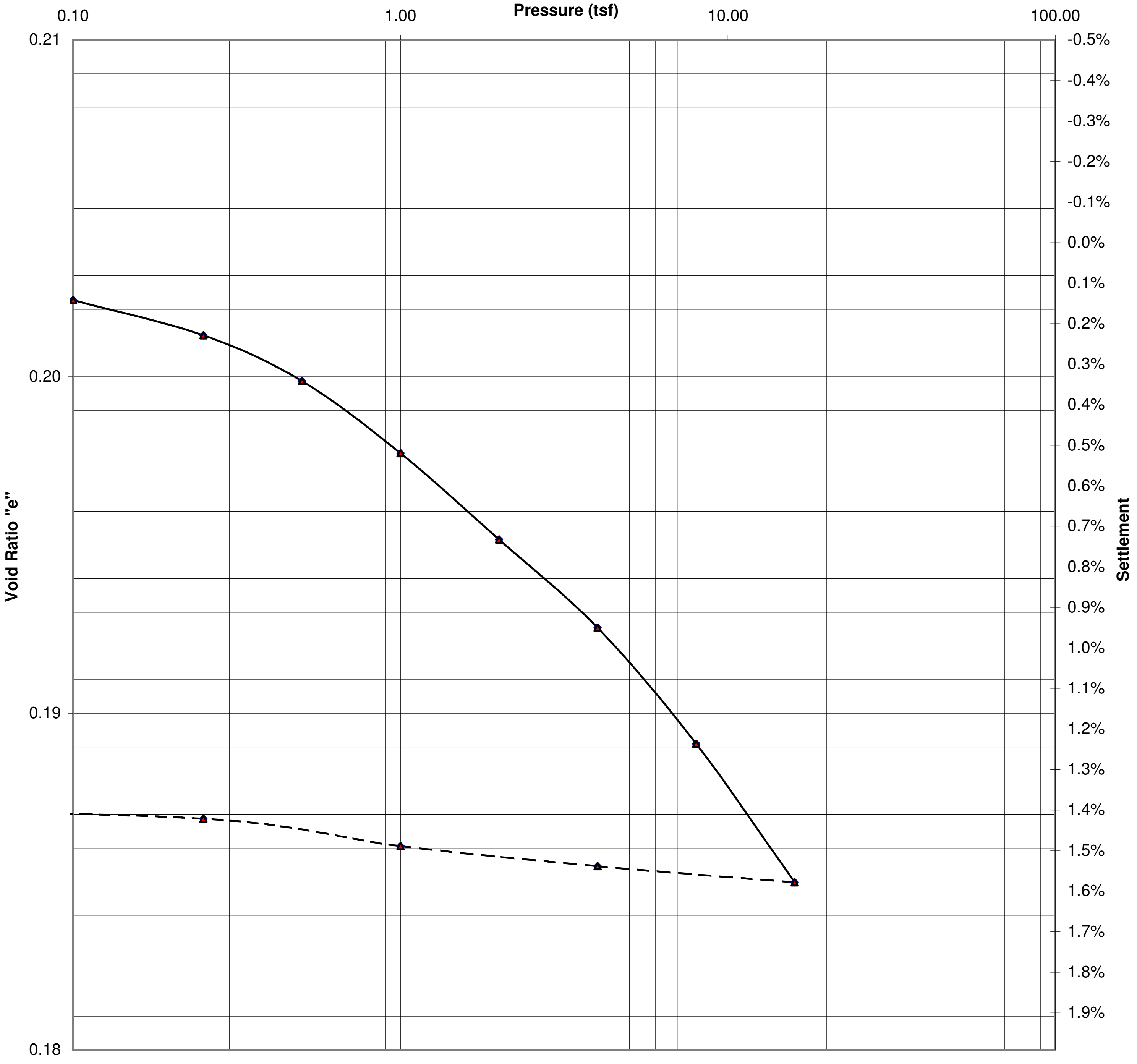
E_o(tsf) = 229
N_{ave} (bpf) = 46
P_y(tsf) = 26.0

E_o / P_l* = 7.6
E_o / N = 5.0
P_y / P_l* = 0.87



NOTES: Points Used for E_o Calculation: 14 to 26 Good test; just starting to yield at end of test.

Void Ratio and % Settlement vs. Log of Pressure



Project: PolyMet

Date: 5/4/10

Sample #:

Boring #: J003

Depth ft: 10-13

Job #: 7397

Soil Type: Silty Clayey Sand w/gravel (SC-SM/SC)

Initial W/C (%): 6.8

Dry Density (pcf): 142.1

LL:

PL:

PI:

Gs: 2.74 (Assumed)

Organic Content (%):

Initial Height (in.): 0.770

Diameter (in.): 2.504

e_o= 0.204

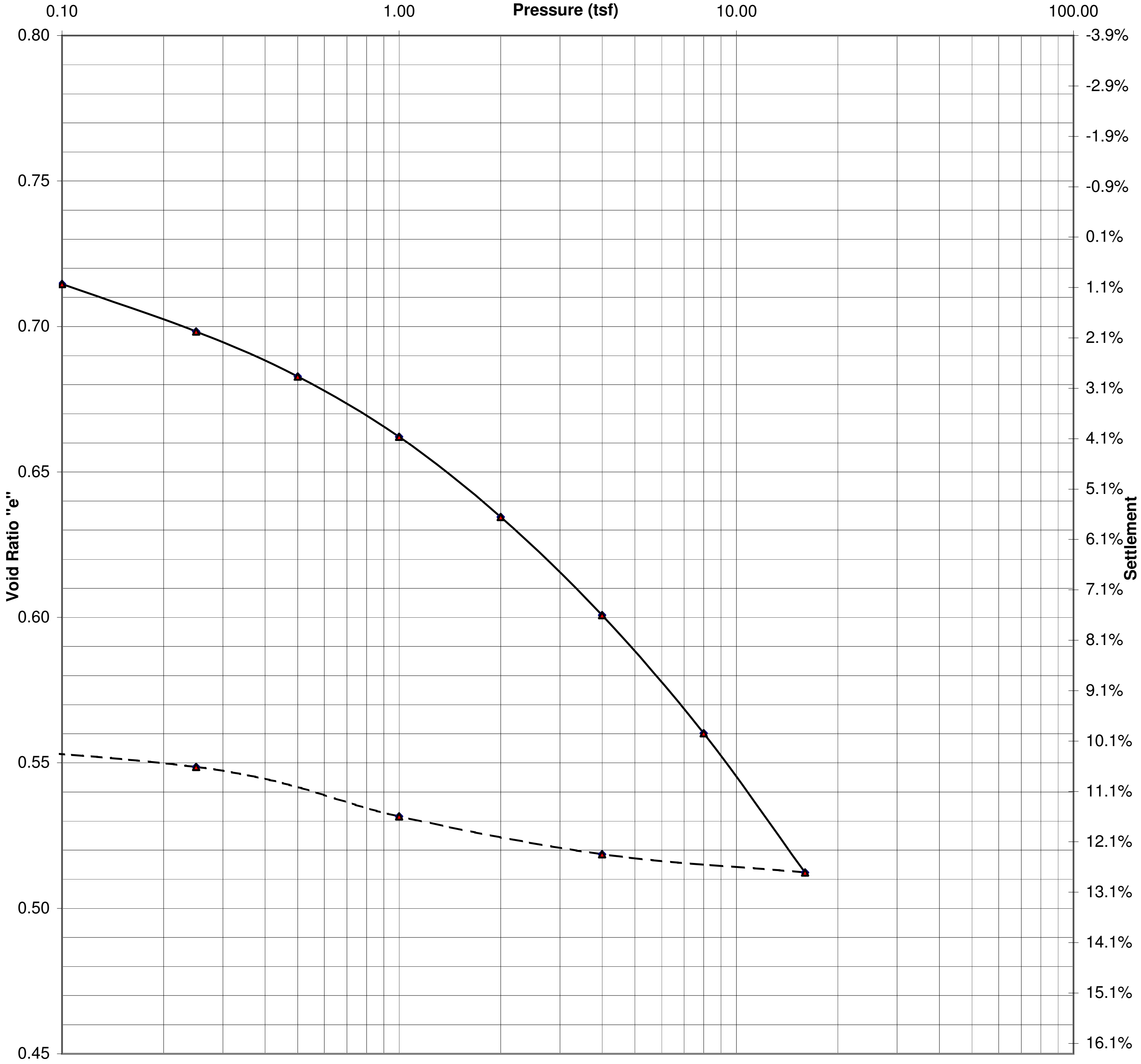
Preconsolidation Pressure (Pc): N/A

Compression Index (Cc): N/A

Recompression Index (Cr): ≅ 0.001

Remarks: Specimen incrementally loaded with the load doubling at end of primary plus 30 minutes. Specimen was extremely dense. Pc does not appear to have been reached at 16 tsf.

Void Ratio and % Settlement vs. Log of Pressure



Project: PolyMet				Date: 5/4/10
Sample #:	Boring #: J003T	Depth ft: 1.5-3.5		Job #: 7397
Soil Type: Clayey Sand (SC)				
Initial W/C (%): 27.6	Dry Density (pcf): 97.0	LL: PL: PI:		Gs: 2.69 (Assumed)
Organic Content (%):	Initial Height (in.): 0.770	Diameter (in.): 2.504	e_o= 0.732	
Preconsolidation Pressure (Pc): 1.6 tsf	Compression Index (Cc): 0.155	Recompression Index (Cr): ≅ 0.02		

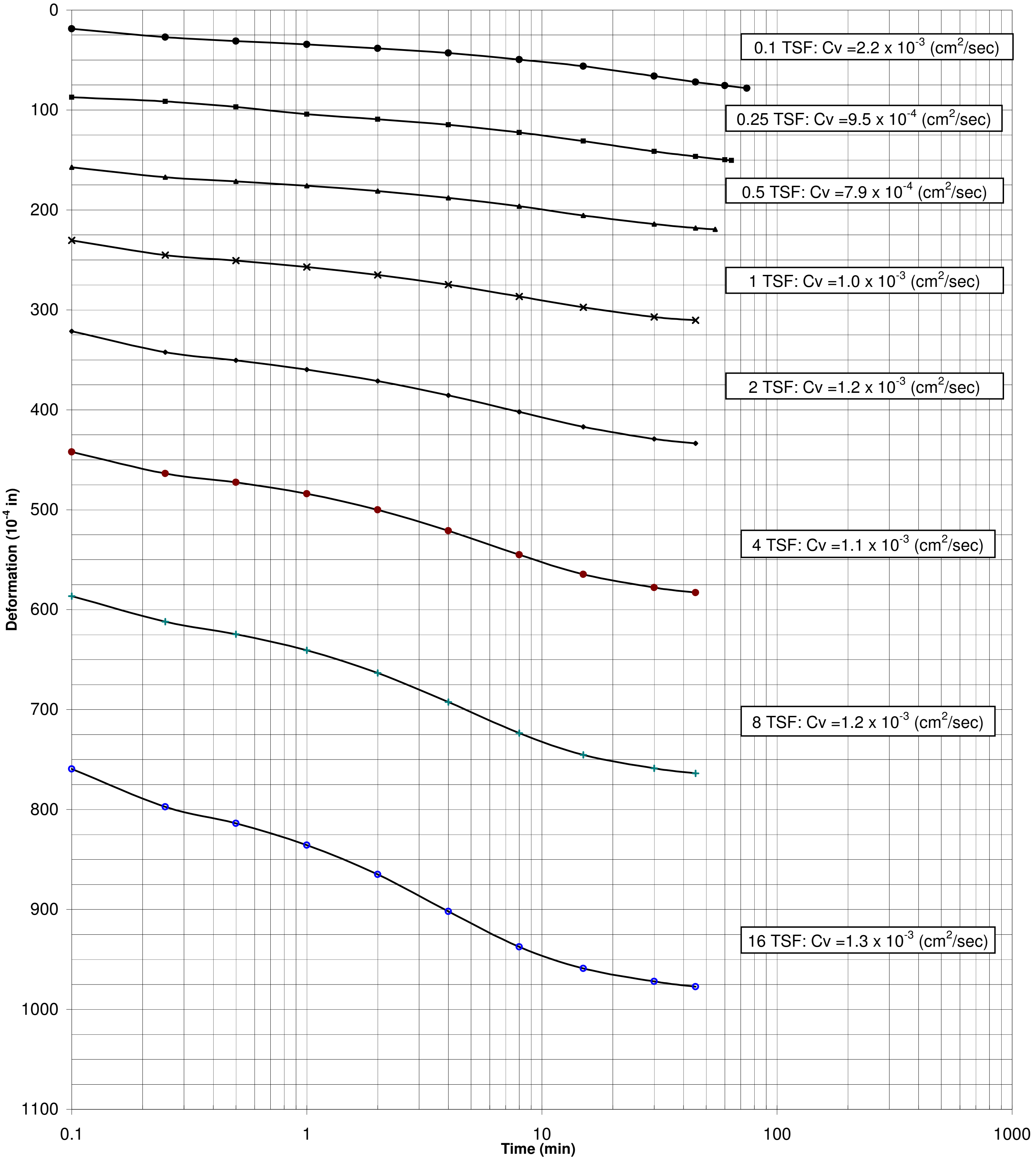
Remarks: Specimen incrementally loaded with the load doubling at end of primary plus 30 minutes.

9301 Bryant Ave. South, Suite 107

SOIL
ENGINEERING
TESTING, INC.

Bloomington, Minnesota 55420-3436

Consolidation Log of Time Curves



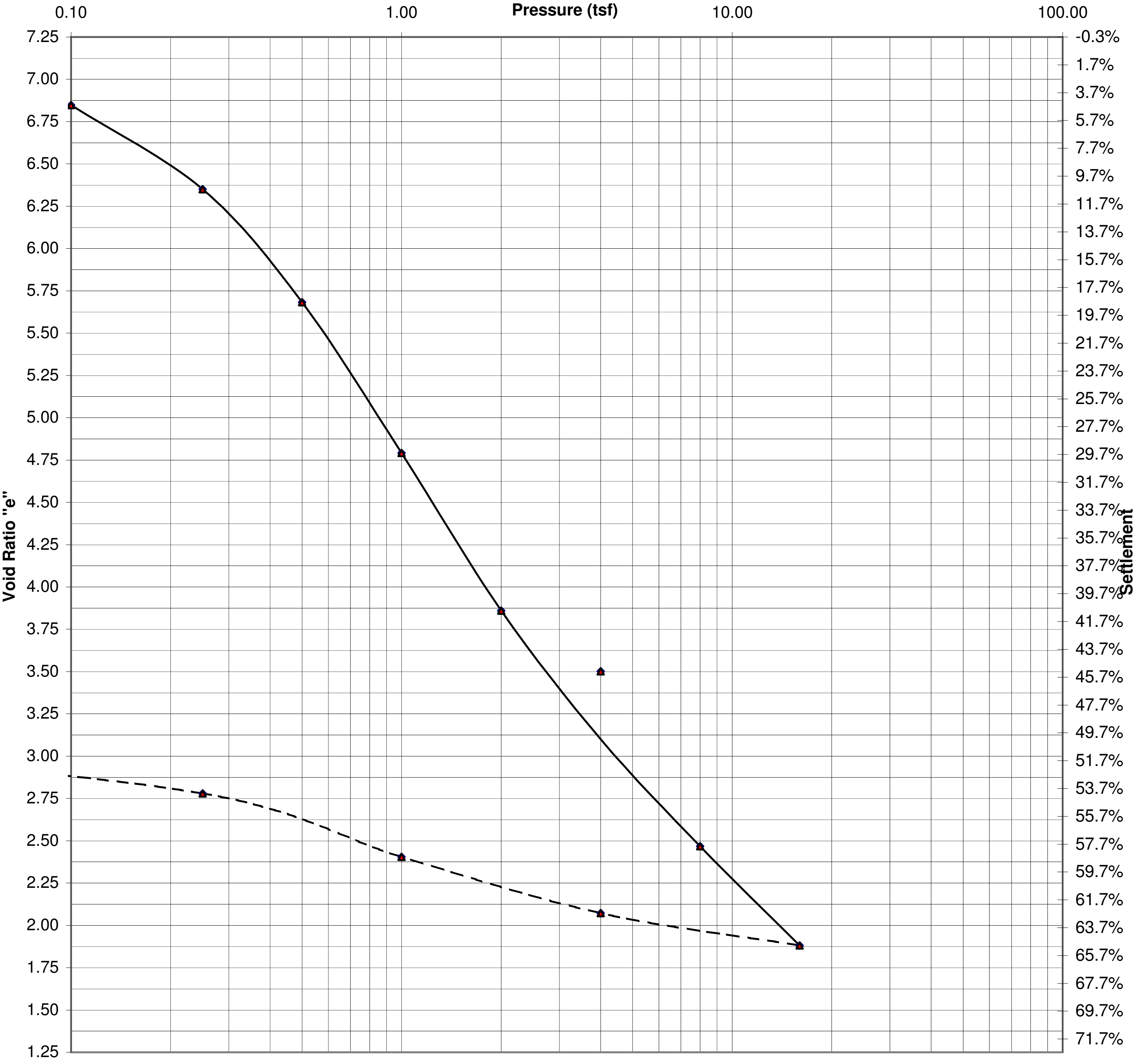
Project: PolyMet			Date: 5/4/10
Sample #:	Boring #: J003T	Depth ft: 1.5-3.5	Job #: 7397

9301 Bryant Ave. South, Suite 107

SOIL
ENGINEERING
TESTING, INC.

Bloomington, Minnesota 55420-3436

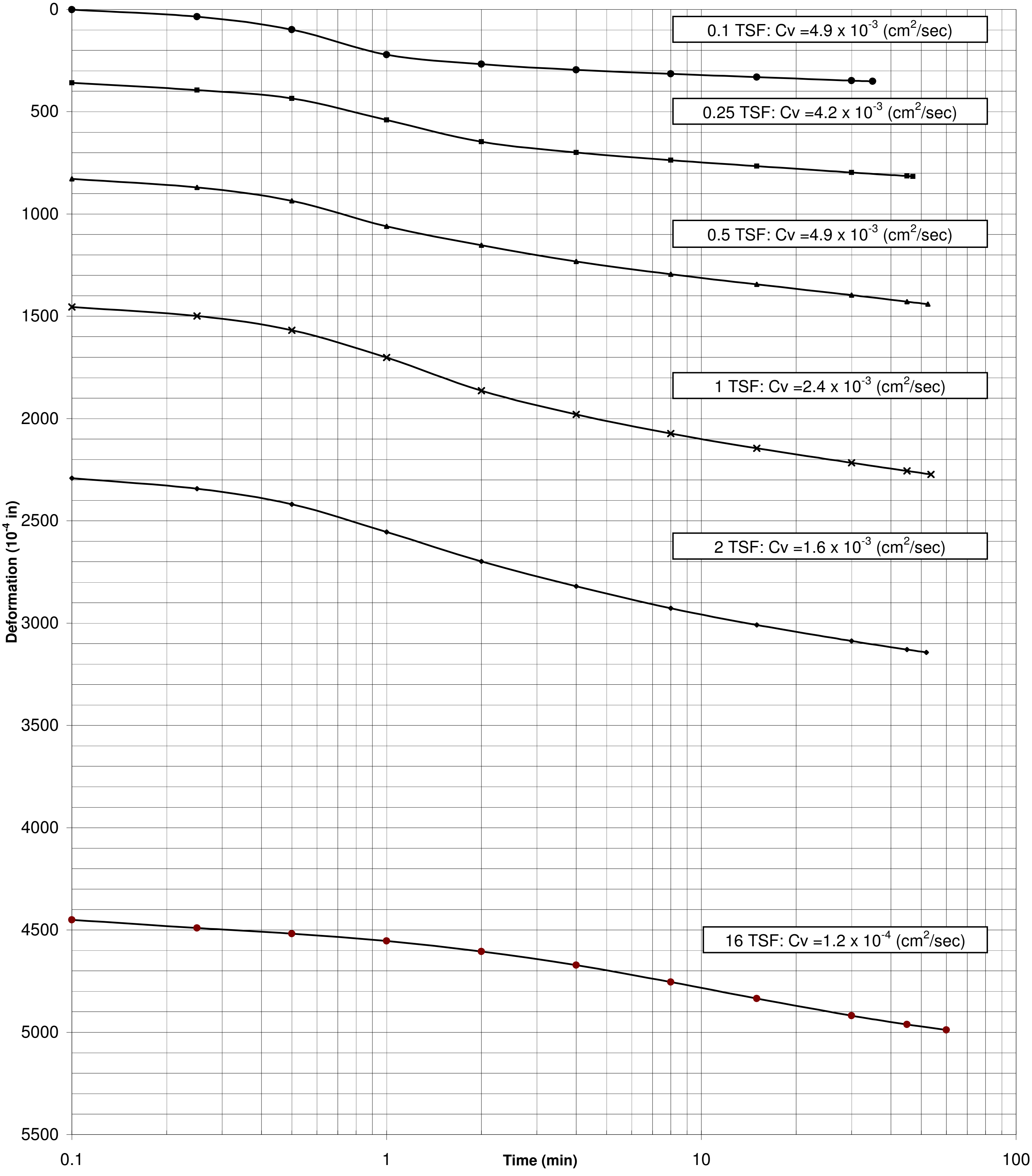
Void Ratio and % Settlement vs. Log of Pressure



Project: PolyMet			Date: 5/4/10
Sample #:	Boring #: J027	Depth ft: 1.5-3.5	Job #: 7397
Soil Type: Hemic Peat w/wood stems (PT)			
Initial W/C (%): 404.6	Dry Density (pcf): 12.8	LL: PL: PI:	Gs: 1.68
Organic Content (%):	Initial Height (in.): 0.768	Diameter (in.): 2.504	e_o= 7.225
Preconsolidation Pressure (Pc): 0.25 tsf	Compression Index (Cc): 2.82	Recompression Index (Cr): ≅ 0.50	

Remarks: Specimen incrementally loaded with the load doubling at end of primary plus 30 minutes. Maximum displacement limit reached at during 4 tsf load; consequently time readings were not attained for 4 tsf and 8 tsf.

Consolidation Log of Time Curves



Project: PolyMet			Date: 5/4/10
Sample #:	Boring #: J027	Depth ft: 1.5-3.5	Job #: 7397

9301 Bryant Ave. South, Suite 107

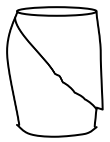
SOIL
ENGINEERING
TESTING, INC.

Bloomington, Minnesota 55420-3436

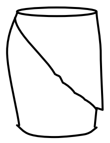
TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J003** Sample #: Type: **3T** Depth (ft): **15-18**
Soil Type: **Silty Clayey Sand w/a little gravel (SC-SM)**



◆



■

△

+

X

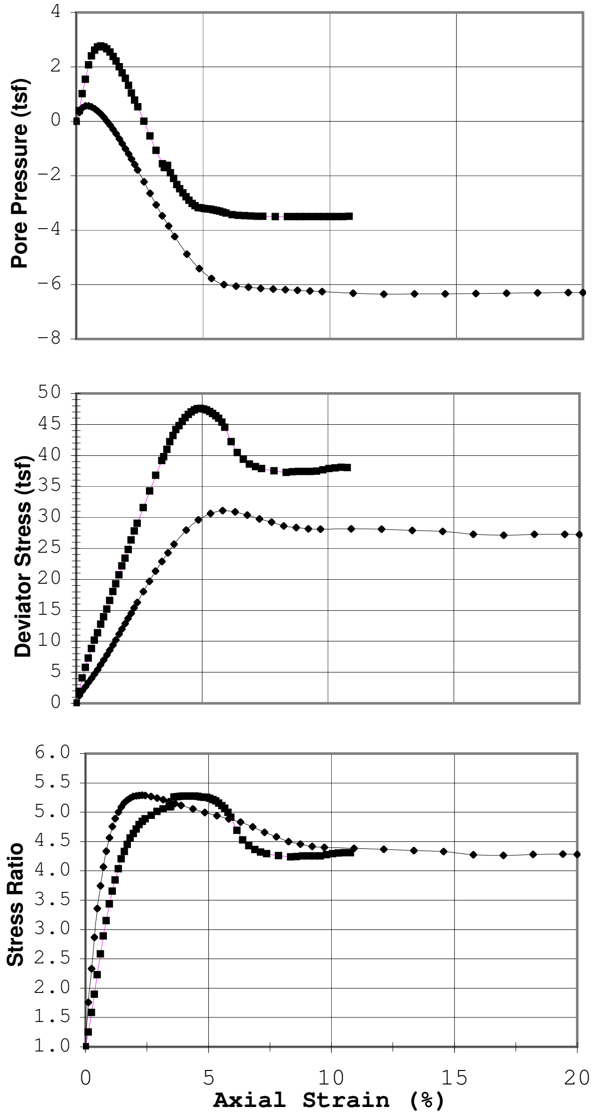
Failure Criterion: **Max. Stress Ratio**
Angle of internal friction, **φ' =** **42.9 °**
Apparent Cohesion, **c' =** **0.02 (tsf)**

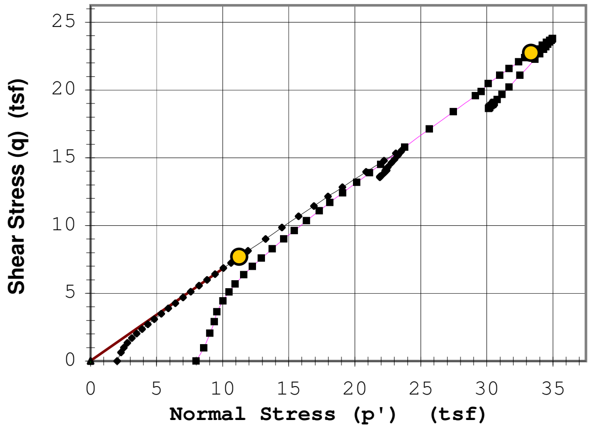
Test Date:	4/8/10	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00206	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.68

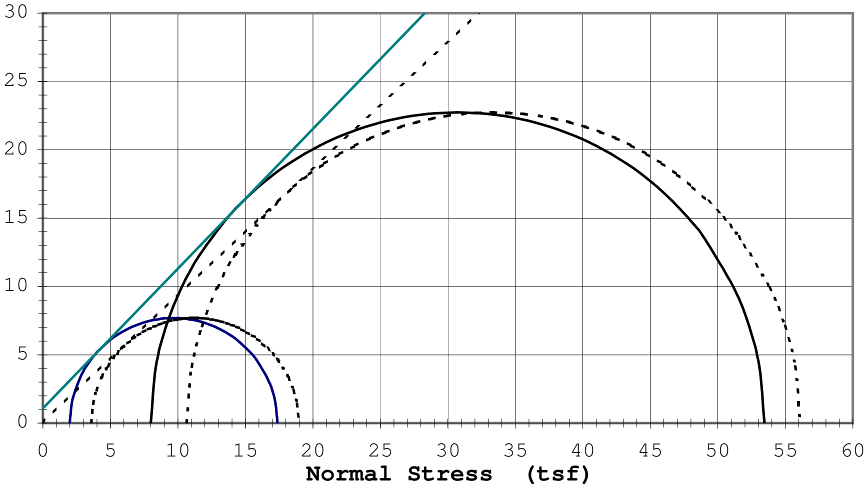
Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94			
Height (in)	4.12	4.12			
Water Content (%)	7.8	8.3			
Dry Density (pcf)	140.1	136.2			
Void Ratio	0.19	0.23			
After Consolidation					
Diameter (in)	1.93	1.93			
Height (in)	4.12	4.11			
Water Content (%)	6.5	7.7			
Dry Density (pcf)	142.4	138.7			
Void Ratio	0.18	0.21			
Back Pressure (tsf)	5.8	5.8			
Minor Principal Stress (tsf)	2.00	8.00			
Max. Deviator Stress (tsf)	31.11	47.58			
Ultimate Deviator Stress (tsf)	27.21	38.01			
Deviator Stress at Failure (tsf)	15.37	45.46			
Max. Pore Pressure Buildup (tsf)	0.56	2.76			
Pore Pressure Parameter "B"	1.0	1.0			
Pct. Axial Strain at Failure	2.3	4.2			

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
3rd specimen was not viable due to a 2.5" piece of gravel located in center of specimen.







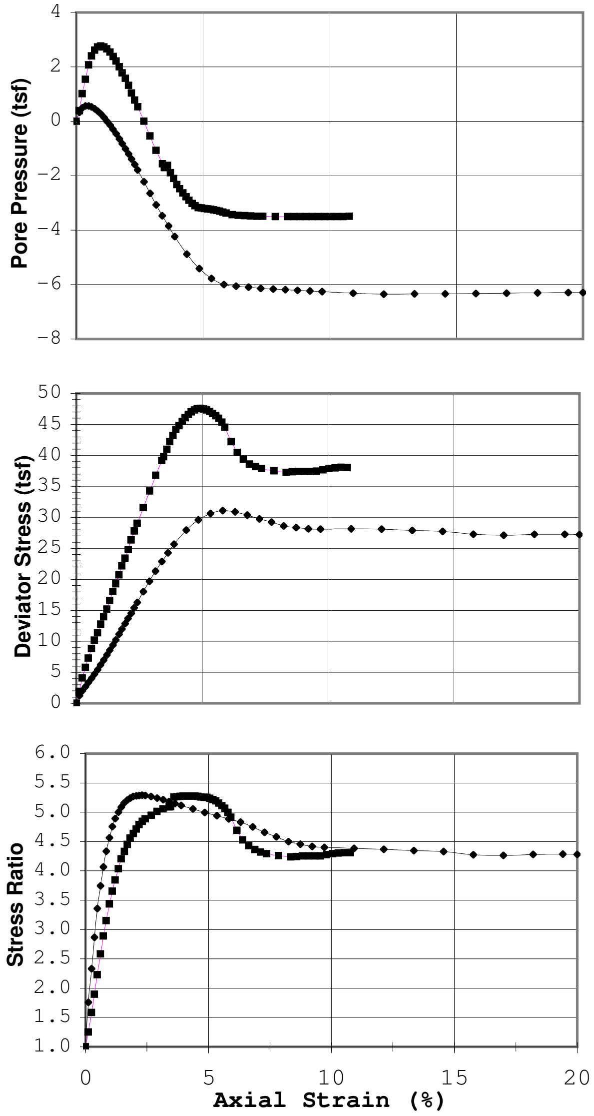
Rupture Envelope at Failure
α = 34.2 ° a = 0.0 (tsf)

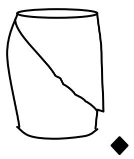
------------ Effective φ': 42.9 ° c'= 0.02 (tsf)
________ Total φ': 45.6 ° c= 1.09 (tsf)

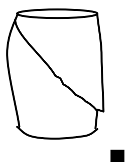
TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J003** Sample #: Type: **3T** Depth (ft): **15-18**
Soil Type: **Silty Clayey Sand w/a little gravel (SC-SM)**




◆


■

△

+

X

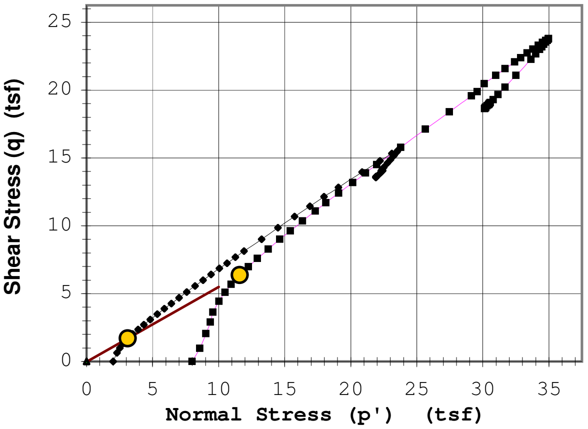
Failure Criterion: **Max. Pore Pressure**
Angle of internal friction, **φ' =** **33.5 °**
Apparent Cohesion, **c' =** **0.00 (tsf)**

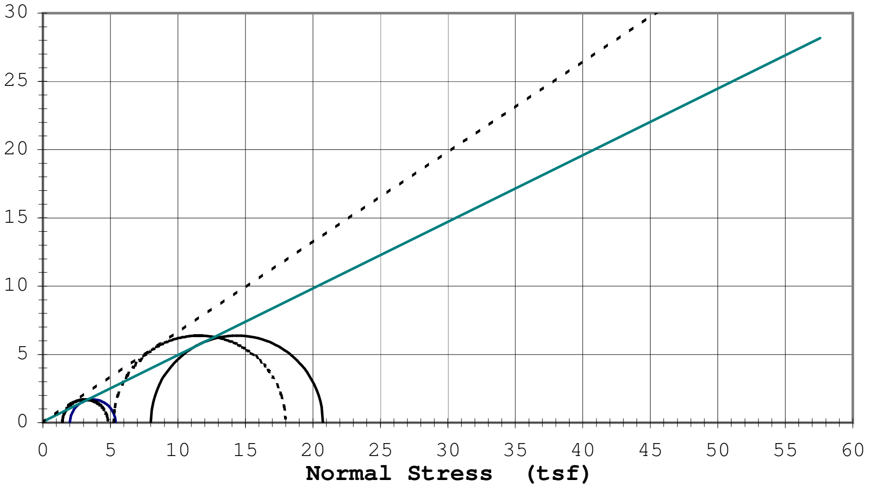
Test Date:	4/8/10	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00206	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94			
Height (in)	4.12	4.12			
Water Content (%)	7.8	8.3			
Dry Density (pcf)	140.1	136.2			
Void Ratio	0.19	0.23			
After Consolidation					
Diameter (in)	1.93	1.93			
Height (in)	4.12	4.11			
Water Content (%)	6.5	7.7			
Dry Density (pcf)	142.4	138.7			
Void Ratio	0.18	0.21			
Back Pressure (tsf)	5.8	5.8			
Minor Principal Stress (tsf)	2.00	8.00			
Max. Deviator Stress (tsf)	31.11	47.58			
Ultimate Deviator Stress (tsf)	27.21	38.01			
Deviator Stress at Failure (tsf)	3.38	12.75			
Max. Pore Pressure Buildup (tsf)	0.56	2.76			
Pore Pressure Parameter "B"	1.0	1.0			
Pct. Axial Strain at Failure	0.5	1.0			

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
3rd specimen was not viable due to a 2.5" piece of gravel located in center of specimen.





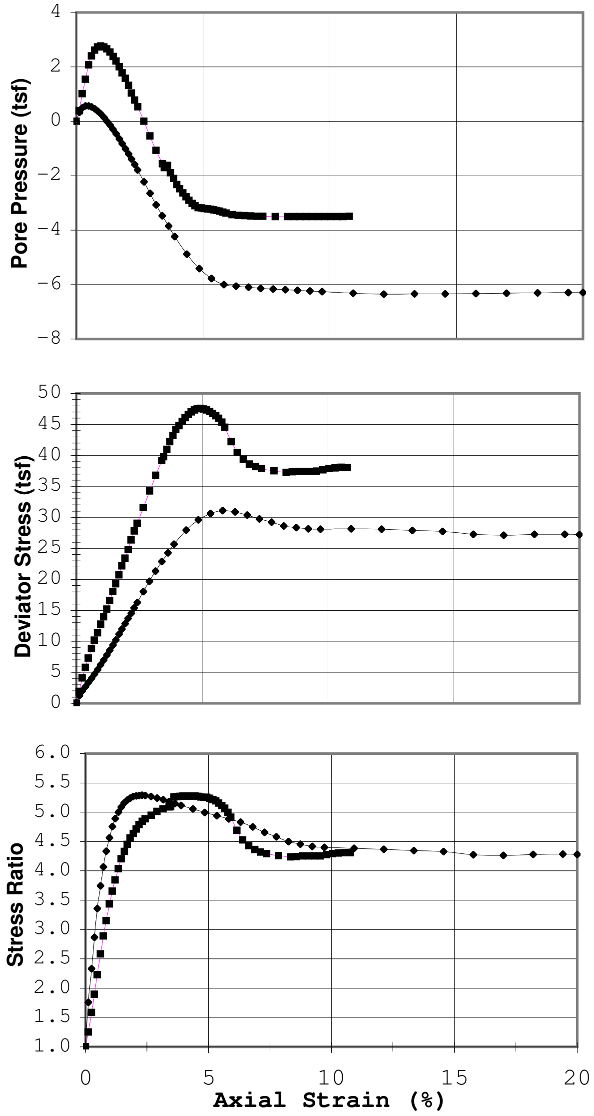
Rupture Envelope at Failure
α = 28.9 ° a = 0.0 (tsf)

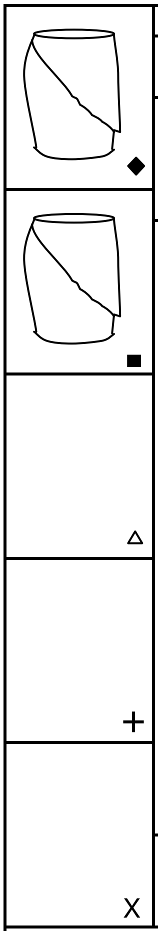
------------	Effective φ':	33.5 °	c'=	0.00 (tsf)
________	Total φ':	26.0 °	c=	0.08 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J003** Sample #: Type: **3T** Depth (ft): **15-18**
Soil Type: **Silty Clayey Sand w/a little gravel (SC-SM)**





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, **φ' = 42.4 °**

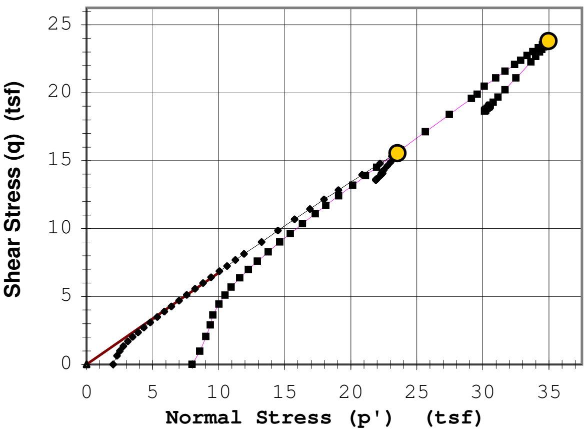
Apparent Cohesion, **c' = 0.00 (tsf)**

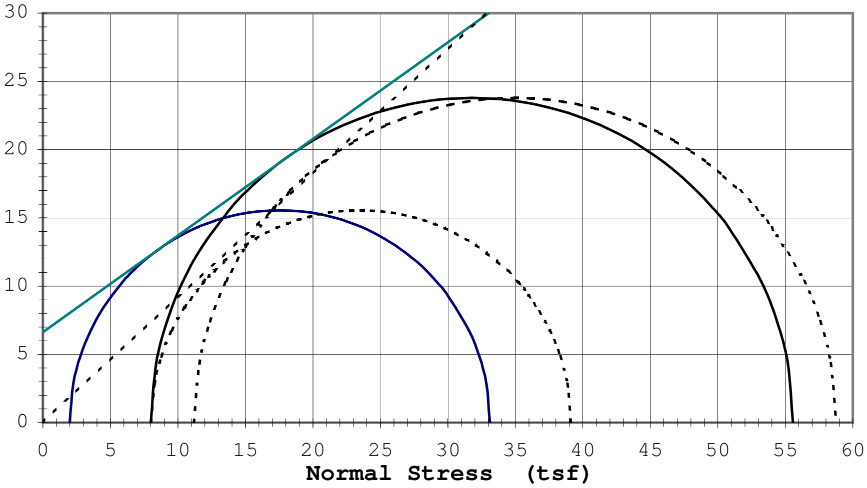
Test Date:	4/8/10	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00206	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94			
Height (in)	4.12	4.12			
Water Content (%)	7.8	8.3			
Dry Density (pcf)	140.1	136.2			
Void Ratio	0.19	0.23			
After Consolidation					
Diameter (in)	1.93	1.93			
Height (in)	4.12	4.11			
Water Content (%)	6.5	7.7			
Dry Density (pcf)	142.4	138.7			
Void Ratio	0.18	0.21			
Back Pressure (tsf)	5.8	5.8			
Minor Principal Stress (tsf)	2.00	8.00			
Max. Deviator Stress (tsf)	31.11	47.58			
Ultimate Deviator Stress (tsf)	27.21	38.01			
Deviator Stress at Failure (tsf)	31.11	47.58			
Max. Pore Pressure Buildup (tsf)	0.56	2.76			
Pore Pressure Parameter "B"	1.0	1.0			
Pct. Axial Strain at Failure	5.8	4.9			

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
3rd specimen was not viable due to a 2.5" piece of gravel located in center of specimen.





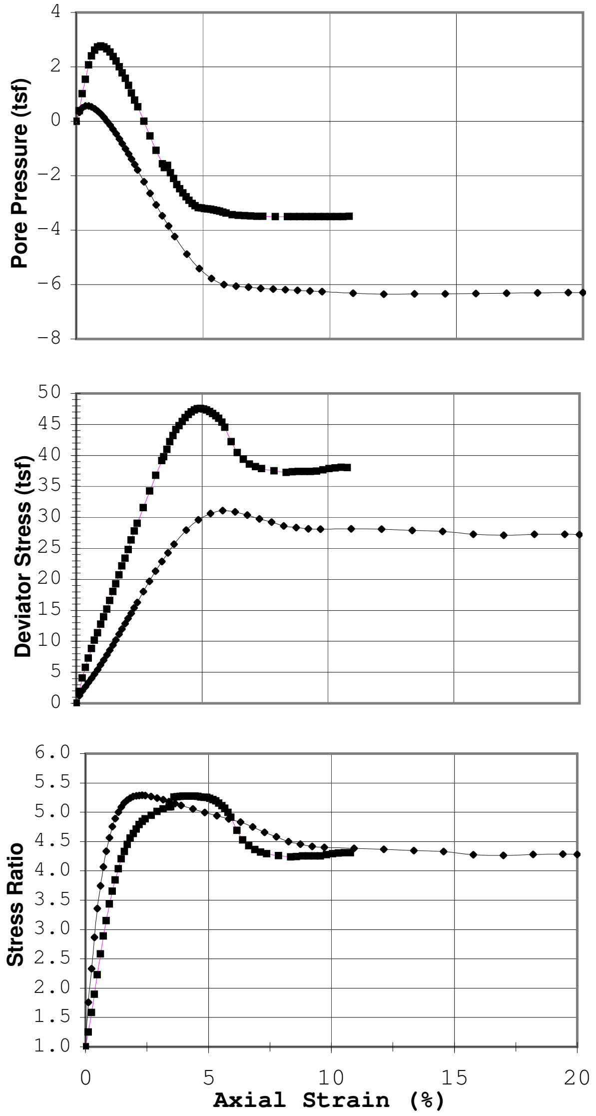
Rupture Envelope at Failure
α = 34.0 ° a = 0.0 (tsf)

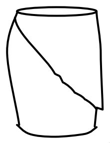
------------	Effective φ':	42.4 °	c'=	0.00 (tsf)
________	Total φ':	35.3 °	c=	6.62 (tsf)

TRIAXIAL TEST ASTM: D 4767

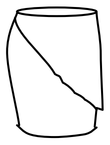
Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J003** Sample #: Type: **3T** Depth (ft): **15-18**
Soil Type: **Silty Clayey Sand w/a little gravel (SC-SM)**





◆



■

△

+

X

Failure Criterion: **Given Strain of: 10%**
Angle of internal friction, **φ' = 36.6 °**
Apparent Cohesion, **c' = 0.92 (tsf)**

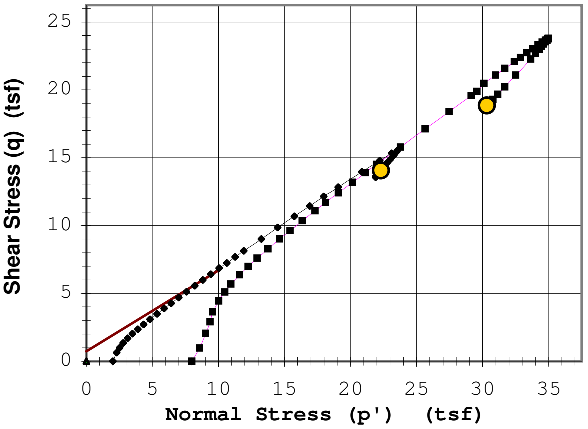
Test Date: 4/8/10
Test Type: CU w/pp
Strain Rate (in/min): 0.00206
Strain Rate (%/min): 0.050

Liquid Limit:
Plastic Limit:
Plasticity Index:
Spec. Gravity (Assumed): 2.68

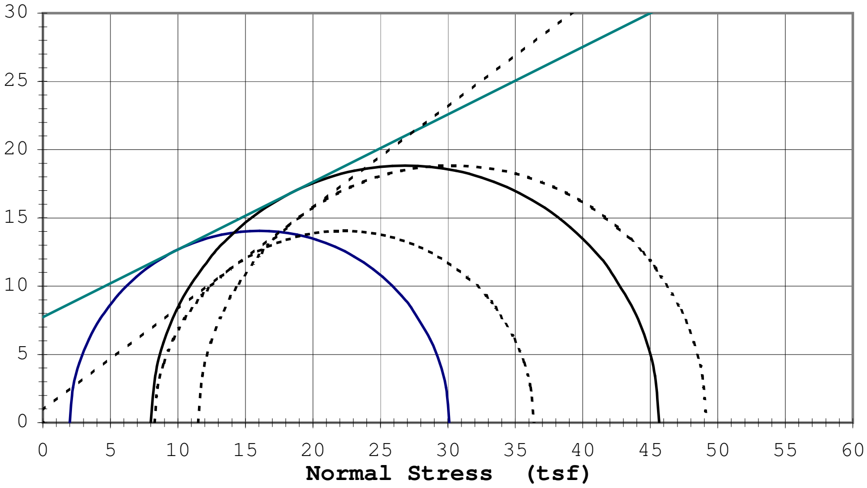
Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94			
Height (in)	4.12	4.12			
Water Content (%)	7.8	8.3			
Dry Density (pcf)	140.1	136.2			
Void Ratio	0.19	0.23			
After Consolidation					
Diameter (in)	1.93	1.93			
Height (in)	4.12	4.11			
Water Content (%)	6.5	7.7			
Dry Density (pcf)	142.4	138.7			
Void Ratio	0.18	0.21			
Back Pressure (tsf)	5.8	5.8			
Minor Principal Stress (tsf)	2.00	8.00			
Max. Deviator Stress (tsf)	31.11	47.58			
Ultimate Deviator Stress (tsf)	27.21	38.01			
Deviator Stress at Failure (tsf)	28.10	37.67			
Max. Pore Pressure Buildup (tsf)	0.56	2.76			
Pore Pressure Parameter "B"	1.0	1.0			
Pct. Axial Strain at Failure	10.0	10.0			

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
3rd specimen was not viable due to a 2.5" piece of gravel located in center of specimen.



Rupture Envelope at Failure
α = 30.8 ° a = 0.7 (tsf)



------------	Effective φ':	36.6 °	c'=	0.92 (tsf)
________	Total φ':	26.3 °	c=	7.73 (tsf)

Triaxial Plot Data Job: 7397

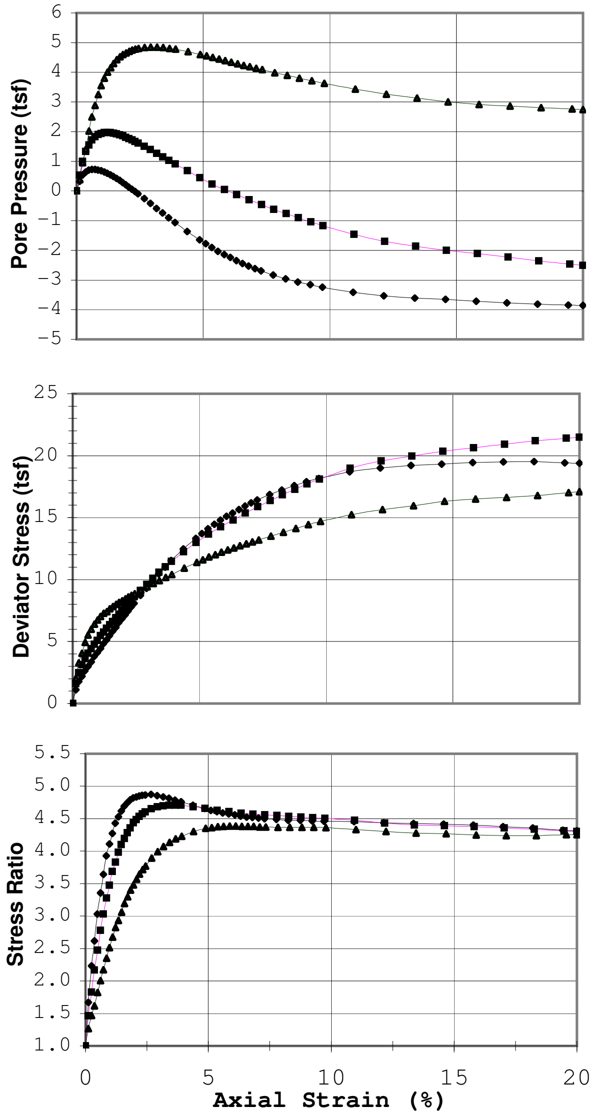
Boring: J003 Depth: 15-18 Date: 40303

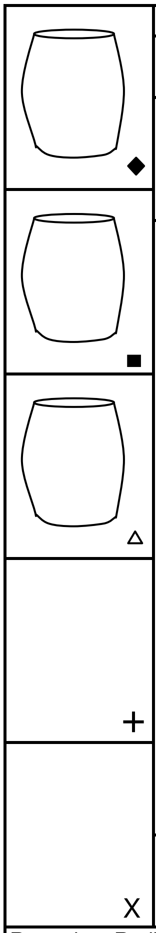
Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00									
0.12	1.27	0.33	0.12	1.93	0.39									
0.24	2.00	0.49	0.24	4.09	1.01									
0.37	2.69	0.56	0.36	5.80	1.54									
0.49	3.38	0.56	0.49	7.29	2.07									
0.61	4.04	0.53	0.61	8.85	2.40									
0.73	4.72	0.46	0.73	10.18	2.61									
0.85	5.42	0.38	0.85	11.35	2.73									
0.97	6.17	0.27	0.97	12.75	2.76									
1.09	6.99	0.14	1.09	13.97	2.73									
1.21	7.79	0.00	1.22	15.20	2.66									
1.34	8.56	-0.14	1.34	16.58	2.54									
1.46	9.40	-0.30	1.46	18.01	2.38									
1.58	10.25	-0.46	1.58	19.27	2.21									
1.70	11.14	-0.65	1.70	20.70	2.01									
1.82	11.97	-0.82	1.82	22.18	1.77									
1.94	12.84	-1.01	1.94	23.38	1.57									
2.06	13.71	-1.20	2.07	24.81	1.32									
2.18	14.50	-1.38	2.19	26.36	1.04									
2.31	15.37	-1.58	2.31	27.78	0.77									
2.43	16.26	-1.79	2.43	29.01	0.53									
2.67	18.04	-2.23	2.67	31.57	0.01									
2.91	19.70	-2.64	2.92	34.25	-0.54									
3.16	21.34	-3.07	3.16	36.79	-1.07									
3.40	22.87	-3.47	3.40	39.15	-1.57									
3.64	24.27	-3.85	3.48	39.75	-1.71									
3.88	25.66	-4.23	3.61	40.96	-1.62									
4.37	27.94	-4.89	3.73	42.18	-1.89									
4.85	29.60	-5.41	3.85	43.16	-2.11									
5.34	30.65	-5.78	3.97	44.15	-2.33									
5.83	31.11	-6.00	4.09	44.78	-2.48									
6.31	30.87	-6.06	4.21	45.46	-2.64									
6.80	30.37	-6.10	4.33	46.06	-2.78									
7.28	29.75	-6.14	4.46	46.58	-2.90									
7.77	29.22	-6.17	4.58	47.01	-3.02									
8.25	28.63	-6.19	4.70	47.31	-3.11									
8.74	28.35	-6.21	4.82	47.53	-3.18									
9.22	28.13	-6.24	4.94	47.58	-3.19									
9.71	28.10	-6.26	5.06	47.49	-3.21									
10.92	28.16	-6.32	5.19	47.32	-3.23									
12.14	28.12	-6.35	5.31	47.06	-3.23									
13.35	27.89	-6.34	5.43	46.74	-3.25									
14.56	27.75	-6.34	5.55	46.39	-3.28									
15.78	27.28	-6.32	5.67	45.98	-3.31									
16.99	27.14	-6.32	5.79	45.34	-3.35									
18.20	27.25	-6.31	5.91	44.52	-3.38									
19.42	27.26	-6.30	6.16	42.18	-3.43									
20.00	27.21	-6.29	6.40	40.43	-3.46									
			6.64	39.35	-3.47									
			6.89	38.60	-3.49									
			7.13	38.16	-3.49									
			7.37	37.85	-3.50									
			7.86	37.48	-3.50									
			8.35	37.25	-3.50									
			8.59	37.33	-3.50									
			8.83	37.40	-3.50									
			9.08	37.41	-3.50									
			9.32	37.41	-3.50									
			9.56	37.43	-3.50									
			9.80	37.67	-3.50									
			10.05	37.88	-3.50									
			10.29	37.97	-3.50									
			10.53	38.06	-3.50									
			10.78	38.01	-3.50									

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J010** Sample #: Type: **3T** Depth (ft): **5.5-8**
Soil Type: **Silty Sand w/a little gravel (SM)**





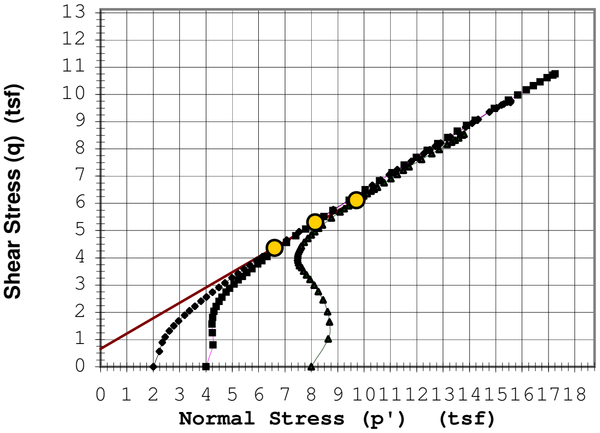
Failure Criterion:	**Max. Stress Ratio**
Angle of internal friction, **ϕ' =**	**34.2 °**
Apparent Cohesion, **c' =**	**0.80 (tsf)**

Test Date:	4/13/10	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00206	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.72

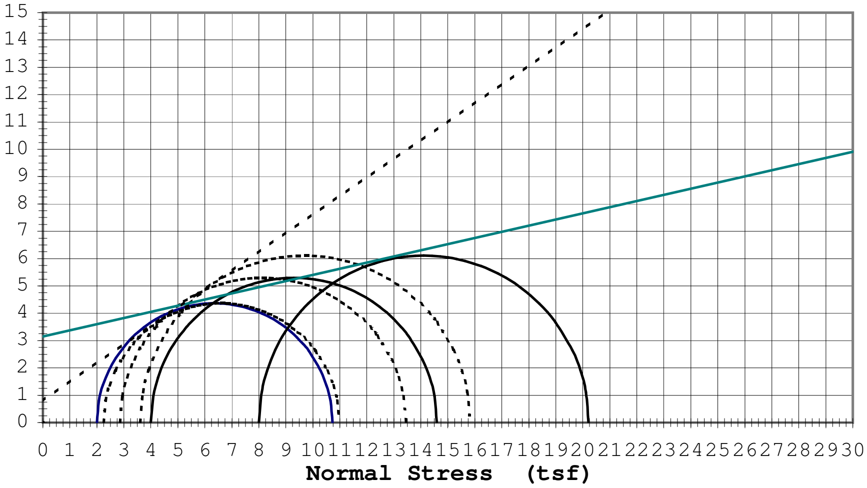
Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	4.12	4.12	4.12		
Water Content (%)	9.8	8.9	14.2		
Dry Density (pcf)	133.8	126.7	123.3		
Void Ratio	0.27	0.34	0.38		
After Consolidation					
Diameter (in)	1.93	1.92	1.90		
Height (in)	4.12	4.11	4.09		
Water Content (%)	9.3	11.1	11.1		
Dry Density (pcf)	135.6	130.5	130.4		
Void Ratio	0.25	0.30	0.30		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	19.52	21.50	17.10		
Ultimate Deviator Stress (tsf)	19.41	21.50	17.10		
Deviator Stress at Failure (tsf)	8.72	10.59	12.21		
Max. Pore Pressure Buildup (tsf)	0.73	1.97	4.85		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	2.7	3.4	5.9		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
Specimens varied in density leading to higher maximum strengths at lower consolidation pressures.



Rupture Envelope at Failure	
α = 29.4 °	a = 0.7 (tsf)

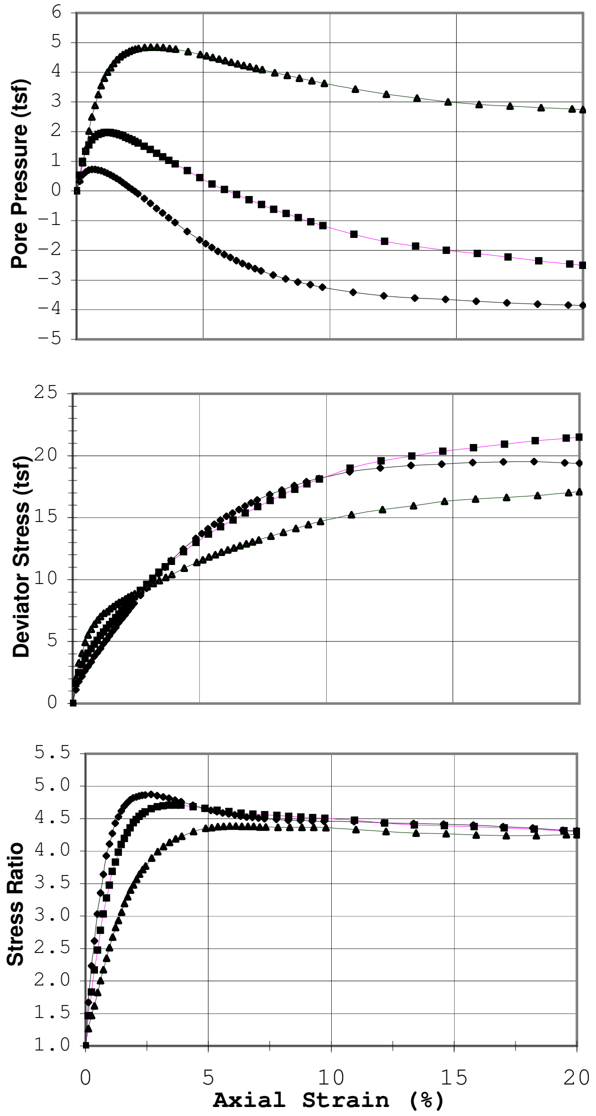


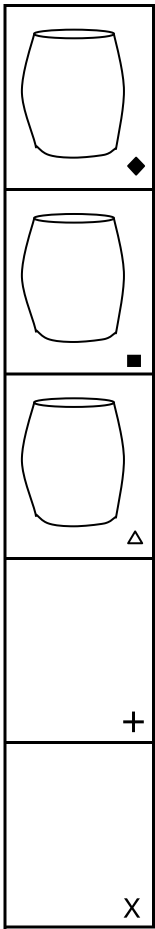
------------	Effective ϕ':	34.2 °	c'=	0.80 (tsf)
________	Total ϕ':	12.7 °	c=	3.15 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J010** Sample #: Type: **3T** Depth (ft): **5.5-8**
Soil Type: **Silty Sand w/a little gravel (SM)**





Failure Criterion: **Max. Pore Pressure**
Angle of internal friction, **φ' = 36.4 °**
Apparent Cohesion, **c' = 0.00 (tsf)**

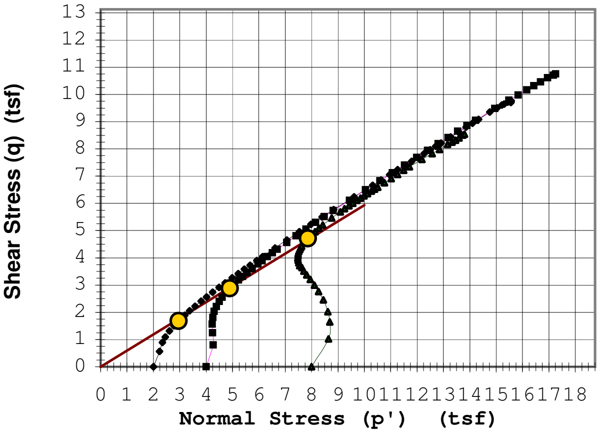
Test Date: 4/13/10
Test Type: CU w/pp
Strain Rate (in/min): 0.00206
Strain Rate (%/min): 0.050

Liquid Limit:
Plastic Limit:
Plasticity Index:
Spec. Gravity (Assumed): 2.72

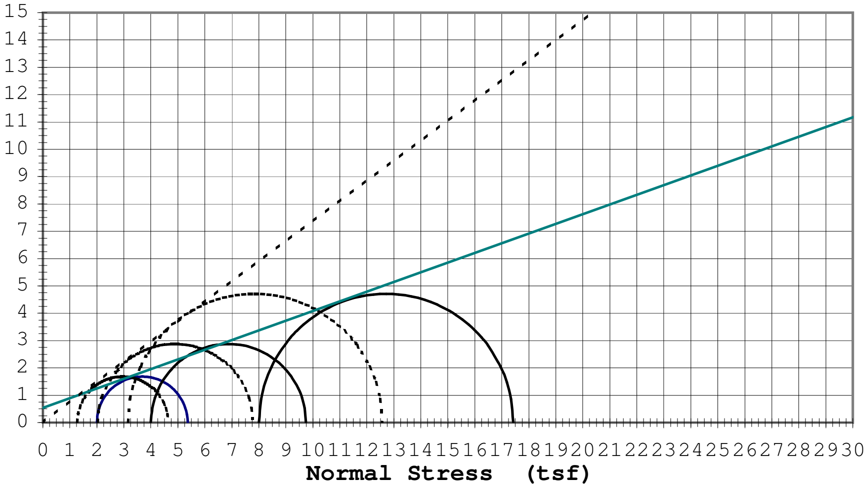
Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	4.12	4.12	4.12		
Water Content (%)	9.8	8.9	14.2		
Dry Density (pcf)	133.8	126.7	123.3		
Void Ratio	0.27	0.34	0.38		
After Consolidation					
Diameter (in)	1.93	1.92	1.90		
Height (in)	4.12	4.11	4.09		
Water Content (%)	9.3	11.1	11.1		
Dry Density (pcf)	135.6	130.5	130.4		
Void Ratio	0.25	0.30	0.30		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	19.52	21.50	17.10		
Ultimate Deviator Stress (tsf)	19.41	21.50	17.10		
Deviator Stress at Failure (tsf)	3.36	5.75	9.43		
Max. Pore Pressure Buildup (tsf)	0.73	1.97	4.85		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	0.7	1.2	2.9		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
Specimens varied in density leading to higher maximum strengths at lower consolidation pressures.



Rupture Envelope at Failure
α = 30.7 ° a = 0.0 (tsf)

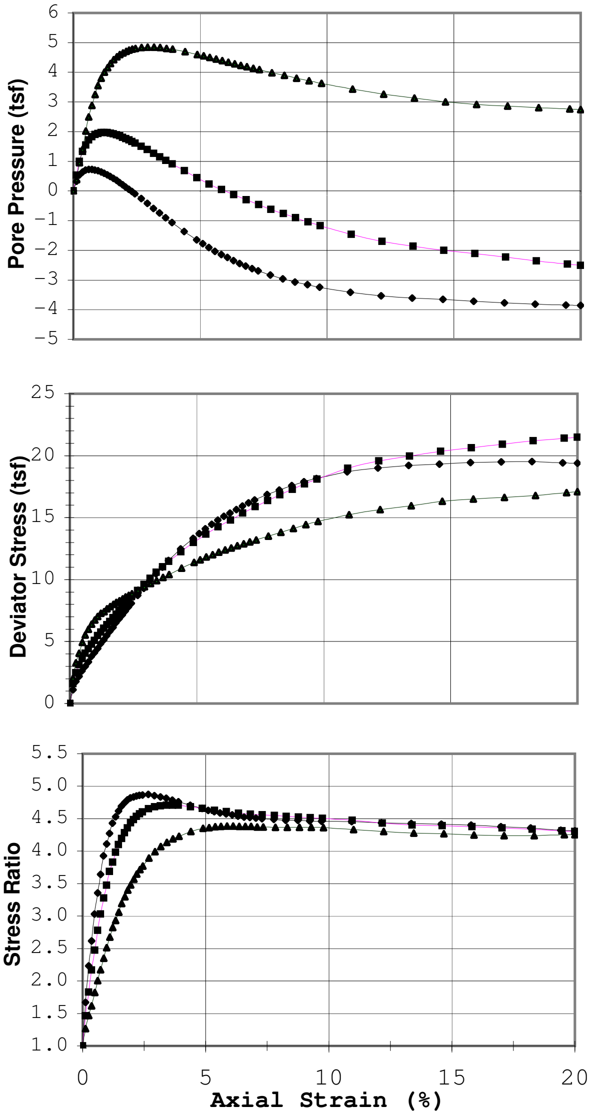


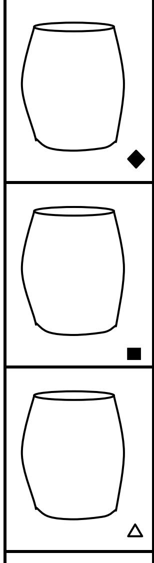
------------	Effective φ':	36.4 °	c'=	0.00 (tsf)
________	Total φ':	19.5 °	c=	0.54 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project: **PolyMet**
Boring #: **J010** Sample #: Type: **3T** Depth (ft): **5.5-8**
Soil Type: **Silty Sand w/a little gravel (SM)**





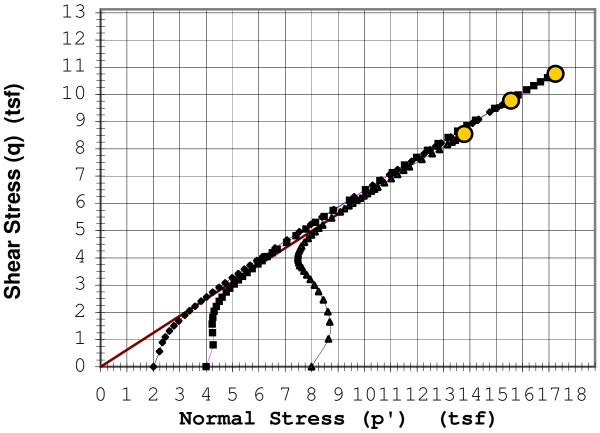
Failure Criterion: **Max. Deviator Stress**
Angle of internal friction, **ϕ' =** **38.5 °**
Apparent Cohesion, **c' =** **0.00 (tsf)**

Test Date: 4/13/10
Test Type: CU w/pp
Strain Rate (in/min): 0.00206
Strain Rate (%/min): 0.050
Liquid Limit:
Plastic Limit:
Plasticity Index:
Spec. Gravity (Assumed): 2.72

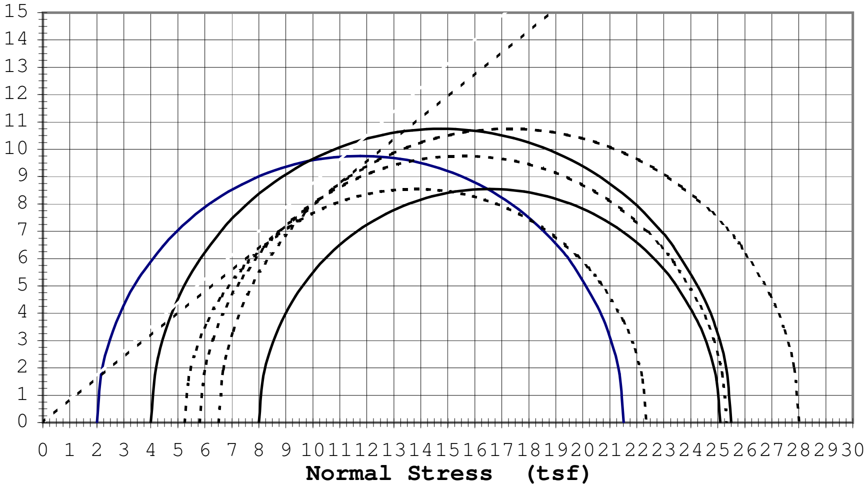
Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	4.12	4.12	4.12		
Water Content (%)	9.8	8.9	14.2		
Dry Density (pcf)	133.8	126.7	123.3		
Void Ratio	0.27	0.34	0.38		
After Consolidation					
Diameter (in)	1.93	1.92	1.90		
Height (in)	4.12	4.11	4.09		
Water Content (%)	9.3	11.1	11.1		
Dry Density (pcf)	135.6	130.5	130.4		
Void Ratio	0.25	0.30	0.30		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	19.52	21.50	17.10		
Ultimate Deviator Stress (tsf)	19.41	21.50	17.10		
Deviator Stress at Failure (tsf)	19.52	21.50	17.10		
Max. Pore Pressure Buildup (tsf)	0.73	1.97	4.85		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	18.2	20.0	20.0		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
Specimens varied in density leading to higher maximum strengths at lower consolidation pressures.



Rupture Envelope at Failure
α = 31.9 ° a = 0.0 (tsf)

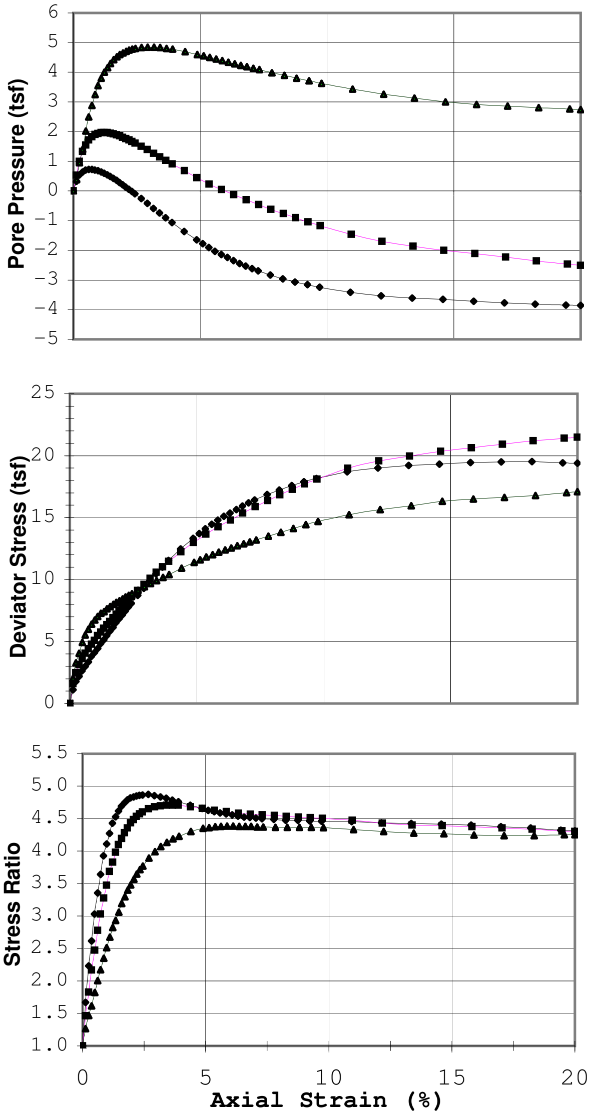


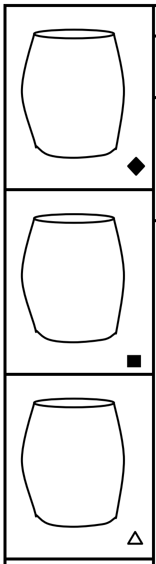
------------ Effective ϕ': 38.5 ° c'= 0.00 (tsf)
________ Total ϕ': ° c= (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/5/10**

Project:	**PolyMet**						
Boring #:	**J010**	Sample #:		Type:	**3T**	Depth (ft):	**5.5-8**
Soil Type:	**Silty Sand w/a little gravel (SM)**						



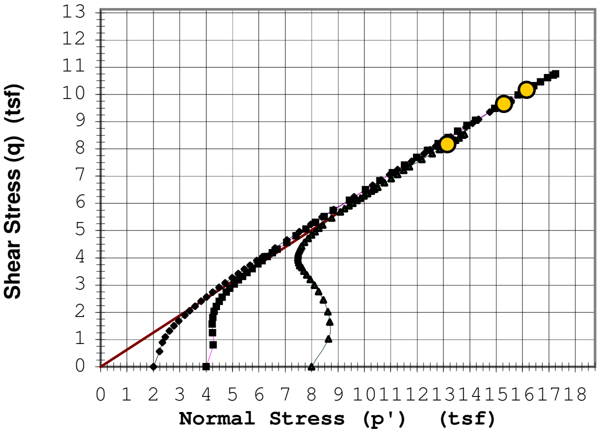


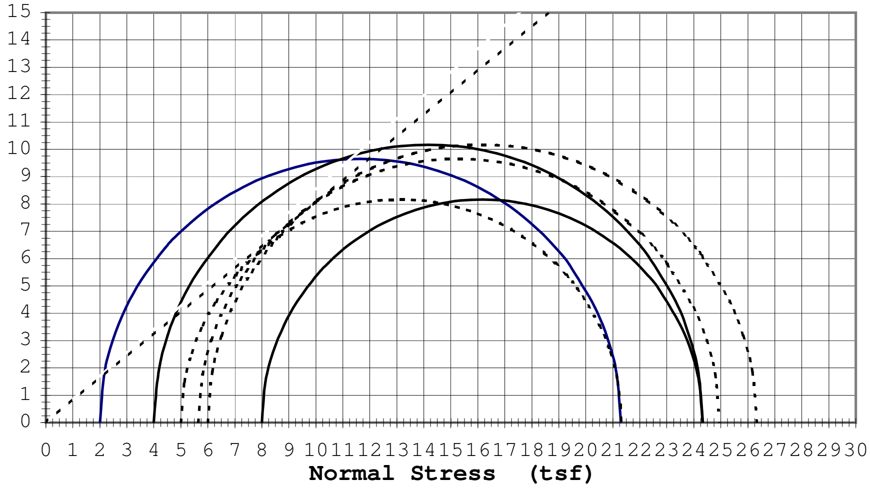
Failure Criterion:	**Given Strain of: 15%**				
Angle of internal friction, **ϕ' =**	**38.9 °**				
Apparent Cohesion, **c' =**	**0.00 (tsf)**				
Test Date:	4/13/10	Liquid Limit:			
Test Type:	CU w/pp	Plastic Limit:			
Strain Rate (in/min):	0.00206	Plasticity Index:			
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.72		

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	4.12	4.12	4.12		
Water Content (%)	9.8	8.9	14.2		
Dry Density (pcf)	133.8	126.7	123.3		
Void Ratio	0.27	0.34	0.38		
After Consolidation					
Diameter (in)	1.93	1.92	1.90		
Height (in)	4.12	4.11	4.09		
Water Content (%)	9.3	11.1	11.1		
Dry Density (pcf)	135.6	130.5	130.4		
Void Ratio	0.25	0.30	0.30		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	19.52	21.50	17.10		
Ultimate Deviator Stress (tsf)	19.41	21.50	17.10		
Deviator Stress at Failure (tsf)	19.31	20.34	16.33		
Max. Pore Pressure Buildup (tsf)	0.73	1.97	4.85		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	15.0	15.0	15.0		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.
Specimens varied in density leading to higher maximum strengths at lower consolidation pressures.





Rupture Envelope at Failure
α = 32.1 ° a = 0.0 (tsf)

------------	Effective ϕ':	38.9 °	c'=	0.00	(tsf)
________	Total ϕ':	°	c=		(tsf)

Triaxial Plot Data

Job: 7397

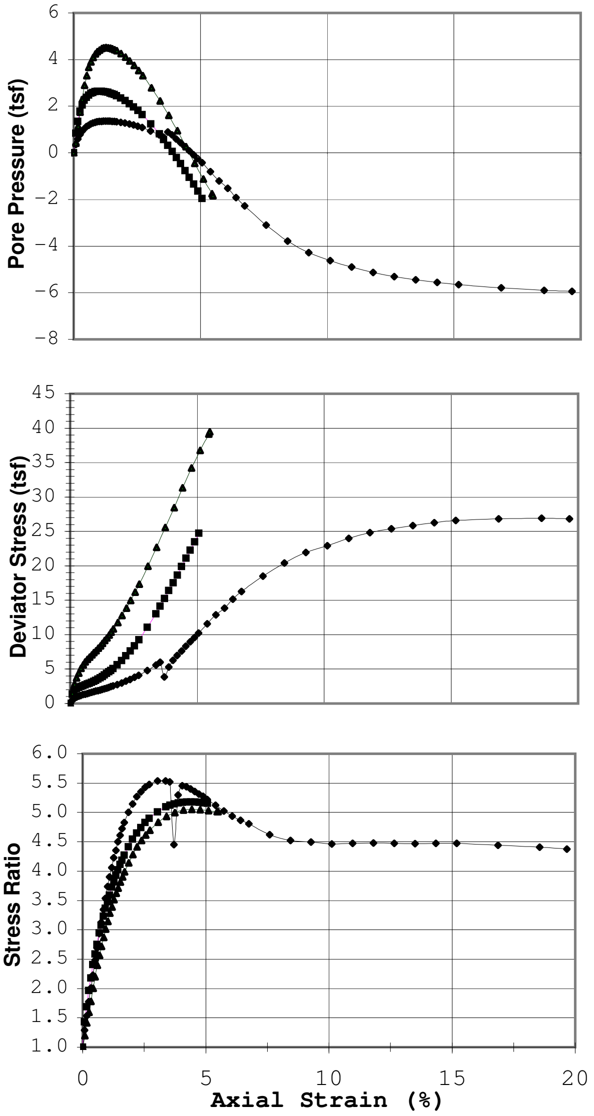
Boring: J010 Depth: 5.5-8 Date: 5/5/10

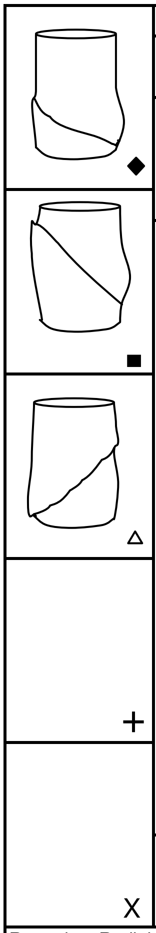
Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
0.12	1.12	0.33	0.12	1.61	0.53	0.12	2.04	0.38						
0.24	1.79	0.55	0.24	2.49	0.99	0.24	3.29	0.96						
0.36	2.20	0.64	0.37	3.13	1.33	0.37	4.05	1.41						
0.49	2.63	0.70	0.49	3.61	1.55	0.49	4.92	2.02						
0.61	3.00	0.73	0.61	4.06	1.72	0.61	5.53	2.50						
0.73	3.36	0.73	0.73	4.42	1.82	0.73	5.99	2.88						
0.85	3.79	0.71	0.85	4.79	1.90	0.86	6.41	3.25						
0.97	4.11	0.68	0.97	5.10	1.94	0.98	6.74	3.55						
1.09	4.44	0.64	1.10	5.46	1.97	1.10	7.03	3.81						
1.21	4.82	0.59	1.22	5.75	1.97	1.22	7.27	4.01						
1.34	5.13	0.55	1.34	6.07	1.96	1.35	7.42	4.16						
1.46	5.47	0.49	1.46	6.36	1.95	1.47	7.63	4.30						
1.58	5.83	0.42	1.58	6.62	1.93	1.59	7.83	4.43						
1.70	6.15	0.36	1.71	6.91	1.90	1.71	8.00	4.52						
1.82	6.52	0.28	1.83	7.20	1.85	1.83	8.16	4.60						
1.94	6.84	0.21	1.95	7.55	1.81	1.96	8.30	4.66						
2.06	7.16	0.13	2.07	7.79	1.76	2.08	8.45	4.71						
2.19	7.46	0.06	2.19	8.07	1.71	2.20	8.60	4.75						
2.31	7.80	-0.02	2.31	8.35	1.66	2.32	8.74	4.78						
2.43	8.09	-0.09	2.44	8.62	1.61	2.45	8.86	4.80						
2.67	8.72	-0.25	2.68	9.12	1.50	2.69	9.15	4.84						
2.91	9.30	-0.41	2.92	9.61	1.39	2.94	9.43	4.85						
3.16	9.91	-0.58	3.17	10.11	1.27	3.18	9.68	4.85						
3.40	10.47	-0.74	3.41	10.59	1.14	3.42	9.93	4.83						
3.64	11.00	-0.90	3.65	11.03	1.03	3.67	10.17	4.81						
3.88	11.54	-1.07	3.90	11.46	0.91	3.91	10.41	4.78						
4.37	12.48	-1.37	4.38	12.23	0.68	4.40	10.92	4.69						
4.86	13.33	-1.65	4.87	12.98	0.45	4.89	11.38	4.60						
5.10	13.71	-1.78	5.36	13.66	0.24	5.14	11.60	4.55						
5.34	14.10	-1.91	5.84	14.24	0.05	5.38	11.83	4.50						
5.58	14.47	-2.03	6.33	14.81	-0.13	5.63	12.02	4.45						
5.83	14.80	-2.14	6.82	15.36	-0.30	5.87	12.21	4.39						
6.07	15.10	-2.24	7.31	15.89	-0.47	6.11	12.39	4.34						
6.31	15.37	-2.34	7.79	16.38	-0.62	6.36	12.56	4.29						
6.56	15.65	-2.44	8.28	16.83	-0.76	6.60	12.72	4.24						
6.80	15.94	-2.53	8.77	17.29	-0.90	6.85	12.90	4.18						
7.04	16.19	-2.62	9.25	17.72	-1.04	7.09	13.04	4.13						
7.28	16.43	-2.69	9.74	18.10	-1.17	7.34	13.19	4.09						
7.77	16.87	-2.84	10.96	18.97	-1.46	7.83	13.51	3.99						
8.26	17.23	-2.96	12.18	19.57	-1.70	8.32	13.82	3.89						
8.74	17.59	-3.07	13.39	19.95	-1.86	8.81	14.12	3.81						
9.23	17.89	-3.16	14.61	20.34	-2.00	9.29	14.43	3.72						
9.71	18.16	-3.25	15.83	20.64	-2.11	9.78	14.69	3.63						
10.93	18.70	-3.41	17.05	20.91	-2.23	11.01	15.23	3.43						
12.14	19.01	-3.54	18.26	21.21	-2.35	12.23	15.66	3.26						
13.35	19.22	-3.61	19.48	21.41	-2.46	13.45	15.95	3.13						
14.57	19.31	-3.65	20.00	21.50	-2.51	14.68	16.33	3.00						
15.78	19.44	-3.72				15.90	16.49	2.92						
17.00	19.49	-3.77				17.12	16.63	2.86						
18.21	19.52	-3.81				18.35	16.80	2.81						
19.42	19.42	-3.85				19.57	17.02	2.77						
20.00	19.41	-3.86				20.00	17.10	2.75						

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/4/10**

Project:	**PolyMet**						
Boring #:	**J027**	Sample #:		Type:	**3T**	Depth (ft):	**10-12.5**
Soil Type:	**Silty Sand w/gravel (SM)**						





Failure Criterion:	**Max. Stress Ratio**
Angle of internal friction, **ϕ' =**	**41.7 °**
Apparent Cohesion, **c' =**	**0.16 (tsf)**

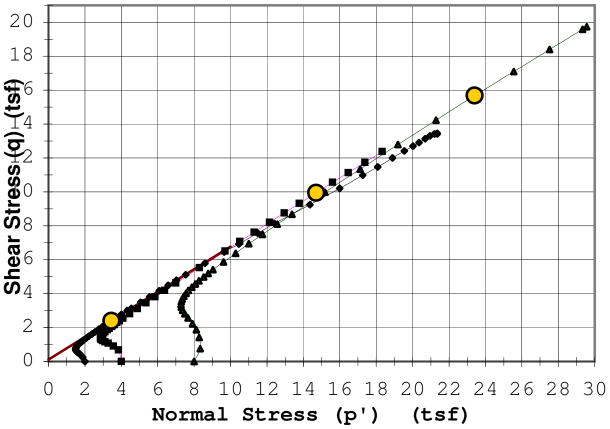
Test Date:	4/6/10	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.0297	Plasticity Index:	
Strain Rate (%/min):	0.501	Spec. Gravity (Assumed):	2.68

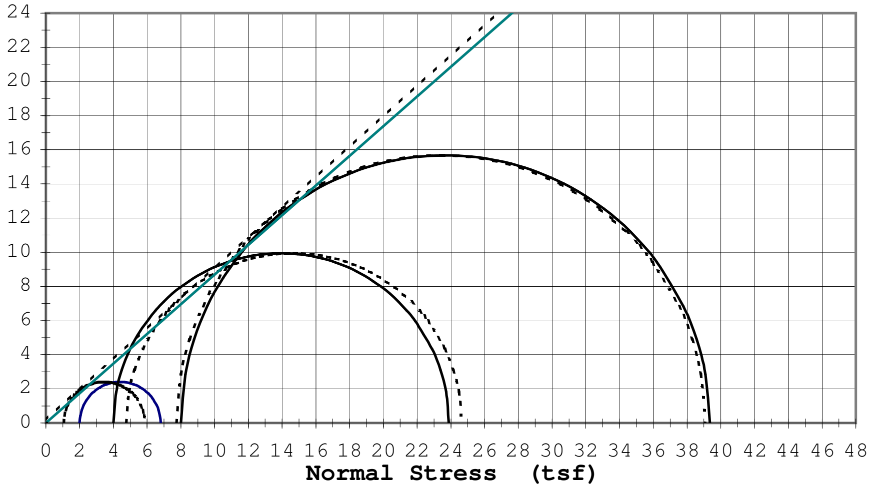
Before Consolidation	A	B	C	D	E
Diameter (in)	2.88	2.88	2.88		
Height (in)	5.98	5.98	5.98		
Water Content (%)	8.1	8.5	7.5		
Dry Density (pcf)	140.7	139.5	139.7		
Void Ratio	0.19	0.20	0.20		
After Consolidation					
Diameter (in)	2.87	2.86	2.88		
Height (in)	5.93	5.92	5.87		
Water Content (%)	6.3	6.2	6.4		
Dry Density (pcf)	143.3	143.4	142.7		
Void Ratio	0.17	0.17	0.17		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	26.92				
Ultimate Deviator Stress (tsf)	26.82				
Deviator Stress at Failure (tsf)	4.80	19.88	31.35		
Max. Pore Pressure Buildup (tsf)	1.36	2.64	4.51		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	3.0	4.4	4.4		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

Samples tripped load cell max switch on highest confinement pressures at 5% strain. Switch was also tripped for lowest load; however, triax was manually overridden and run to completion at lowest confinement.





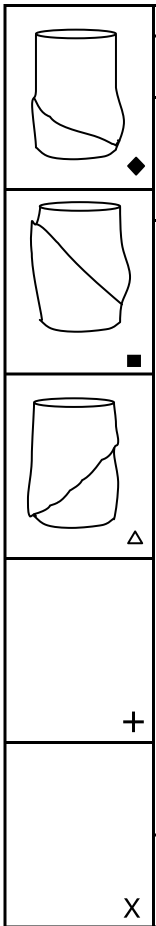
Rupture Envelope at Failure
α = 33.6 ° a = 0.1 (tsf)

------------	Effective ϕ':	41.7 °	c'=	0.16 (tsf)
________	Total ϕ':	41.0 °	c=	0.00 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/4/10**

Project: **PolyMet**
Boring #: **J027** Sample #: Type: **3T** Depth (ft): **10-12.5**
Soil Type: **Silty Sand w/gravel (SM)**



Failure Criterion: **Max. Pore Pressure**
Angle of internal friction, **ϕ' =** **33.0 °**
Apparent Cohesion, **c' =** **0.09 (tsf)**

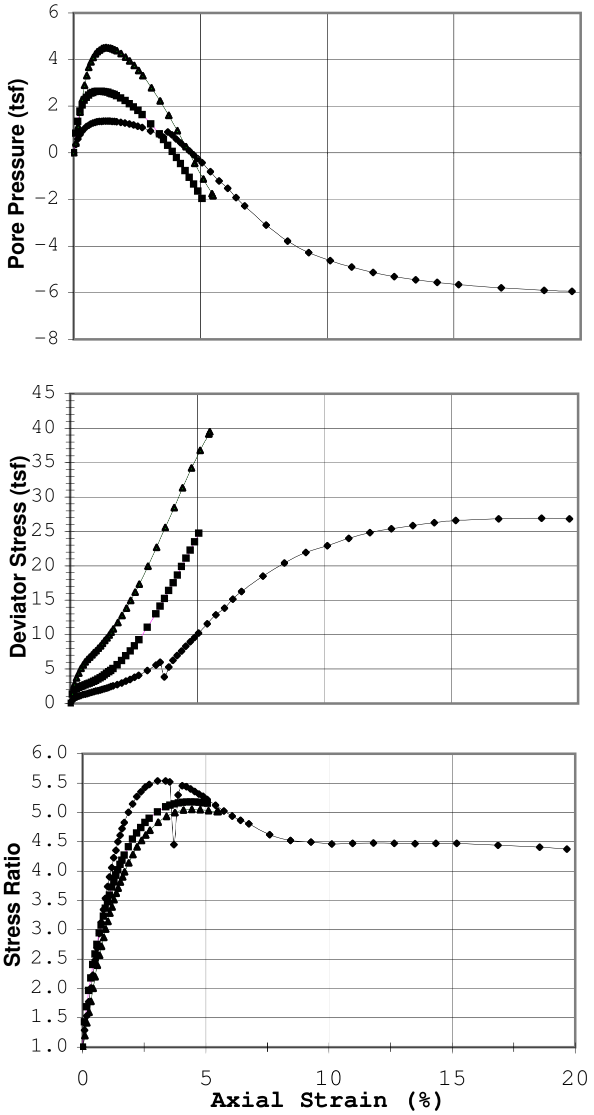
Test Date:	4/6/10	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.0297	Plasticity Index:	
Strain Rate (%/min):	0.501	Spec. Gravity (Assumed):	2.68

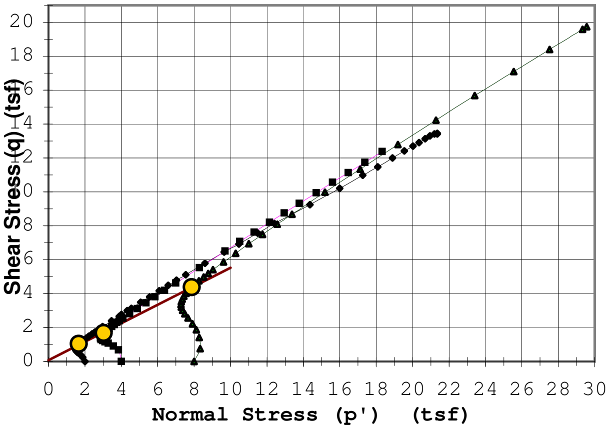
Before Consolidation	A	B	C	D	E
Diameter (in)	2.88	2.88	2.88		
Height (in)	5.98	5.98	5.98		
Water Content (%)	8.1	8.5	7.5		
Dry Density (pcf)	140.7	139.5	139.7		
Void Ratio	0.19	0.20	0.20		
After Consolidation					
Diameter (in)	2.87	2.86	2.88		
Height (in)	5.93	5.92	5.87		
Water Content (%)	6.3	6.2	6.4		
Dry Density (pcf)	143.3	143.4	142.7		
Void Ratio	0.17	0.17	0.17		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	26.92				
Ultimate Deviator Stress (tsf)	26.82				
Deviator Stress at Failure (tsf)	2.06	3.36	8.76		
Max. Pore Pressure Buildup (tsf)	1.36	2.64	4.51		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	1.3	1.0	1.3		

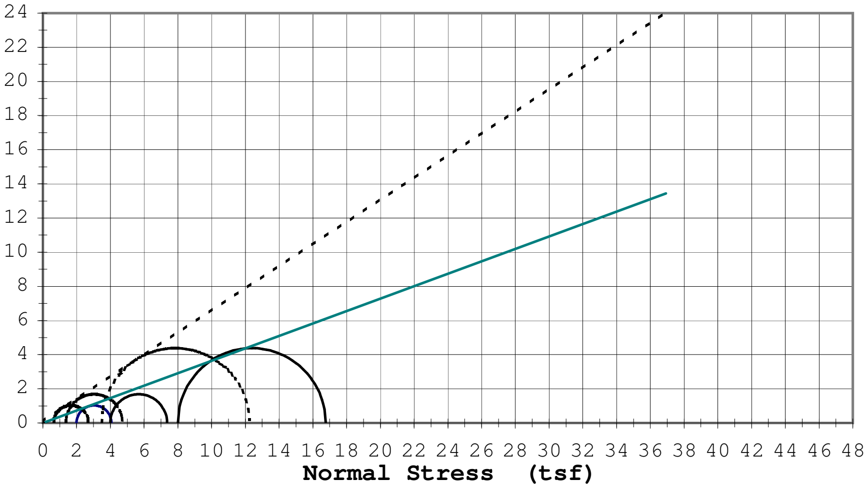
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

Samples tripped load cell max switch on highest confinement pressures at 5% strain. Switch was also tripped for lowest load; however, triax was manually overridden and run to completion at lowest confinement.







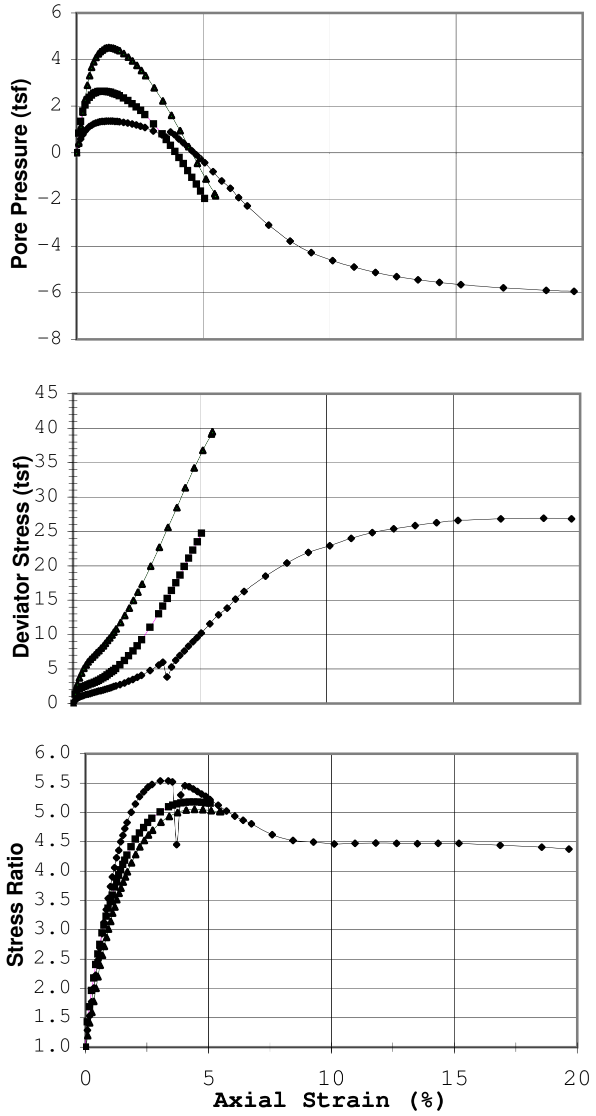
Rupture Envelope at Failure
α = 28.6 ° a = 0.1 (tsf)

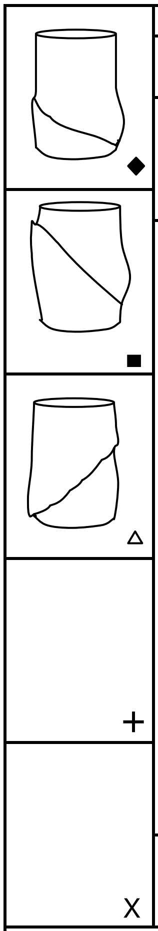
------------	Effective ϕ':	33.0 °	c'=	0.09 (tsf)
________	Total ϕ':	20.0 °	c=	0.00 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7397**
Date: **5/4/10**

Project: **PolyMet**
Boring #: **J027** Sample #: Type: **3T** Depth (ft): **10-12.5**
Soil Type: **Silty Sand w/gravel (SM)**





Failure Criterion: **Given Strain of: 5%**
Angle of internal friction, φ' = **41.7 °**
Apparent Cohesion, c' = **0.18 (tsf)**

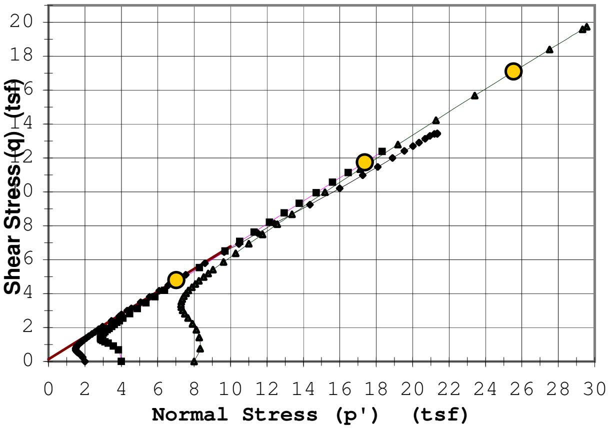
Test Date: 4/6/10
Test Type: CU w/pp
Strain Rate (in/min): 0.0297
Strain Rate (%/min): 0.501
Liquid Limit:
Plastic Limit:
Plasticity Index:
Spec. Gravity (Assumed): 2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	2.88	2.88	2.88		
Height (in)	5.98	5.98	5.98		
Water Content (%)	8.1	8.5	7.5		
Dry Density (pcf)	140.7	139.5	139.7		
Void Ratio	0.19	0.20	0.20		
After Consolidation					
Diameter (in)	2.87	2.86	2.88		
Height (in)	5.93	5.92	5.87		
Water Content (%)	6.3	6.2	6.4		
Dry Density (pcf)	143.3	143.4	142.7		
Void Ratio	0.17	0.17	0.17		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	2.00	4.00	8.00		
Max. Deviator Stress (tsf)	26.92				
Ultimate Deviator Stress (tsf)	26.82				
Deviator Stress at Failure (tsf)	9.57	23.47	34.20		
Max. Pore Pressure Buildup (tsf)	1.36	2.64	4.51		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	5.0	5.0	5.0		

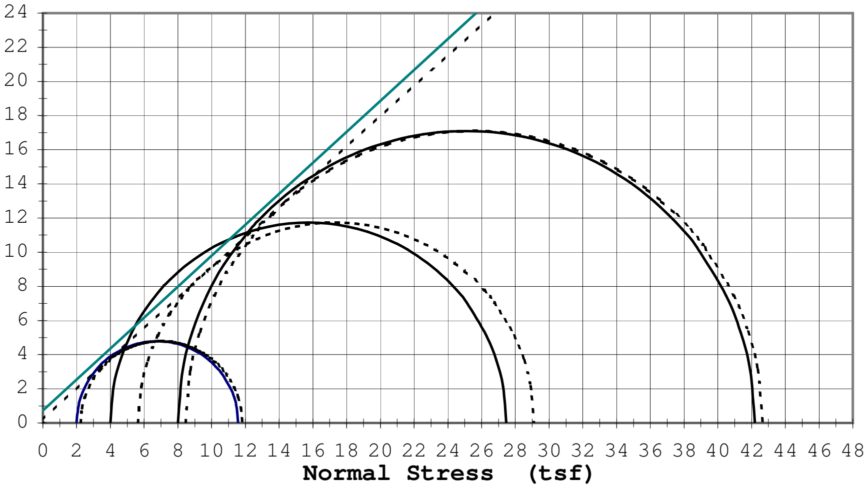
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

Samples tripped load cell max switch on highest confinement pressures at 5% strain. Switch was also tripped for lowest load; however, triax was manually overridden and run to completion at lowest confinement.



Rupture Envelope at Failure
α = 33.6 ° a = 0.1 (tsf)



------------	Effective φ':	41.7 °	c'=	0.18 (tsf)
________	Total φ':	42.2 °	c=	0.74 (tsf)

Triaxial Plot Data

Job: 7397

Boring: J027 Depth: 10-12.5

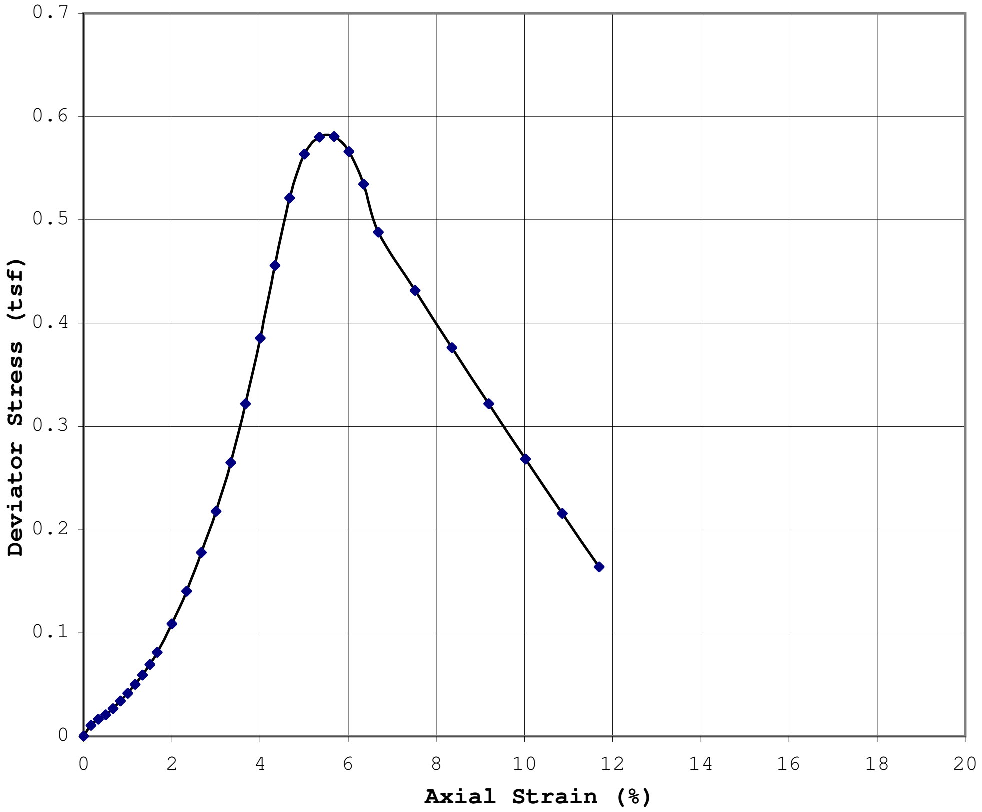
Date: 5/5/2010

Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
0.08	0.48	0.35	0.08	1.36	0.84	0.09	1.50	0.41						
0.17	0.75	0.60	0.17	1.82	1.35	0.17	2.84	1.14						
0.25	0.94	0.79	0.25	2.14	1.78	0.26	3.73	1.75						
0.34	1.08	0.93	0.34	2.31	2.04	0.34	4.44	2.30						
0.42	1.18	1.04	0.42	2.46	2.25	0.43	5.13	2.90						
0.51	1.29	1.13	0.51	2.57	2.38	0.51	5.62	3.31						
0.59	1.37	1.19	0.59	2.68	2.47	0.60	6.05	3.66						
0.67	1.46	1.24	0.68	2.82	2.55	0.68	6.41	3.91						
0.76	1.54	1.28	0.76	2.93	2.59	0.77	6.72	4.09						
0.84	1.63	1.31	0.85	3.07	2.62	0.85	7.05	4.24						
0.93	1.70	1.33	0.93	3.22	2.64	0.94	7.37	4.34						
1.01	1.80	1.34	1.01	3.36	2.64	1.02	7.68	4.41						
1.10	1.88	1.35	1.10	3.52	2.64	1.11	8.05	4.47						
1.18	1.97	1.36	1.18	3.73	2.63	1.19	8.36	4.50						
1.27	2.06	1.36	1.27	3.90	2.62	1.28	8.76	4.51						
1.35	2.15	1.36	1.35	4.12	2.59	1.36	9.15	4.51						
1.43	2.25	1.36	1.44	4.35	2.56	1.45	9.51	4.49						
1.52	2.34	1.35	1.52	4.59	2.53	1.53	9.96	4.46						
1.60	2.44	1.34	1.61	4.80	2.49	1.62	10.38	4.43						
1.69	2.55	1.33	1.69	5.08	2.45	1.70	10.83	4.38						
1.86	2.76	1.31	1.86	5.63	2.35	1.88	11.74	4.26						
2.02	2.99	1.28	2.03	6.24	2.24	2.05	12.77	4.11						
2.19	3.24	1.24	2.20	6.91	2.11	2.22	13.87	3.93						
2.36	3.49	1.20	2.37	7.62	1.96	2.39	14.99	3.74						
2.53	3.80	1.14	2.54	8.39	1.81	2.56	16.19	3.52						
2.70	4.11	1.08	2.71	9.25	1.63	2.73	17.36	3.31						
3.04	4.80	0.94	3.04	11.06	1.24	3.07	19.95	2.79						
3.37	5.56	0.77	3.38	13.03	0.82	3.41	22.68	2.23						
3.54	5.98	0.68	3.55	14.14	0.57	3.75	25.58	1.60						
3.71	3.84	0.89	3.72	15.24	0.32	4.09	28.46	0.95						
3.88	5.30	0.77	3.89	16.40	0.06	4.43	31.35	0.26						
4.05	6.28	0.59	4.06	17.50	-0.20	4.77	34.20	-0.46						
4.22	6.97	0.43	4.23	18.64	-0.46	5.12	36.78	-1.13						
4.39	7.63	0.27	4.39	19.88	-0.76	5.46	39.15	-1.75						
4.55	8.34	0.09	4.56	21.11	-1.06	5.50	39.46	-1.83						
4.72	8.97	-0.08	4.73	22.26	-1.34									
4.89	9.57	-0.24	4.90	23.47	-1.64									
5.06	10.22	-0.42	5.07	24.74	-1.96									
5.40	11.57	-0.81												
5.74	12.90	-1.20												
6.07	13.87	-1.52												
6.41	15.14	-1.92												
6.75	16.26	-2.27												
7.59	18.50	-3.11												
8.43	20.41	-3.79												
9.28	21.96	-4.28												
10.12	22.93	-4.62												
10.97	23.99	-4.90												
11.81	24.81	-5.13												
12.65	25.40	-5.31												
13.50	25.83	-5.45												
14.34	26.25	-5.55												
15.18	26.59	-5.65												
16.87	26.82	-5.79												
18.56	26.92	-5.90												
19.66	26.82	-5.95												

Unconfined Stress/Strain Curves

ASTM: D2166

Project: PolyMet
Client: Barr Engineering Company
Remarks:
Job: 7397
Date: 5/5/10



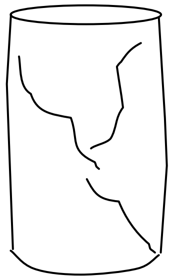
Boring: J003T
Depth: 5 - 7 (Top)
Sample #:
Soil Type: Silty Clay (CL/CL-ML)

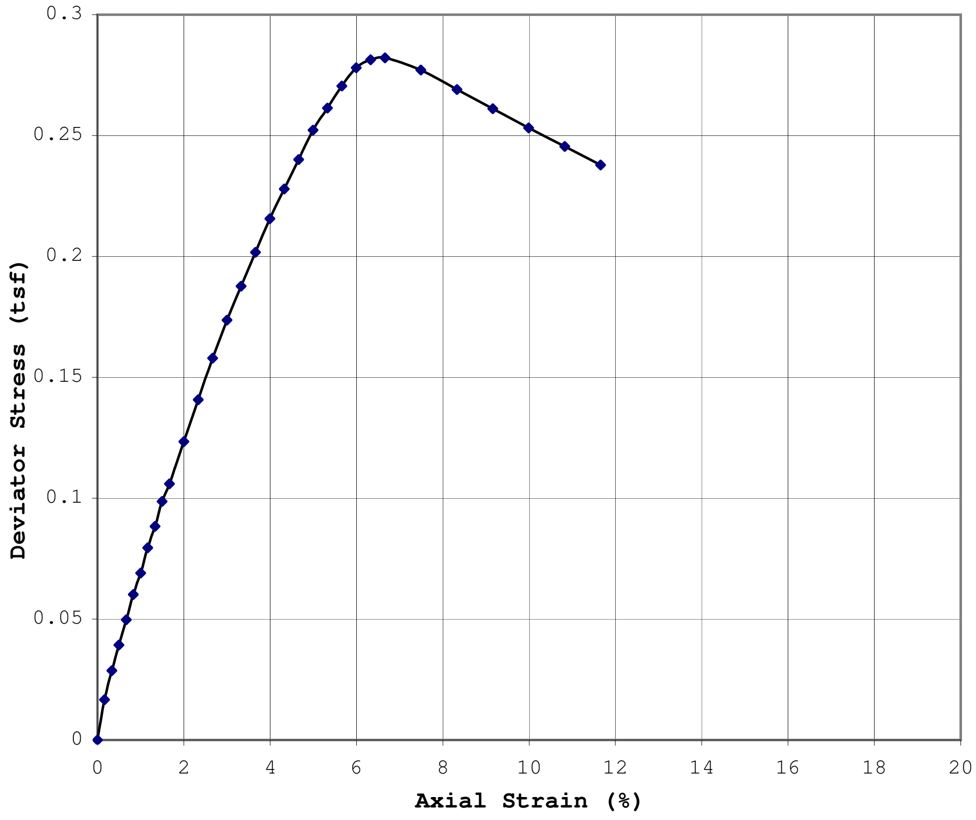
Strain Rate (in/min): 0.050
Sample Type: 3T
Dia. (in) 2.86
Ht. (in) 5.99
Height to Diameter Ratio: 2.09

Unconfined Comp. Strength: 0.58 tsf
Strain at Failure (%): 5.68

W.C. (%): 21.8
Yd (pcf): 105.2

Sketch of Specimen After Failure





Boring: J027
Depth: 4.5 - 6.5 (Top)
Sample #:
Soil Type: Sapric Peat (PT)

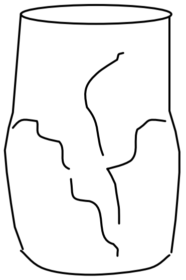
Strain Rate (in/min): 0.050
Sample Type: 3T

Dia. (in): 2.84
Ht. (in): 6.01
Height to Diameter Ratio: 2.11

Unconfined Comp. Strength: 0.28 tsf
Strain at Failure (%): 6.66

W.C. (%): 310.0
Yd (pcf): 16.9

Sketch of Specimen After Failure



Hydraulic Conductivity Test Data

Project: PolyMet

Date: 5/5/2010

Reported To: Barr Engineering Company

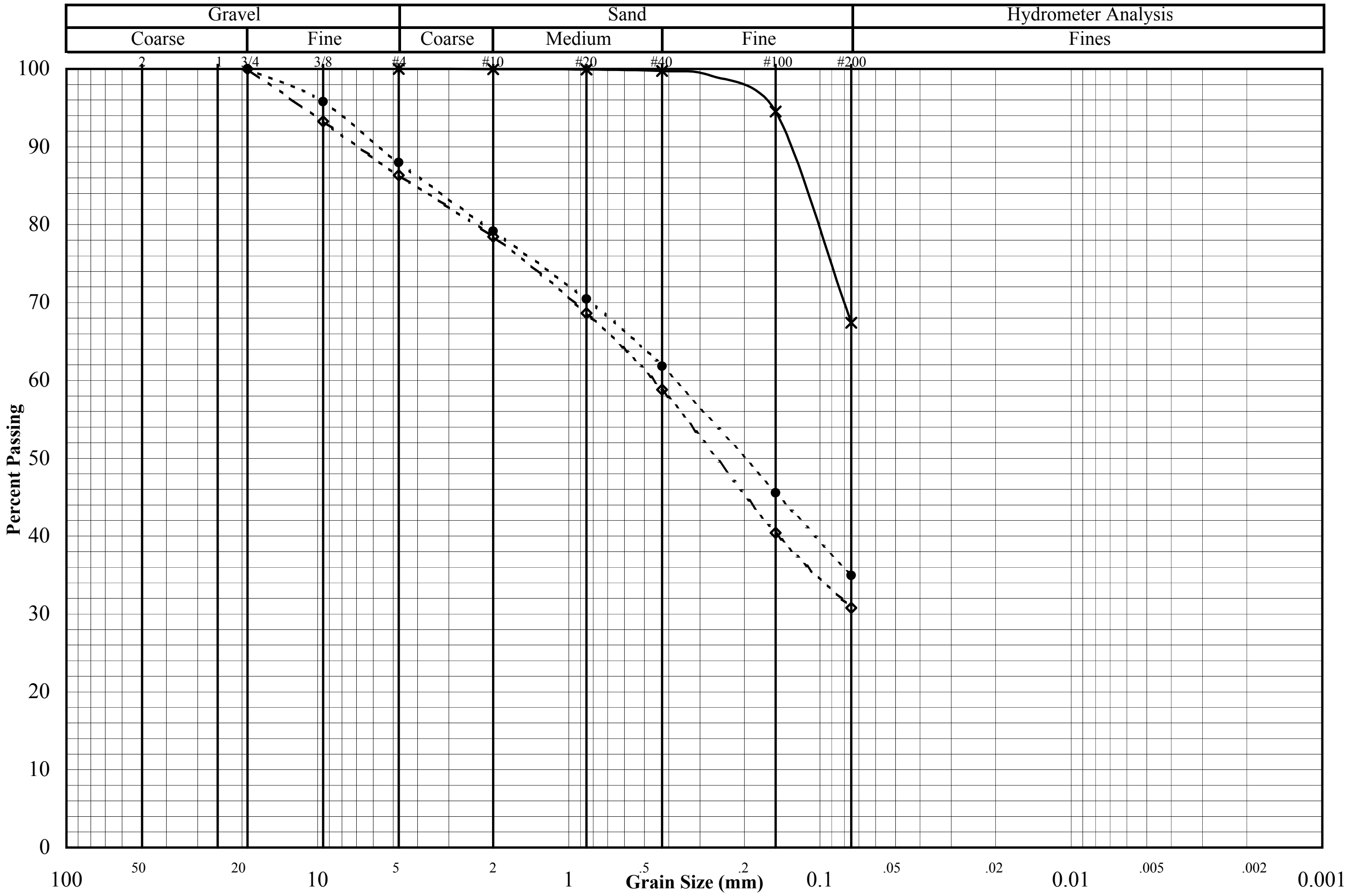
Job No.: 7397

	Boring No.:	J003	J010	J010	J027			
	Sample No.:							
	Depth (ft)	10-13	5.5-8 (mid)	14-16.5 (mid)	4.5-6.5			
	Location:							
	Sample Type:	3T	3T	3T	3T			
	Soil Type:	Silty Clayey Sand w/gravel, gray (SC-SM/SM)	Silty Sand w/a little gravel (SM/SC-SM)	Silty Sand w/gravel (SM/SC-SM)	Sapric Peat w/a few pieces of stems and wood (PT)			
	Atterberg Limits							
	LL							
	PL							
	PI							
	Permeability Test	Undisturbed	Undisturbed	Undisturbed	Undisturbed			
Before Test Conditions:	Saturation %:							
	Porosity:							
	Ht. (in):	3.31	2.87	3.00	3.42			
	Dia. (in):	2.89	2.87	2.86	2.82			
	Dry Density (pcf):	134.2	134.7	138.1	16.0			
	Water Content:	9.0%	11.2%	8.1%	327.6%			
	Test Type:	Falling	Falling	Falling	Falling			
	Max Head (ft):	5.0	5.0	5.0	5.0			
	Confining press. (Effective-psi):	2.0	2.0	2.0	2.0			
	Trial No.:	12-16	3-7	6-10	7-11			
	Water Temp °C:	22.0	22.0	22.0	21.0			
	% Compaction							
	% Saturation (After Test)	99.4%	99.1%	99.4%				
	Coefficient of Permeability							
	K @ 20 °C (cm/sec)	**3.1×10^{-7}**	**4.7×10^{-7}**	**9.4×10^{-7}**	**3.6×10^{-7}**			
	K @ 20 °C (ft/min)	**6.2×10^{-7}**	**9.3×10^{-7}**	**1.8×10^{-6}**	**7.0×10^{-7}**			
	Notes:							

Grain Size Distribution ASTM D422

Job No. :	**7397**		
Project:	PolyMet	Test Date:	4/29/10
Reported To:	Barr Engineering Company	Report Date:	5/3/10

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
⁎	J003		4.5-6	Jar	Sandy Silty Clay (CL-ML/CL)
●	J003		19.5-21	Jar	Clayey Sand w/a little gravel (SC)
◇	J010		4.5-6	Jar	Silty Sand w/a little gravel (SM)



Other Tests

	⁎	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content	25.0	8.1	8.2
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	⁎	●	◇
Mass (g)	144.6	301.1	229.3
2"			
1.5"			
1"			
3/4"		100.0	100.0
3/8"		95.8	93.2
#4	100.0	88.0	86.3
#10	100.0	79.2	78.5
#20	99.9	70.5	68.6
#40	99.7	61.8	58.8
#100	94.5	45.5	40.4
#200	67.4	34.9	30.8

	⁎	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

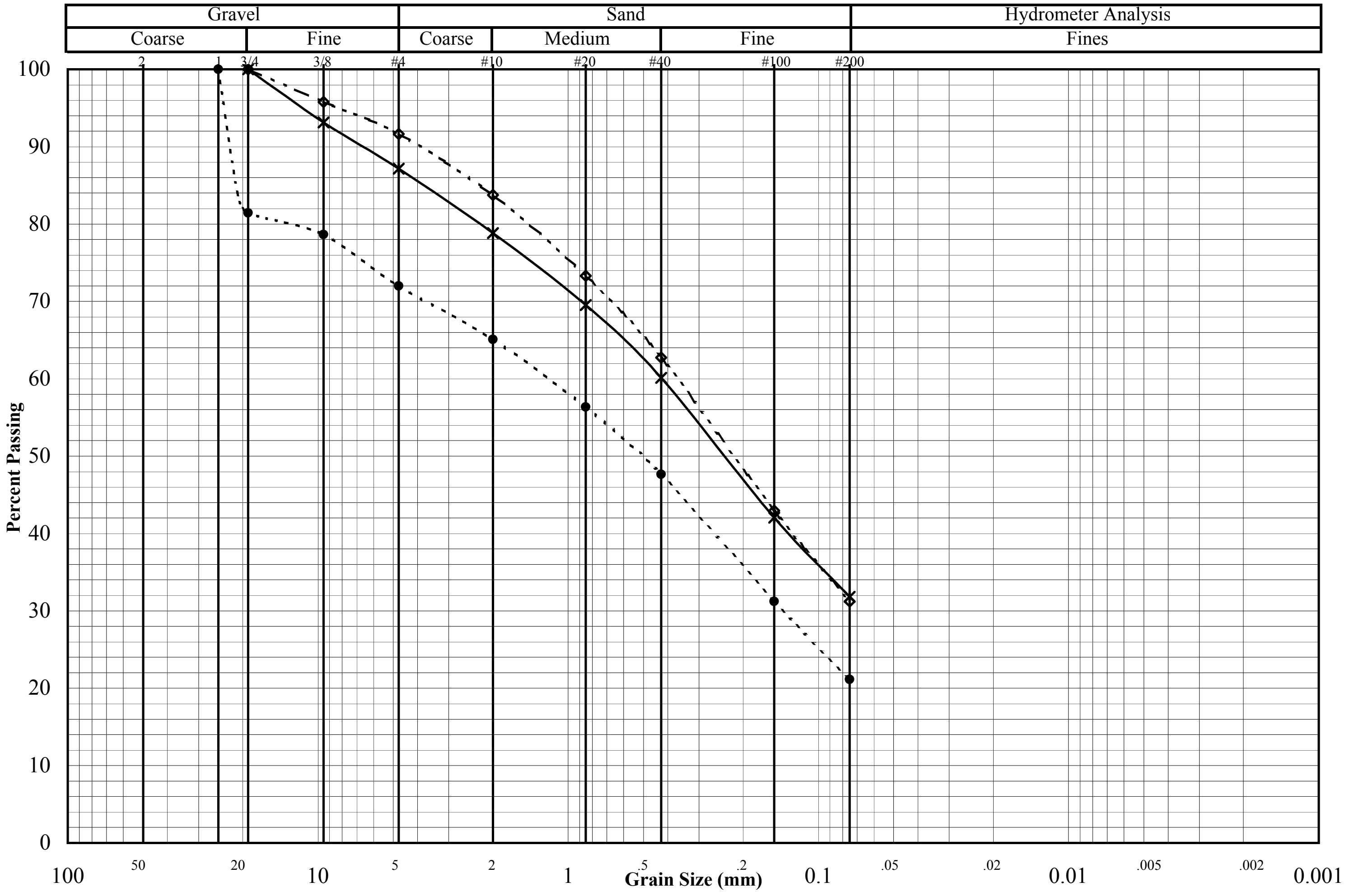
Remarks:

Grain Size Distribution ASTM D422

Job No. : **7397**

Project:	PolyMet	Test Date:	4/29/10
Reported To:	Barr Engineering Company	Report Date:	5/3/10

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
✱	J010		9.5-11	Jar	Silty Sand w/a little gravel (SM)
●	J027		12-13.5	Jar	Silty Sand w/gravel (SM)
◇	J027		22-23.5	Jar	Silty Sand w/a little gravel (SM)



Other Tests

	✱	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content	7.8	7.1	6.6
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	✱	●	◇
Mass (g)	298.1	247.9	277.7
2"			
1.5"			
1"		100.0	
3/4"	100.0	81.5	100.0
3/8"	93.1	78.7	95.8
#4	87.1	72.0	91.7
#10	78.8	65.1	83.8
#20	69.5	56.3	73.3
#40	60.1	47.6	62.7
#100	42.1	31.2	42.9
#200	31.8	21.1	31.2

	✱	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **7397**

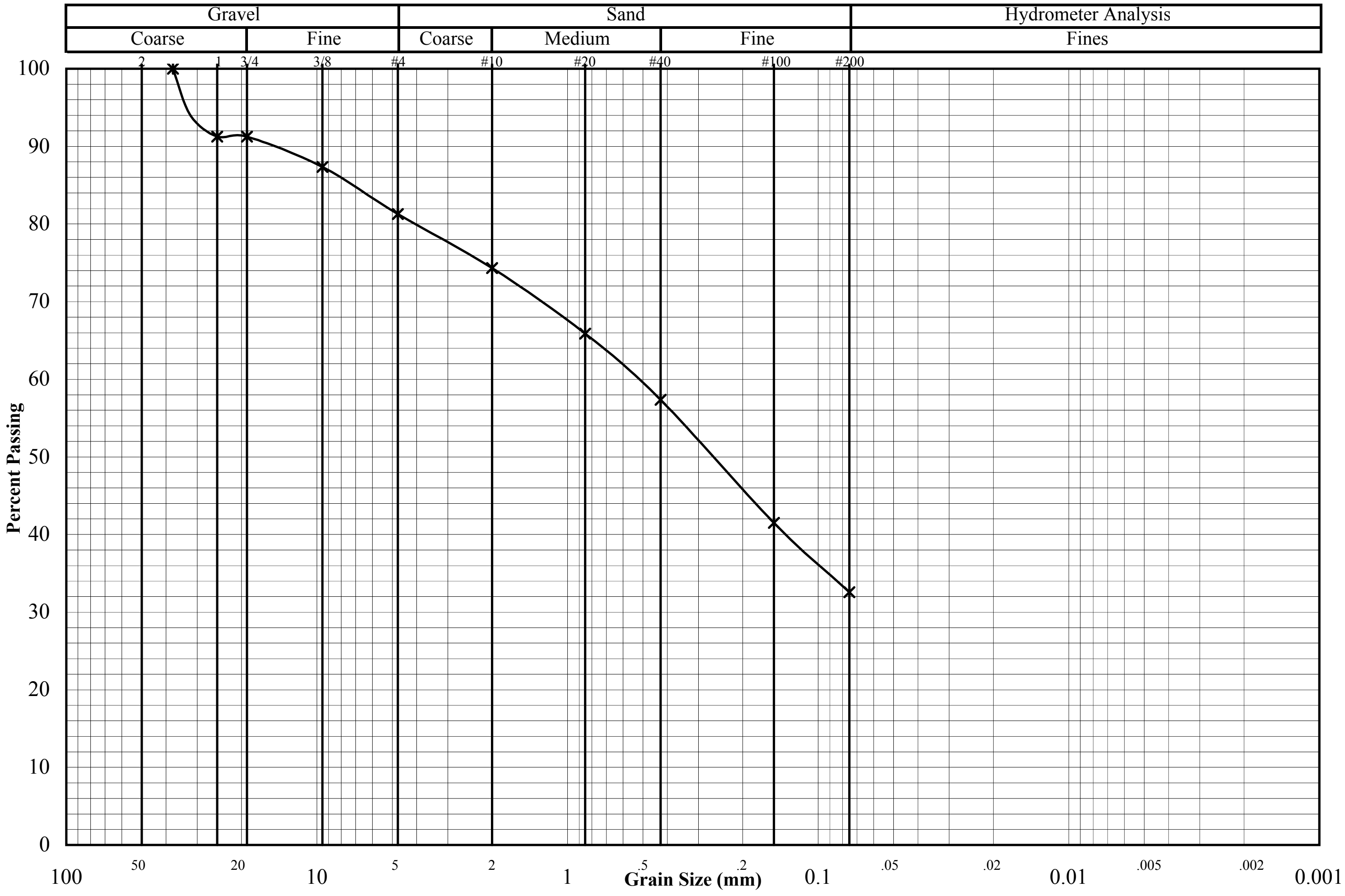
Project: PolyMet

Test Date: 4/29/10

Reported To: Barr Engineering Company

Report Date: 5/3/10

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
∗	J037		9.5-11	Jar	Silty Sand w/gravel (SM)
●					
◇					



Other Tests

	∗	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content	8.4		
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	∗	●	◇
Mass (g)	360.4		
2"			
1.5"	100.0		
1"	91.2		
3/4"	91.2		
3/8"	87.4		
#4	81.3		
#10	74.3		
#20	65.9		
#40	57.3		
#100	41.5		
#200	32.6		

	∗	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Laboratory Test Summary

Project: **Polymet** **Job:** **7397**

Client: **Barr Engineering Company** **Date:** **5/3/10**

Sample Information & Classification

Boring No.	J003	J027				
Sample No.						
Depth	0-2	4.5-6				
Sample Type	Jar	Jar				
Classification	Sapric Peat (PT)	Sapric Peat w/a few pieces of stems and wood (PT)				
Moisture Content (%)	328.7	287.3				

Organic Content (ASTM:D2974)

Organic Content (%)	40.6	52.8				

Attachment F

Depth to Bedrock Boring ID and Coordinate Location

Table 1
Depth to Bedrock Data - Category 1 Stockpile

ID	Easting	Northing	Depth (ft)
26024	2899039.8	736964	40
07-551C	2897364.3	735116.6	17.6
10-571C	2895923.4	734404.5	30.4
10-572C	2896441.8	734404.9	11.7
10-573C	2898280.8	737636.9	9.5
10-574C	2897307.4	735649	17.7
MW-05-09	2898244.9	737485	13
SB-05-10	2898269	738706	4
TGP-4	2896257.1	734678.1	13.5
TGP-5	2895791.3	734529.8	14
TGP-6	2895633.1	735044.8	20
V06-126	2903006.8	740029.6	19
V06-128	2902328.4	739385.5	17
V06-131	2901635.8	739460.1	12
V06-132	2901651.5	740054.1	17
V06-136	2900980.5	738724.1	17
V06-137	2901002.6	739383.7	11
V06-138	2901064.1	739987.6	9
V06-140	2900373.5	738680.6	7
V06-141	2900395.6	739320.6	8
V06-144	2899740.1	738699.5	9
V06-145	2899745.8	739339.4	7
V06-65	2895040.6	733961.1	17
V06-66	2894289.1	733983	15
V06-67	2894284.9	734606.5	13
V06-70	2895664.2	733902.8	28
V06-72	2896411.4	734609.4	19
V06-73	2895535.3	734559	13
V06-74	2895036.4	734669.9	10
V06-75	2896998	735259.9	4
V06-78	2895002.7	735273.7	18
V06-79	2896983.9	735968.8	9
V06-80	2896344.1	735918.7	21
V06-82	2895031.4	735900.5	21
V06-83	2894388.2	735922.6	13
V06-84	2894346.5	735203.9	27
V06-85	2896399	736555.4	6
V06-86	2895690.2	736557.7	11
V06-87	2895043.7	736550.3	16
V06-89	2896293.1	737208.3	7
V06-90	2896936.3	737202.6	5
V06-91	2896943.8	736543	10
V06-92	2897554.1	736583.2	7
V06-93	2897594.4	735881	8
V06-94	2898224.5	735826	6
V06-95	2897588.7	735241	18
V06-96	2898243.3	736515.2	23
V06-98	2898091.5	737122.1	30

Table 1
Depth to Bedrock Data - Category 1 Stockpile

ID	Easting	Northing	Depth (ft)
V07-01	2899023.2	737353	23
V07-02	2898514.5	737381.9	38
V07-03	2899061.7	738058.6	8
V07-04	2898428.3	738084.1	5
V07-05	2897726	738056.9	14
V07-06	2897023.8	738003.4	9
V07-11	2898325.7	738674.6	6
V07-12	2899051	738695.3	11
V07-63	2900915.3	738386	8

Table 2

Depth to Bedrock Data - Category 2/3 Stockpile

ID	Easting	Northing	Depth (ft)
RS-17B	2907889.1	737407.6	11
TGP-10	2909310.1	738095.3	8
TGP-11	2910688.5	738008.6	6
TGP-12	2909910.3	738355.4	5
TGP-13	2909796.2	737784.2	9
TGP-14	2909274.6	737622.7	3.5
TGP-15	2907926.4	737200.9	11.5
TGP-8	2908447.1	738022	4.5
TGP-9	2908811.7	737792.8	8.5
V06-01	2907933.1	737148.4	7
V06-02	2908129.2	737729.5	1.5
V06-03	2908513.2	737697.2	1
V06-05	2909041.7	737533.8	18
V06-06	2909041.1	738012.9	2
V06-07	2909056.9	738456	5
V06-101	2912232.7	739073.9	3
V06-102	2912313.9	739684.4	1
V06-110	2908769	737819	2
V06-117	2908673.8	737815.6	5
V06-12	2909786.3	737774.4	9
V06-13	2909749.7	738200.9	16
V06-16	2910334.1	737965.5	9
V06-17	2910399	738513.6	2
V06-30	2911731.7	738223.3	1
V06-31	2911780	738912.5	1
V06-32	2911071.3	738842.6	4.5
V06-33	2911003.2	738222.3	6
V06-37	2912981.5	738638.4	3
V06-38	2912944.6	739173.3	24
V06-39	2912963.5	739757.4	16
V06-54	2912322	738499.7	1

Table 3
Depth to Bedrock Data - Category 4 Stockpile

ID	Easting	Northing	Depth (ft)
26013	2903513.3	738815.5	8.7
26033	2903830.1	738320	8
26038	2902726.9	738789.4	9
26046	2903147.7	738180	5
26060	2903516.8	738812	10
00-327C	2903150.4	738883	5
00-329B	2902373	738564	13
00-330C	2903328.7	738664.9	5
00-333B	2902433.3	738668	10
00-335B	2902623.2	738332.7	17
00-336B	2902833.4	738642	11
00-338B	2902900.8	738360	11
00-343C	2903797.2	739094	7
00-357C	2902886.5	738494	5
05-447G	2902809.4	737893.4	10.8
07-557C	2903638.4	738135	9
99-301B	2902879.4	738507	8.5
99-302B	2904215.9	738942	9
99-303B	2902503.6	738527	14
99-305BC	2903421.5	738283.3	9
99-306B	2904003.4	738854	11
99-314B	2903067.8	739052	7
99-315B	2903635.2	739307	28
99-316B	2903380.4	739094	15
99-318C	2903736.5	738538	10
99-320C	2903377.2	738396	10
RS-05A	2902806.1	737941.6	13
RS-12	2903622.1	739320.2	22
V07-09	2903297.4	738671.4	5

Table 4
Depth to Bedrock Data - Ore Surge Pile

ID	Easting	Northing	Depth (ft)
26075	2905238	736082	6
RS-18A	2904940.5	736178.5	8
V06-23	2905971.6	736459.9	8.5
V06-24	2905987.3	736948.9	8
V07-77	2905558.9	735875.2	9

Attachment G

Underdrain Design Computations

OBJECTIVE:

The objective is to estimate the required underdrain pipe sizes capable of accommodating seepage flows due to consolidation of subgrade materials when subjected to waste rock loading. Four cases were analyzed:

- Case 1: A double drained layer assuming relatively pervious fractured bedrock and a hydraulic conductivity of subgrade soils of $1x10^{-7}$ cm/sec.
- Case 2: A single drained layer assuming impervious bedrock surface and a hydraulic conductivity of subgrade soils of $1x10^{-7}$ cm/sec.
- Case 3: A double drained layer with a hydraulic conductivity of subgrade soils of $1x10^{-5}$ cm/sec.
- Case 4: A single drained layer with a subgrade soils hydraulic conductivity of $1x10^{-5}$ cm/sec.

GIVEN:

- Maximum depth to bedrock (see Attachment 2).
- Maximum height of stockpile fill year 1, year 5 and year 20 (see Attachment 2).
- Underdrain pipe layout configuration.

GEOMETRY:

- Figure 1 shows the depth to bedrock isopach map and site layout.

MATERIAL PROPERTIES:

- The parameters presented in Table 1 were used for the underdrain calculations.

Table 1
Material Parameters

Case	Parameter	Value
1 and 2	Consolidation coefficient (C_v) (m^2/day) [1]	0.075
1 thru 4	Rock waste unit weight (kN/m^3)[1]	19.98
1 thru 4	Manning (ASD N-12)[2]	0.012

[1] per Golder (2006)
[2] ASD (2007)

METHOD:

Flow Rate Calculation

The seepage flow from the compressible soil layer can be calculated from Darcy's equation:

$$v = -K_s \frac{\partial h}{\partial z} \quad (1)$$

where: v = water flux;
K_s = coefficient of permeability; and
$\partial h/\partial z$ = hydraulic gradient in the z direction.

The pressure head can be calculated from the developed pore water pressure:

$$h = \frac{u}{\gamma_w} \quad (2)$$

where: h = total head;
u = average pressure; and
γ_w = water unit weight

One can utilize Terzaghi's consolidation theory to determine the pore pressure distribution within a compressible soil layer as:

$$u = \sum_{n=1}^{n=\infty} \left(\frac{1}{H} \int_0^{2H} u_i \sin \frac{n\,\pi\,z}{2H}\, dz \right) \sin\left(\frac{n\,\pi\,z}{2H}\right) \exp\left(\frac{-n^2 \pi^2 T_v}{4}\right) \quad (3)$$

where: u = pore pressure;
H = length of the longest drainage path;
n = 2m + 1
z = location of point of evaluation in the z direction; and
T_v = nondimensional time factor is equal to C_v t / H^2, where C_v is the coefficient of consolidation and t is time.

For the case of a constant water pressure with depth, Equation 3 can be simplified to (Das 1997):

$$u_{(z,t)} = \sum_{m=0}^{m=\infty} \frac{2u_0}{M} \sin\left(\frac{M\,z}{H}\right) \exp(-M^2\,T_v) \qquad (4)$$

where: u_0 = initial water pore pressure
M = (2m + 1) $\pi/2$

Combining Equations 1, 2, and 4, one obtains the expression for Darcy's velocity as:

$$v_{(z,t)} = -\frac{Ks}{\gamma_w} \sum_{m=1}^{m=\infty} \frac{2\,u_0}{H} \cos\left(\frac{M\,z}{H}\right) \exp(-M^2\,T_v) \qquad (5)$$

For Case 1, where a double drained layer is assumed, the length of the longest drainage path (H) is equal to half of the total layer thickness. For Case 2, where a single drainage path is considered, the length of the longest drainage path (H) is equal to the total thickness of the compressible layer.

A flow rate reporting to a single underdrain pipe can be approximated as:

$$q = v_{(0,t)}\,A \qquad (6)$$

where: q = flow rate;
$v_{(0,t)}$ = water flux at z=0; and
A= loading area reporting to a single underdrain pipe;

Equation 6 was used to determine required underdrain pipe capacities.

Selection of Equivalent Loading Time

Equations 5 and 6 assume instantaneous loading scenarios. In reality, the waste rock stockpiles are loaded gradually. Therefore, underdrain flows were determined for an equivalent loading time, the time expected to provide an estimate of a maximum seepage flow reporting to an underdrain pipe over the loading area under consideration. The following procedure was used to calculate the equivalent loading time in (days):

- Estimate the waste rock stockpile footprint;
- Calculate the area per day required to cover the waste rock stockpile footprint for the years 1, 5, 10, 15, and 20. The following equation was used:

$$area\ per\ day = \frac{waste\ rock\ stockpile\ total\ area\ for\ the\ evaluated\ year}{number\ of\ days\ required\ to\ cover\ the\ area\ for\ the\ evaluated\ year}$$

- Estimate the tertiary underdrain pipe tributary area (i.e., loading area reporting to a single tertiary pipe).

$$tributary\ area = maximum\ pipe\ length\ x\ maximum\ pipe\ spacing$$

- The number of days (equivalent loading time) required to cover the tributary area of an underdrain pipe is calculated by:

$$number\ of\ days = \frac{tributary\ area}{area\ per\ day}$$

- Both cumulative tertiary pipe flows and the corresponding tributary areas for years 1, 5, 10, 15, and 20 were considered for the primary and secondary pipe sizing.

Discharge Rate Calculation

Discharge rates were calculated from the Manning's equation:

$$Q = \frac{1.486\ A\ R^{2/3}\ S^{1/2}}{n} \tag{7}$$

where: Q = pipe capacity (cfs);
n = Manning's "n";
A = cross-sectional flow area of the pipe (ft^2);
R = hydraulic radius (ft), where R = A/P, P is the wetted perimeter in ft;
S = pipe slope (feet/foot)

For a specific full-flowing pipe the parameters n, A, and R could be defined as constants. The conveyance factor for a specific pipe size can then be defined as:

$$k = \frac{1.486\ A\ R^{2/3}}{n} \tag{8}$$

After substituting Equation 8 in Equation 7, Manning's formula can be reduced to:

$$Q = k\ S^{1/2} \tag{9}$$

Equation 9 can be written as:

$$k = \frac{Q}{S^{1/2}} \qquad (10)$$

Attachment 3 shows the conveyance factor for different pipe sizes (ADS, 2007).

Tertiary Underdrain Pipes

The tertiary underdrain pipes were designed based on:

- The tributary area (e.g 350 ft x 100 ft); and
- The flux rate at the calculated equivalent loading time (equal to the number of days required to cover the tributary area for a single underdrain pipe).

Secondary Underdrain Collector Pipes

The secondary underdrain pipes were designed to accommodate the time-variant flux from the tertiary underdrain pipes. The flow was calculated using the loading rate required to cover the corresponding stockpile footprint and the time required to load the corresponding tributary area:

$$Q_{secondary} = Av_{(0,T1)} + Av_{(0,T2)} \cdots + Av_{(0,Tn-1)} + Av_{(0,T\boldsymbol{n})} \qquad (11)$$

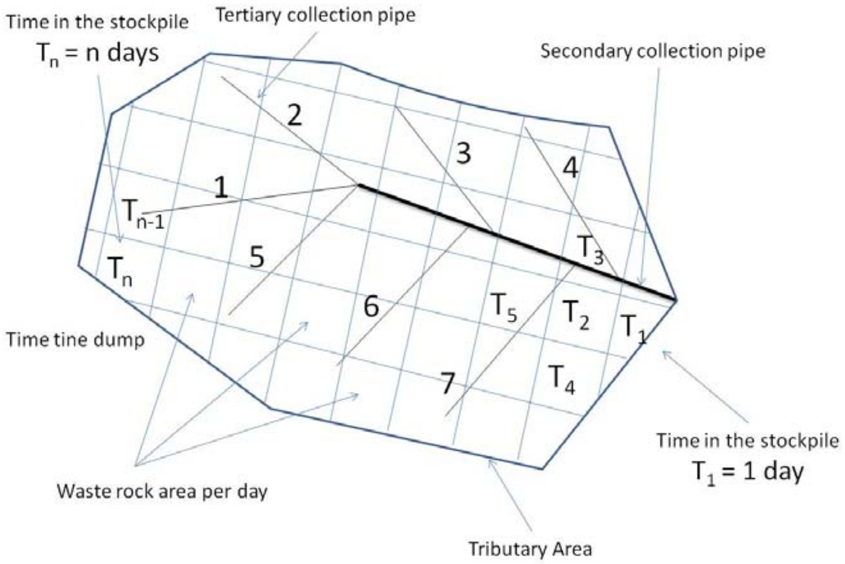
$$Q_{secondary} = A \sum_{T=1\ day}^{T=n\ days} v_{(0,T)} \qquad (12)$$

where:

$Q_{secondary}$ = water flow in the secondary pipe (volume per day);
A = calculated loading rate (area per day) required to cover the waste rock stockpile footprint under consideration in N years;
$v_{(0,T)}$ = calculated seepage rate at time T and Z=0 (see Equation 5);

The number of days “n” can be calculated from the following expression:

$$number\ of\ days = \frac{tributary\ area}{area\ per\ day}$$



The tributary area "A" can be estimated by multiplying the tertiary pipe spacing (100 ft) with the total length of tertiary pipes.

ASSUMPTIONS:

- Minimum drain pipe slope 0.5%;
- Compressible subgrade soil layer is homogenous;
- The compressible subgrade soil layer is saturated;
- Darcy's law is valid;
- The coefficient of consolidation C_v is constant during the consolidation;
- A factor of safety (FS) of 1.2 will be applied to the capacity of pipes;
- The maximum length for the Category 1 Stockpile tertiary underdrain pipe is 350 feet;
- The maximum pipe length for the waste rock stockpile tertiary underdrain collector pipe is 256 feet except for Category 1 Stockpile;
- The maximum spacing between tertiary underdrain pipes is 100 feet;
- The parameters in Table 2 were used for seepage calculations and underdrain pipe sizing.

Table 2
Assumed Material Parameters for Calculations

Case	***Parameter***	
1 and 2	Consolidation coefficient (C_v) (m^2/day)[1]	0.075
1 and 2	Soil Hydraulic Conductivity (Ks) (cm/sec)	$1x10^{-7}$
3 and 4	Consolidation coefficient (C_v) (m^2/day)	0.058
3 and 4	Soil Hydraulic Conductivity (Ks) (cm/sec)	$1x10^{-5}$

CALCULATIONS:

Flow Rate Calculation

Flow rate calculations for each considered case are shown in the following attachments:

- Attachment 4-1: Case 1 and Case 2, Category 1 Stockpile, year 1;
- Attachment 4-1-1: Case 1 and Case 2, Category 1 Stockpile, year 20;
- Attachment 4-2: Case 3 and Case 4, Category 1 Stockpile, year 1;
- Attachment 4-2-1: Case 3 and Case 4, Category 1 Stockpile, year 20;

- Attachment 4-3: Case 1 and Case 2, Ore Surge Pile, year 1;
- Attachment 4-4: Case 3 and Case 4, Ore Surge Pile, year 1;

- Attachment 4-5: Case 1 and Case 2, Category 4 Stockpile, year 1;
- Attachment 4-5-1: Case 1 and Case 2, Category 4 Stockpile, year 20;
- Attachment 4-6: Case 3 and Case 4, Category 4 Stockpile, year 1;
- Attachment 4-6-1: Case 3 and Case 4, Category 4 Stockpile, year 20;

- Attachment 4-9: Case 1 and Case 2, Category 2/3 Stockpile, year 1;
- Attachment 4-9-1: Case 1 and Case 2, Category 2/3 Stockpile, year 20;
- Attachment 4-10: Case 3 and Case 4, Category 2/3 Stockpile, year 1;
- Attachment 4-10-1: Case 3 and Case 4, Category 2/3 Stockpile, year 20;

Time Selection

- The equivalent loading time calculations are shown in Attachment 5.

Tertiary Underdrain Pipes

Detailed calculations used for the tertiary underdrain pipe sizing are enclosed as:

- Attachment 6-1: Calculations for Ks=1x10^{-7} cm/sec;
- Attachment 6-2: Calculations for Ks= 1x10^{-5} cm/sec.

Primary and Secondary Underdrain Pipes

The primary and secondary underdrain pipes will be laid approximately perpendicular to the stockpile liner contours. The pipes were sized to collect the inflows from the corresponding tributary areas as shown in the following Attachments:

- Attachment 7-1: Category 1 Stockpile, year 1;
- Attachment 7-2 Ore Surge Pile, year 1;
- Attachment 7-3: Category 4 Stockpile, year 1;
- Attachment 7-5: Category 2/3 Stockpile, year 1;

RESULTS:

Calculations indicate that Case 4 is critical for the tertiary pipe sizing. The calculated pipe diameter varies from 6-inch to 18-inch.

REFERENCES:

Das, B. M. (1997). *Advanced soil mechanics*, Taylor & Francis, Washington, DC.

Advanced Drainage Systems, Inc. ADS (2007). *Section 3 - Drainage handbook*, Ohio. August, 2007.

ATTACHMENT 1

CONSOLIDATION PARAMETERS

ONE-DIMENSIONAL CONSOLIDATION

ASTM D 2435

Polymet/Mine Waste Impound Dsgn/MN
053-2209

SAMPLE: **G06-TP5 @ 0.5'-4'**

DATE: 5/16/2006
TECH: RT
REVIEW: JEO

SAMPLE DATA, GENERAL		**SAMPLE DATA, INITIAL**		**SAMPLE DATA, FINAL**	
height (in)	1.075	total height (in)	1.075	total height (in)	0.982
diameter (in)	1.928	height of solids (in)	0.678	height of solids (in)	0.678
area (in^2)	2.919	height of voids (in)	0.397	height of voids (in)	0.304
volume (in^3)	3.138	void ratio	0.585	void ratio	0.448
specimen weight,wet (g)	104.82	dry density (pcf)	106.2	dry density (pcf)	116.5
specimen weight,dry (g)	87.67	moist density (pcf)	127.2	moist density (pcf)	139.8
water weight (g)	17.15				

DESCRIPTION

Olive brown clayey sand

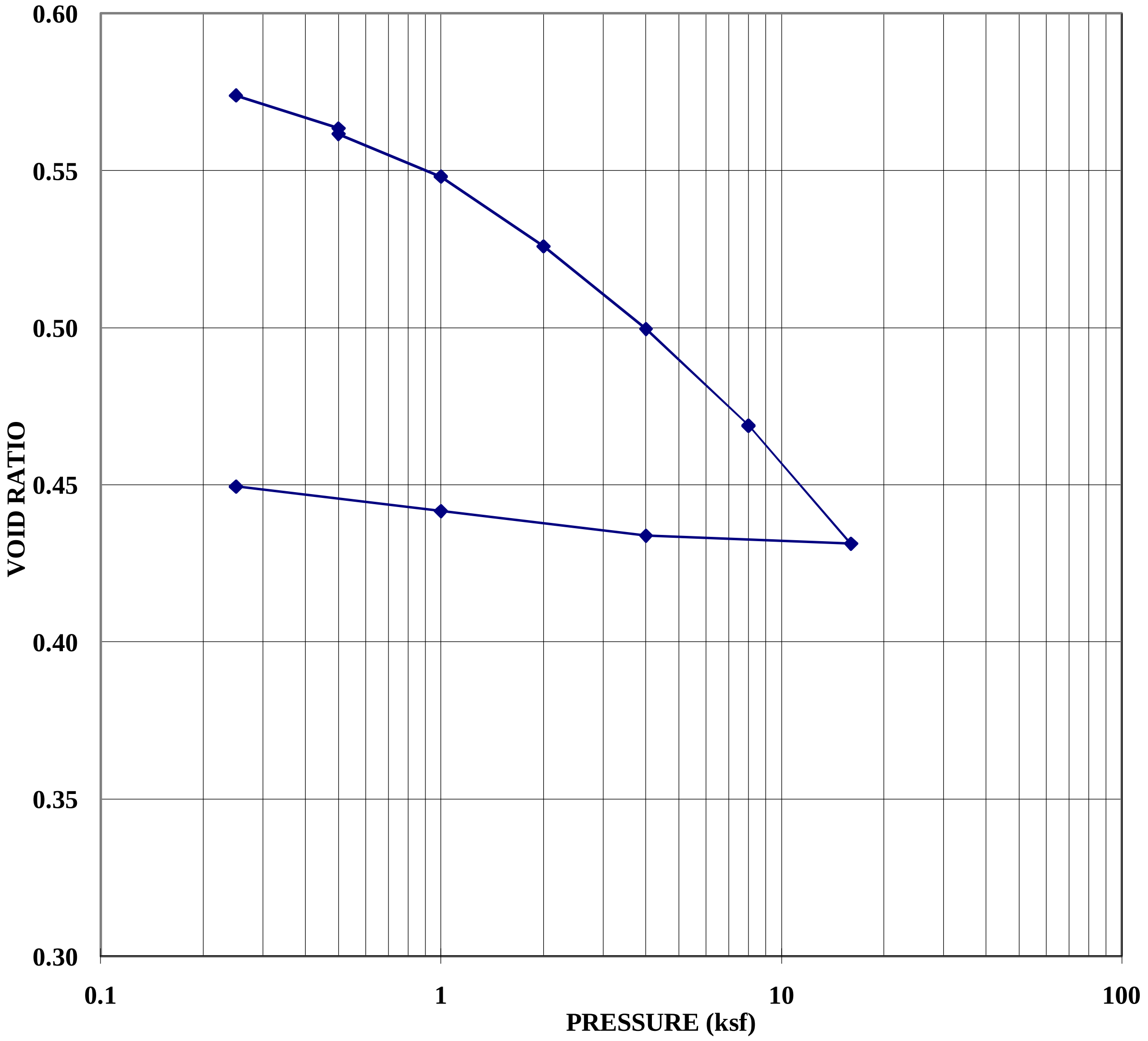
LL:	-	
PL:	-	
PI:	-	
Gs:	2.70	*Assumed*

MOISTURE CONTENT, INITIAL		**MOISTURE CONTENT, FINAL**	
tare #	G5	tare #	M9
wt soil&tare,moist	48.94	wt soil&tare,moist	127.60
wt soil&tare,dry	43.22	wt soil&tare,dry	110.60
wt tare	13.98	wt tare	25.54
wt moisture	5.72	wt moisture	17.00
wt dry soil	29.24	wt dry soil	85.06
% moisture	19.6%	% moisture	20.0%

PRESSURE (ksf)	h100 Sample Height	D50 Sample Height	t50 TIME (min)	Sample Density (pcf)	VOID RATIO e	DRAINAGE PATH (DOUBLE DRAINAGE) H (in)	DRAINAGE PATH (DOUBLE DRAINAGE) H (cm)	DRAINAGE PATH (DOUBLE DRAINAGE) H^2 (in^2)	DRAINAGE PATH (DOUBLE DRAINAGE) H^2 (cm^2)	COEFFICIENT OF CONSOLIDATION Cv (cm^2/sec)	COEFFICIENT OF CONSOLIDATION (ft^2/day)	Cc
0.250	1.0662	-	-	107.1	0.574	-	-	-	-	-	-	-
0.500	1.0591	-	-	107.8	0.563	-	-	-	-	-	-	-
0.500	1.0579	-	-	107.9	0.562	-	-	-	-	-	-	-
1.0	1.0487	1.0542	0.6288	108.8	0.548	0.5271	1.3389	0.2778	1.7925	9.36E-03	8.73E-01	0.045
2.0	1.0337	1.0412	0.5571	110.4	0.526	0.5206	1.3224	0.2710	1.7487	1.03E-02	9.62E-01	0.074
4.0	1.0159	1.0236	0.9694	112.4	0.500	0.5118	1.3000	0.2619	1.6900	5.72E-03	5.34E-01	0.087
8.0	0.9950	1.0046	0.6170	114.7	0.469	0.5023	1.2759	0.2523	1.6279	8.66E-03	8.08E-01	0.102
16.0	0.9696	0.9822	0.5803	117.7	0.431	0.4911	1.2474	0.2412	1.5561	8.80E-03	8.21E-01	0.125
4.0	0.9713	-	-	117.5	0.434	-	-	-	-	-	-	-
1.0	0.9766	-	-	116.9	0.442	-	-	-	-	-	-	-
0.250	0.9819	-	-	116.2	0.449	-	-	-	-	-	-	-

GOLDER ASSOCIATES INC.
LAKEWOOD, COLORADO

ONE-DIMENSIONAL CONSOLIDATION



SAMPLE #: G06-TP5 @ 0.5'-4'

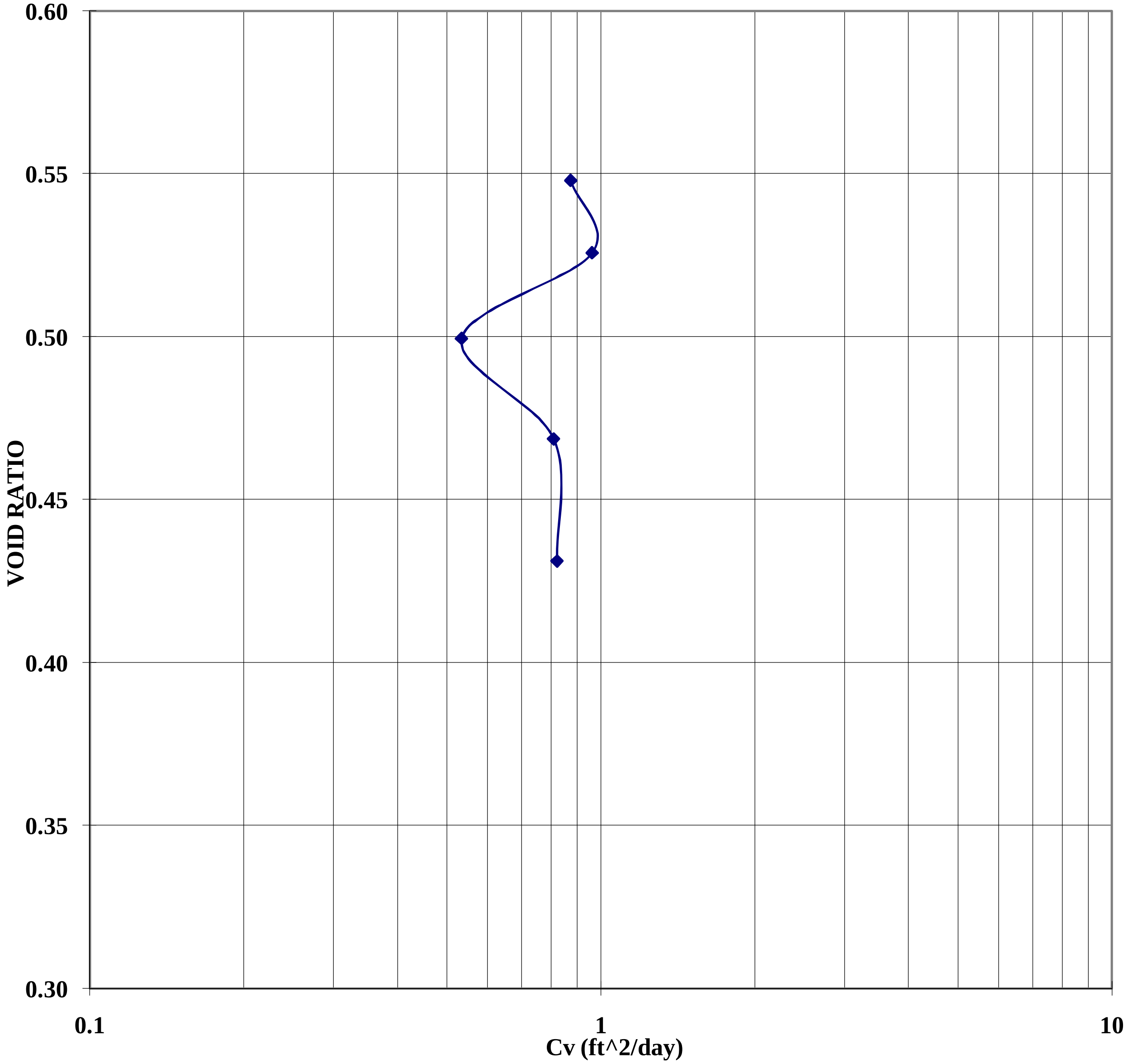
DESCRIPTION: Olive brown clayey sand

DATE	5/16/2006
TECH	RT
REVIEW	JEO

Polymet/Mine Waste Impound Dsgn/MN
053-2209

GOLDER ASSOCIATES INC.
LAKEWOOD, COLORADO

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

ATTACHMENT 2

MAXIMUM DEPTHS TO BEDROCK

Attachment 2: Bedrock Depths and Stockpile Heights For Various Years

	Proposed Stockpile name	max depth to bedrock (ft)	max depth to bedrock (m)	max height of stockpile fill 1-yr (ft)	max height of stockpile fill 1-yr (m)	max height of stockpile fill 5-yr (ft)	max height of stockpile fill 5-yr (m)	max height of stockpile fill 20-yr (ft)	max height of stockpile fill 20-yr (m)
1	Category 1 Stockpile	38	11.58	40	12.19	120	36.58	240	73.15
2	Ore Surge Pile	10	3.05	40	12.19	40	12.19	na	na
3	Category 4 Stockpile	28	8.53	40	12.19	80	24.38	90	27.43
5	Category 2/3 Stockpile	40	12.19	40	12.19	80	24.38	160	48.77

ATTACHMENT 3

CONVEYANCE FACTORS (ADS, 2007)

Table 3-1
Conveyance Factors (Standard Units)

Design Manning's Values for HDPE Pipe *		
Product	**Diameter**	**Design Manning's "n"**
N-12®, N-12® ST, and N-12® WT	4" - 60"	"n" = 0.012
AASHTO and Single Wall	18" - 24" 12" - 15" 10" 8" 3" - 6"	"n" = 0.024 "n" = 0.022 "n" = 0.019 "n" = 0.019 "n" = 0.017
Smoothwall	3" - 6"	"n" = 0.009 **
Conveyance Equations: k = Q/(s^0.5) Q = k s^0.5		

Conveyance Factors for Circular Pipe Flowing Full																		
		Manning's "n" Values																
Dia. (in.)	**Area (sq. ft.)**	**0.009**	**0.010**	**0.011**	**0.012**	**0.013**	**0.014**	**0.015**	**0.016**	**0.017**	**0.018**	**0.019**	**0.020**	**0.021**	**0.022**	**0.023**	**0.024**	**0.025**
3	0.05	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
4	0.09	2.7	2.5	2.2	2.1	1.9	1.8	1.6	1.5	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.0	1.0
6	0.20	8.1	7.3	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.1	3.8	3.6	3.5	3.3	3.2	3.0	2.9
8	0.35	17.5	15.7	14.3	13.1	12.1	11.2	10.5	9.8	9.2	8.7	8.3	7.9	7.5	7.1	6.8	6.5	6.3
10	0.55	31.6	28.5	25.9	23.7	21.9	20.3	19.0	17.8	16.8	15.8	15.0	14.2	13.6	12.9	12.4	11.9	11.4
12	0.79	51.5	46.3	42.1	38.6	35.6	33.1	30.9	28.9	27.2	25.7	24.4	23.2	22.1	21.1	20.1	19.3	18.5
15	1.23	93.3	84.0	76.3	70.0	64.6	60.0	56.0	52.5	49.4	46.7	44.2	42.0	40.0	38.2	36.5	35.0	33.6
18	1.77	151.7	136.6	124.1	113.8	105.0	97.5	91.0	85.3	80.3	75.9	71.9	68.3	65.0	62.1	59.4	56.9	54.6
21	2.41	228.9	206.0	187.3	171.6	158.4	147.1	137.3	128.7	121.2	114.4	108.4	103.0	98.1	93.6	89.6	85.8	82.4
24	3.14	326.8	294.1	267.3	245.1	226.2	210.1	196.1	183.8	173.0	163.4	154.8	147.0	140.0	133.7	127.9	122.5	117.6
27	3.98	447.3	402.6	366.0	335.5	309.7	287.6	268.4	251.6	236.8	223.7	211.9	201.3	191.7	183.0	175.0	167.8	161.0
30	4.91	592.5	533.2	484.7	444.3	410.2	380.9	355.5	333.3	313.7	296.2	280.6	266.6	253.9	242.4	231.8	222.2	213.3
33	5.94	763.9	687.5	625.0	572.9	528.9	491.1	458.3	429.7	404.4	382.0	361.9	343.8	327.4	312.5	298.9	286.5	275.0
36	7.07	963.4	867.1	788.2	722.6	667.0	619.3	578.0	541.9	510.0	481.7	456.4	433.5	412.9	394.1	377.0	361.3	346.8
42	9.62	1453.2	1307.9	1189.0	1089.9	1006.1	934.2	871.9	817.5	769.4	726.6	688.4	654.0	622.8	594.5	568.7	545.0	523.2
45	11.04	1746.8	1572.1	1429.2	1310.1	1209.3	1122.9	1048.1	982.6	924.8	873.4	827.4	786.1	748.6	714.6	683.5	655.0	628.8
48	12.57	2074.8	1867.4	1697.6	1556.1	1436.4	1333.8	1244.9	1167.1	1098.4	1037.4	982.8	933.7	889.2	848.8	811.9	778.1	746.9
54	15.90	2840.5	2556.4	2324.0	2130.4	1966.5	1826.0	1704.3	1597.8	1503.8	1420.2	1345.5	1278.2	1217.4	1162.0	1111.5	1065.2	1022.6
60	19.63	3762.0	3385.8	3078.0	2821.5	2604.4	2418.4	2257.2	2116.1	1991.6	1881.0	1782.0	1692.9	1612.3	1539.0	1472.1	1410.7	1354.3
72	28.27	6117.3	5505.6	5005.1	4588.0	4235.1	3932.6	3670.4	3441.0	3238.6	3058.7	2897.7	2752.8	2621.7	2502.5	2393.7	2294.0	2202.2

* Utah Water Research Laboratory, "Manning Friction Coefficient Testing of 4-, 10-, 12- and 15-inch Corrugated Plastic Pipe"[3]

** "Lingedburg, Michael, "Civil Engineer Reference Manual"[4]

ATTACHMENT 4

FLOW RATE CALCULATIONS

Note: Project configuration has changed since the original preparation of this Attachment. For the SDEIS and FEIS, the Category 3 Lean Ore Stockpile has been eliminated, and the Lean Ore Surge Pile is referred to as the Ore Surge Pile.

Attachment 4-1: Case 1 and Case 2, Category 1 Stockpile, year 1;

Column height	H_T	11.58	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate (m/day)	
	For z= 0.0	
	Case1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	11.6	5.8
0	-3.583E-02	-7.165E-02
1	-4.274E-03	-4.274E-03
2	-3.022E-03	-3.022E-03
4	-2.137E-03	-2.137E-03
10	-1.352E-03	-1.352E-03
20	-9.558E-04	-9.558E-04
30	-7.804E-04	-7.804E-04
50	-6.045E-04	-6.043E-04
100	-4.274E-04	-4.177E-04
200	-3.022E-04	-2.377E-04
365	-2.204E-04	-9.563E-05
1000	-9.018E-05	-2.877E-06
2000	-2.270E-05	-1.155E-08
3000	-5.714E-06	-4.637E-11
4000	-1.438E-06	-1.862E-13
5000	-3.621E-07	-7.474E-16

Attachment 4-1-1: Case 1 and Case 2, Category 1 Stockpile year 20;

Column height	H_T	11.58	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	1413.5	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	11.6	5.8
0	-2.150E-01	-4.299E-01
1	-2.565E-02	-2.565E-02
2	-1.813E-02	-1.813E-02
5	-1.147E-02	-1.147E-02
10	-8.110E-03	-8.110E-03
20	-5.735E-03	-5.735E-03
43	-3.911E-03	-3.911E-03
100	-2.565E-03	-2.506E-03
200	-1.813E-03	-1.426E-03
365	-1.322E-03	-5.738E-04
400	-1.253E-03	-4.730E-04
1000	-5.411E-04	-1.726E-05
2000	-1.362E-04	-6.930E-08
3000	-3.428E-05	-2.782E-10
3650	-1.399E-05	-7.705E-12
4000	-8.630E-06	-1.117E-12
5000	-2.172E-06	-4.484E-15

Attachment 4-2: Case 3 and Case 4, Category 1 Stockpile, year 1;

Column height	H_T	11.58	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	11.6	5.8
0	-3.583E+00	-7.165E+00
1	-4.861E-01	-4.861E-01
2	-3.437E-01	-3.437E-01
4	-2.430E-01	-2.430E-01
10	-1.537E-01	-1.537E-01
20	-1.087E-01	-1.087E-01
30	-8.874E-02	-8.874E-02
50	-6.874E-02	-6.874E-02
100	-4.861E-02	-4.831E-02
200	-3.437E-02	-3.055E-02
400	-2.415E-02	-1.300E-02
1000	-1.233E-02	-1.005E-03
2000	-4.243E-03	-1.409E-05
3000	-1.460E-03	-1.976E-07
4000	-5.024E-04	-2.771E-09
5000	-1.729E-04	-3.885E-11

Attachment 4-2-1: Case 3 and Case 4, Category 1 Stockpile, year 20

Column height	H_T	11.58	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	1413.5	kN/m^2
Consolidation coef.	cv	0.058	m^2/day

	Flux Rate m/day	
	For z=	0.0
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	11.6	5.8
0	-2.150E+01	-4.299E+01
1	-2.916E+00	-2.916E+00
2	-2.062E+00	-2.062E+00
5	-1.304E+00	-1.304E+00
10	-9.222E-01	-9.222E-01
20	-6.521E-01	-6.521E-01
44	-4.397E-01	-4.397E-01
100	-2.916E-01	-2.898E-01
200	-2.062E-01	-1.833E-01
365	-1.521E-01	-9.057E-02
400	-1.449E-01	-7.800E-02
1000	-7.399E-02	-6.029E-03
2000	-2.546E-02	-8.454E-05
3000	-8.760E-03	-1.185E-06
3650	-4.379E-03	-7.402E-08
4000	-3.014E-03	-1.662E-08
5000	-1.037E-03	-2.331E-10

Attachment 4-3: Case 1 and Case 2, Ore Surge Pile, year 1

Column height	H_T	3.05	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	3.0	1.5
0	-1.361E-01	-2.723E-01
1	-4.274E-03	-4.274E-03
2	-3.022E-03	-3.022E-03
4	-2.137E-03	-2.135E-03
10	-1.352E-03	-1.230E-03
20	-9.519E-04	-5.533E-04
30	-7.553E-04	-2.494E-04
48	-5.236E-04	-5.944E-05
100	-1.857E-04	-9.434E-07
200	-2.534E-05	-3.269E-10
400	-4.717E-07	-3.924E-17
1000	-3.042E-12	-6.790E-38
2000	-6.799E-21	-1.693E-72
3000	-1.519E-29	-4.223E-107
4000	-3.395E-38	-1.053E-141
5000	-7.587E-47	-2.626E-176

Attachment 4-4: Case 3 and Case 4, Ore Surge Pile, year 1

Column height	H_T	3.05	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	3.0	1.5
0	-1.361E+01	-2.723E+01
1	-4.861E-01	-4.861E-01
2	-3.437E-01	-3.437E-01
4	-2.430E-01	-2.430E-01
10	-1.537E-01	-1.481E-01
20	-1.086E-01	-7.941E-02
30	-8.789E-02	-4.288E-02
48	-6.517E-02	-1.414E-02
100	-2.917E-02	-5.742E-04
200	-6.252E-03	-1.211E-06
400	-2.871E-04	-5.384E-12
1000	-2.780E-08	-4.734E-28
2000	-5.677E-15	-8.232E-55
3000	-1.159E-21	-1.431E-81
4000	-2.367E-28	-2.489E-108
5000	-4.834E-35	-4.328E-135

Attachment 4-5: Case 1 and Case 2, Category 4 Stockpile, year 1

Column height	H_T	8.53	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	8.5	4.3
0	-4.862E-02	-9.724E-02
1	-4.274E-03	-4.274E-03
2	-3.022E-03	-3.022E-03
4	-2.137E-03	-2.137E-03
10	-1.352E-03	-1.352E-03
20	-9.558E-04	-9.558E-04
30	-7.804E-04	-7.799E-04
48	-6.169E-04	-6.091E-04
100	-4.274E-04	-3.521E-04
200	-2.975E-04	-1.274E-04
400	-1.760E-04	-1.669E-05
1000	-3.832E-05	-3.751E-08
2000	-3.020E-06	-1.447E-12
3000	-2.380E-07	-5.583E-17
4000	-1.876E-08	-2.154E-21
5000	-1.478E-09	-8.309E-26

Attachment 4-5-1: Case 1 and Case 2, Category 4 Stockpile, year 20

Column height	H_T	8.53	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	530.0	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	8.5	4.3
0	-1.094E-01	-2.188E-01
1	-9.617E-03	-9.617E-03
2	-6.800E-03	-6.800E-03
5	-4.301E-03	-4.301E-03
10	-3.041E-03	-3.041E-03
20	-2.150E-03	-2.150E-03
50	-1.360E-03	-1.339E-03
100	-9.616E-04	-7.921E-04
159	-7.593E-04	-4.348E-04
365	-4.330E-04	-5.359E-05
400	-3.961E-04	-3.755E-05
1000	-8.622E-05	-8.441E-08
2000	-6.795E-06	-3.256E-12
3000	-5.355E-07	-1.256E-16
4000	-4.220E-08	-4.846E-21
5000	-3.326E-09	-1.869E-25

Attachment 4-6: Case 3 and Case 4, Category 4 Stockpile, year 1

Column height	H_T	8.53	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	8.5	4.3
0	-4.862E+00	-9.724E+00
1	-4.861E-01	-4.861E-01
2	-3.437E-01	-3.437E-01
5	-2.174E-01	-2.174E-01
10	-1.537E-01	-1.537E-01
20	-1.087E-01	-1.087E-01
30	-8.874E-02	-8.874E-02
48	-7.016E-02	-6.995E-02
100	-4.861E-02	-4.440E-02
200	-3.424E-02	-2.019E-02
400	-2.220E-02	-4.193E-03
1000	-6.816E-03	-3.755E-05
2000	-9.555E-04	-1.450E-08
3000	-1.339E-04	-5.600E-12
4000	-1.878E-05	-2.162E-15
5000	-2.632E-06	-8.350E-19

Attachment 4-6-1: Case 3 and Case 4, Category 4 Stockpile, year 20

Column height	H_T	8.53	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	530.0	kN/m^2
Consolidation coef.	cv	0.06	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	8.5	4.3
0	-1.094E+01	-2.188E+01
1	-1.094E+00	-1.094E+00
2	-7.733E-01	-7.733E-01
5	-4.891E-01	-4.891E-01
10	-3.458E-01	-3.458E-01
20	-2.445E-01	-2.445E-01
50	-1.547E-01	-1.541E-01
100	-1.094E-01	-9.989E-02
159	-8.667E-02	-6.271E-02
365	-5.357E-02	-1.242E-02
400	-4.995E-02	-9.435E-03
1000	-1.534E-02	-8.449E-05
2000	-2.150E-03	-3.263E-08
3000	-3.014E-04	-1.260E-11
4000	-4.225E-05	-4.865E-15
5000	-5.922E-06	-1.879E-18

Attachment 4-7: Case 1 and Case 2, Category 3 Lean Ore Stockpile, year 1

Column height	H_T	6.71	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	6.7	3.4
0	-6.188E-02	-1.238E-01
1	-4.274E-03	-4.274E-03
2	-3.022E-03	-3.022E-03
6	-1.745E-03	-1.745E-03
10	-1.352E-03	-1.352E-03
20	-9.558E-04	-9.547E-04
30	-7.804E-04	-7.698E-04
50	-6.045E-04	-5.442E-04
100	-4.253E-04	-2.386E-04
200	-2.721E-04	-4.600E-05
400	-1.193E-04	-1.709E-06
1000	-1.010E-05	-8.774E-11
2000	-1.648E-07	-6.220E-18
3000	-2.689E-09	-4.409E-25
4000	-4.387E-11	-3.126E-32
5000	-7.158E-13	-2.216E-39

Attachment 4-7-1: Case 1 and Case 2, Category 3 Lean Ore Stockpile, year 20

Column height	H_T	6.71	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	1177.9	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	6.7	3.4
0	-3.094E-01	-6.188E-01
1	-2.137E-02	-2.137E-02
2	-1.511E-02	-1.511E-02
5	-9.558E-03	-9.558E-03
10	-6.758E-03	-6.758E-03
20	-4.779E-03	-4.774E-03
50	-3.022E-03	-2.721E-03
93	-2.209E-03	-1.339E-03
200	-1.360E-03	-2.300E-04
365	-6.889E-04	-1.521E-05
400	-5.965E-04	-8.547E-06
1000	-5.049E-05	-4.387E-10
2000	-8.238E-07	-3.110E-17
3000	-1.344E-08	-2.205E-24
4000	-2.193E-10	-1.563E-31
5000	-3.579E-12	-1.108E-38

Attachment 4-8: Case 3 and Case 4, Category 3 Lean Ore Stockpile, year 1

Column height	H_T	6.71	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	6.7	3.4
0	-6.188E+00	-1.238E+01
1	-4.861E-01	-4.861E-01
2	-3.437E-01	-3.437E-01
6	-1.984E-01	-1.984E-01
10	-1.537E-01	-1.537E-01
20	-1.087E-01	-1.087E-01
50	-6.874E-02	-6.589E-02
30	-8.874E-02	-8.846E-02
100	-4.856E-02	-3.465E-02
200	-3.294E-02	-9.701E-03
400	-1.733E-02	-7.604E-04
1000	-2.567E-03	-3.662E-07
2000	-1.064E-04	-1.084E-12
3000	-4.415E-06	-3.206E-18
4000	-1.831E-07	-9.486E-24
5000	-7.594E-09	-2.807E-29

Attachment 4-8-1: Case 3 and Case 4, Category 3 Lean Ore Stockpile, year 20

Column height	H_T	6.71	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	1177.9	kN/m^2
Consolidation coef.	cv	0.058	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	6.7	3.4
0	-3.094E+01	-6.188E+01
1	-2.430E+00	-2.430E+00
2	-1.718E+00	-1.718E+00
5	-1.087E+00	-1.087E+00
10	-7.685E-01	-7.685E-01
20	-5.434E-01	-5.434E-01
50	-3.437E-01	-3.294E-01
93	-2.519E-01	-1.894E-01
200	-1.647E-01	-4.851E-02
365	-9.684E-02	-5.936E-03
400	-8.663E-02	-3.802E-03
1000	-1.283E-02	-1.831E-06
2000	-5.322E-04	-5.418E-12
3000	-2.207E-05	-1.603E-17
4000	-9.155E-07	-4.743E-23
5000	-3.797E-08	-1.403E-28

Attachment 4-9: Case 1 and Case 2, Category 2/3 Stockpile, year 1

Column height	H_T	12.19	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	12.2	6.1
0	-3.404E-02	-6.807E-02
1	-4.274E-03	-4.274E-03
2	-3.022E-03	-3.022E-03
4	-2.137E-03	-2.137E-03
10	-1.352E-03	-1.352E-03
20	-9.558E-04	-9.558E-04
36	-7.124E-04	-7.124E-04
50	-6.045E-04	-6.044E-04
100	-4.274E-04	-4.214E-04
200	-3.022E-04	-2.515E-04
365	-2.218E-04	-1.106E-04
400	-2.107E-04	-9.287E-05
1000	-9.801E-05	-4.680E-06
2000	-2.822E-05	-3.218E-08
3000	-8.127E-06	-2.212E-10
4000	-2.340E-06	-1.521E-12
5000	-6.738E-07	-1.046E-14

Attachment 4-9-1: Case 1 and Case 2, Category 2/3 Stockpile, year 20

Column height	H_T	12.19	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	942.3	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	12.2	6.1
0	-1.361E-01	-2.723E-01
1	-1.710E-02	-1.710E-02
2	-1.209E-02	-1.209E-02
5	-7.646E-03	-7.646E-03
10	-5.407E-03	-5.407E-03
20	-3.823E-03	-3.823E-03
50	-2.418E-03	-2.418E-03
100	-1.710E-03	-1.686E-03
228	-1.132E-03	-8.749E-04
365	-8.871E-04	-4.422E-04
400	-8.428E-04	-3.715E-04
1000	-3.920E-04	-1.872E-05
2000	-1.129E-04	-1.287E-07
3000	-3.251E-05	-8.850E-10
4000	-9.360E-06	-6.085E-12
5000	-2.695E-06	-4.184E-14

Attachment 4-10: Case 3 and Case 4, Category 2/3 Stockpile, year 1

Column height	H_T	12.19	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.06	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	12.2	6.1
0	-3.404E+00	-6.807E+00
1	-4.861E-01	-4.861E-01
2	-3.437E-01	-3.437E-01
5	-2.174E-01	-2.174E-01
10	-1.537E-01	-1.537E-01
20	-1.087E-01	-1.087E-01
36	-8.101E-02	-8.101E-02
50	-6.874E-02	-6.874E-02
100	-4.861E-02	-4.845E-02
200	-3.437E-02	-3.158E-02
365	-2.540E-02	-1.669E-02
400	-2.422E-02	-1.459E-02
1000	-1.300E-02	-1.447E-03
2000	-4.962E-03	-3.076E-05
3000	-1.895E-03	-6.539E-07
4000	-7.235E-04	-1.390E-08
5000	-2.763E-04	-2.955E-10

Attachment 4-10-1: Case 3 and Case 4, Category 2/3 Stockpile, year 20

Column height	H_T	12.19	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	942.3	kN/m^2
Consolidation coef.	cv	0.06	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 3	Case 4
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	12.2	6.1
0	-1.361E+01	-2.723E+01
1	-1.944E+00	-1.944E+00
2	-1.375E+00	-1.375E+00
5	-8.695E-01	-8.695E-01
10	-6.148E-01	-6.148E-01
20	-4.347E-01	-4.347E-01
50	-2.750E-01	-2.750E-01
100	-1.944E-01	-1.938E-01
200	-1.375E-01	-1.263E-01
228	-1.288E-01	-1.133E-01
400	-9.689E-02	-5.835E-02
1000	-5.201E-02	-5.788E-03
2000	-1.985E-02	-1.230E-04
3000	-7.579E-03	-2.616E-06
4000	-2.894E-03	-5.560E-08
5000	-1.105E-03	-1.182E-09

ATTACHMENT 5

EQUIVALENT LOADING TIMES

Note: Project configuration has changed since the original preparation of this Attachment. For the SDEIS and FEIS, the Category 3 Lean Ore Stockpile has been eliminated, and the Lean Ore Surge Pile is referred to as the Ore Surge Pile.

Attachment 5: Equivalent Loading Times

Waste Rock Stockpile Footprint (ft^{2})

		Year 1	Year 5	Year 10	Year 15	Year 20
1	Category 1 Stockpile	3031253	13025197	16412619	16412619	16412619
2	Lean Ore Surge Pile	2375443	2375442	2375884	2375442	2759736
3	Category 4 Stockpile	194781	1743009	2759691	2759736	
4	Category 3 Lean Ore Stockpile	1540756	2778949	4257310	6830487	6830487
5	Category 2/3 Stockpile	257713	1115804	2041077	3135871	3135871

Area per day required to cover the footprint at the corresponding year

		ft^{2}/day	ft^{2}/day	ft^{2}/day	ft^{2}/day	ft^{2}/day
1	Category 1 Stockpile	8304.8	7137.1	4496.6	2997.7	2248.3
2	Lean Ore Surge Pile	6508.1	1301.6	650.9	433.9	378.0
3	Category 4 Stockpile	533.6	955.1	756.1	504.1	
4	Category 3 Lean Ore Stockpile	4221.3	1522.7	1166.4	1247.6	935.7
5	Category 2/3 Stockpile	706.1	611.4	559.2	572.8	429.6

Maximum Underdrain Pipe Tributary Area (350 ft x 100 ft and 256 ft x 100 ft)

		ft^{2}	ft^{2}	ft^{2}	ft^{2}	ft^{2}
1	Category 1 Stockpile	35000.0	35000.0	35000.0	35000.0	35000.0
2	Lean Ore Surge Pile	25600.0	25600.0	25600.0	25600.0	25600.0
3	Category 4 Stockpile	25600.0	25600.0	25600.0	25600.0	
4	Category 3 Lean Ore Stockpile	25600.0	25600.0	25600.0	25600.0	25600.0
5	Category 2/3 Stockpile	25600.0	25600.0	25600.0	25600.0	25600.0

Number of Days Required to Cover the Maximum Tributary Area of a Under Drain Pipe

		Year 1 Days	Year 5 Days	Year 10 Days	Year 15 Days	Year 20 Days	Years 1- 20 Total Days
1	Category 1 Stockpile	4	5	8	12	16	44
2	Lean Ore Surge Pile	4	20	39	59	68	190
3	Category 4 Stockpile	48	27	34	51		
4	Category 3 Lean Ore Stockpile	6	17	22	21	27	93
5	Category 2/3 Stockpile	36	42	46	45	60	228

ATTACHMENT 6

SIZING OF TERTIARY UNDERDRAIN PIPES

Note: Project configuration has changed since the original preparation of this Attachment. For the SDEIS and FEIS, the Category 3 Lean Ore Stockpile has been eliminated, and the Lean Ore Surge Pile is referred to as the Ore Surge Pile.

Attachment 6-1: Tertiary underdrain pipe selection assuming Ks=1e-7 cm/sec

FLUX (m/day)

		For Year 1		time	For Year 1		time
		Single layer	Double layer	days	Single layer	Double layer	days
1	Category 1 Stockpile	2.1E-03	2.1E-03	4	3.9E-03	3.9E-03	44
2	Lean Ore Surge Pile	2.1E-03	2.1E-03	4			
3	Category 4 Stockpile	6.2E-04	6.1E-04	48	7.6E-04	4.3E-04	159
4	Category 3 Lean Ore Stockpile	1.7E-03	1.7E-03	6	2.2E-03	1.3E-03	93
5	Category 2/3 Stockpile	7.1E-04	7.1E-04	36	1.1E-03	8.7E-04	228

Factored FLUX (m/day) FS=1.2

		For Year 1		For Year 20	
		Single layer	Double layer	Single layer	Double layer
1	Category 1 Stockpile	2.6E-03	2.6E-03	4.7E-03	4.7E-03
2	Lean Ore Surge Pile	2.6E-03	2.6E-03		
3	Category 4 Stockpile	7.4E-04	7.3E-04	9.1E-04	5.2E-04
4	Category 3 Lean Ore Stockpile	2.1E-03	2.1E-03	2.7E-03	1.6E-03
5	Category 2/3 Stockpile	8.5E-04	8.5E-04	1.4E-03	1.0E-03

FLOW (ft3/sec)

		For Year 1		For Year 20	
		Single layer	Double layer	Single layer	Double layer
1	Category 1 Stockpile	3.4E-03	3.4E-03	6.2E-03	6.2E-03
2	Lean Ore Surge Pile	3.4E-03	3.4E-03		
3	Category 4 Stockpile	9.8E-04	9.7E-04	1.2E-03	6.9E-04
4	Category 3 Lean Ore Stockpile	2.8E-03	2.8E-03	3.5E-03	2.1E-03
5	Category 2/3 Stockpile	1.1E-03	1.1E-03	1.8E-03	1.4E-03

Commodity Factor k S=0.5%

		For Year 1		For Year 20	
		Single layer	Double layer	Single layer	Double layer
1	Category 1 Stockpile	0.048	0.048	0.088	0.088
2	Lean Ore Surge Pile	0.048	0.048		
3	Category 4 Stockpile	0.0139	0.0137	0.0171	0.0098
4	Category 3 Lean Ore Stockpile	0.039	0.039	0.050	0.030
5	Category 2/3 Stockpile	0.016	0.016	0.026	0.020

Selected Pipe Dia (in)

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
2	Category 1 Stockpile	3	3	3	3
3	Lean Ore Surge Pile	3	3		
4	Category 4 Stockpile	3	3	3	3
5	Category 3 Lean Ore Stockpile	3	3	3	3
6	Category 2/3 Stockpile	3	3	3	3

Selected Pipe commodity value k (ASD 2008) n=0.012

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
2	Category 1 Stockpile	1.0	1.0	1.0	1.0
3	Lean Ore Surge Pile	1.0	1.0		
4	Category 4 Stockpile	1.0	1.0	1.0	1.0
5	Category 3 Lean Ore Stockpile	1.0	1.0	1.0	1.0
6	Category 2/3 Stockpile	1.0	1.0	1.0	1.0

Attachment 6-2: Tertiary underdrain pipe selection assuming Ks=1e-5 cm/sec

FLUX (m/day)

		Year 1		time	Year 20		time
		Single layer	Double layer	days	Single layer	Double layer	days
1	Category 1 Stockpile	2.4E-01	2.4E-01	4	4.4E-01	4.4E-01	44
2	Lean Ore Surge Pile	2.4E-01	2.4E-01	4			
3	Category 4 Stockpile	7.0E-02	7.0E-02	48	8.7E-02	6.3E-02	159
4	Category 3 Lean Ore Stockpile	2.0E-01	2.0E-01	6	2.5E-01	1.9E-01	93
5	Category 2/3 Stockpile	8.1E-02	8.1E-02	36	1.3E-01	1.1E-01	228

Factored FLUX (m/day) FS=1.2

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
1	Category 1 Stockpile	2.9E-01	2.9E-01	5.3E-01	5.3E-01
2	Lean Ore Surge Pile	2.9E-01	2.9E-01		
3	Category 4 Stockpile	8.4E-02	8.4E-02	1.0E-01	7.5E-02
4	Category 3 Lean Ore Stockpile	2.4E-01	2.4E-01	3.0E-01	2.3E-01
5	Category 2/3 Stockpile	9.7E-02	9.7E-02	1.5E-01	1.4E-01

FLOW (ft3/sec)

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
1	Category 1 Stockpile	3.9E-01	3.9E-01	7.0E-01	7.0E-01
2	Lean Ore Surge Pile	3.9E-01	3.9E-01		
3	Category 4 Stockpile	1.1E-01	1.1E-01	1.4E-01	1.0E-01
4	Category 3 Lean Ore Stockpile	3.2E-01	3.2E-01	4.0E-01	3.0E-01
5	Category 2/3 Stockpile	1.3E-01	1.3E-01	2.1E-01	1.8E-01

Commodity Factor k S=0.5%

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
1	Category 1 Stockpile	5.5	5.5	9.9	9.9
2	Lean Ore Surge Pile	5.5	5.5		
3	Category 4 Stockpile	1.6	1.6	2.0	1.4
4	Category 3 Lean Ore Stockpile	4.5	4.5	5.7	4.3
5	Category 2/3 Stockpile	1.8	1.8	2.9	2.6

Selected Pipe Dia (in)

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
2	Category 1 Stockpile	6	6	8	8
3	Lean Ore Surge Pile	6	6		
4	Category 4 Stockpile	4	4	6	6
5	Category 3 Lean Ore Stockpile	6	6	6	6
6	Category 2/3 Stockpile	4	4	6	6

Selected Pipe commodity value k (ASD 2008) n=0.012

		Year 1		Year 20	
		Single layer	Double layer	Single layer	Double layer
2	Category 1 Stockpile	6.10	6.10	13.10	13.10
3	Lean Ore Surge Pile	6.10	6.10		
4	Category 4 Stockpile	2.10	2.10	6.10	6.10
5	Category 3 Lean Ore Stockpile	6.10	6.10	6.10	6.10
6	Category 2/3 Stockpile	2.10	2.10	6.10	6.10

ATTACHMENT 7

SIZING OF PRIMARY AND SECONDARY UNDERDRAIN PIPES

Note: Project configuration has changed since the original preparation of this Attachment. For the SDEIS and FEIS, the Category 3 Lean Ore Stockpile has been eliminated, and the Lean Ore Surge Pile is referred to as the Ore Surge Pile.

Attachment 7-1: Category 1 Stockpile, year 1;

Column height	H_T	11.58	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day
time	t	1	day

Flux Rate m/day
For z= 0.0
Case 3
Single drain
$H=H_T$ 11.6

BRANCH 1

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	240	24000.0	24000.0	8304.8	2.0	7.691E+02	0.3	4.4	8	
2	435	43500.0	67500.0	8304.8	8.0	3.076E+03	1.3	17.8	10	
3	535	53500.0	121000.0	8304.8	14.0	5.383E+03	2.2	31.1	12	
4	550	55000.0	176000.0	8304.8	21.0	8.075E+03	3.3	46.7	15	
5	560	56000.0	232000.0	8304.8	27.0	1.038E+04	4.2	60.0	15	
6	570	57000.0	289000.0	8304.8	34.0	1.307E+04	5.3	75.6	18	
7	520	52000.0	341000.0	8304.8	41.0	1.577E+04	6.4	91.1	18	
8	580	58000.0	399000.0	8304.8	48.0	1.846E+04	7.5	106.7	18	
9	550	55000.0	454000.0	8304.8	54.0	2.076E+04	8.5	120.0	21	
10	460	46000.0	500000.0	8304.8	60.0	2.307E+04	9.4	133.4	21	
11	430	43000.0	543000.0	8304.8	65.0	2.499E+04	10.2	144.5	21	
12	-		543000.0	8304.8	65.0	2.499E+04	10.2	144.5	21	
13	30	3000.0	546000.0	7137.1	76.0	2.511E+04	10.3	145.2	21	
14	390	39000.0	585000.0	7137.1	81.0	2.677E+04	10.9	154.7	21	
15	320	32000.0	617000.0	7137.1	86.0	2.842E+04	11.6	164.3	21	
16	370	37000.0	654000.0	7137.1	91.0	3.007E+04	12.3	173.8	24	
17	410	41000.0	695000.0	7137.1	97.0	3.205E+04	13.1	185.3	24	
18	545	54500.0	749500.0	7137.1	105.0	3.470E+04	14.2	200.6	24	
19	590	59000.0	808500.0	7137.1	113.0	3.734E+04	15.3	215.9	24	
20	590	59000.0	867500.0	7137.1	121.0	3.999E+04	16.3	231.1	24	
21	510	51000.0	918500.0	7137.1	128.0	4.230E+04	17.3	244.5	24	
22	350	35000.0	953500.0	7137.1	133.0	4.395E+04	18.0	254.1	27	
23	700	70000.0	1023500.0	7137.1	143.0	4.726E+04	19.3	273.2	27	
24	700	70000.0	1093500.0	7137.1	153.0	5.056E+04	20.7	292.3	27	
25	700	70000.0	1163500.0	7137.1	163.0	5.386E+04	22.0	311.4	27	
26	700	70000.0	1233500.0	7137.1	172.0	5.684E+04	23.2	328.6	27	
27	700	70000.0	1303500.0	7137.1	182.0	6.014E+04	24.6	347.7	30	
28	700	70000.0	1373500.0	7137.1	192.0	6.345E+04	25.9	366.8	30	
29	700	70000.0	1443500.0	7137.1	202.0	6.675E+04	27.3	385.9	30	
30	700	70000.0	1513500.0	7137.1	212.0	7.006E+04	28.6	405.0	30	
31	700	70000.0	1583500.0	7137.1	221.0	7.303E+04	29.9	422.1	30	
32	700	70000.0	1653500.0	7137.1	231.0	7.634E+04	31.2	441.3	30	
33	700	70000.0	1723500.0	7137.1	241.0	7.964E+04	32.6	460.4	33	
34	700	70000.0	1793500.0	7137.1	251.0	8.295E+04	33.9	479.5	33	
35	700	70000.0	1863500.0	7137.1	261.0	8.625E+04	35.3	498.6	33	
36	700	70000.0	1933500.0	7137.1	270.0	8.922E+04	36.5	515.7	33	
37	700	70000.0	2003500.0	7137.1	280.0	9.253E+04	37.8	534.9	33	
38	700	70000.0	2073500.0	7137.1	290.0	9.583E+04	39.2	554.0	33	
39	700	70000.0	2143500.0	7137.1	300.0	9.914E+04	40.5	573.1	36	
39	-		3583200.0	7137.1	502.0	1.659E+05	67.8	958.9	42	inflow from branches # 7 & 6

BRANCH 2

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	330	33000.0	33000.0	7137.1	4.0	9.201E+02	0.4	5.3	8	
2	530	53000.0	86000.0	7137.1	12.0	1.854E+03	0.8	10.7	8	
3	600	60000.0	146000.0	7137.1	20.0	2.510E+03	1.0	14.5	10	
4	636	63600.0	209600.0	7137.1	29.0	3.107E+03	1.3	18.0	10	
5	680	68000.0	277600.0	7137.1	38.0	3.618E+03	1.5	20.9	10	
6	630	63000.0	340600.0	7137.1	47.0	4.072E+03	1.7	23.5	10	
7	360	36000.0	376600.0	7137.1	52.0	4.306E+03	1.8	24.9	12	
8	310	31000.0	407600.0	7137.1	57.0	4.529E+03	1.9	26.2	12	
9	470	47000.0	454600.0	7137.1	63.0	4.784E+03	2.0	27.7	12	
10	-		409800.0	7137.1	57.0	4.529E+03	1.9	26.2	12	inflow from branch#2a
11	580	58000.0	467800.0	7137.1	65.0	4.866E+03	2.0	28.1	12	
12	580	58000.0	525800.0	7137.1	73.0	5.184E+03	2.1	30.0	12	
13	650	65000.0	590800.0	7137.1	82.0	5.521E+03	2.3	31.9	12	
14	630	63000.0	653800.0	7137.1	91.0	5.839E+03	2.4	33.8	12	
15	630	63000.0	716800.0	7137.1	100.0	6.143E+03	2.5	35.5	12	
16	630	63000.0	779800.0	7137.1	109.0	6.433E+03	2.6	37.2	12	
17	500	50000.0	829800.0	7137.1	116.0	6.651E+03	2.7	38.4	12	
18	350	35000.0	864800.0	7137.1	121.0	6.803E+03	2.8	39.3	15	
19	280	28000.0	892800.0	7137.1	125.0	6.921E+03	2.8	40.0	15	

BRANCH 2a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**1673**	167300.0	167300.0	7137.1	23.0	2.721E+03	1.1	15.7	10	
2	**990**	99000.0	266300.0	7137.1	37.0	3.565E+03	1.5	20.6	10	
3	**605**	60500.0	326800.0	7137.1	45.0	3.976E+03	1.6	23.0	10	
4	**550**	55000.0	381800.0	7137.1	53.0	4.352E+03	1.8	25.2	12	
5	280	28000.0	409800.0	7137.1	57.0	4.529E+03	1.9	26.2	12	

BRANCH 3

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	240	24000.0	24000.0	7137.1	3.0	7.549E+02	0.3	4.4	8	
2	480	48000.0	72000.0	7137.1	10.0	1.659E+03	0.7	9.6	8	
3	480	48000.0	120000.0	7137.1	16.0	2.202E+03	0.9	12.7	8	
4	640	64000.0	184000.0	7137.1	25.0	2.855E+03	1.2	16.5	10	
5	690	69000.0	253000.0	7137.1	35.0	3.455E+03	1.4	20.0	10	
6	350	35000.0	288000.0	7137.1	40.0	3.723E+03	1.5	21.5	10	
7	680	68000.0	356000.0	7137.1	49.0	4.167E+03	1.7	24.1	12	
8	-		646400.0	7137.1	90.0	5.805E+03	2.4	33.6	12	inflow from bracnh #3a
9	-		728900.0	7137.1	102.0	6.209E+03	2.5	35.9	12	inflow from branch #4
10	-		1621700.0	7137.1	227.0	9.486E+03	3.9	54.8	15	inflow from branch#2

BRANCH 3a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**1244**	124400.0	124400.0	7137.1	17.0	2.282E+03	0.9	13.2	10	
2	**990**	99000.0	223400.0	7137.1	31.0	3.227E+03	1.3	18.7	10	
3	**410**	41000.0	264400.0	7137.1	37.0	3.565E+03	1.5	20.6	10	
4	**50**	5000.0	269400.0	7137.1	37.0	3.565E+03	1.5	20.6	10	
5	**210**	21000.0	290400.0	7137.1	40.0	3.723E+03	1.5	21.5	10	

BRANCH 4

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	150	15000.0	15000.0	7137.1	2.0	5.641E+02	0.2	3.3	8	
2	**235**	23500.0	38500.0	7137.1	5.0	1.068E+03	0.4	6.2	8	
3	**240**	24000.0	62500.0	7137.1	8.0	1.445E+03	0.6	8.4	8	
4	**200**	20000.0	82500.0	7137.1	11.0	1.759E+03	0.7	10.2	8	

BRANCH 5

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	230	23000.0	23000.0	7137.1	3.0	7.549E+02	0.3	4.4	8	
2	420	42000.0	65000.0	7137.1	9.0	1.555E+03	0.6	9.0	8	
3	620	62000.0	127000.0	7137.1	17.0	2.282E+03	0.9	13.2	10	
4	510	51000.0	178000.0	7137.1	24.0	2.789E+03	1.1	16.1	10	
5	**370**	37000.0	215000.0	7137.1	30.0	3.167E+03	1.3	18.3	10	
6	**150**	15000.0	230000.0	7137.1	32.0	3.285E+03	1.3	19.0	10	
7	160	16000.0	246000.0	7137.1	34.0	3.399E+03	1.4	19.7	10	

BRANCH 6

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	190	19000.0	19000.0	7137.1	2.0	5.641E+02	0.2	3.3	8	
2	210	21000.0	40000.0	7137.1	5.0	1.068E+03	0.4	6.2	8	
3	**760**	76000.0	116000.0	7137.1	16.0	2.202E+03	0.9	12.7	8	
4	**1108**	110800.0	226800.0	7137.1	31.0	3.227E+03	1.3	18.7	10	
5	**1013**	101300.0	328100.0	7137.1	45.0	3.976E+03	1.6	23.0	10	
6	232	23200.0	351300.0	7137.1	49.0	4.167E+03	1.7	24.1	12	
7	257	25700.0	451000.0	7137.1	63.0	4.784E+03	2.0	27.7	12	includes inflow from branch #6a
8	**360**	36000.0	487000.0	7137.1	68.0	4.987E+03	2.0	28.8	12	
9	**620**	62000.0	549000.0	7137.1	76.0	5.298E+03	2.2	30.6	12	
10	670	67000.0	616000.0	7137.1	86.0	5.664E+03	2.3	32.7	12	
11	700	70000.0	686000.0	7137.1	96.0	6.010E+03	2.5	34.7	12	
12	700	70000.0	756000.0	7137.1	105.0	6.306E+03	2.6	36.5	12	
13	700	70000.0	826000.0	7137.1	115.0	6.620E+03	2.7	38.3	12	
14	700	70000.0	896000.0	7137.1	125.0	6.921E+03	2.8	40.0	15	
15	350	35000.0	931000.0	7137.1	130.0	7.068E+03	2.9	40.9	15	
16	-		1177000.0	7137.1	164.0	7.994E+03	3.3	46.2	15	inflow from branch #5

BRANCH 6a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**740**	74000.0	74000.0	7137.1	10.0	1.659E+03	0.7	9.6	8	

BRANCH 7

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	490	49000.0	49000.0	7137.1	6.0	1.203E+03	0.5	7.0	8	
2	360	36000.0	85000.0	7137.1	11.0	1.759E+03	0.7	10.2	8	
3	370	37000.0	122000.0	7137.1	17.0	2.282E+03	0.9	13.2	10	
4	610	61000.0	183000.0	7137.1	25.0	2.855E+03	1.2	16.5	10	
5	570	57000.0	240000.0	7137.1	33.0	3.343E+03	1.4	19.3	10	
6	330	33000.0	273000.0	7137.1	38.0	3.618E+03	1.5	20.9	10	
7	**970**	97000.0	370000.0	7137.1	51.0	4.260E+03	1.7	24.6	12	
8	262	26200.0	396200.0	7137.1	55.0	4.441E+03	1.8	25.7	12	
9	340	34000.0	430200.0	7137.1	60.0	4.658E+03	1.9	26.9	12	
10	330	33000.0	463200.0	7137.1	64.0	4.825E+03	2.0	27.9	12	
11	455	45500.0	508700.0	7137.1	71.0	5.106E+03	2.1	29.5	12	
12	-		583700.0	7138.1	81.0	5.485E+03	2.2	31.7	12	inflow from branch #8

BRANCH 8

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	85	8500.0	8500.0	7137.1	1.0	3.305E+02	0.1	1.9	8	
2	355	35500.0	44000.0	7137.1	6.0	1.203E+03	0.5	7.0	8	
3	250	25000.0	69000.0	7137.1	9.0	1.555E+03	0.6	9.0	8	
4	60	6000.0	75000.0	7137.1	10.0	1.659E+03	0.7	9.6	8	

BRANCH 9

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	110	11000.0	11000.0	7137.1	1.0	3.305E+02	0.1	1.9	8	
2	380	38000.0	49000.0	7137.1	6.0	1.203E+03	0.5	7.0	8	
3	410	41000.0	90000.0	7137.1	12.0	1.854E+03	0.8	10.7	8	
4	300	30000.0	120000.0	7137.1	16.0	2.202E+03	0.9	12.7	8	
5	234	23400.0	143400.0	7137.1	20.0	2.510E+03	1.0	14.5	10	

BRANCH 10

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	240	24000.0	24000.0	7137.1	3.0	7.549E+02	0.3	4.4	8	
2	500	50000.0	74000.0	7137.1	10.0	1.659E+03	0.7	9.6	8	
3	650	65000.0	139000.0	7137.1	19.0	2.436E+03	1.0	14.1	10	
4	700	70000.0	209000.0	7137.1	29.0	3.107E+03	1.3	18.0	10	
5	700	70000.0	279000.0	7137.1	39.0	3.671E+03	1.5	21.2	10	
6	700	70000.0	349000.0	7137.1	48.0	4.120E+03	1.7	23.8	12	
7	200	20000.0	369000.0	7137.1	51.0	4.260E+03	1.7	24.6	12	
8	140	14000.0	526400.0	7137.1	73.0	5.184E+03	2.1	30.0	12	includes inflow from branch #9

BRANCH 11

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**180**	18000.0	18000.0	7137.1	2.0	5.641E+02	0.2	3.3	8	
2	**320**	32000.0	50000.0	7137.1	7.0	1.328E+03	0.5	7.7	8	
3	**370**	37000.0	87000.0	7137.1	12.0	1.854E+03	0.8	10.7	8	
4	-		202200.0	7137.1	28.0	3.046E+03	1.2	17.6	10	inflow from branch #11a
5	700	70000.0	272200.0	7137.1	38.0	3.618E+03	1.5	20.9	10	
6	630	63000.0	335200.0	7137.1	46.0	4.024E+03	1.6	23.3	10	
7	375	37500.0	372700.0	7137.1	52.0	4.306E+03	1.8	24.9	12	
8	100	10000.0	382700.0	7137.1	53.0	4.352E+03	1.8	25.2	12	
9	-		909100.0	7138.1	127.0	6.981E+03	2.9	40.4	15	inflow from branch #10
10	-		2578700.0	7139.1	361.0	1.208E+04	4.9	69.9	15	inflow from branch #12

BRANCH 11a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**502**	50200.0	50200.0	7137.1	7.0	1.328E+03	0.5	7.7	8	
2	**315**	31500.0	81700.0	7137.1	11.0	1.759E+03	0.7	10.2	8	
3	**335**	33500.0	115200.0	7137.1	16.0	2.202E+03	0.9	12.7	8	

BRANCH 12

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	350	35000.0	35000.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	490	49000.0	84000.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	570	57000.0	141000.0	8305.8	16.0	2.563E+03	1.0	14.8	10	
4	530	53000.0	194000.0	8306.8	23.0	3.167E+03	1.3	18.3	10	
5	490	49000.0	243000.0	8307.8	29.0	3.617E+03	1.5	20.9	10	
6	-		893500.0	8308.8	107.0	7.416E+03	3.0	42.9	15	inflow from branch #12b
7	-		893500.0	8309.8	107.0	7.417E+03	3.0	42.9	15	inflow from branch #12c
8	270	27000.0	920500.0	8310.8	110.0	7.528E+03	3.1	43.5	15	
9	480	48000.0	968500.0	8311.8	116.0	7.746E+03	3.2	44.8	15	
10	700	70000.0	1038500.0	8312.8	124.0	8.027E+03	3.3	46.4	15	
11	-		1256000.0	8313.8	151.0	8.914E+03	3.6	51.5	15	inflow from branch #12d
12	350	35000.0	1291000.0	8314.8	155.0	9.039E+03	3.7	52.3	15	
13	-		1354600.0	8315.8	162.0	9.254E+03	3.8	53.5	15	inflow from branch #12e
14	440	44000.0	1398600.0	8316.8	168.0	9.435E+03	3.9	54.5	15	
15	700	70000.0	1468600.0	8317.8	176.0	9.671E+03	4.0	55.9	15	
16	700	70000.0	1538600.0	8318.8	184.0	9.901E+03	4.0	57.2	15	
17	700	70000.0	1608600.0	8319.8	193.0	1.015E+04	4.2	58.7	15	
18	610	61000.0	1669600.0	8320.8	200.0	1.035E+04	4.2	59.8	15	

BRANCH 12a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	355	35500.0	35500.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	345	34500.0	70000.0	8304.8	8.0	1.681E+03	0.7	9.7	8	
3	**190**	19000.0	89000.0	8305.8	10.0	1.931E+03	0.8	11.2	8	
4	**100**	10000.0	99000.0	8306.8	11.0	2.047E+03	0.8	11.8	8	

BRANCH 12b

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	350	35000.0	35000.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	410	41000.0	76000.0	8304.8	9.0	1.809E+03	0.7	10.5	8	
3	480	48000.0	124000.0	8305.8	14.0	2.367E+03	1.0	13.7	10	
4	560	56000.0	180000.0	8306.8	21.0	3.005E+03	1.2	17.4	10	
5	650	65000.0	245000.0	8307.8	29.0	3.617E+03	1.5	20.9	10	
6	700	70000.0	315000.0	8308.8	37.0	4.150E+03	1.7	24.0	12	
7	680	68000.0	482000.0	8309.8	58.0	5.324E+03	2.2	30.8	12	includes inflow from branch # 12a
8	475	47500.0	529500.0	8310.8	63.0	5.571E+03	2.3	32.2	12	
9	395	39500.0	569000.0	8311.8	68.0	5.808E+03	2.4	33.6	12	
10	515	51500.0	620500.0	8312.8	74.0	6.082E+03	2.5	35.2	12	
11	300	30000.0	650500.0	8313.8	78.0	6.259E+03	2.6	36.2	12	

BRANCH 12c

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	320	32000.0	32000.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	475	47500.0	79500.0	8304.8	9.0	1.809E+03	0.7	10.5	8	
3	635	63500.0	143000.0	8305.8	17.0	2.656E+03	1.1	15.4	10	
4	660	66000.0	209000.0	8306.8	25.0	3.323E+03	1.4	19.2	10	
5	600	60000.0	269000.0	8307.8	32.0	3.824E+03	1.6	22.1	10	
6	180	18000.0	287000.0	8308.8	34.0	3.958E+03	1.6	22.9	10	

BRANCH 12d

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	100	10000.0	10000.0	8304.8	1.0	3.845E+02	0.2	2.2	8	
2	275	27500.0	37500.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
3	480	48000.0	85500.0	8305.8	10.0	1.931E+03	0.8	11.2	8	
4	525	52500.0	138000.0	8306.8	16.0	2.563E+03	1.0	14.8	10	
5	295	29500.0	167500.0	8307.8	20.0	2.922E+03	1.2	16.9	10	
6	440	44000.0	211500.0	8308.8	25.0	3.324E+03	1.4	19.2	10	
7	60	6000.0	217500.0	8309.8	26.0	3.399E+03	1.4	19.7	10	

BRANCH 12e

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**136**	13600.0	13600.0	8304.8	1.0	3.845E+02	0.2	2.2	8	
2	**230**	23000.0	36600.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
3	**170**	17000.0	53600.0	8305.8	6.0	1.400E+03	0.6	8.1	8	
4	**100**	10000.0	63600.0	8306.8	7.0	1.545E+03	0.6	8.9	8	

BRANCH 13

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	430	43000.0	43000.0	8304.8	5.0	1.243E+03	0.5	7.2	8	
2	620	62000.0	105000.0	8304.8	12.0	2.158E+03	0.9	12.5	8	
3	670	67000.0	172000.0	8305.8	20.0	2.921E+03	1.2	16.9	10	
4	600	60000.0	232000.0	8306.8	27.0	3.472E+03	1.4	20.1	10	
5	550	55000.0	287000.0	8307.8	34.0	3.957E+03	1.6	22.9	10	
6	410	41000.0	328000.0	8308.8	39.0	4.274E+03	1.7	24.7	12	
7	260	26000.0	354000.0	8309.8	42.0	4.455E+03	1.8	25.8	12	

BRANCH 14

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	420	42000.0	42000.0	8304.8	5.0	1.243E+03	0.5	7.2	8	
2	225	22500.0	64500.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	245	24500.0	89000.0	8305.8	10.0	1.931E+03	0.8	11.2	8	
4	225	22500.0	111500.0	8306.8	13.0	2.265E+03	0.9	13.1	8	
5	-		601500.0	8307.8	72.0	5.989E+03	2.4	34.6	12	inflow from branches #14b & 14c
6	-		601500.0	8308.8	72.0	5.990E+03	2.4	34.6	12	
7	420	42000.0	643500.0	8309.8	77.0	6.212E+03	2.5	35.9	12	
8	470	47000.0	690500.0	8310.8	83.0	6.471E+03	2.6	37.4	12	
9	665	66500.0	757000.0	8311.8	91.0	6.801E+03	2.8	39.3	15	
10	690	69000.0	826000.0	8312.8	99.0	7.117E+03	2.9	41.1	15	
11	500	50000.0	876000.0	8313.8	105.0	7.346E+03	3.0	42.5	15	
12	180	18000.0	894000.0	8314.8	107.0	7.421E+03	3.0	42.9	15	
12	-		1248000.0	8315.8	150.0	8.885E+03	3.6	51.4	15	inflow from branch #13
13	140	14000.0	1262000.0	8316.8	151.0	8.917E+03	3.6	51.5	15	
14	-		1396000.0	8317.8	167.0	9.406E+03	3.8	54.4	15	inflow from branch #15

BRANCH 14a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	305	30500.0	30500.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	605	60500.0	91000.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	645	64500.0	155500.0	8305.8	18.0	2.747E+03	1.1	15.9	10	
4	515	51500.0	207000.0	8306.8	24.0	3.246E+03	1.3	18.8	10	
5	430	43000.0	250000.0	8307.8	30.0	3.687E+03	1.5	21.3	10	
6	305	30500.0	280500.0	8308.8	33.0	3.892E+03	1.6	22.5	10	
7	200	20000.0	300500.0	8309.8	36.0	4.087E+03	1.7	23.6	10	

BRANCH 14b

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	305	30500.0	30500.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	620	62000.0	92500.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
3	350	35000.0	127500.0	8305.8	15.0	2.467E+03	1.0	14.3	10	
4	-		300500.0	8306.8	36.0	4.086E+03	1.7	23.6	10	inflow from branch #14a

BRANCH 14c

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	230	23000.0	23000.0	8304.8	2.0	6.564E+02	0.3	3.8	8	
2	360	36000.0	59000.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	640	64000.0	123000.0	8305.8	14.0	2.367E+03	1.0	13.7	10	
4	665	66500.0	189500.0	8306.8	22.0	3.087E+03	1.3	17.8	10	

BRANCH 15

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	400	40000.0	40000.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	350	35000.0	75000.0	8304.8	9.0	1.809E+03	0.7	10.5	8	
3	410	41000.0	116000.0	8305.8	13.0	2.265E+03	0.9	13.1	8	
4	180	18000.0	134000.0	8306.8	16.0	2.563E+03	1.0	14.8	10	

BRANCH 16

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	200	20000.0	20000.0	8304.8	2.0	6.564E+02	0.3	3.8	8	
2	505	50500.0	70500.0	8304.8	8.0	1.681E+03	0.7	9.7	8	
3	660	66000.0	136500.0	8305.8	16.0	2.563E+03	1.0	14.8	10	
4	510	51000.0	187500.0	8306.8	22.0	3.087E+03	1.3	17.8	10	
5	640	64000.0	251500.0	8307.8	30.0	3.687E+03	1.5	21.3	10	
6	375	37500.0	289000.0	8308.8	34.0	3.958E+03	1.6	22.9	10	
7	-		446500.0	8309.8	53.0	5.067E+03	2.1	29.3	12	inflow from branch #16a
8	-		538000.0	8310.8	64.0	5.619E+03	2.3	32.5	12	inflow from branch #16b
9	410	41000.0	579000.0	8311.8	69.0	5.855E+03	2.4	33.8	12	
10	495	49500.0	628500.0	8312.8	75.0	6.127E+03	2.5	35.4	12	
11	**916**	91600.0	720100.0	8313.8	86.0	6.598E+03	2.7	38.1	12	
12	**435**	43500.0	763600.0	8314.8	91.0	6.803E+03	2.8	39.3	15	
13	**460**	46000.0	809600.0	8315.8	97.0	7.042E+03	2.9	40.7	15	
14	200	20000.0	829600.0	8316.8	99.0	7.120E+03	2.9	41.2	15	

BRANCH 16a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	55	5500.0	5500.0	8304.8	1.0	3.845E+02	0.2	2.2	8	
2	565	56500.0	62000.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	610	61000.0	123000.0	8305.8	14.0	2.367E+03	1.0	13.7	10	
4	**345**	34500.0	157500.0	8306.8	18.0	2.747E+03	1.1	15.9	10	

BRANCH 16b

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	340	34000.0	34000.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	295	29500.0	63500.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	280	28000.0	91500.0	8305.8	11.0	2.047E+03	0.8	11.8	8	

BRANCH 17

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	320	32000.0	32000.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	525	52500.0	84500.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	590	59000.0	143500.0	8305.8	17.0	2.656E+03	1.1	15.4	10	
4	600	60000.0	203500.0	8306.8	24.0	3.246E+03	1.3	18.8	10	
5	610	61000.0	264500.0	8307.8	31.0	3.756E+03	1.5	21.7	10	
6	650	65000.0	329500.0	8308.8	39.0	4.274E+03	1.7	24.7	12	
7	350	35000.0	364500.0	8309.8	43.0	4.513E+03	1.8	26.1	12	
8	-		531000.0	8310.8	63.0	5.571E+03	2.3	32.2	12	inflow from branch #17a
9	420	42000.0	573000.0	8311.8	68.0	5.808E+03	2.4	33.6	12	
10	435	43500.0	616500.0	8312.8	74.0	6.082E+03	2.5	35.2	12	
11	-		689000.0	8313.8	82.0	6.431E+03	2.6	37.2	12	inflow from branch #17b
12	105	10500.0	699500.0	8314.8	84.0	6.516E+03	2.7	37.7	12	

BRANCH 17a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	185	18500.0	18500.0	8304.8	2.0	6.564E+02	0.3	3.8	8	
2	350	35000.0	53500.0	8304.8	6.0	1.400E+03	0.6	8.1	8	
3	235	23500.0	77000.0	8305.8	9.0	1.809E+03	0.7	10.5	8	
4	470	47000.0	124000.0	8306.8	14.0	2.368E+03	1.0	13.7	10	
5	340	34000.0	158000.0	8307.8	19.0	2.836E+03	1.2	16.4	10	
6	85	8500.0	166500.0	8308.8	20.0	2.922E+03	1.2	16.9	10	

BRANCH 17b

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	565	56500.0	56500.0	8304.8	6.0	1.400E+03	0.6	8.1	8	
2	160	16000.0	72500.0	8304.8	8.0	1.681E+03	0.7	9.7	8	

BRANCH 18

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	340	34000.0	34000.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	400	40000.0	74000.0	8304.8	8.0	1.681E+03	0.7	9.7	8	
3	400	40000.0	114000.0	8305.8	13.0	2.265E+03	0.9	13.1	8	
4	400	40000.0	154000.0	8306.8	18.0	2.747E+03	1.1	15.9	10	
5	-		1196000.0	8307.8	143.0	8.654E+03	3.5	50.0	15	inflow from branches #17 & 18a
6	-		1196000.0	8308.8	143.0	8.655E+03	3.5	50.0	15	
7	350	35000.0	1231000.0	8309.8	148.0	8.815E+03	3.6	51.0	15	
6	450	45000.0	1276000.0	8310.8	153.0	8.973E+03	3.7	51.9	15	
7	485	48500.0	1324500.0	8311.8	159.0	9.159E+03	3.7	52.9	15	
8	450	45000.0	1369500.0	8312.8	164.0	9.311E+03	3.8	53.8	15	
9	575	57500.0	1427000.0	8313.8	171.0	9.520E+03	3.9	55.0	15	
10	170	17000.0	1444000.0	8314.8	173.0	9.580E+03	3.9	55.4	15	
11	-		3004500.0	8315.8	361.0	1.408E+04	5.8	81.4	18	inflow from branches #16 & 19

BRANCH 18a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	510	51000.0	51000.0	8304.8	6.0	1.400E+03	0.6	8.1	8	
2	505	50500.0	101500.0	8304.8	12.0	2.158E+03	0.9	12.5	8	
3	660	66000.0	167500.0	8305.8	20.0	2.921E+03	1.2	16.9	10	
4	700	70000.0	237500.0	8306.8	28.0	3.545E+03	1.4	20.5	10	
5	700	70000.0	307500.0	8307.8	37.0	4.149E+03	1.7	24.0	12	
6	350	35000.0	342500.0	8308.8	41.0	4.395E+03	1.8	25.4	12	

BRANCH 19

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	442	44200.0	44200.0	8304.8	5.0	1.243E+03	0.5	7.2	8	
2	520	52000.0	96200.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
3	650	65000.0	161200.0	8305.8	19.0	2.835E+03	1.2	16.4	10	
4	660	66000.0	227200.0	8306.8	27.0	3.472E+03	1.4	20.1	10	
5	700	70000.0	297200.0	8307.8	35.0	4.022E+03	1.6	23.2	10	
6	700	70000.0	367200.0	8308.8	44.0	4.571E+03	1.9	26.4	12	
7	700	70000.0	437200.0	8309.8	52.0	5.014E+03	2.0	29.0	12	
8	700	70000.0	507200.0	8310.8	61.0	5.473E+03	2.2	31.6	12	
9	170	17000.0	524200.0	8311.8	63.0	5.571E+03	2.3	32.2	12	
10	-		730900.0	8312.8	87.0	6.639E+03	2.7	38.4	12	inflow from branch #19a

BRANCH 19a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	510	51000.0	51000.0	8304.8	6.0	1.400E+03	0.6	8.1	8	
2	612	61200.0	112200.0	8304.8	13.0	2.264E+03	0.9	13.1	8	
3	435	43500.0	155700.0	8305.8	18.0	2.747E+03	1.1	15.9	10	
4	360	36000.0	191700.0	8306.8	23.0	3.167E+03	1.3	18.3	10	
5	150	15000.0	206700.0	8307.8	24.0	3.246E+03	1.3	18.8	10	

BRANCH 20

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	265	26500.0	26500.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	590	59000.0	85500.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	490	49000.0	134500.0	8305.8	16.0	2.563E+03	1.0	14.8	10	
4	700	70000.0	204500.0	8306.8	24.0	3.246E+03	1.3	18.8	10	
5	-		417000.0	8307.8	50.0	4.905E+03	2.0	28.4	12	inflow from branch #20a

BRANCH 20a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	290	29000.0	29000.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	650	65000.0	94000.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
3	**885**	88500.0	182500.0	8305.8	21.0	3.005E+03	1.2	17.4	10	
4	**300**	30000.0	212500.0	8306.8	25.0	3.323E+03	1.4	19.2	10	

BRANCH 21

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	300	30000.0	30000.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	620	62000.0	92000.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
3	700	70000.0	162000.0	8305.8	19.0	2.835E+03	1.2	16.4	10	
4	700	70000.0	232000.0	8306.8	27.0	3.472E+03	1.4	20.1	10	
5	-		354000.0	8307.8	42.0	4.454E+03	1.8	25.7	12	inflow from branch #21a
6	-		533000.0	8308.8	64.0	5.618E+03	2.3	32.5	12	inflow from branch #21b
7	-		533000.0	8309.8	64.0	5.618E+03	2.3	32.5	12	
8	700	70000.0	603000.0	8310.8	72.0	5.991E+03	2.4	34.6	12	
9	420	42000.0	645000.0	8311.8	77.0	6.214E+03	2.5	35.9	12	
10	700	70000.0	715000.0	8312.8	86.0	6.597E+03	2.7	38.1	12	
11	-		885500.0	8313.8	106.0	7.383E+03	3.0	42.7	15	inflow from branch #21c
12	555	55500.0	941000.0	8314.8	113.0	7.641E+03	3.1	44.2	15	
13	650	65000.0	1006000.0	8315.8	120.0	7.891E+03	3.2	45.6	15	
14	390	39000.0	1045000.0	8316.8	125.0	8.066E+03	3.3	46.6	15	
15	320	32000.0	1077000.0	8317.8	129.0	8.203E+03	3.4	47.4	15	
16	110	11000.0	1088000.0	8318.8	130.0	8.238E+03	3.4	47.6	15	
17	-		2003500.0	8319.8	240.0	1.139E+04	4.7	65.8	15	inflow from branches # 20 & 22

BRANCH 21a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	310	31000.0	31000.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	560	56000.0	87000.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	350	35000.0	122000.0	8305.8	14.0	2.367E+03	1.0	13.7	10	

BRANCH 21b

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	385	38500.0	38500.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	605	60500.0	99000.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
3	490	49000.0	148000.0	8305.8	17.0	2.656E+03	1.1	15.4	10	
4	310	31000.0	179000.0	8306.8	21.0	3.005E+03	1.2	17.4	10	

BRANCH 21c

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	85	8500.0	8500.0	8304.8	1.0	3.845E+02	0.2	2.2	8	
2	300	30000.0	38500.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
3	270	27000.0	65500.0	8305.8	7.0	1.545E+03	0.6	8.9	8	
4	315	31500.0	97000.0	8306.8	11.0	2.047E+03	0.8	11.8	8	
5	490	49000.0	146000.0	8307.8	17.0	2.657E+03	1.1	15.4	10	
6	245	24500.0	170500.0	8308.8	20.0	2.922E+03	1.2	16.9	10	

BRANCH 22

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	290	29000.0	29000.0	8304.8	3.0	8.784E+02	0.4	5.1	8	
2	600	60000.0	89000.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	655	65500.0	154500.0	8305.8	18.0	2.747E+03	1.1	15.9	10	
4	680	68000.0	222500.0	8306.8	26.0	3.398E+03	1.4	19.6	10	
5	700	70000.0	292500.0	8307.8	35.0	4.022E+03	1.6	23.2	10	
6	700	70000.0	362500.0	8308.8	43.0	4.513E+03	1.8	26.1	12	
7	700	70000.0	432500.0	8309.8	52.0	5.014E+03	2.0	29.0	12	
8	660	66000.0	498500.0	8310.8	59.0	5.375E+03	2.2	31.1	12	

Attachment 7-2: Lean Ore Surge Pile, year 1

Column height	H_T	3.05	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day
	t	1	day

Flux Rate m/day
For z= 0.0
Case 3
Single drain
$H=H_T$
3.0

BRANCH 1

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	106	10600.0	10600.0	8304.8	1.0	3.845E+02	0.2	2.2	6	
2	120	12000.0	22600.0	8304.8	2.0	7.691E+02	0.3	4.4	6	
3	159	15900.0	38500.0	8305.8	4.0	1.538E+03	0.6	8.9	8	
4	256	25600.0	64100.0	8306.8	7.0	2.692E+03	1.1	15.6	10	
5	137	13700.0	77800.0	8307.8	9.0	3.462E+03	1.4	20.0	10	
6	256	25600.0	103400.0	8308.8	12.0	4.617E+03	1.9	26.7	12	
7	138	13800.0	117200.0	8309.8	14.0	5.387E+03	2.2	31.1	12	
8	256	25600.0	142800.0	8310.8	17.0	6.542E+03	2.7	37.8	12	
9	137	13700.0	156500.0	8311.8	18.0	6.927E+03	2.8	40.0	15	
10	256	25600.0	182100.0	8312.8	21.0	8.083E+03	3.3	46.7	15	
11	256	25600.0	207700.0	8313.8	24.0	9.239E+03	3.8	53.4	15	
12	96	9600.0	217300.0	8314.8	26.0	1.001E+04	4.1	57.9	15	
13	116	11600.0	228900.0	8315.8	27.0	1.040E+04	4.2	60.1	15	
14	**284**	28400.0	257300.0	8316.8	30.0	1.155E+04	4.7	66.8	15	
15	133	13300.0	270600.0	8317.8	32.0	1.232E+04	5.0	71.2	18	
16	**101**	10100.0	280700.0	8318.8	33.0	1.271E+04	5.2	73.5	18	
17			355100.0	8319.8	42.0	1.618E+04	6.6	93.5	18	Inflow from branch 1a
18	121	12100.0	367200.0	8320.8	44.0	1.695E+04	6.9	98.0	18	
19	**92**	9200.0	376400.0	8321.8	45.0	1.734E+04	7.1	100.2	18	
20	125	12500.0	388900.0	8322.8	46.0	1.773E+04	7.2	102.5	18	
21	**125**	12500.0	401400.0	8323.8	48.0	1.850E+04	7.6	106.9	18	
22	129	12900.0	414300.0	8324.8	49.0	1.889E+04	7.7	109.2	18	
23	**257**	25734.0	440034.0	8325.8	52.0	2.005E+04	8.2	115.9	21	Actual length 123 ft
24	124	12400.0	452434.0	8326.8	54.0	2.082E+04	8.5	120.3	21	
25	**276**	27643.0	480077.0	8327.8	57.0	2.198E+04	9.0	127.0	21	Actual length 126 ft
26	122	12200.0	492277.0	8328.8	59.0	2.275E+04	9.3	131.5	21	
27	**126**	12600.0	504877.0	8329.8	60.0	2.314E+04	9.5	133.8	21	
28	127	12700.0	517577.0	8330.8	62.0	2.392E+04	9.8	138.2	21	
29	**111**	11100.0	528677.0	8331.8	63.0	2.430E+04	9.9	140.5	21	
30	130	13000.0	541677.0	8332.8	65.0	2.508E+04	10.3	145.0	21	
31	**44**	4400.0	546077.0	8333.8	65.0	2.508E+04	10.3	145.0	21	
32	86	8600.0	554677.0	8334.8	66.0	2.547E+04	10.4	147.2	21	
33	**32**	3200.0	557877.0	8335.8	66.0	2.547E+04	10.4	147.2	21	
34			1156618.0	8336.8	138.0	5.327E+04	21.8	307.9	27	Inflow from branch #5
35	**89**	8900.0	1165518.0	8337.8	139.0	5.366E+04	21.9	310.2	27	

BRANCH 1a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulate d (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	98	9800.0	9800.0	8304.8	1.0	3.845E+02	0.2	2.2	6	
2	185	18500.0	28300.0	8304.8	3.0	1.154E+03	0.5	6.7	8	
3	181	18100.0	46400.0	8305.8	5.0	1.923E+03	0.8	11.1	8	
4	280	28000.0	74400.0	8306.8	8.0	3.077E+03	1.3	17.8	10	

BRANCH 2

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	120	12000.0	12000.0	8304.8	1.0	3.845E+02	0.2	2.2	6	
2	173	17300.0	29300.0	8304.8	3.0	8.784E+02	0.4	5.1	6	
3	146	14600.0	43900.0	8305.8	5.0	1.243E+03	0.5	7.2	8	
4	256	25600.0	69500.0	8306.8	8.0	1.681E+03	0.7	9.7	8	
5	120	12000.0	81500.0	8307.8	9.0	1.810E+03	0.7	10.5	8	
6	256	25600.0	107100.0	8308.8	12.0	2.159E+03	0.9	12.5	8	
7	256	25600.0	132700.0	8309.8	15.0	2.468E+03	1.0	14.3	10	
8	161	16100.0	148800.0	8310.8	17.0	2.658E+03	1.1	15.4	10	
9	256	25600.0	174400.0	8311.8	20.0	2.923E+03	1.2	16.9	10	
10	149	14900.0	189300.0	8312.8	22.0	3.089E+03	1.3	17.9	10	
11	256	25600.0	214900.0	8313.8	25.0	3.325E+03	1.4	19.2	10	
12	166	16600.0	231500.0	8314.8	27.0	3.474E+03	1.4	20.1	10	
13	256	25600.0	257100.0	8315.8	30.0	3.687E+03	1.5	21.3	10	
14	177	17700.0	274800.0	8316.8	33.0	3.889E+03	1.6	22.5	10	
15	256	25600.0	300400.0	8317.8	36.0	4.081E+03	1.7	23.6	10	
16	182	18200.0	318600.0	8318.8	38.0	4.204E+03	1.7	24.3	12	
17	256	25600.0	344200.0	8319.8	41.0	4.380E+03	1.8	25.3	12	
18	190	19000.0	363200.0	8320.8	43.0	4.494E+03	1.8	26.0	12	
19	251	25100.0	388300.0	8321.8	46.0	4.657E+03	1.9	26.9	12	
20	256	25600.0	413900.0	8322.8	49.0	4.812E+03	2.0	27.8	12	
21	178	17800.0	431700.0	8323.8	51.0	4.912E+03	2.0	28.4	12	
22	171	17100.0	448800.0	8324.8	53.0	5.009E+03	2.0	29.0	12	
23	140	14000.0	462800.0	8325.8	55.0	5.103E+03	2.1	29.5	12	
24	254	25400.0	488200.0	8326.8	58.0	5.239E+03	2.1	30.3	12	
25	185	18500.0	506700.0	8327.8	60.0	5.326E+03	2.2	30.8	12	
26	205	20500.0	527200.0	8328.8	63.0	5.451E+03	2.2	31.5	12	
27	270	27000.0	554200.0	8329.8	66.0	5.571E+03	2.3	32.2	12	
28	110	11000.0	565200.0	8330.8	67.0	5.610E+03	2.3	32.4	12	
29	317	31700.0	596900.0	8331.8	71.0	5.759E+03	2.4	33.3	12	
30	306	30600.0	627500.0	8332.8	75.0	5.899E+03	2.4	34.1	12	
31			1061776.0	8333.8	127.0	7.108E+03	2.9	41.1	15	Inflow from branch #3
32			1136489.0	8334.8	136.0	7.236E+03	3.0	41.8	15	Inflow from branch #2a

BRANCH 2a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**399**	39913.0	39913.0	8304.8	4.0	1.071E+03	0.4	6.2	8	Actual length 240 ft
2	**348**	34800.0	74713.0	8304.8	8.0	1.681E+03	0.7	9.7	8	

BRANCH 3

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**284**	28358.0	28358.0	8304.8	3.0	8.784E+02	0.4	5.1	6	Actual length 210 ft
2	142	14200.0	42558.0	8304.8	5.0	1.243E+03	0.5	7.2	8	
3	275	27500.0	70058.0	8305.8	8.0	1.681E+03	0.7	9.7	8	
4	194	19400.0	89458.0	8306.8	10.0	1.931E+03	0.8	11.2	8	
5	207	20700.0	110158.0	8307.8	13.0	2.265E+03	0.9	13.1	8	
6	337	33700.0	143858.0	8308.8	17.0	2.657E+03	1.1	15.4	10	
7	192	19200.0	163058.0	8309.8	19.0	2.836E+03	1.2	16.4	10	
8	343	34300.0	197358.0	8310.8	23.0	3.168E+03	1.3	18.3	10	
9	193	19300.0	216658.0	8311.8	26.0	3.399E+03	1.4	19.6	10	
10	180	18000.0	234658.0	8312.8	28.0	3.545E+03	1.4	20.5	10	
11	185	18500.0	253158.0	8313.8	30.0	3.686E+03	1.5	21.3	10	
12	342	34200.0	287358.0	8314.8	34.0	3.953E+03	1.6	22.9	10	
13	191	19100.0	306458.0	8315.8	36.0	4.080E+03	1.7	23.6	10	
14	169	16900.0	323358.0	8316.8	38.0	4.203E+03	1.7	24.3	12	
15	363	36300.0	359658.0	8317.8	43.0	4.492E+03	1.8	26.0	12	
16	164	16400.0	376058.0	8318.8	45.0	4.602E+03	1.9	26.6	12	
17	**461**	46118.0	422176.0	8319.8	50.0	4.861E+03	2.0	28.1	12	Actual length 349 ft
19	**121**	12100.0	434276.0	8320.8	52.0	4.959E+03	2.0	28.7	12	

BRANCH 4

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	157	15700.0	15700.0	8304.8	1.0	3.845E+02	0.2	2.2	6	
2	198	19800.0	35500.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
3	192	19200.0	54700.0	8305.8	6.0	1.400E+03	0.6	8.1	8	
4	245	24500.0	79200.0	8306.8	9.0	1.810E+03	0.7	10.5	8	
5	319	31900.0	111100.0	8307.8	13.0	2.265E+03	0.9	13.1	8	
6	264	26400.0	137500.0	8308.8	16.0	2.564E+03	1.0	14.8	10	
7		0.0	236600.0	8309.8	28.0	3.544E+03	1.4	20.5	10	Inflow from branch #4a

BRANCH 4a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	349	34900.0	34900.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	293	29300.0	64200.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	349	34900.0	99100.0	8305.8	11.0	2.047E+03	0.8	11.8	8	

BRANCH 5

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**452**	45154.0	45154.0	8304.8	5.0	1.243E+03	0.5	7.2	8	Actual length 175 ft
2	159	15900.0	61054.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	**358**	35808.0	96862.0	8305.8	11.0	2.047E+03	0.8	11.8	8	Actual length 148 ft
4	160	16000.0	112862.0	8306.8	13.0	2.265E+03	0.9	13.1	8	
5	**332**	33225.0	146087.0	8307.8	17.0	2.657E+03	1.1	15.4	10	Actual length 131 ft
6	155	15500.0	161587.0	8308.8	19.0	2.836E+03	1.2	16.4	10	
7	**276**	27555.0	189142.0	8309.8	22.0	3.088E+03	1.3	17.8	10	Actual length 134 ft
8	154	15400.0	204542.0	8310.8	24.0	3.247E+03	1.3	18.8	10	
9	**252**	25150.0	229692.0	8311.8	27.0	3.473E+03	1.4	20.1	10	Actual length 135 ft
10	160	16000.0	245692.0	8312.8	29.0	3.616E+03	1.5	20.9	10	
11	**216**	21577.0	267269.0	8313.8	32.0	3.822E+03	1.6	22.1	10	Actual length 127 ft
12	157	15700.0	282969.0	8314.8	34.0	3.953E+03	1.6	22.9	10	
13	**176**	17605.0	300574.0	8315.8	36.0	4.080E+03	1.7	23.6	10	Actual length 132 ft
14	184	18400.0	318974.0	8316.8	38.0	4.203E+03	1.7	24.3	12	
15		0.0	418074.0	8317.8	50.0	4.859E+03	2.0	28.1	12	Inflow from branch #4
16	**572**	57160.0	475234.0	8318.8	57.0	5.189E+03	2.1	30.0	12	Actual length 146 ft
17	157	15700.0	490934.0	8319.8	59.0	5.278E+03	2.2	30.5	12	
18	**573**	57298.0	548232.0	8320.8	65.0	5.526E+03	2.3	31.9	12	Actual length 190 ft
19	153	15300.0	563532.0	8321.8	67.0	5.604E+03	2.3	32.4	12	
20	**214**	21409.0	584941.0	8322.8	70.0	5.716E+03	2.3	33.0	12	Actual length 185 ft
21	138	13800.0	598741.0	8323.8	71.0	5.753E+03	2.4	33.3	12	

478	- Indicates areas where secondary piping acts as tertiary piping.
512	- Relevant areas converted to equivalent tertiary piping length for ease of table calculations.
125	- Indicates areas where secondary piping acts as tertiary piping, and where equivalent lengths are used.

Attachment 7-3: Category 4 Stockpile, year 1

Column height	H_T	8.53	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day
	t	1	day

Flux Rate m/day
For z= 0.0
Case 3
Single drain
$H=H_T$
8.5

BRANCH 1

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	383	38300.0	38300.0	8304.8	4.0	1.538E+03	0.6	8.9	8	
2	410	41000.0	79300.0	8304.8	9.0	3.461E+03	1.4	20.0	10	
3	491	49100.0	128400.0	8304.8	15.0	5.768E+03	2.4	33.3	12	
4	512	51200.0	179600.0	8304.8	21.0	8.075E+03	3.3	46.7	15	
5	512	51200.0	230800.0	8304.8	27.0	1.038E+04	4.2	60.0	15	
6	512	51200.0	282000.0	8304.8	33.0	1.269E+04	5.2	73.3	18	
7	512	51200.0	333200.0	8304.8	40.0	1.538E+04	6.3	88.9	18	
8	250	25000.0	358200.0	8304.8	43.0	1.653E+04	6.8	95.6	18	
9	-		436200.0	8304.8	52.0	2.000E+04	8.2	115.6	21	inflow from branch #2
10	512	51200.0	487400.0	8304.8	58.0	2.230E+04	9.1	128.9	21	
11	512	51200.0	538600.0	8304.8	64.0	2.461E+04	10.1	142.3	21	
12	512	51200.0	589800.0	8304.8	71.0	2.730E+04	11.2	157.8	21	
13	410	41000.0	630800.0	8304.8	75.0	2.884E+04	11.8	166.7	21	
14	420	42000.0	672800.0	8304.8	81.0	3.115E+04	12.7	180.0	24	
15	380	38000.0	710800.0	8304.8	85.0	3.268E+04	13.4	188.9	24	
16	484	48400.0	759200.0	8304.8	91.0	3.499E+04	14.3	202.3	24	
17	484	48400.0	807600.0	8304.8	97.0	3.730E+04	15.2	215.6	24	
18	512	51200.0	858800.0	8304.8	103.0	3.961E+04	16.2	228.9	24	
19	512	51200.0	910000.0	8304.8	109.0	4.191E+04	17.1	242.3	24	
20	-		1239100.0	8304.8	149.0	5.729E+04	23.4	331.2	27	inflow from branch #3

BRANCH 2

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	680	68000.0	68000.0	8304.8	8.0	3.076E+03	1.3	17.8	10	
2	100	10000.0	78000.0	8304.8	9.0	3.461E+03	1.4	20.0	10	

BRANCH 3

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**580**	58000.0	58000.0	8304.8	6.0	2.307E+03	0.9	13.3	10	
2	**316**	31600.0	89600.0	8304.8	10.0	3.845E+03	1.6	22.2	10	
3	580	58000.0	147600.0	8305.8	17.0	6.538E+03	2.7	37.8	12	
4	570	57000.0	204600.0	8306.8	24.0	9.231E+03	3.8	53.4	15	
5	520	52000.0	256600.0	8307.8	30.0	1.154E+04	4.7	66.7	15	
6	350	35000.0	291600.0	8308.8	35.0	1.346E+04	5.5	77.8	18	
7	300	30000.0	321600.0	8309.8	38.0	1.462E+04	6.0	84.5	18	
8	75	7500.0	329100.0	8310.8	39.0	1.501E+04	6.1	86.7	18	

BRANCH 4

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	105	10500.0	10500.0	8304.8	1.0	3.845E+02	0.2	2.2	6	
2	225	22500.0	33000.0	8304.8	3.0	8.784E+02	0.4	5.1	6	
3	250	25000.0	58000.0	8304.8	6.0	1.400E+03	0.6	8.1	8	
4	255	25500.0	83500.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
5	290	29000.0	112500.0	8304.8	13.0	2.264E+03	0.9	13.1	8	
6	350	35000.0	147500.0	8304.8	17.0	2.656E+03	1.1	15.4	10	
7	345	34500.0	182000.0	8304.8	21.0	3.004E+03	1.2	17.4	10	
8	375	37500.0	219500.0	8304.8	26.0	3.397E+03	1.4	19.6	10	
9	-		219500.0	8304.8	26.0	3.397E+03	1.4	19.6	10	
10	590	59000.0	278500.0	8304.8	33.0	3.890E+03	1.6	22.5	10	
11	675	67500.0	346000.0	8304.8	41.0	4.393E+03	1.8	25.4	12	
12	690	69000.0	415000.0	8304.8	49.0	4.849E+03	2.0	28.0	12	
13	600	60000.0	475000.0	8304.8	57.0	5.270E+03	2.2	30.5	12	
14	350	35000.0	510000.0	8304.8	61.0	5.470E+03	2.2	31.6	12	
15	610	61000.0	571000.0	8304.8	68.0	5.804E+03	2.4	33.5	12	
16	450	45000.0	616000.0	8304.8	74.0	6.076E+03	2.5	35.1	12	
17	435	43500.0	659500.0	8304.8	79.0	6.296E+03	2.6	36.4	12	
18	440	44000.0	703500.0	8304.8	84.0	6.508E+03	2.7	37.6	12	
19	350	35000.0	738500.0	8304.8	88.0	6.673E+03	2.7	38.6	12	
20	-		1977600.0	8304.8	238.0	1.131E+04	4.6	65.4	15	inflow from branch #1

478	- indicates value includes estimate of areas where secondary piping acts as tertiary piping. - Relevant areas converted to equivalent tertiary piping length for ease of table

Attachment 7-4: Category 3 Lean Ore Stockpile, year 1

Column height	H_T	6.71	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.058	m^2/day
	t	1	day

Flux Rate m/day
For z= 0.0
Case 3
Single drain
$H=H_T$
6.7

BRANCH 1

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**556**	55600.0	55600.0	8304.8	6.0	2.307E+03	0.9	13.3	10	
2	512	51200.0	106800.0	8304.8	12.0	4.614E+03	1.9	26.7	12	
3	477	47700.0	154500.0	8305.8	18.0	6.922E+03	2.8	40.0	15	
4	429	42900.0	197400.0	8306.8	23.0	8.846E+03	3.6	51.1	15	
5	380	38000.0	235400.0	8307.8	28.0	1.077E+04	4.4	62.3	15	
6	256	25600.0	261000.0	8308.8	31.0	1.193E+04	4.9	68.9	15	
7	365	36500.0	297500.0	8309.8	35.0	1.347E+04	5.5	77.8	18	
8	366	36600.0	334100.0	8310.8	40.0	1.539E+04	6.3	89.0	18	
9	**519**	51900.0	386000.0	8311.8	46.0	1.770E+04	7.2	102.3	18	
10	**241**	24100.0	410100.0	8312.8	49.0	1.886E+04	7.7	109.0	18	
11	**340**	34000.0	444100.0	8313.8	53.0	2.040E+04	8.3	117.9	21	
12	**654**	65400.0	509500.0	8314.8	61.0	2.348E+04	9.6	135.7	21	
13	**455**	45500.0	555000.0	8315.8	66.0	2.541E+04	10.4	146.9	21	

BRANCH 2

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**355**	35500.0	35500.0	8304.8	4.0	1.538E+03	0.6	8.9	8	
2	256	25600.0	61100.0	8304.8	7.0	2.692E+03	1.1	15.6	10	
3	512	51200.0	112300.0	8305.8	13.0	4.999E+03	2.0	28.9	12	
4	512	51200.0	163500.0	8306.8	19.0	7.308E+03	3.0	42.2	15	
5	463	46300.0	209800.0	8307.8	25.0	9.617E+03	3.9	55.6	15	
6	399	39900.0	249700.0	8308.8	30.0	1.154E+04	4.7	66.7	15	
7	328	32800.0	282500.0	8309.8	33.0	1.270E+04	5.2	73.4	18	
8	**618**	61800.0	344300.0	8310.8	41.0	1.578E+04	6.4	91.2	18	
9	**551**	55100.0	399400.0	8311.8	48.0	1.847E+04	7.6	106.8	18	

BRANCH 3

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**417**	41700.0	41700.0	8304.8	5.0	1.923E+03	0.8	11.1	8	
2	512	51200.0	92900.0	8304.8	11.0	4.230E+03	1.7	24.4	12	
3	512	51200.0	144100.0	8305.8	17.0	6.538E+03	2.7	37.8	12	
4	512	51200.0	195300.0	8306.8	23.0	8.846E+03	3.6	51.1	15	
5	512	51200.0	246500.0	8307.8	29.0	1.116E+04	4.6	64.5	15	
6	477	47700.0	294200.0	8308.8	35.0	1.346E+04	5.5	77.8	18	
7	410	41000.0	335200.0	8309.8	40.0	1.539E+04	6.3	89.0	18	
8	383	38300.0	373500.0	8310.8	44.0	1.693E+04	6.9	97.9	18	
9	256	25600.0	399100.0	8311.8	48.0	1.847E+04	7.6	106.8	18	
10	196	19600.0	418700.0	8312.8	50.0	1.924E+04	7.9	111.2	18	
11	154	15400.0	434100.0	8313.8	52.0	2.002E+04	8.2	115.7	21	
12	99	9900.0	444000.0	8314.8	53.0	2.040E+04	8.3	117.9	21	
13		1229300.0	1673300.0	8315.8	201.0	7.739E+04	31.6	447.4	33	inflow from branch #4
14		1628700.0	3302000.0	8316.8	397.0	1.529E+05	62.5	883.7	42	inflow from branch #2
15	430	43000.0	3345000.0	8317.8	402.0	1.548E+05	63.3	894.9	42	
16	**200**	20000.0	3365000.0	8318.8	404.0	1.556E+05	63.6	899.5	42	
17		575000.0	3940000.0	8319.8	473.0	1.822E+05	74.5	1053.2	42	inflow from branch #1

BRANCH 4

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**356**	35600.0	35600.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	512	51200.0	86800.0	8304.8	10.0	1.931E+03	0.8	11.2	8	
3	512	51200.0	138000.0	8305.8	16.0	2.563E+03	1.0	14.8	10	
4	512	51200.0	189200.0	8306.8	22.0	3.087E+03	1.3	17.8	10	
5	512	51200.0	240400.0	8307.8	28.0	3.545E+03	1.4	20.5	10	
6	512	51200.0	291600.0	8308.8	35.0	4.023E+03	1.6	23.3	10	
7	512	51200.0	342800.0	8309.8	41.0	4.395E+03	1.8	25.4	12	
8	512	51200.0	394000.0	8310.8	47.0	4.742E+03	1.9	27.4	12	
9	424	42400.0	436400.0	8311.8	52.0	5.015E+03	2.0	29.0	12	
10	512	51200.0	487600.0	8312.8	58.0	5.326E+03	2.2	30.8	12	
11		731800.0	1219400.0	8313.8	146.0	8.749E+03	3.6	50.6	15	includes inflow from branch # 5

BRANCH 5

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**462**	46200.0	46200.0	8304.8	5.0	1.243E+03	0.5	7.2	8	
2	512	51200.0	435300.0	8304.8	52.0	5.011E+03	2.0	29.0	12	includes inflow from branch #5a
3	356	35600.0	470900.0	8305.8	56.0	5.220E+03	2.1	30.2	12	
4	256	25600.0	559500.0	8306.8	67.0	5.758E+03	2.4	33.3	12	includes flow from branch #5b
5	**369**	36900.0	596400.0	8307.8	71.0	5.944E+03	2.4	34.4	12	
6	**842**	84200.0	680600.0	8308.8	81.0	6.384E+03	2.6	36.9	12	

BRANCH 5a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**182**	18200.0	18200.0	8304.8	2.0	6.564E+02	0.3	3.8	6	
2	**775**	77500.0	95700.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
3	**352**	35200.0	130900.0	8305.8	15.0	2.467E+03	1.0	14.3	10	
4	**983**	98300.0	229200.0	8306.8	27.0	3.472E+03	1.4	20.1	10	
5	**1087**	108700.0	337900.0	8307.8	40.0	4.334E+03	1.8	25.1	12	

BRANCH 5b

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**404**	40400.0	40400.0	8304.8	4.0	1.071E+03	0.4	6.2	8	
2	**226**	22600.0	63000.0	8304.8	7.0	1.545E+03	0.6	8.9	8	

BRANCH 6

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**243**	24300.0	24300.0	8304.8	2.0	6.564E+02	0.3	3.8	6	
2	**242**	24200.0	48500.0	8304.8	5.0	1.243E+03	0.5	7.2	8	
3	**241**	24100.0	72600.0	8305.8	8.0	1.681E+03	0.7	9.7	8	
4	**212**	21200.0	93800.0	8306.8	11.0	2.047E+03	0.8	11.8	8	
5	**195**	19500.0	113300.0	8307.8	13.0	2.265E+03	0.9	13.1	8	
6	**800**	80000.0	193300.0	8308.8	23.0	3.168E+03	1.3	18.3	10	

BRANCH 7

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**274**	27400.0	27400.0	8304.8	3.0	8.784E+02	0.4	5.1	6	
2	**321**	32100.0	59500.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	**326**	32600.0	92100.0	8305.8	11.0	2.047E+03	0.8	11.8	8	
4	326	32600.0	124700.0	8306.8	15.0	2.467E+03	1.0	14.3	10	
5	326	32600.0	157300.0	8307.8	18.0	2.747E+03	1.1	15.9	10	
6	326	32600.0	189900.0	8308.8	22.0	3.088E+03	1.3	17.8	10	
7	316	31600.0	221500.0	8309.8	26.0	3.399E+03	1.4	19.7	10	
8	472	47200.0	268700.0	8310.8	32.0	3.826E+03	1.6	22.1	10	
9	512	51200.0	319900.0	8311.8	38.0	4.214E+03	1.7	24.4	12	
10	512	51200.0	371100.0	8312.8	44.0	4.573E+03	1.9	26.4	12	
11	512	51200.0	422300.0	8313.8	50.0	4.909E+03	2.0	28.4	12	
12	512	51200.0	473500.0	8314.8	56.0	5.225E+03	2.1	30.2	12	
13	470	47000.0	520500.0	8315.8	62.0	5.526E+03	2.3	31.9	12	
14	441	44100.0	564600.0	8316.8	67.0	5.765E+03	2.4	33.3	12	
15	384	38400.0	603000.0	8317.8	72.0	5.996E+03	2.5	34.7	12	
16	**344**	34400.0	637400.0	8318.8	76.0	6.175E+03	2.5	35.7	12	
17	**150**	15000.0	652400.0	8319.8	78.0	6.264E+03	2.6	36.2	12	
18	**130**	13000.0	665400.0	8320.8	79.0	6.308E+03	2.6	36.5	12	
19	**120**	12000.0	677400.0	8321.8	81.0	6.394E+03	2.6	37.0	12	
20	**140**	14000.0	1820200.0	8322.8	218.0	1.076E+04	4.4	62.2	15	includes inflow from branch # 9
21	**229**	22900.0	1843100.0	8323.8	221.0	1.084E+04	4.4	62.6	15	
22			2036400.0	8324.8	244.0	1.138E+04	4.7	65.8	15	inflow from Branch #6
23	**184**	18400.0	2054800.0	8325.8	246.0	1.142E+04	4.7	66.0	15	
24	**190**	19000.0	2073800.0	8326.8	249.0	1.149E+04	4.7	66.4	15	
25	**427**	42700.0	2116500.0	8327.8	254.0	1.160E+04	4.7	67.1	15	
26	**517**	51700.0	2168200.0	8328.8	260.0	1.173E+04	4.8	67.8	15	

BRANCH 8

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**507**	50700.0	50700.0	8304.8	6.0	1.400E+03	0.6	8.1	8	
2	512	51200.0	101900.0	8304.8	12.0	2.158E+03	0.9	12.5	8	
3	512	51200.0	153100.0	8305.8	18.0	2.747E+03	1.1	15.9	10	
4	512	51200.0	204300.0	8306.8	24.0	3.246E+03	1.3	18.8	10	
5	512	51200.0	255500.0	8307.8	30.0	3.687E+03	1.5	21.3	10	
6	182	18200.0	273700.0	8308.8	32.0	3.825E+03	1.6	22.1	10	
7	**527**	52700.0	326400.0	8309.8	39.0	4.274E+03	1.7	24.7	12	

BRANCH 9

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	161	16100.0	16100.0	8304.8	1.0	3.845E+02	0.2	2.2	6	
2	607	60700.0	76800.0	8304.8	9.0	1.809E+03	0.7	10.5	8	
3	63	6300.0	83100.0	8305.8	10.0	1.931E+03	0.8	11.2	8	
4	157	15700.0	98800.0	8306.8	11.0	2.047E+03	0.8	11.8	8	
5			935900.0	8307.8	112.0	7.597E+03	3.1	43.9	15	inflows from branches # 8 & 10
6			1043600.0	8308.8	125.0	8.055E+03	3.3	46.6	15	inflow from branch # 9a
7	332	33200.0	1076800.0	8309.8	129.0	8.192E+03	3.3	47.4	15	
8	520	52000.0	1128800.0	8310.8	135.0	8.392E+03	3.4	48.5	15	

BRANCH 9a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**939**	93900.0	93900.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
2	**138**	13800.0	107700.0	8304.8	12.0	2.158E+03	0.9	12.5	8	

BRANCH 10

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**916**	91600.0	91600.0	8304.8	11.0	2.047E+03	0.8	11.8	8	
2	**133**	13300.0	104900.0	8304.8	12.0	2.158E+03	0.9	12.5	8	
3	**320**	32000.0	136900.0	8305.8	16.0	2.563E+03	1.0	14.8	10	
4			195600.0	8306.8	23.0	3.167E+03	1.3	18.3	10	inflow from branch #10a
5	**1169**	116900.0	312500.0	8307.8	37.0	4.149E+03	1.7	24.0	12	
6	**40**	4000.0	316500.0	8308.8	38.0	4.212E+03	1.7	24.3	12	
7	**421**	42100.0	358600.0	8309.8	43.0	4.513E+03	1.8	26.1	12	
8	**372**	37200.0	395800.0	8310.8	47.0	4.742E+03	1.9	27.4	12	
9	**399**	39900.0	435700.0	8311.8	52.0	5.015E+03	2.0	29.0	12	
10	**494**	49400.0	485100.0	8312.8	58.0	5.326E+03	2.2	30.8	12	
11	256	25600.0	510700.0	8313.8	61.0	5.475E+03	2.2	31.7	12	

BRANCH 10a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**587**	58700.0	58700.0	8304.8	7.0	1.545E+03	0.6	8.9	8	

BRANCH 11

`	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**828**	82800.0	82800.0	8304.8	9.0	1.809E+03	0.7	10.5	8	
2	199	19900.0	102700.0	8304.8	12.0	2.158E+03	0.9	12.5	8	
3	**1123**	112300.0	215000.0	8305.8	25.0	3.322E+03	1.4	19.2	10	
4	670	67000.0	282000.0	8306.8	33.0	3.891E+03	1.6	22.5	10	
5	256	25600.0	307600.0	8307.8	37.0	4.149E+03	1.7	24.0	12	
6	200	20000.0	327600.0	8308.8	39.0	4.274E+03	1.7	24.7	12	
7	178	17800.0	504600.0	8309.8	60.0	5.424E+03	2.2	31.4	12	includes inflow from branch #11a
8	117	11700.0	516300.0	8310.8	62.0	5.522E+03	2.3	31.9	12	

BRANCH 11a

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**1592**	159200.0	159200.0	8304.8	19.0	2.835E+03	1.2	16.4	10	

478 - indicates value includes estimate of areas where secondary piping acts as tertiary piping.
- Relevant areas converted to equivalent tertiary piping length for ease of table

Attachment 7-5: Category 2/3 Stockpile, year 1

Column height	H_T	12.19	m
Hydrulic cond.	k	8.64E-03	m/day
Water density	γ_w	9.81	kN/m^3
Soil density	γ_s	19.98	kN/m^3
Load on surface	p	235.6	kN/m^2
Consolidation coef.	cv	0.06	m^2/day
	t	1.00	day

Flux Rate
m/day
For z= 0.0
Case 3
Single drain
$H=H_T$
12.2

BRANCH 1

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**758**	75800.0	75800.0	8304.8	9.0	3.461E+03	1.4	20.0	10	
2	**446**	44600.0	120400.0	8304.8	14.0	5.383E+03	2.2	31.1	12	
3	**658**	65800.0	186200.0	8305.8	22.0	8.461E+03	3.5	48.9	15	
4	461	46100.0	232300.0	8306.8	27.0	1.038E+04	4.2	60.0	15	
5	575	57500.0	289800.0	8307.8	34.0	1.308E+04	5.3	75.6	18	
6	620	62000.0	351800.0	8308.8	42.0	1.616E+04	6.6	93.4	18	
7	150	15000.0	366800.0	8309.8	44.0	1.693E+04	6.9	97.9	18	
8	450	45000.0	411800.0	8310.8	49.0	1.886E+04	7.7	109.0	18	
9	510	51000.0	462800.0	8311.8	55.0	2.117E+04	8.7	122.4	21	
10	550	55000.0	517800.0	8312.8	62.0	2.386E+04	9.8	137.9	21	

BRANCH 2

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**745**	74500.0	74500.0	8304.8	8.0	3.076E+03	1.3	17.8	10	
2	512	51200.0	125700.0	8304.8	15.0	5.768E+03	2.4	33.3	12	
3	**758**	75800.0	201500.0	8305.8	24.0	9.230E+03	3.8	53.4	15	
4	410	41000.0	242500.0	8306.8	29.0	1.115E+04	4.6	64.5	15	
5	700	70000.0	312500.0	8307.8	37.0	1.423E+04	5.8	82.3	18	

BRANCH 3

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	256	25600.0	25600.0	8304.8	3.0	1.154E+03	0.5	6.7	8	
2	460	46000.0	71600.0	8304.8	8.0	3.076E+03	1.3	17.8	10	
3	385	38500.0	110100.0	8305.8	13.0	4.999E+03	2.0	28.9	12	
4	430	43000.0	153100.0	8306.8	18.0	6.923E+03	2.8	40.0	15	
5	**765**	76500.0	229600.0	8307.8	27.0	1.039E+04	4.2	60.0	15	
6	280	28000.0	257600.0	8308.8	31.0	1.193E+04	4.9	68.9	15	
7	380	38000.0	295600.0	8309.8	35.0	1.347E+04	5.5	77.8	18	
8	385	38500.0	334100.0	8310.8	40.0	1.539E+04	6.3	89.0	18	
9	-		646600.0	8311.8	77.0	2.963E+04	12.1	171.3	21	inflow from branch #2
10	435	43500.0	690100.0	8312.8	83.0	3.195E+04	13.1	184.7	24	
11	200	20000.0	710100.0	8313.8	85.0	3.272E+04	13.4	189.1	24	
12	-		1248700.0	8314.8	150.0	5.775E+04	23.6	333.8	27	inflow from branch #5
13	-		2827700.0	8315.8	340.0	1.309E+05	53.5	756.7	42	Inflow from branches #1 & 7

BRANCH 4

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**500**	50000.0	50000.0	8304.8	6.0	2.307E+03	0.9	13.3	10	
2	456	45600.0	95600.0	8304.8	11.0	4.230E+03	1.7	24.4	12	
3	**430**	43000.0	138600.0	8305.8	16.0	6.153E+03	2.5	35.6	12	
4	**692**	69200.0	207800.0	8306.8	25.0	9.615E+03	3.9	55.6	15	
5	**176**	17600.0	225400.0	8307.8	27.0	1.039E+04	4.2	60.0	15	

BRANCH 5

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**326**	32600.0	32600.0	8304.8	3.0	1.154E+03	0.5	6.7	8	
2	**607**	60700.0	93300.0	8304.8	11.0	4.230E+03	1.7	24.4	12	
3	**639**	63900.0	157200.0	8305.8	18.0	6.922E+03	2.8	40.0	15	
4	**605**	60500.0	217700.0	8306.8	26.0	1.000E+04	4.1	57.8	15	
5	485	48500.0	266200.0	8307.8	32.0	1.231E+04	5.0	71.2	18	
6	-		491600.0	8308.8	59.0	2.270E+04	9.3	131.2	21	inflow from branch #4
7	470	47000.0	538600.0	8309.8	64.0	2.462E+04	10.1	142.3	21	

BRANCH 6

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	256	25600.0	25600.0	8304.8	3.0	8.784E+02	0.4	5.1	6	
2	356	35600.0	61200.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	439	43900.0	105100.0	8305.8	12.0	2.158E+03	0.9	12.5	8	
4	472	47200.0	152300.0	8306.8	18.0	2.747E+03	1.1	15.9	10	
5	434	43400.0	195700.0	8307.8	23.0	3.168E+03	1.3	18.3	10	
6	474	47400.0	243100.0	8308.8	29.0	3.617E+03	1.5	20.9	10	
7	470	47000.0	290100.0	8309.8	34.0	3.958E+03	1.6	22.9	10	
8	474	47400.0	337500.0	8310.8	40.0	4.336E+03	1.8	25.1	12	
9	256	25600.0	363100.0	8311.8	43.0	4.515E+03	1.8	26.1	12	

BRANCH 7

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	235	23500.0	23500.0	8304.8	2.0	6.564E+02	0.3	3.8	6	
2	369	36900.0	60400.0	8304.8	7.0	1.545E+03	0.6	8.9	8	
3	472	47200.0	107600.0	8305.8	12.0	2.158E+03	0.9	12.5	8	
4	491	49100.0	156700.0	8306.8	18.0	2.747E+03	1.1	15.9	10	
5	491	49100.0	205800.0	8307.8	24.0	3.246E+03	1.3	18.8	10	
6	456	45600.0	251400.0	8308.8	30.0	3.688E+03	1.5	21.3	10	
7	246	24600.0	276000.0	8309.8	33.0	3.892E+03	1.6	22.5	10	
8	**681**	68100.0	344100.0	8310.8	41.0	4.396E+03	1.8	25.4	12	
9	598	59800.0	403900.0	8311.8	48.0	4.798E+03	2.0	27.7	12	
10	-		767000.0	8312.8	92.0	6.842E+03	2.8	39.5	15	inflow from branch # 6
11	430	43000.0	810000.0	8313.8	97.0	7.040E+03	2.9	40.7	15	
12	410	41000.0	851000.0	8314.8	102.0	7.233E+03	3.0	41.8	15	
13	**435**	43500.0	894500.0	8315.8	107.0	7.422E+03	3.0	42.9	15	
14	**366**	36600.0	1061200.0	8316.8	127.0	8.134E+03	3.3	47.0	15	includes inflow from bracnh # 8

BRANCH 8

Segment	Plan Length of Tertiary Pipng (ft)	Tributary Area (ft^2)	Cumulated Tributary Area (ft^2)	Area per day (ft2/day)	T (days)	Flow (m3/day)	Cumulative Flow (ft3/s)	k	Dia. (in)	Notes
1	**177**	17700.0	17700.0	8304.8	2.0	6.564E+02	0.3	3.8	6	
2	**499**	49900.0	67600.0	8304.8	8.0	1.681E+03	0.7	9.7	8	
3	**375**	37500.0	105100.0	8305.8	12.0	2.158E+03	0.9	12.5	8	
4	**250**	25000.0	130100.0	8306.8	15.0	2.467E+03	1.0	14.3	10	

478	- Indicates value includes estimate of areas where secondary piping acts as tertiary piping. - Relevant areas converted to equivalent tertiary piping length for ease of table calculations.

Attachment H

Geotechnical Modeling Work Plan

NorthMet Geotechnical Modeling Work Plan

Version 3 5/3/2013

This document is the Work Plan for geotechnical modeling of the NorthMet Project as requested by the Geotechnical Stability Impact Assessment Planning Summary Memo, NorthMet Project EIS, dated May 18, 2011. The findings from the geotechnical modeling will be incorporated into a 3-Volume Geotechnical Data Package – and summarized and referenced as needed. NorthMet Project Geotechnical Data Package Volumes 1 through 3 will consist of:

- Volume 1 – Flotation Tailings Basin
- Volume 2 – Hydrometallurgical Residue Facility
- Volume 3 – Stockpiles

Project:

The project that will be evaluated is the project described in the Co-lead Agency Draft Alternative Summary as amended 03/04/11. This Work Plan will be reviewed and amended as necessary in response to project changes in the event such changes require substantive changes to previously analyzed facility designs.

Background:

The NorthMet Project includes two material disposal facilities that include dams, consisting of the Flotation Tailings Basin for final deposition of flotation tailings, and the Hydrometallurgical Residue Facility for final deposition of the hydrometallurgical residue. The Flotation Tailings Basin and Hydrometallurgical Residue Facility are designed using an iterative process whereby facility capacity requirements and geotechnical requirements are utilized to determine the facility geometry and overall sizing requirements to contain the tailings and residue expected to be generated through the life of the project. A third type of material disposal facility, which does not require dams but does entail foundation and slope construction, is the waste rock stockpiles at the Mine Site (a.k.a. Stockpiles).

An important input parameter to the facility designs are the slope stability Factors of Safety. Applicable slope stability Factors of Safety are selected and then the facilities (Flotation Tailings Basin and Hydrometallurgical Residue Facility) are configured to achieve these Factors of Safety as computed by modeling performed during facility design. In the case of Stockpiles, MDNR-mandated design requirements have been developed that result in acceptable Factors of Safety.

The slope stability analysis methods that are used to compute slope stability Factors of Safety are not required universally. In other words, some types of analysis are appropriate to some facility configurations while not applicable to other configurations. For example, undrained strength stability analysis (USSA) for slope stability is appropriate for the upstream construction approach planned for the Flotation Tailings Basin. It is not necessary for the Hydrometallurgical Residue Facility which will utilize downstream construction with a liner system. Within this context the Geotechnical Modeling Work Plans for the Flotation Tailings Basin, Hydrometallurgical Residue Facility, and Stockpiles are outlined below.

Flotation Tailings Basin Geotechnical Model for SDEIS, FEIS and Permitting:

The objective of the Flotation Tailings Basin Geotechnical Modeling for the SDEIS, FEIS and Permitting is to demonstrate the ability of the Critical Cross-Section (i.e., Cross-Section F; that cross-section anticipated to yield the lowest slope stability Factors of Safety as indicated in the Preliminary Geotechnical Evaluation – March 2009) to comply with the required global slope stability Factors of Safety. The information content of the November 21, 2012 Geotechnical Data Package – Volume 1 – Version 3, Flotation Tailings Basin (which now supersedes and entirely replaces the Preliminary Geotechnical Evaluation – March 2009) will be updated and formatted to accommodate the Co-lead Agency Comments and to incorporate updated slope stability analysis for scenarios derived from the February 25 and 26, 2013 Geotechnical Workshop (February Workshop) with the Co-lead Agency geotechnical team.. This will be Geotechnical Data Package – Volume 1 – Version 4, Flotation Tailings Basin. The following is a step-by-step summary of the planned Flotation Tailings Basin geotechnical modeling process. Descriptions of previously completed process steps, outcomes of which are reported in Geotechnical Data Package – Volume 1 – Version 3, are preserved below to maintain Work Plan continuity. Work Plan updates derived specifically from the February Workshop are noted as such.

The following paragraphs describe the work that will be included in Geotechnical Data Package – Volume 1 – Version 4, Flotation Tailings Basin which is expected to provide information for the SDEIS.

1. Gather existing conditions data (i.e. basin topography, stratigraphy, soil and tailings strength and hydraulic characteristics), and other data as needed to support geotechnical modeling and Flotation Tailings Basin design. Note – this data has previously been compiled and presented in the Preliminary Geotechnical Evaluation – March 2009. This information will be incorporated into the Geotechnical Data Package – Volume 1, which will present the analyses outlined in this Work Plan. Results of in-laboratory testing of liquefied shear strength of NorthMet flotation tailings, completed subsequent the March 2009 evaluation, will be incorporated into the work prescribed in this Geotechnical Modeling Work Plan.

2. Develop Flotation Tailings Basin slope cross-sections (i.e., geometry and stratigraphy for existing and planned conditions) for the Flotation Tailings Basin for seepage and stability modeling. Models will utilize surveyed cross-sections of the existing basin and proposed cross-sections of future dam raises; existing models will be reconfigured as needed to accommodate the modeling approach outlined in this Work Plan. This information will then be incorporated into the Geotechnical Data Package – Volume 1.

3. Develop seepage and stability models of the Flotation Tailings Basin using Geo-Slope International, Inc. modeling software (i.e., SLOPE/W, SEEP/W, SIGMA/W and QUAKE/W; or other appropriate geomechanical models) as necessary.

4. Using geotechnical data from Step 1, establish design data for use in Effective Stress Stability Analysis and Undrained Strength Stability Analysis. Also utilize established criteria (Olson and Stark – 2003 “Yield Strength Ratio and Liquefaction Analysis of

Slopes and Embankments" as updated by Olson 2009) to determine which materials behave in a contractive manner and could transition from non-liquefied strengths to liquefied (steady state) strengths.

Produce graphical representations of each strength data set and basis for selection of design parameters. Plots should include the number of data used to develop each plot.

5. Utilize design data to design slopes to achieve the following:

    a. Effective Stress Stability Analysis (ESSA) – Factor of Safety $\geq$ 1.5 for conditions using drained (i.e., effective-stress based) shear strength parameters. Analyze the following effective stress stability scenarios:

        i. Existing conditions.
        ii. Normal operating condition at incremental lift heights up to maximum dam height for normal pool elevation with steady-state seepage conditions and including reduced infiltration rates for bentonite amended exterior face of new dams.
        iii. Long-term closure conditions (at 2,000 years) using design drained shear strengths with aging factors included (for decomposition and secondary compression).

    b. Undrained Strength Stability Analysis (USSA) – Factor of Safety $\geq$ 1.3 for conditions using undrained yield shear strengths for materials that are expected to behave in an undrained manner (i.e., end of construction case per dam raise). Analyze the following undrained strength stability scenarios:

        i. Normal operating condition at incremental lift heights up to maximum dam height for normal pool elevation and including reduced infiltration rates for bentonite amended exterior face of new dams.
        ii. Veneer stability to evaluate the stability of the bentonite amended exterior face of new dams. Veneer stability will be evaluated by computing the infinite slope Factor of Safety (using the no-seepage formulation where tailings seepage is not emerging on the slope, and the parallel-seepage formulation where tailings seepage is emerging on the slope), with the soil friction angle chosen as a conservative value based on literature review. Laboratory direct shear testing will be performed to measure a friction angle for site-specific bentonite amended tailings and the Factor of Safety will then be recomputed. Slope design will be adjusted as needed to achieve Factor of a Safety $\geq$ 1.3 for veneer stability.

    c. Liquefaction Triggering and Post-Triggering Analysis – Factor of Safety $\geq$ 1.1 for post-triggering slope stability considering liquefied shear strengths (computed from design liquefied strength ratios) applied to segments of materials in the triggering stability analysis with $FS_{triggering} < 1.1$; design drained strengths applied to materials above the capillary zone; and yield shear strength (computed from design yield strength ratios) for all other materials. From the February 2013 workshop, analyze the following credible triggering scenarios:

i. Baseline – Lift 8

  - Realistic phreatic surface from seepage analysis including capillarity.
  - Normal pool steady-state seepage.
  - Capillarity – 10’ above computed steady-state phreatic line.
  - Liquefied shear strengths applied below top of capillary zone to materials triggered to liquefy (i.e., design liquefied shear strength utilized for flotation tailings and LTVSMC fine tailings/slimes in materials that are triggered to liquefy).

ii. Elevated Phreatic Surface (i.e., drain ineffective) – Lift 8

  - Permeability of plugged drain set to permeability of flotation tailings.
  - Normal pool steady-state seepage.
  - Capillarity – 10’ above computed steady-state phreatic line.
  - Liquefied shear strengths applied below top of capillary zone to materials triggered to liquefy (i.e., design liquefied shear strength utilized for flotation tailings and LTVSMC fine tailings/slimes in materials that are triggered to liquefy).
  - Consideration of baseline effective vertical stresses (prior to rise in phreatic surface).

iii. High Construction Rate of Loading – Lift 1

  - 15’ of construction fill placed rapidly.
  - Baseline phreatic surface including capillarity.
  - Normal pool steady-state seepage.
  - Capillarity – 10’ above computed steady-state phreatic line.
  - Liquefied shear strengths applied below top of capillary zone to materials triggered to liquefy (design liquefied shear strength utilized for flotation tailings and LTVSMC fine tailings/slimes in materials that are triggered to liquefy).
  - Consideration of baseline effective vertical stresses (prior to new fill placement).

iv. Local Erosion/Scour of Slope (pipe break) – Lift 8

  - Incrementally remove material above buttress (retrogressive).
  - Baseline phreatic surface including capillarity.
  - Normal pool steady-state seepage.
  - Capillarity – 10’ above computed steady-state phreatic line.

- Liquefied shear strengths applied below top of capillary zone to materials triggered to liquefy (design liquefied shear strength utilized for flotation tailings and LTVSMC fine tailings/slimes in materials that are triggered to liquefy).
- Consideration of baseline effective vertical stresses (prior to erosion).

v. Elevated Phreatic Surface (drain ineffective) w/High Pond – Lift 1

- Elevated Pond (drain ineffective).
- Permeability of plugged drain set to permeability of flotation tailings.
- Steady-state seepage with elevated pond set at overflow elevation.
- Capillarity – 10’ above computed steady state phreatic line.
- Liquefied shear strengths applied below top of capillary zone to materials triggered to liquefy (design liquefied shear strength utilized for flotation tailings and LTVSMC fine tailings/slimes in materials that are triggered to liquefy).
- Consideration of initial effective vertical stresses (prior to placement of 1st lift).

vi. Long-Term Case (20, 200, and 2000 years after closure)

- Final geometry including surface erosion of material above buttress.
- Impoundment phreatic surface drained down (as determined by analysis) reflecting bentonite cover.
- Surcharge load from surficial pond.
- Pond set at overflow elevation.
- Design drained shear strengths with aging factors included (for decomposition and secondary compression), applied to materials above the top of the capillary zone.
- Design liquefied shear strengths for flotation tailings and LTVSMC fine tailings/slimes) with aging factors included (for decomposition and secondary compression), applied to materials below the top of the capillary zone.

d. Lift 8 Baseline Conditions assuming Unknown Triggering Mechanism – Factor of Safety ≥ 1.1 for post-triggering slope stability applying design liquefied shear strengths to all LTVSMC fine tailings and slimes and all Flotation Tailings below top of capillary zone.

i. Lift 8
ii. Realistic phreatic surface from seepage analysis including capillarity.
iii. Normal pool steady-state seepage.
iv. Capillarity – 10’ above computed steady-state phreatic line.

   v. Design liquefied shear strengths applied below top of capillary zone to all LTVSMC fine tailings and slimes and all Flotation Tailings.

e. Seismic Liquefaction (i.e., induced by seismic event).

   i. Perform a screening analysis for triggering of liquefaction based on Boulanger and Idriss (2004). If the factor of safety against triggering is less than 1.2 for a seismic event with a 2475-year return period, perform further seismic triggering analyses as described below.
   ii. Develop material damping coefficients for LTVSMC and NorthMet tailings.
   iii. Use Geo-Slope software to compute initial stresses and steady-state pore-water pressure distribution.
   iv. Apply earthquake loads via appropriate geomechanical models (such as QUAKE/W, FLAC, Plaxis, or others; earthquake loads to be obtained from probabilistic seismic hazard analysis [PSHA]) and compare results to a SLOPE/W yield undrained model (or other appropriate model) to identify the elements within the model that liquefy as a result of the seismic loading.
   v. Use published triggering relationships and model results to determine segments along the slip surface where liquefaction will be triggered (Olson & Stark, 2003, Yield Strength Ratios and Liquefaction Analysis of Slopes and Embankments).
   vi. Perform slope stability analysis in SLOPE/W or other appropriate geomechanical model (using liquefied shear strengths applied to elements shown to liquefy) to compute FS_{Flow} for the entire cross section.

      - If $FS_{Flow} > 1.2$ no further action is needed.
      - If $FS_{Flow} < 1.0$ modify or redesign cross section.
      - If $FS_{Flow} >1.0$ and < 1.2, perform deformation modeling in SIGMA/W or other suitable geomechanical model to predict the magnitude of deformation. If the level of deformation is acceptable to Dam Safety, no further action is needed. If the level of deformation is unacceptable to Dam Safety, modify or redesign cross section.

6. Reporting:

Volume 1 – Version 4 will present the background/supporting information and results of the Flotation Tailings Basin geotechnical analyses described in this Work Plan. It will contain the pertinent content previously presented in the Preliminary Geotechnical Evaluation – March 2009 and Geotechnical Data Packages – Volume 1 – Versions 1 through 3. However, analysis methods and results will supersede contents of the previously published Geotechnical Evaluation and Data Packages. Included in Volume 1 – Version 4 (and/or the Flotation Tailings Management Plan) will be descriptions and drawings depicting existing conditions and what will be built, results of geotechnical analyses for operating and post-closure conditions, and presentation of all model input parameters and model outputs. Where model input parameters are derived from multiple data points, the approach utilized for input parameter selection will be described. Included will be a description of how stability is anticipated to vary over time following

Flotation Tailings Basin closure. Include design and operating requirements necessary to maintain required slope stability Factors of Safety for the critical slope cross-section (assumed to be Cross-Section F for SDEIS modeling). This detail shall be included in Volume 1 – Version 4 and/or the Flotation Tailings Management Plan.

The following paragraphs describe the work that will be included in a future Geotechnical Data Package – Volume 1 – Version 5, Flotation Tailings Basin, which is expected to provide information for the FEIS and Dam Safety permitting.

1. After MDNR publication of the SDEIS and prior to Final EIS (FEIS) publication and Permitting, execute a supplement to this Work Plan to include:

    a. For normal operation conditions with maximum lift height perform a sensitivity analysis using the USSA slope stability model with yield undrained shear strength values. The Flotation Tailings Basin designer's engineering judgment shall be used to establish a range for these data inputs and the basis for the range shall be described. Evaluate the impact of data variability on computed slope stability Factors of Safety for the purpose of focusing operational-phase data gathering on the most critical stability model data inputs.

    b. Prepare and execute a second Sensitivity Analysis the intent of which is to evaluate the variation in Factor of Safety (and the probability of FS < 1.0) for an unknown triggering case, using the ESSA and yield USSR strengths utilized for the current Work Plan, but with $USSR_{(Liq)}$ varied within the range identified during liquefied strength design parameter evaluation.

2. Following MDNR Dam Safety review and approval of Critical Cross-Section modeling process/procedures and outcomes, proceed with modeling cross-sections G (north side of Cell 2E) and N (south side of Cell 1E) for final Flotation Tailings Basin design (for input to FEIS or Permitting as determined by MDNR).

Hydrometallurgical Residue Facility Geotechnical Models for SDEIS, FEIS and Permitting:

The objective of the Hydrometallurgical Residue Facility Geotechnical Modeling for the SDEIS, FEIS and Permitting is to:

- demonstrate the ability of the most sensitive slope cross-section to comply with the required slope stability Factors of Safety for global stability,

- demonstrate the ability of the composite liner system to comply with infinite slope stability Factor of Safety requirements, and to

- demonstrate the capability of the composite liner system to withstand the strain anticipated due to differential settlement that may occur in the facility foundation materials.

The following is a step-by-step summary of the planned Hydrometallurgical Residue Facility geotechnical modeling process.

1. Gather existing conditions data (i.e. facility foundation material stratigraphy and strength data, hydrogeologic data and other data as needed to support geotechnical modeling of the Hydrometallurgical Residue Facility). Note – portions of this data have previously been compiled and presented in the Preliminary Geotechnical Evaluation – March 2009. This information will be incorporated into the Geotechnical Data Package Volume 2 and will be supplemented with additional facility location-specific data. Data on existing baseline water sources at the site, including surface discharges from the surrounding highlands, will be gathered for consideration during hydrometallurgical residue facility design. The facility will be designed to accommodate any such surface discharges and hence these discharges will not impact geotechnical modeling of the hydrometallurgical residue facility.

2. Gather additional residue strength and hydraulic conductivity data and/or representative published data for use in facility design. This information will be incorporated into the Geotechnical Data Package Volume 2 to the extent needed to facilitate the modeling outlined herein.

3. Develop residue facility layout and slope cross-sections (i.e., geometry and stratigraphy for existing and planned conditions) for proposed residue facility stability and deformation modeling. Note – seepage through the residue facility embankments will be inhibited by the composite liner system and seepage modeling will be an unnecessary component of this analysis.

4. Develop global and infinite slope stability models and deformation models of the facility using Geo-Slope International, Inc. modeling software (i.e., SLOPE/W, SEEP/W and SIGMA/W as necessary). Model the following:

    a. Deformation of hydromet residue facility foundation and liner system.

   b. Infinite slope stability of hydromet residue facility liner system (if necessary/applicable).

   c. Global stability of hydromet residue facility embankments.

   Model maximum residue facility dam height with minimum and maximum pond elevation, and post closure – cover effective with minimum pond elevation. Model for effective shear stress conditions. Modeling for undrained shear strength conditions will not be necessary due to lined facility design with imported and mechanically placed dam fill and lack of seepage through the dam.

5. Configure geotechnical data for model input. Model input parameters will be based on data collected for and presented in the Preliminary Geotechnical Evaluation – March 2009. For materials to be imported for construction, engineering judgment will be used to select conservative shear strength parameters for input to the slope stability analysis and liner deformation analysis.

6. Use SLOPE/W to calculate the Factor of Safety for the following conditions:

   a. Effective Stress Stability Analysis (ESSA) – Factor of Safety $\geq$ 1.5

   b. Slope failures on external face and internal face of residue facility embankments.

7. Perform infinite slope stability analysis to confirm that load from residue deposition will be transferred to facility foundation soils and will not induce excess strain in facility liner materials.

8. Perform deformation modeling to predict magnitude of deformation and resulting strain in the facility liner system for comparison to allowable strain in liner system. Allowable strains are material-specific and will be determined from manufacturers specifications for the materials selected for the facility liner.

9. Report final basin design and operating requirements necessary to maintain required slope stability Factor of Safety and deformation requirements.

10. Reporting – the Geotechnical Data Package Volume 2 will present the background/supporting information and results of the Hydrometallurgical Residue Facility geotechnical analyses described in this Work Plan. Included will be descriptions and drawings depicting existing conditions and what will be built, results of geotechnical analyses for operating and post-closure conditions, and presentation of all model input parameters and model outputs. Where model input parameters are derived from multiple data points, the approach utilized for input parameter selection will be described. Included will be a description of how stability is anticipated to vary over time.

Stockpile Geotechnical Models for SDEIS, FEIS and Permitting:

The objective of the Stockpile Geotechnical Modeling for the SDEIS, FEIS and Permitting is to comply with Mn Rule 6132.2400 (stockpile slopes will be as required by 6132.2400 Subp. 2. B. and stockpile foundations will be as required by 6132.2400 Subp. 2. A. (1)). These are design requirements that have been established to insure acceptable slope stability Factors of Safety for global stability and acceptable foundation stability, the latter of which relates to the capability of the geomembrane liner system to withstand the strain anticipated due to differential settlement that may occur in the stockpile foundation materials.

The following is a step-by-step summary of the planned Stockpile geotechnical modeling process.

1. Gather existing conditions data (i.e. facility foundation material stratigraphy and strength data and other data as needed to support foundation design). Existing site information will be utilized for analysis performed in support of the SDEIS and FEIS, with additional data gathered and designs updated as needed for final design in conjunction with permitting. Existing information will be incorporated into the Geotechnical Data Package Volume 3.

2. Configure stockpile slopes to meet or exceed minimum dimensional requirements established by Mn Rule 6132.2400.

3. Perform stockpile subgrade settlement analysis to predict magnitude of deformation and resulting strain in the stockpile liners for comparison to allowable strain in the liner system. Allowable strains are material-specific and will be determined from manufacturers specifications for the materials selected for the stockpile liners.

4. Report final stockpile design and operating requirements necessary to maintain required slope stability Factors of Safety and liner performance requirements.

5. Reporting – the Geotechnical Data Package Volume 3 will present the background/supporting information and results of the Stockpile geotechnical analyses described in this Work Plan. Included will be descriptions and drawings depicting existing conditions and what will be built, results of geotechnical analyses for operating and post-closure conditions, and presentation of all model input parameters and model outputs. Where model input parameters are derived from multiple data points, the approach utilized for input parameter selection will be described. Included will be a description of how stability is anticipated to vary over time.

Attachment I

Stockpile Stability Evaluation

Golder Associates

TECHNICAL MEMORANDUM

Date:	October 19, 2015	**Document No.:**	1132209 TM02 Rev0
To:	Tom Radue	**Company:**	Barr Engineering
From:	Gordan Gjerapic and Brent Bronson	**Email:**	GGjerapic@Golder.com

RE: **WASTE ROCK STOCKPILES STABILITY ANALYSIS**

1.0 INTRODUCTION

This document summarizes the approach and results of preliminary stability analyses for the proposed waste rock stockpiles at the PolyMet NorthMet site located near Babbitt, Minnesota. Due to limited information on subsurface conditions, especially in lowland areas, the analyses presented herein are expected to be updated based on the results of a future Phase II geotechnical investigation.

Stability analyses were conducted for: (1) reactive waste rock stockpiles and (2) the non-reactive waste rock, i.e., Category 1 stockpile. Reactive stockpiles include the Category 2/3 stockpile, Category 4 stockpile, and Ore Surge Pile. The liner system for reactive stockpiles consists of linear low-density polyethylene (LLDPE) geomembrane overlying soil liner or prepared subgrade. The Category 1 stockpile is designed without a liner system and instead uses a groundwater containment system. The Category 1 stockpile will be reclaimed while the reactive stockpile materials will be used to backfill pits prior to closure. Consequently, slope stability analyses for closure configurations were performed only for the Category 1 stockpile.

2.0 OBJECTIVE

Perform slope stability analyses for waste rock stockpiles considering both static and pseudo-static (earthquake loading) conditions. Calculate factors of safety (FS) for operational and reclaimed/closure configurations.

3.0 STABILITY MODEL INPUTS

3.1 Assumptions

3.1.1 Stockpile Geometry

- Nominal lift height is 40 feet
- Temporary operational slopes are 1.4(H):1(V)
- The critical (maximum) subgrade and liner slopes are 0.5%

- Reactive stockpiles design assumptions:
    - Unsuitable soils within the reactive stockpile footprints will be removed and replaced with structural fill
    - Liner system is a minimum of 1 foot of soil liner overlain by LLDPE geomembrane
    - The phreatic surface is located 2 feet above the liner/subgrade surface, i.e., the bottom 2 feet of the waste rock are saturated
    - Stockpiles will be used for pit backfill, i.e., no closure configurations are considered
- Category 1 stockpile design assumptions:
    - Unsuitable soils, if any, within first 100 feet from the toe of the Category 1 stockpile will be excavated and replaced with structural fill
    - Closure bench width is a minimum of 30 feet, measured from the crest of the lower lift to the toe of the next lift
    - Reclamation slope design includes interbench slopes of 3.75(H):1(V)
    - The reclaimed stockpile will be covered with a textured 60-mil polyethylene geomembrane after re-grading is completed. The waste rock surface is expected to be graded smooth and compacted prior to geomembrane placement. Alternatively, a soil bedding layer or selected subgrade soil layer may be placed prior to geomembrane installation to ensure good contact and prevent puncture of the geomembrane.
    - A reclamation cover composed of a 12-inch thick lateral drainage layer will overlie the geomembrane, which will be overlain by an additional 18-inch thick vertical percolation layer.

3.1.2 Site Conditions and Available Data

- Pre-construction topography and current topography
- Geotechnical site and laboratory exploration results
- Peak ground acceleration of 0.05g

3.1.3 Minimum Acceptable Factors of Safety

Factors of safety (FS) for the stability analyses were adopted in accordance with the industry practice for non-impounding structures constructed of mine waste materials with the consideration of economical and safety risks for similar structures, see, e.g., ADEQ (2004) and Solseng et al. (2015).

- Minimum long-term (effective stress) operational FS for deep seated failures is 1.3
- Minimum short-term (total stress) operational FS (if applicable) is 1.0
- Minimum long-term (effective stress) operational FS under pseudo-static conditions is 1.0
- Minimum acceptable FS for static condition at closure is 1.5
- Minimum acceptable FS for pseudo-static conditions at closure is 1.1

3.2 Design Sections

The following critical design sections were analyzed:

3.2.1 *Reactive Stockpiles*

- Design Section R-1 (see Figure 1): Waste rock stockpile, operational configuration, one lift placed in two stages. This configuration represents the initial stockpile conditions considering placement of the first 15 feet of material on top of the liner (Lift 1a) prior to placement of the remaining 25 feet of material (Lift 1b) to reach the specified first lift height of 40 feet. Subsequent lifts with thickness of 40 feet will be placed on top of the first lift (i.e., without the restriction for the two-stage placement required for the first lift to protect the liner system).
  - Initial waste rock fill height of 40 feet placed in two stages (lifts)
  - Interbench slopes at 1.4(H):1(V)
  - Height of the initial stage fill over liner (Lift 1a): 15 feet
  - Height of the remaining fill (Lift 1b): 25 feet
  - Assume 10-foot wide bench between initial 15-foot thick first lift (Lift 1a) and the remainder of the first lift (Lift 2a) extending to 40 feet
- Design Section R-2 (see Figure 2): Waste rock stockpile, operational configuration, ultimate height
  - Waste rock fill height of 160 feet (a maximum height for reactive stockpiles at ultimate buildout)
  - Interbench slopes at 1.4(H):1(V)
  - Waste rock stockpile is constructed in individual lifts with the maximum lift height of 40 feet and the minimum bench width of 30 feet

3.2.2 *Category 1 Stockpile*

- Design Section C1-1 (see Figure 3): Waste rock stockpile, operational configuration, initial construction of the first lift with the maximum lift height of 40 feet
  - Waste rock height of 40 feet
  - Interbench slopes at 1.4(H):1(V)
- Design Section C1-2 (see Figure 4): Waste rock stockpile, operational configuration, ultimate height constructed in 40-foot lifts
  - Waste rock height of 160 feet
  - Interbench slopes at 1.4(H):1(V)
- Design Section C1-3 (see Figure 5): Waste rock stockpile, reclaimed configuration, ultimate height constructed in 40-foot lifts
  - Waste rock height of 240 feet
  - Interbench slopes regraded to 3.75(H):1(V)
  - Proposed cover layer subsurface drain pipes are not shown

The design section geometries are provided in Figures 1 through 5.

3.3 Material Properties

The parameters presented in Table 1 were used in the global slope stability analysis described in Section 4.0.

Table 1: Material Strength Parameters

Material	Total Unit Weight (pcf)	Effective Friction Angle (degrees)	Effective Cohesion (psf)
Waste Rock	126.0	35.5	0.1
Construction Fill	130.6	34.6	0.1
Smooth LLDPE/Soil Liner Interface[1]	N/A	19.0	0.0
Textured Geomembrane/Cover Soil Interface[2]	N/A	29.0	0.0
Existing Subgrade (Peat)	80.0	17.0	0.0
Bedrock	170.0	55.0	200.0

Notes:
1. Estimated from Golder Database (2012).
2. Based on Golder Database (2012) and Bhatia and Kasturi (1996), see Attachment 2.

4.0 STABILITY ANALYSES

Global slope stability was analyzed using Spencer's method (Spencer 1967) implemented in RocScience's two-dimensional limit equilibrium slope stability analysis program SLIDE 6.017 (2012). Minimum FS was determined using the program's search algorithm for both circular and non-circular (block) failure surfaces. Pseudo-static stability analyses were conducted by using a horizontal seismic factor of 0.025 g, which corresponds to half of the peak ground acceleration of 0.05 g (Hynes-Griffin and Franklin 1984). Conceptual geometries for one lift and the ultimate heights were investigated to establish the most sensitive mechanism of failure for the waste rock stockpile slopes.

Input and output files for the SLIDE seepage and slope stability analyses for each design section and loading condition are presented in Attachment 1.

Infinite slope stability analyses were performed for the geomembrane and reclamation cover that will be placed on the Category 1 stockpile. Based on Bhatia and Kasturi (1996) results and Golder Database (2012) on liner interfaces, a residual interface friction angle of 29 degrees between a textured 60-mil polyethylene geomembrane and soil layer at low confining stresses is assumed to calculate the factor of safety at closure (see Attachment 2). Cohesion along the geomembrane/reclamation cover interface is assumed to be zero.

Assuming a one-dimensional cover failure and adequate control of precipitation infiltrating the slope above the cover system geomembrane (via the subsurface drainpipes), the FS can be calculated as follows:

$$FS = tan\,\delta' / tan\,\beta$$

Where: FS = factor of safety

δ' = effective geomembrane-soil interface friction angle

β = slope angle

5.0 RESULTS

Results of the global slope stability analyses for each of the design sections are summarized in Table 2. Design Section R-2 (the temporary operational 1.4(H):1(V) slopes for the reactive stockpiles) exhibits the lowest but still acceptable FS, with a portion of the sliding surface occurring along the stockpile interface with the geomembrane liner.

Table 2: Summary of Slope Stability Analyses, Conceptual Waste Rock Stockpile Geometries

File Name	Design Section	Static or Seismic	Height (ft)	Failure Through	Surface Type	Computed FS	FS Design Criteria
R-1-c	R-1	Static	40	Middle of the waste rock stockpile, exit at toe	Circular	2.04	≥ 1.3
R-1-nc	R-1	Static	40	Middle of the waste rock stockpile, along the liner interface, exit at toe	Block	1.39	≥ 1.3
R-1-nc-s	R-1	Seismic	40	Middle of the waste rock stockpile, along the liner interface, exit at toe	Block	1.31	≥ 1.0
R-2-c	R-2	Static	160	Middle of the waste rock stockpile, exit at toe	Circular	1.55	≥ 1.3
R-2-nc	R-2	Static	160	Middle of the waste rock stockpile, along the liner interface, exit at toe	Block	1.39	≥ 1.3
R-2-nc-s	R-2	Seismic	160	Middle of the waste rock stockpile, along the liner interface, exit at toe	Block	1.30	≥ 1.0
C1-1-c	C1-1	Static	40	Middle of the waste rock stockpile, shallow subgrade, exit near toe	Circular	1.53	≥ 1.3
C1-1-nc	C1-1	Static	40	Middle of the waste rock stockpile, along the waste rock and subgrade interface, exit at toe	Block	1.56	≥ 1.3
C1-1-c-s	C1-1	Seismic	40	Middle of the waste rock stockpile, shallow subgrade, exit near toe	Circular	1.45	≥ 1.0
C1-2-c	C1-2	Static	160	Middle of the waste rock stockpile, through subgrade and structural fill, exit near toe	Circular	1.93	≥ 1.3
C1-2-nc	C1-2	Static	160	Middle of the waste rock stockpile, along the waste rock and subgrade interface, exit at toe	Block	2.09	≥ 1.3
C1-2-c-s	C1-2	Seismic	160	Middle of the waste rock stockpile, through subgrade and structural fill, exit near toe	Circular	1.78	≥ 1.0
C1-3-c	C1-3	Static	240	Middle of the waste rock stockpile, through subgrade and structural fill, exit near toe	Circular	2.31	≥ 1.5
C1-3-c-s	C1-3	Seismic	240	Middle of the waste rock stockpile, through subgrade and structural fill, exit near toe	Circular	2.07	≥ 1.1

Because site soil samples have not been obtained to conduct site-specific laboratory testing to determine the smooth LLDPE/soil liner interface strength, a sensitivity analysis was performed to assess the effect of variability of the interface friction angle on the calculated FS for global stability of the reactive stockpiles. The results for the most critical temporary operational slope (Section R-2) are shown in Table 3. The plot for the accompanying sensitivity analysis is included in Attachment 1.

Table 3: Summary of Sensitivity Analyses for Waste Rock Slope Failure for Different Effective Interface Friction Angles

Design Section	Material	Effective Friction Angle (degrees)	Computed FS	FS Design Criteria
R-2	Smooth LLDPE/Soil Liner Interface	22.6	1.5	≥ 1.3
R-2	Smooth LLDPE/Soil Liner Interface	19.2	1.4	≥ 1.3
R-2	Smooth LLDPE/Soil Liner Interface	15.7	1.3	≥ 1.3

For the Category 1 waste rock stockpile cover, because site soil samples have not been obtained to conduct site-specific laboratory testing to determine the geomembrane/soil liner interface strength, a sensitivity analysis was performed to assess the effect of variability of the interface friction angle on the calculated FS for infinite slope stability of the stockpile cover. Since cover soil imposes low confining stresses on the cover system geomembrane, it has been assumed that a textured geomembrane will be used for the cover system. Results of the infinite slope stability analyses for the geomembrane cover that will be placed on the Category 1 stockpile are summarized in Table 4.

Table 4: Summary of Sensitivity Analyses for Cover Slope Failure for Different Effective Interface Friction Angles

Material	Effective Friction Angle (degrees)	Computed FS	FS Design Criteria
Textured Geomembrane/Soil Interface	28.1	2.0	≥ 1.5
Textured Geomembrane/Soil Interface	24.4	1.7	≥ 1.5
Textured Geomembrane/Soil Interface	21.8	1.5	≥ 1.5

The design criteria for the cover system infinite slope stability are based on achieving an FS equal to or greater than 1.5 using residual geomembrane-soil interface friction angles. Data summarized in Attachment 2 indicate that a friction angle of 21.8 degrees or greater for the textured geomembrane-soil interface is expected to be achievable.

6.0 CONCLUSIONS

All design sections meet the minimum factors of safety (FS) for global stability, assuming an LLDPE geomembrane/soil liner interface friction angle of 19 degrees. The design Section R-2, with the maximum height of failure surface of 160 feet, a slope face of 1.4(H):1(V), and a liner grade of 0.5%, represents the most critical condition, while still meeting FS criteria. Note that the staged first lift placement is expected to result in an increased FS.

The results of the slope stability analysis for the critical design section indicate that a minimum LLDPE/soil liner interface friction angle of 15.7 degrees will be required to achieve an FS of 1.3 under static operating conditions based on a block failure mode.

In general, static conditions are more critical than seismic conditions due to the higher required factors of safety and relatively low design peak ground acceleration.

Closure calculations indicate that a minimum geomembrane/soil interface friction or 21.8 degrees will be required to achieve an FS of 1.5 under static conditions at closure for the design interbench slopes of 3.75H:1V. Project-specific geomembrane-soil interface friction angle testing will be performed prior final cover construction to aid in final geomembrane type selection.

7.0 REFERENCES

Arizona Department of Environmental Quality (ADEQ). 2004. “Arizona Mining Guidance Manual BADCT” Aquifer Protection Program. Publication # TB-04-01. Phoenix, Arizona: Arizona Department of Environmental Quality.

Bhatia, S.K., and G. Kasturi. 1996. “Comparison of PVC and HDPE Geomembranes – Interface Friction Performance” PVC Geomembrane Institute, Champaign, Illinois, USA, November.

Golder Associates Inc. (Golder). 2012. “Direct Shear Database.”

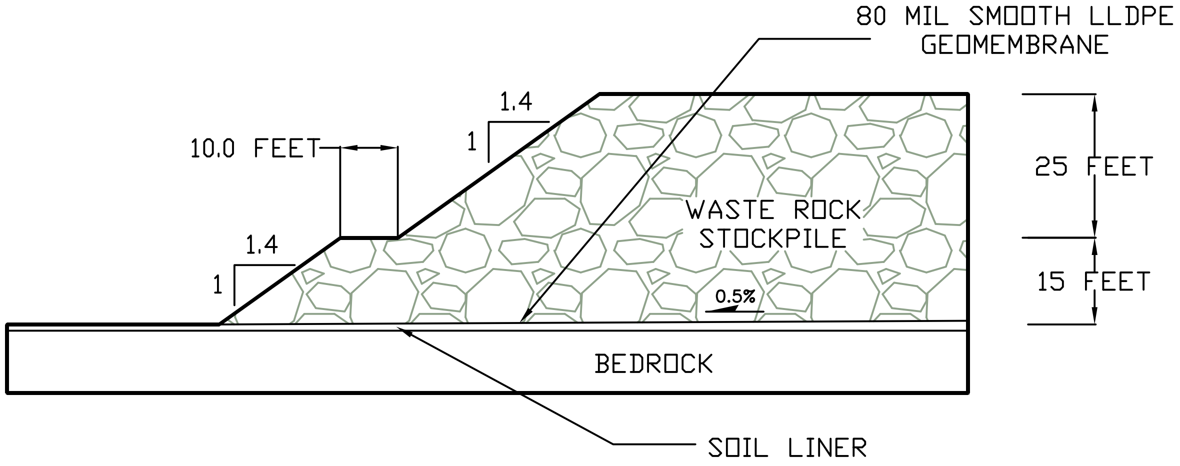
Hynes-Griffin, M.E., and A.G. Franklin. 1984. “Rationalizing the Seismic Coefficient Method” U.S. Department of the Army. Waterways Experiment Station. U.S. Army Corps of Engineers (USACE). Miscellaneous Paper GL-84-13.

RocScience. 2012. SLIDE V6.017, Toronto.

Solseng, P.B., T.W. Skoglund, and S.K. Dickinson, Jr. 2015. “Responsible Tailings Disposal at Minnesota Taconite Mines”, Responsible Mining – Case Studies in Managing Social & Environmental Risks in the Developed World, Michelle E. Jarvie-Eggart Editor, Part VI Tailings and Waste Rock, published by Society for Mining, Metallurgy & Exploration (SME), ISBN-13: 978-0873353731 (ISBN-10: 0873353730).

Spencer, E. 1967. “A Method of Analysis of the Stability of Embankments Assuming Parallel Inter-Slice Forces.” Geotechnique, Vol. XVII, No. 1, pp. 11-26.

FIGURES



Golder Associates **Denver, Colorado**

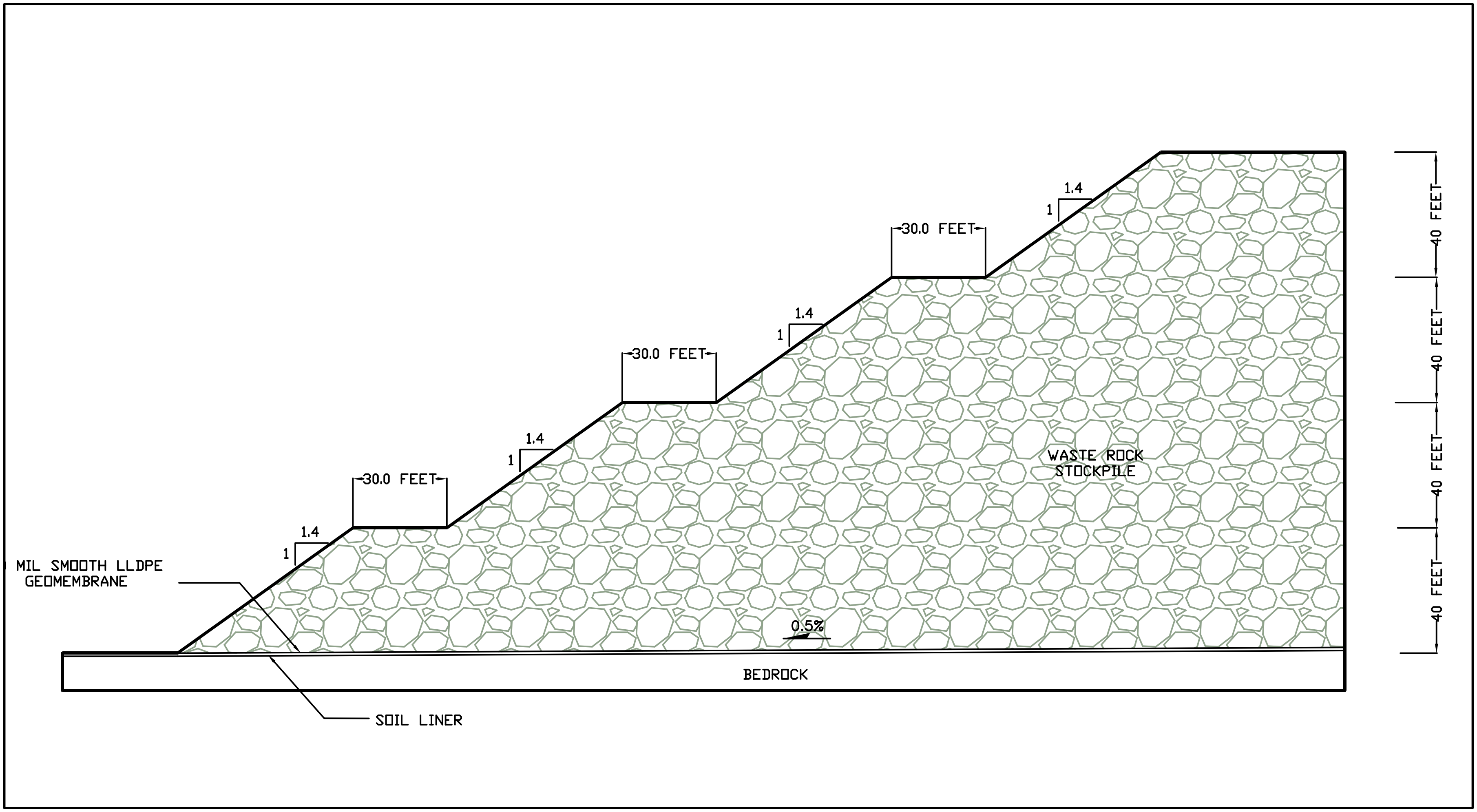
TITLE

DESIGN SECTION R-1

CLIENT/PROJECT

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINESOTA

DRAWN JP	DATE MAY 18, 2012	JOB NO. 113-2209
CHECKED	SCALE N.T.S.	DWG. NO.
REVIEWED	FILE NO. Figures-sections.dwg	FIGURE NO. 1



Golder Associates **Denver, Colorado**

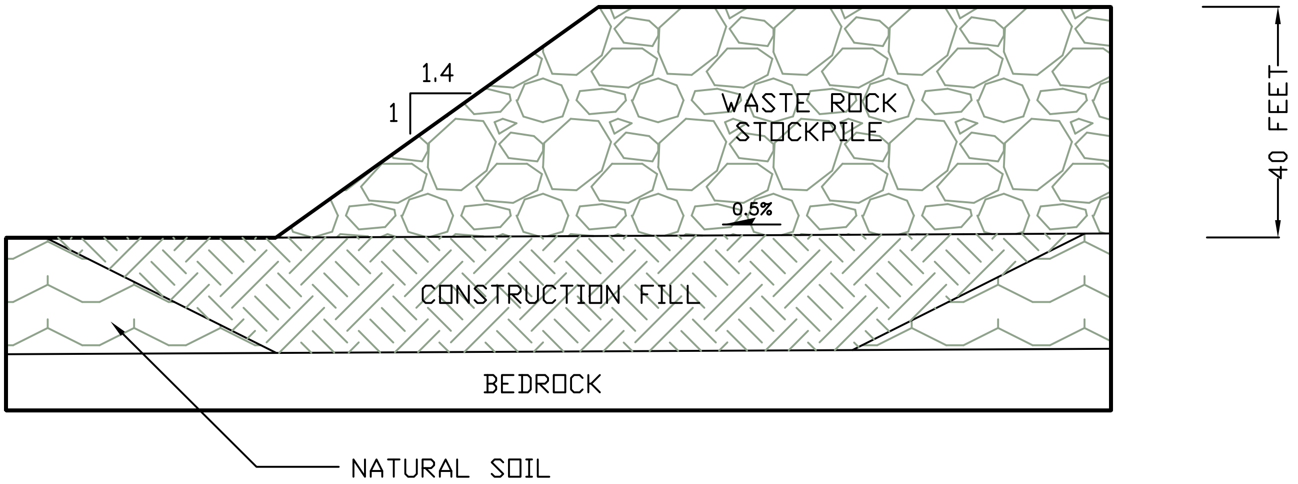
TITLE

DESIGN SECTION R-2

CLIENT/PROJECT

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINESOTA

DRAWN JP	DATE MAY 18, 2012	JOB NO. 113-2209
CHECKED	SCALE N.T.S.	DWG. NO.
REVIEWED	FILE NO. Figures-sections.dwg	FIGURE NO. 2



Golder Associates
Denver, Colorado

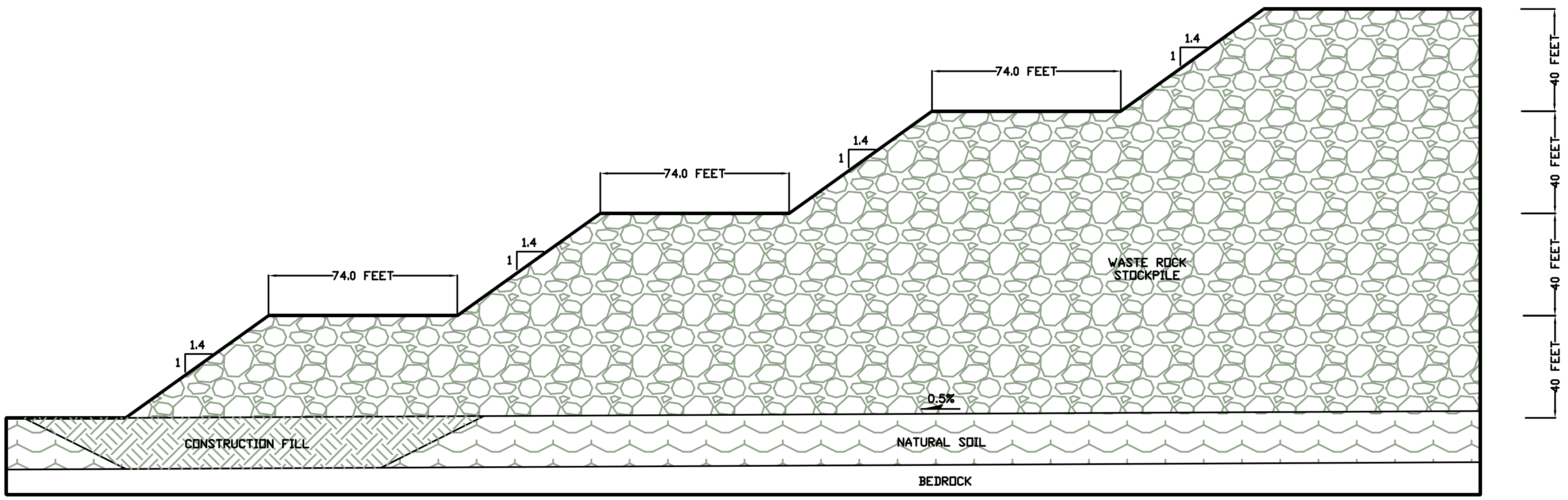
TITLE

DESIGN SECTION C1-1

CLIENT/PROJECT

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINESOTA

DRAWN	JP	DATE	MAY 18, 2012	JOB NO.	113-2209
CHECKED		SCALE	N.T.S.	DWG. NO.	
REVIEWED		FILE NO.	Figures-sections.dwg	FIGURE NO.	3



Golder Associates
Denver, Colorado

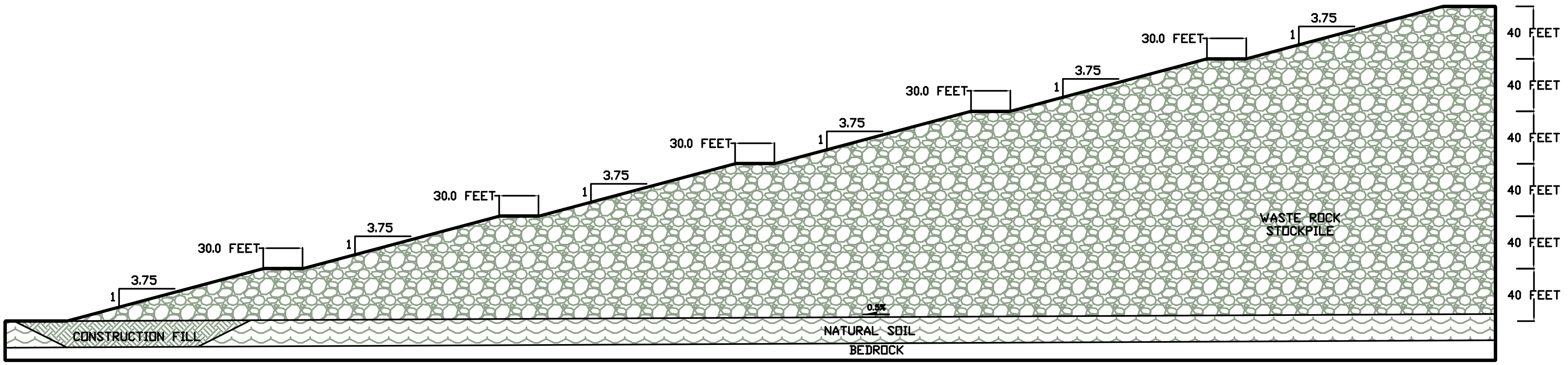
TITLE

DESIGN SECTION C1-2

CLIENT/PROJECT

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINESOTA

DRAWN JP	DATE MAY 18, 2012	JOB NO. 113-2209
CHECKED	SCALE N.T.S.	DWG. NO.
REVIEWED	FILE NO. Figures-sections.dwg	FIGURE NO. **4**



Golder Associates
Denver, Colorado

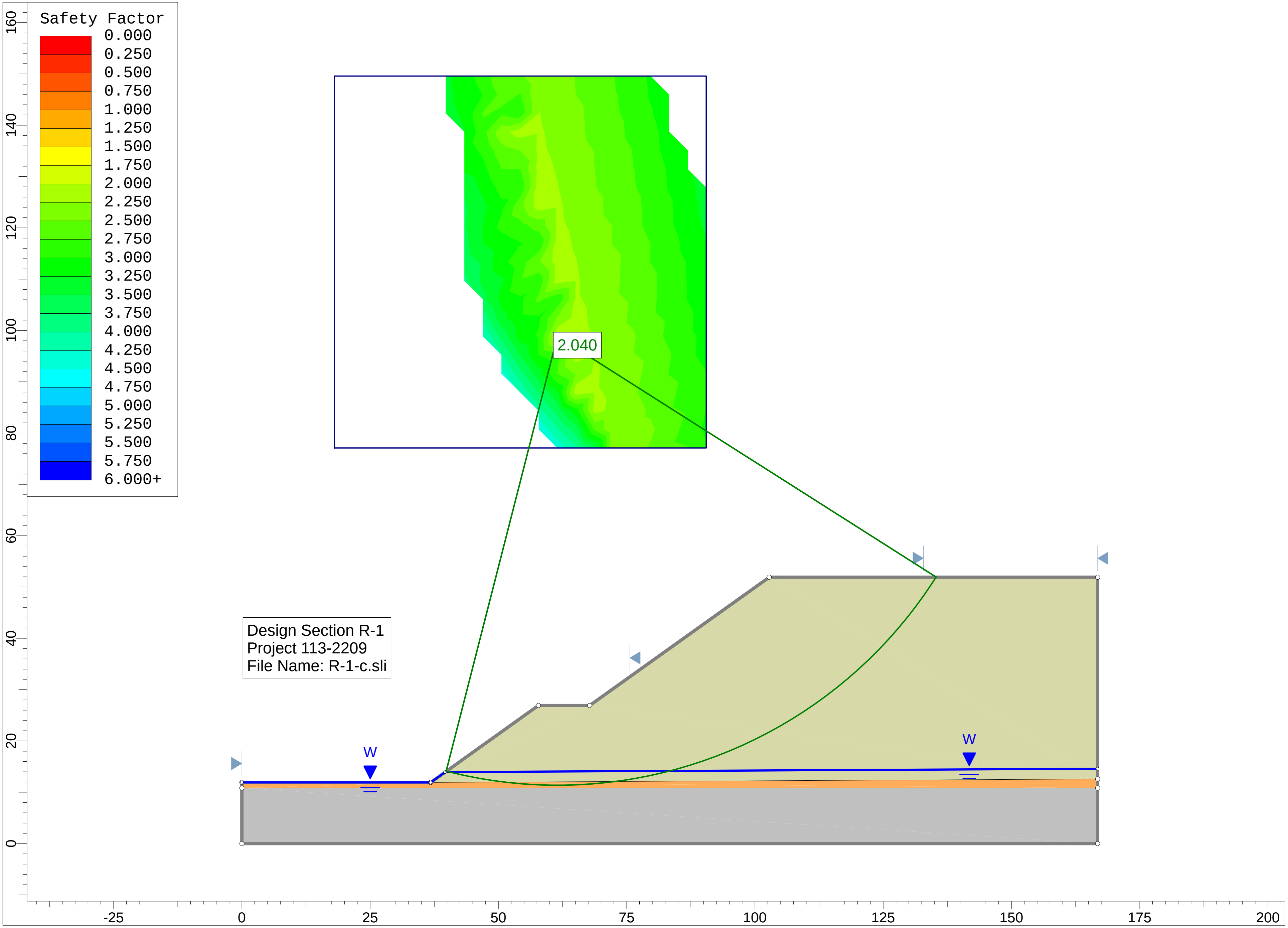
TITLE

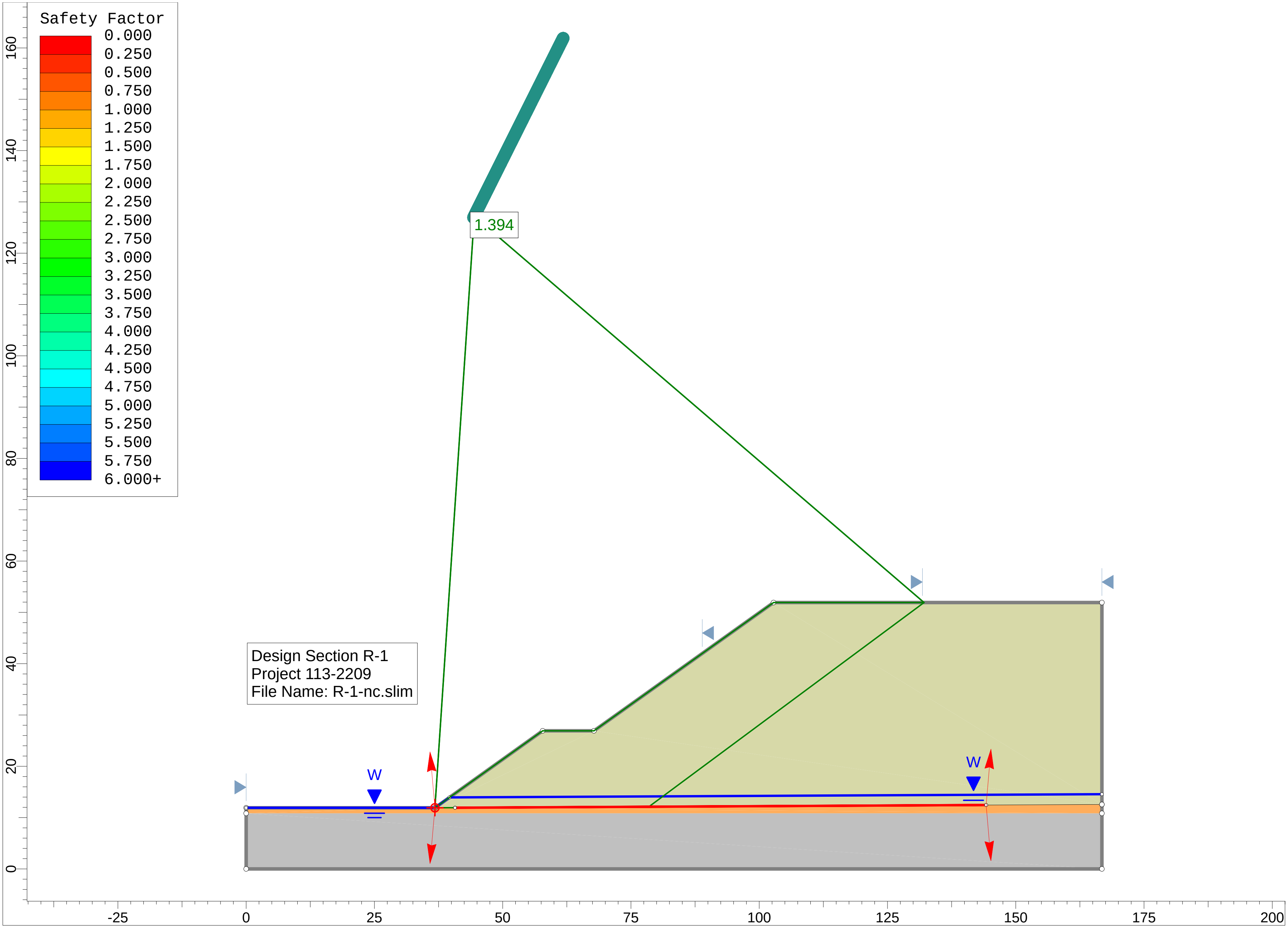
DESIGN SECTION C1-3

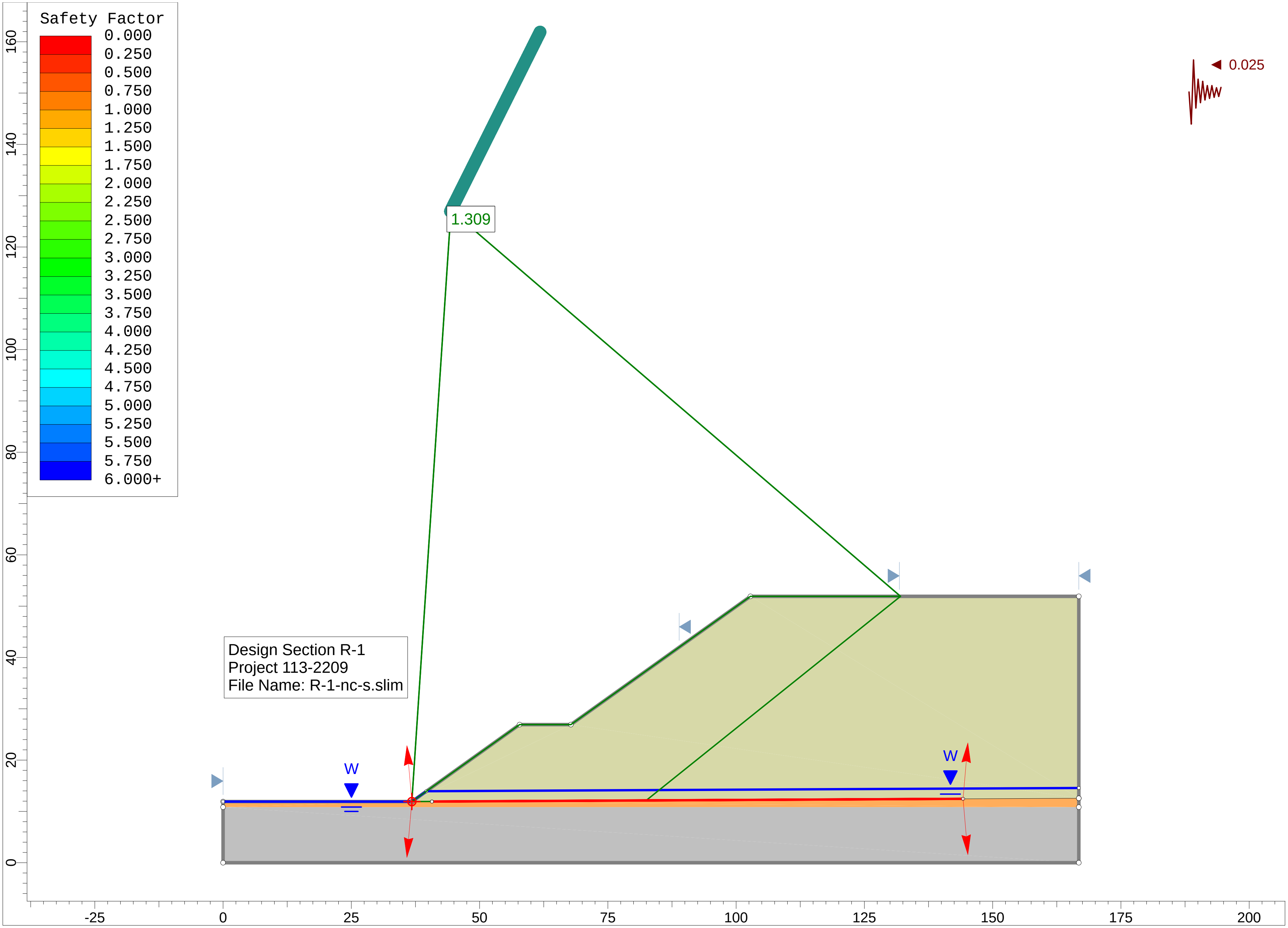
CLIENT/PROJECT
POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINESOTA

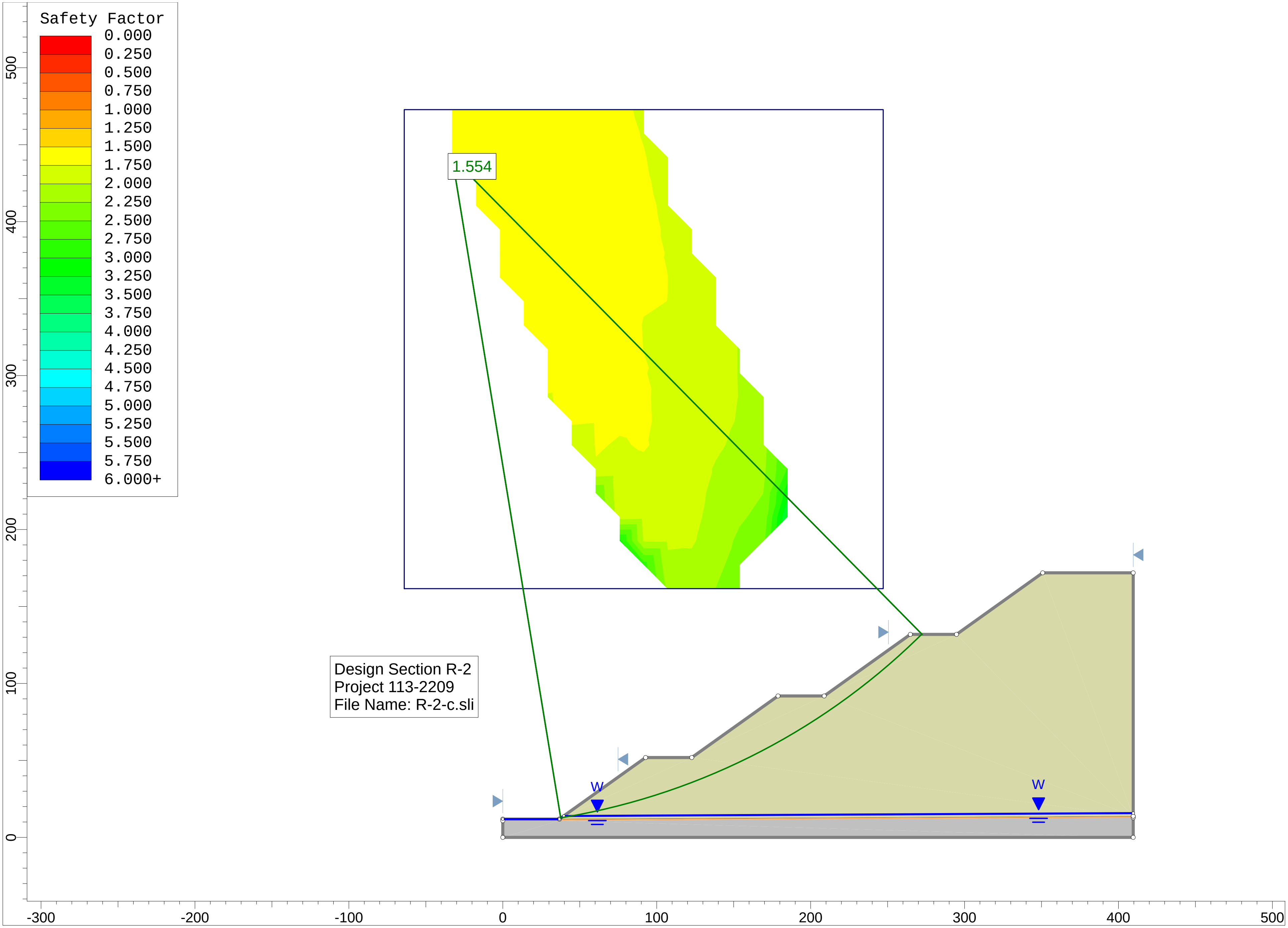
DRAWN JP
CHECKED
REVIEWED
DATE MAY 18, 2012
SCALE N.T.S.
FILE NO. Figures-sections.dwg
JOB NO. 113-2209
DWG. NO.
FIGURE NO. 5

ATTACHMENT 1
SLIDE ANALYSES

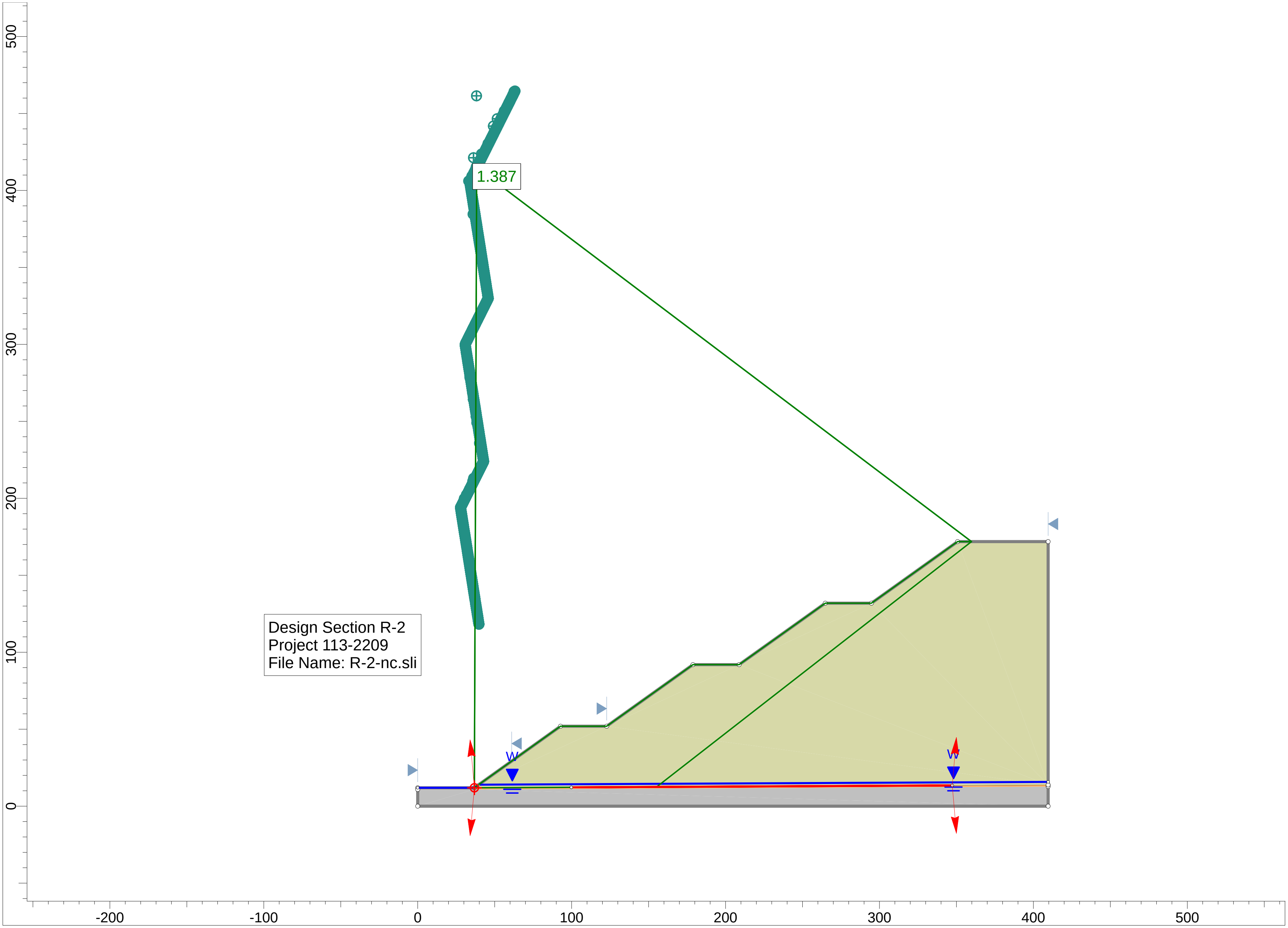

Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.040
Design Section R-1
Project 113-2209
File Name: R-1-c.sli
W
W
160
140
120
100
80
60
40
20
0
-25
0
25
50
75
100
125
150
175
200


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.394
Design Section R-1
Project 113-2209
File Name: R-1-nc.slim
W
W
160
140
120
100
80
60
40
20
0
-25
0
25
50
75
100
125
150
175
200

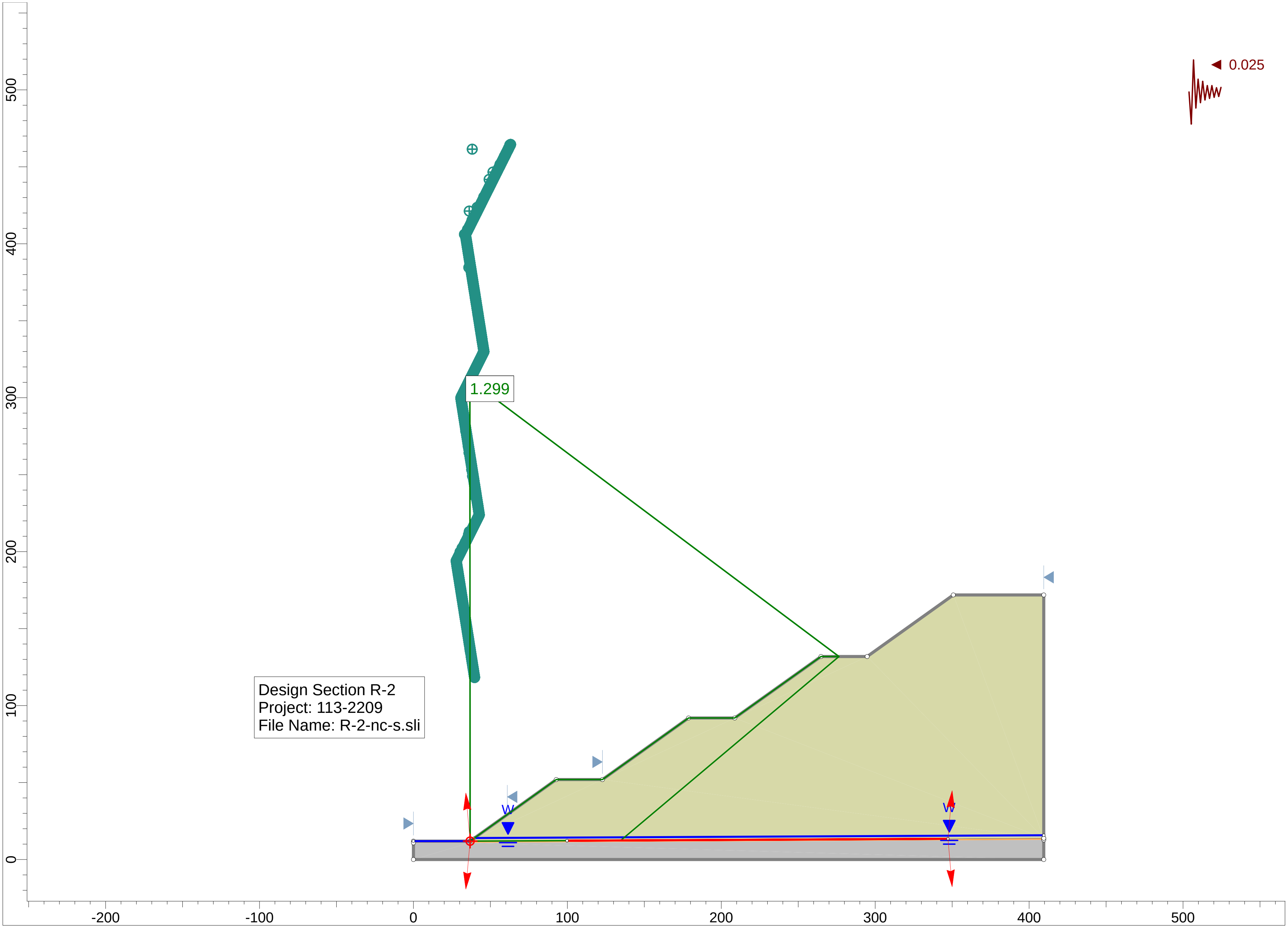

Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.309
0.025
Design Section R-1
Project 113-2209
File Name: R-1-nc-s.slim
W
W
160
140
120
100
80
60
40
20
0
-25
0
25
50
75
100
125
150
175
200

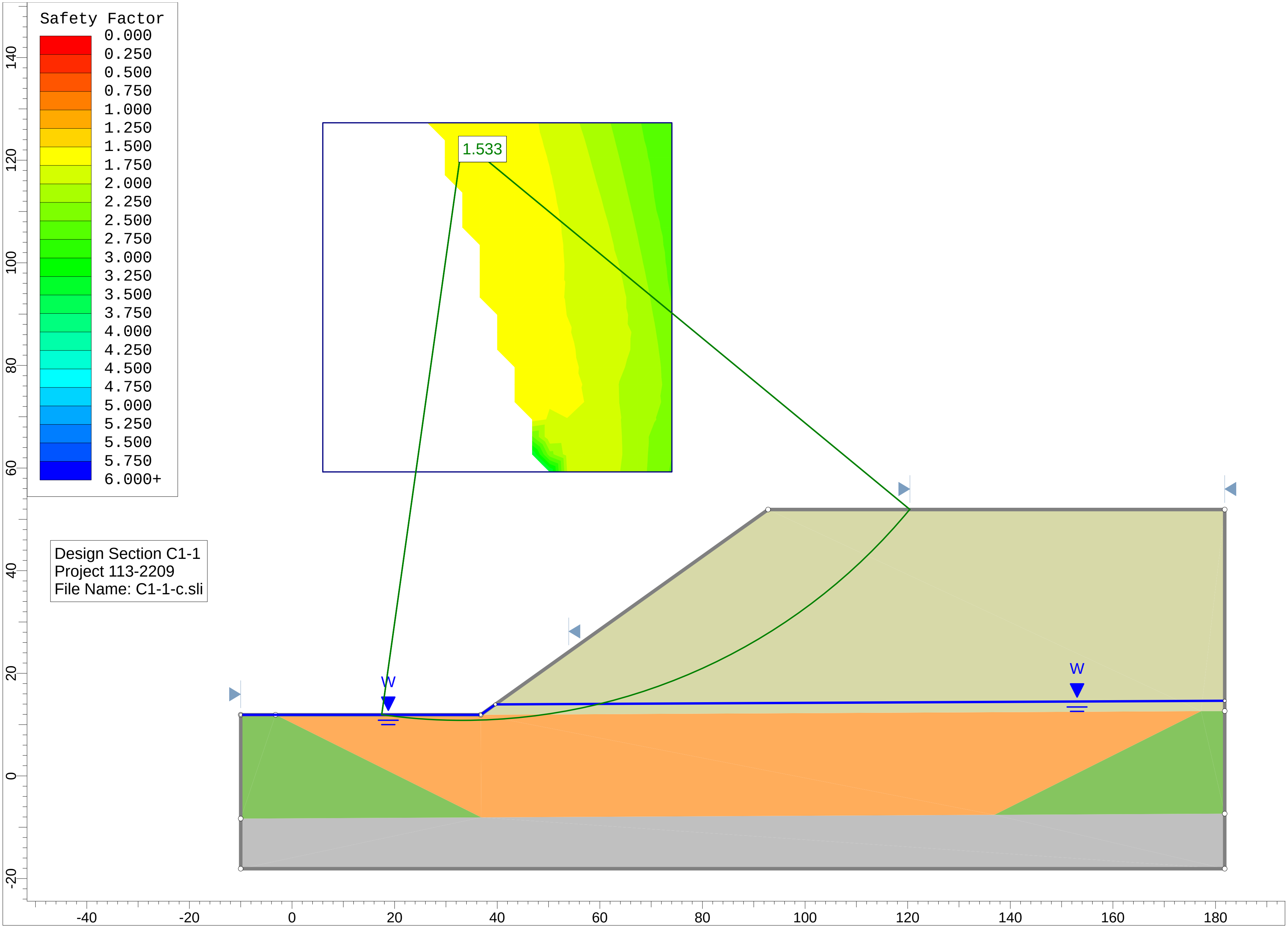


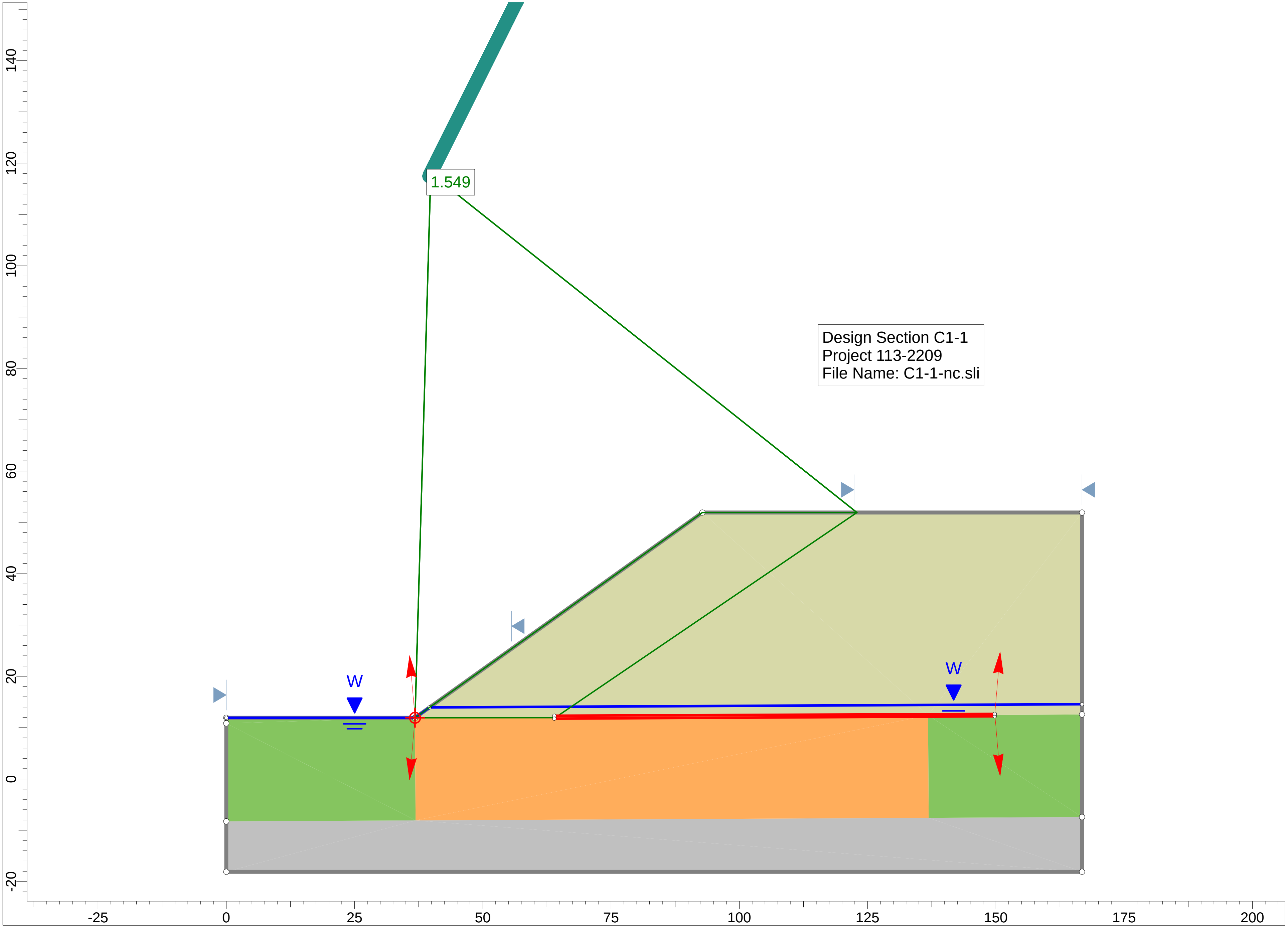
Design Section R-2
Project 113-2209
File Name: R-2-c.sli

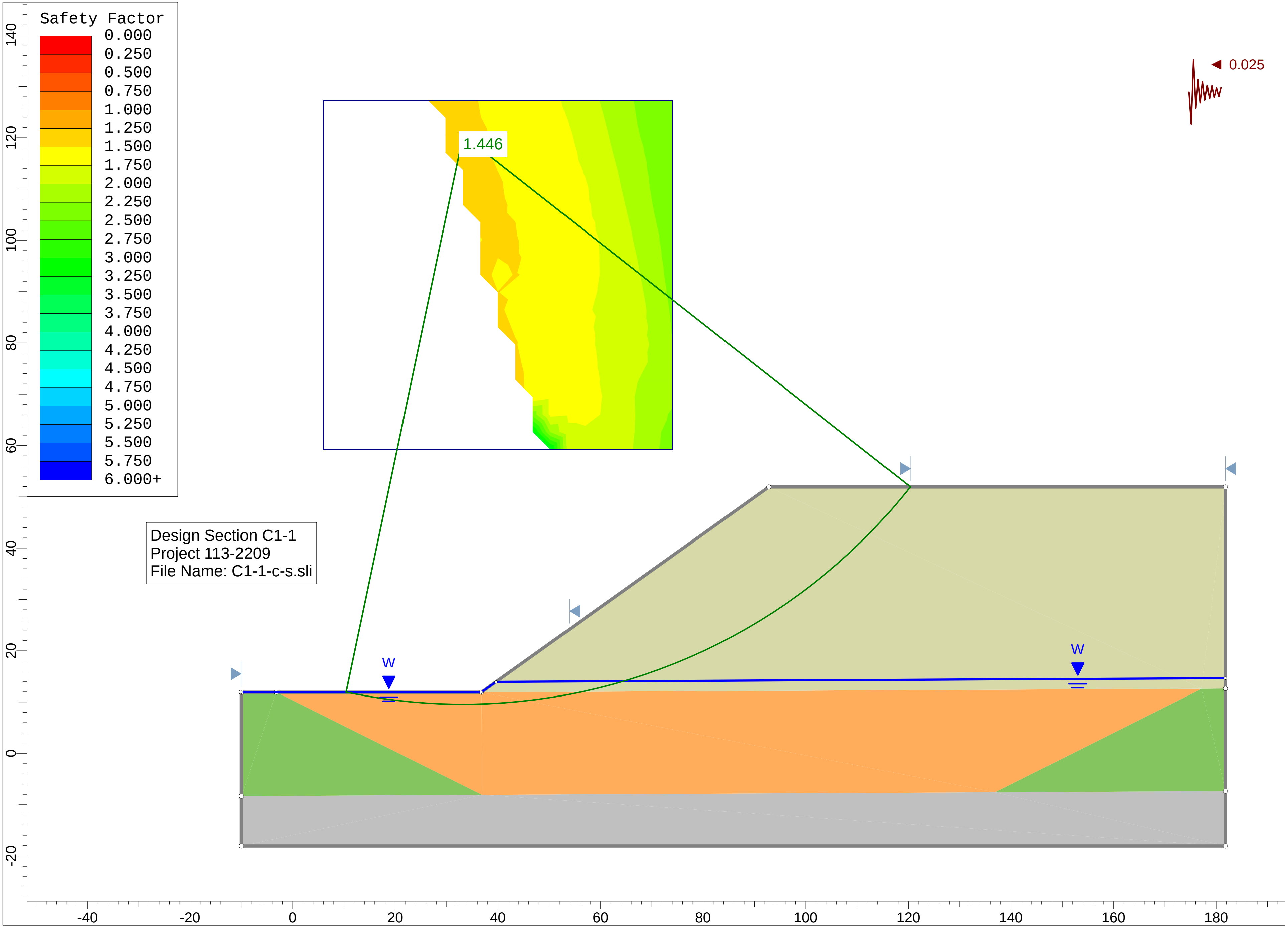


Design Section R-2
Project 113-2209
File Name: R-2-nc.sli

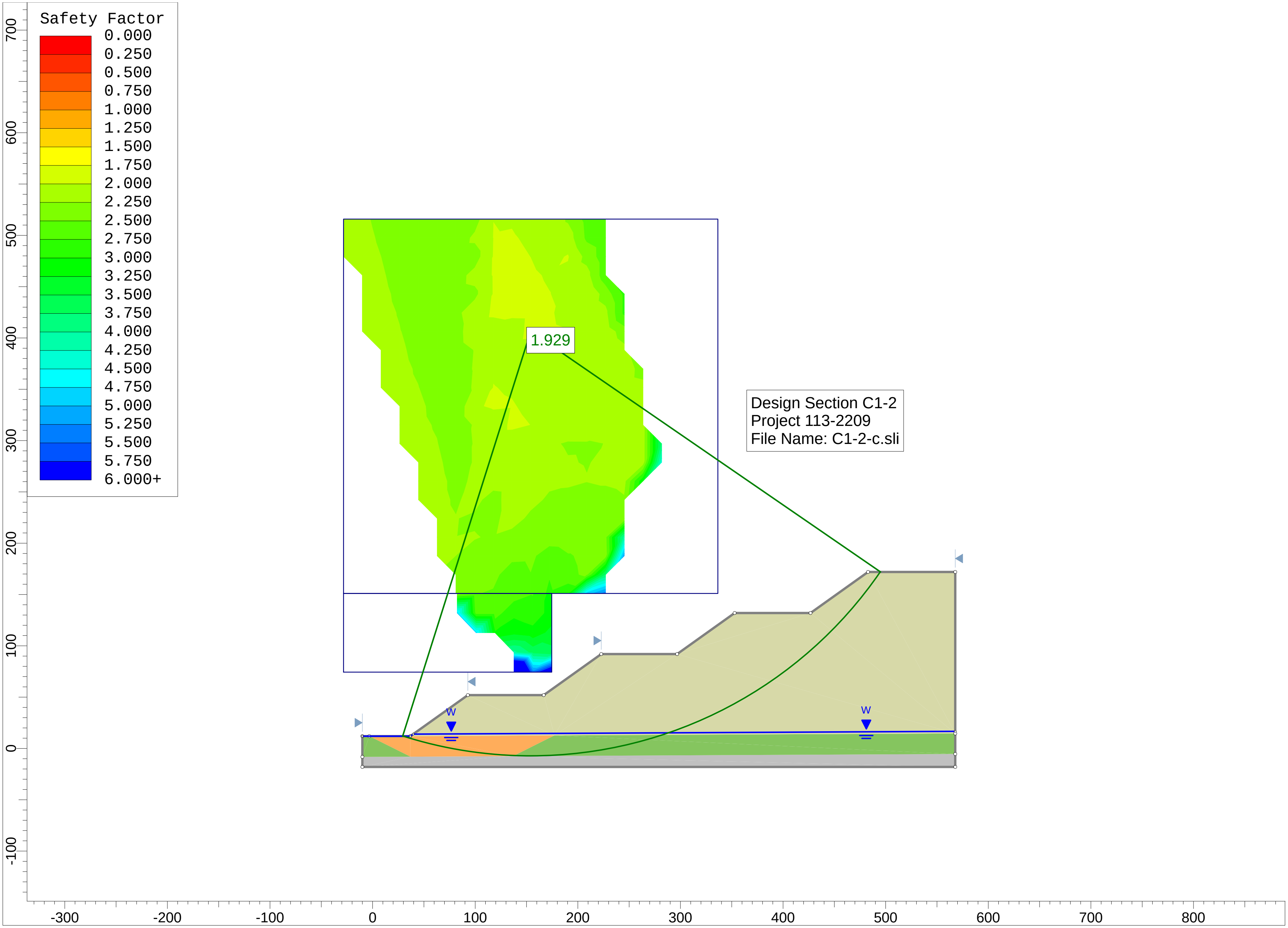

0.025
1.299
Design Section R-2
Project: 113-2209
File Name: R-2-nc-s.sli
W
W
500
400
300
200
100
0
-200
-100
0
100
200
300
400
500


Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.533
Design Section C1-1
Project 113-2209
File Name: C1-1-c.sli
W
W
140
120
100
80
60
40
20
0
-20
-40
-20
0
20
40
60
80
100
120
140
160
180


1.549
Design Section C1-1
Project 113-2209
File Name: C1-1-nc.sli
W
W
140
120
100
80
60
40
20
0
-20
-25
0
25
50
75
100
125
150
175
200



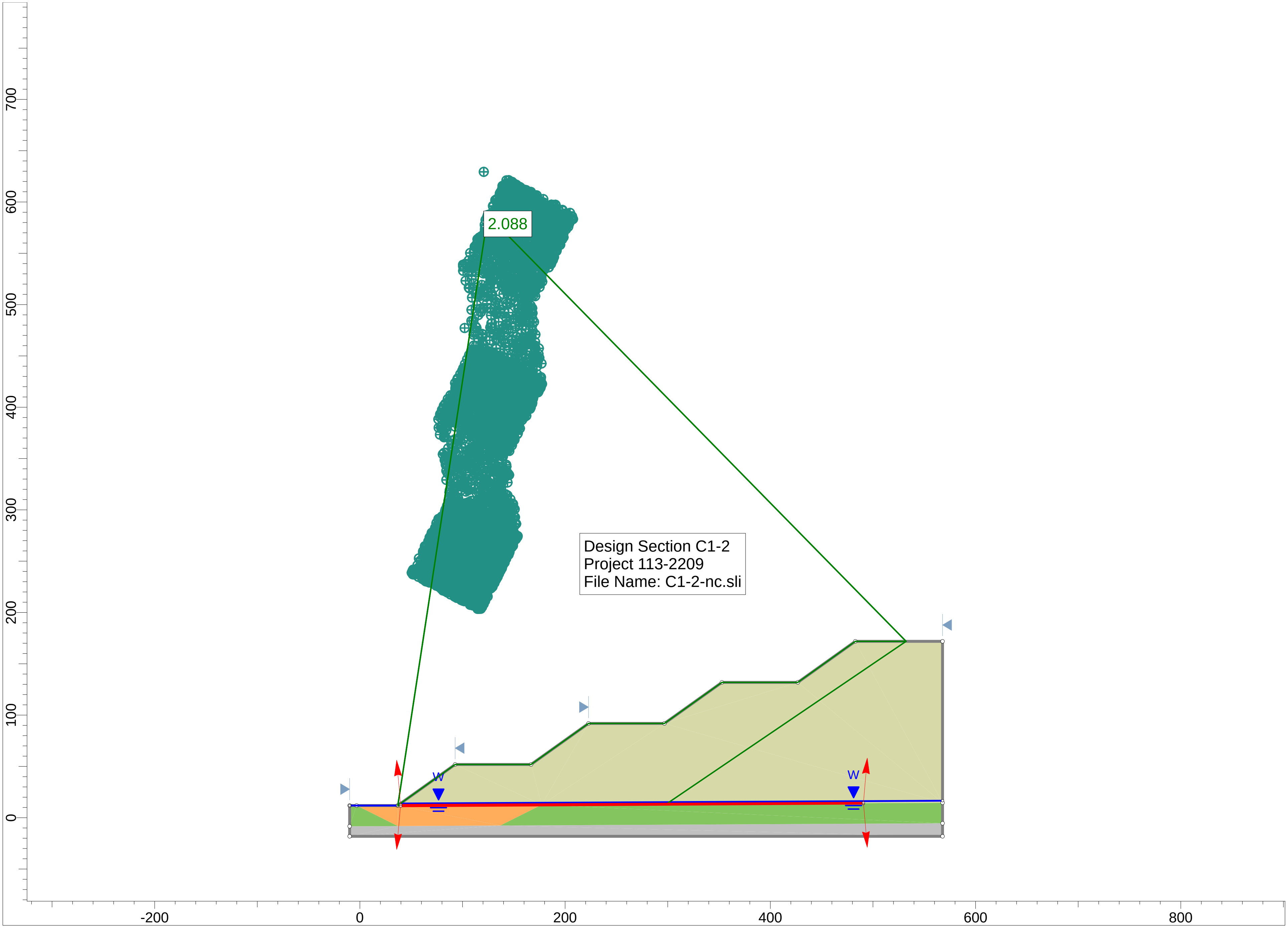
Design Section C1-1
Project 113-2209
File Name: C1-1-c-s.sli



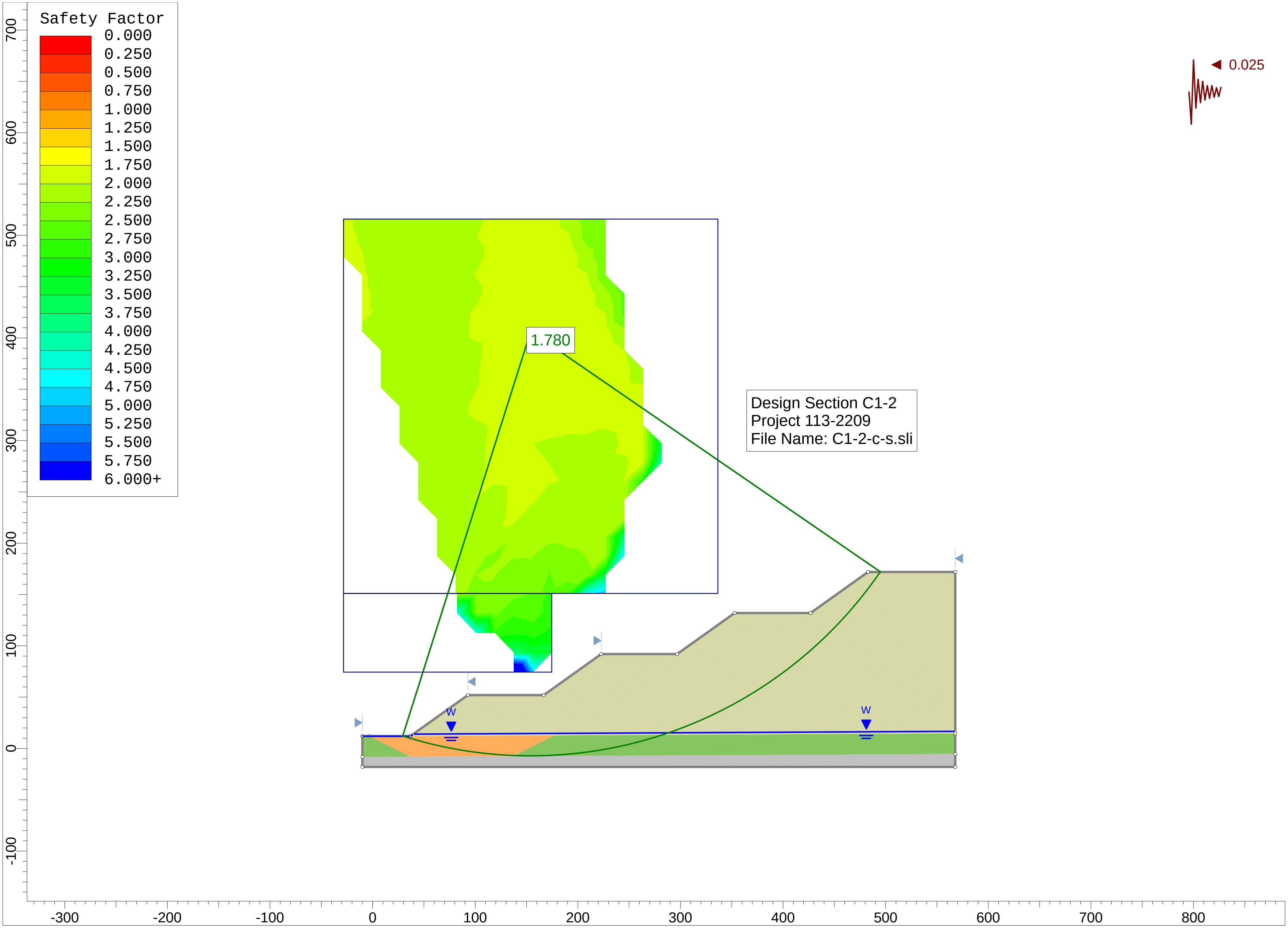
Design Section C1-2
Project 113-2209
File Name: C1-2-c.sli

C1-2-c.slim

Scale: 1:1500



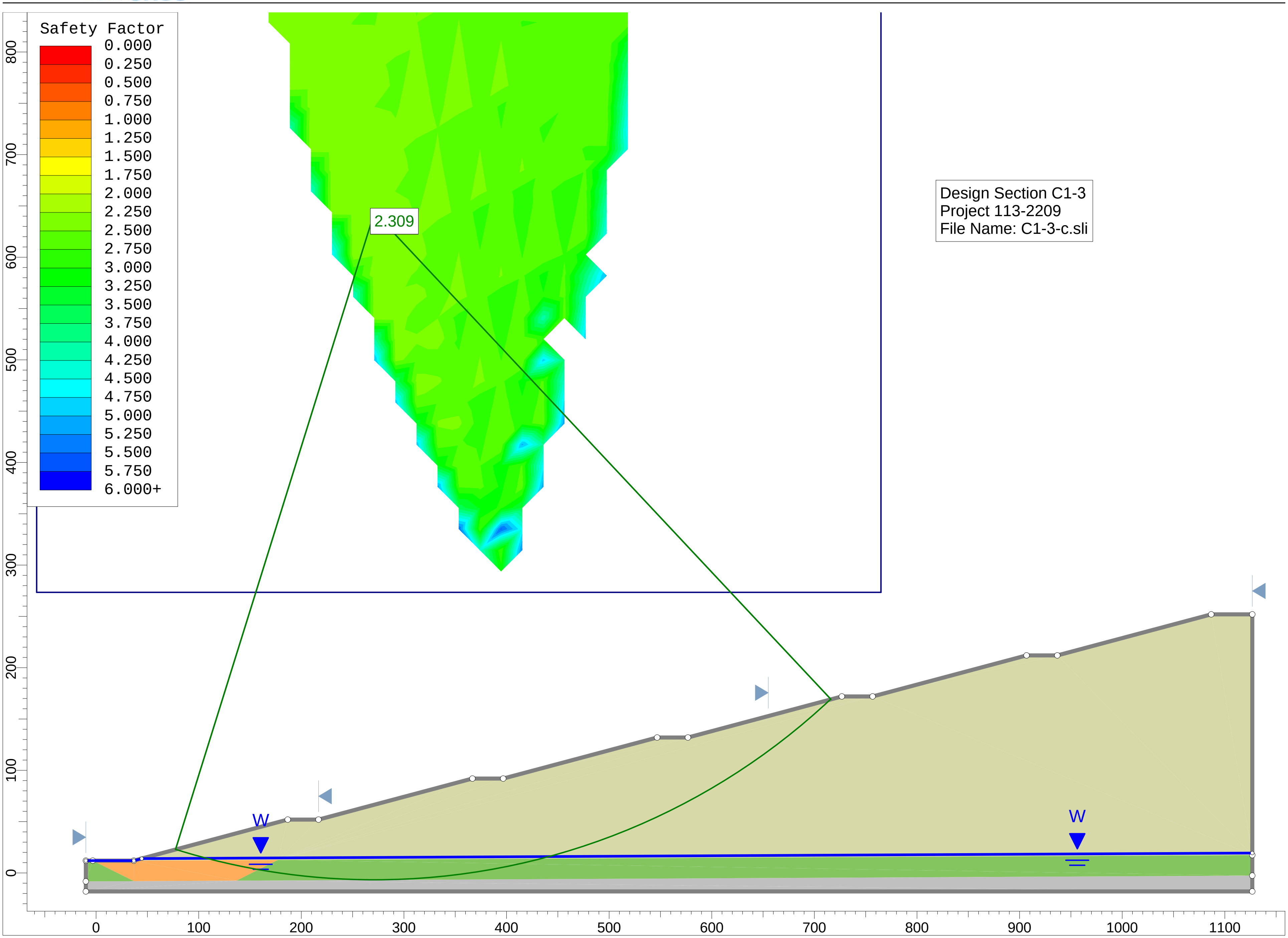
Design Section C1-2
Project 113-2209
File Name: C1-2-nc.sli



Design Section C1-2
Project 113-2209
File Name: C1-2-c-s.sli

SLIDEINTERPRET 6.017

5/18/2012 9:37:53 AM

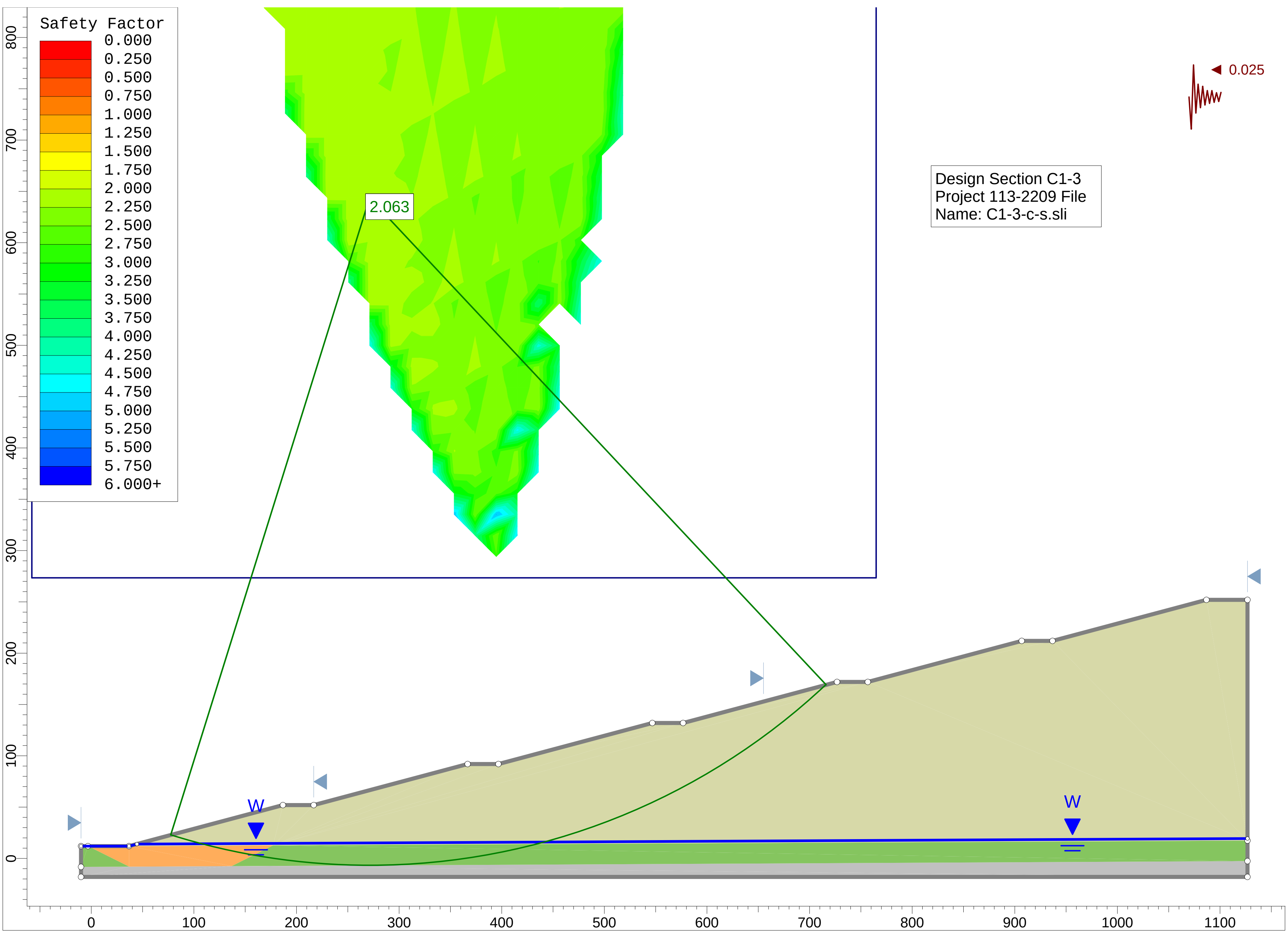


C1-5-c.slim

Scale: 1:1500

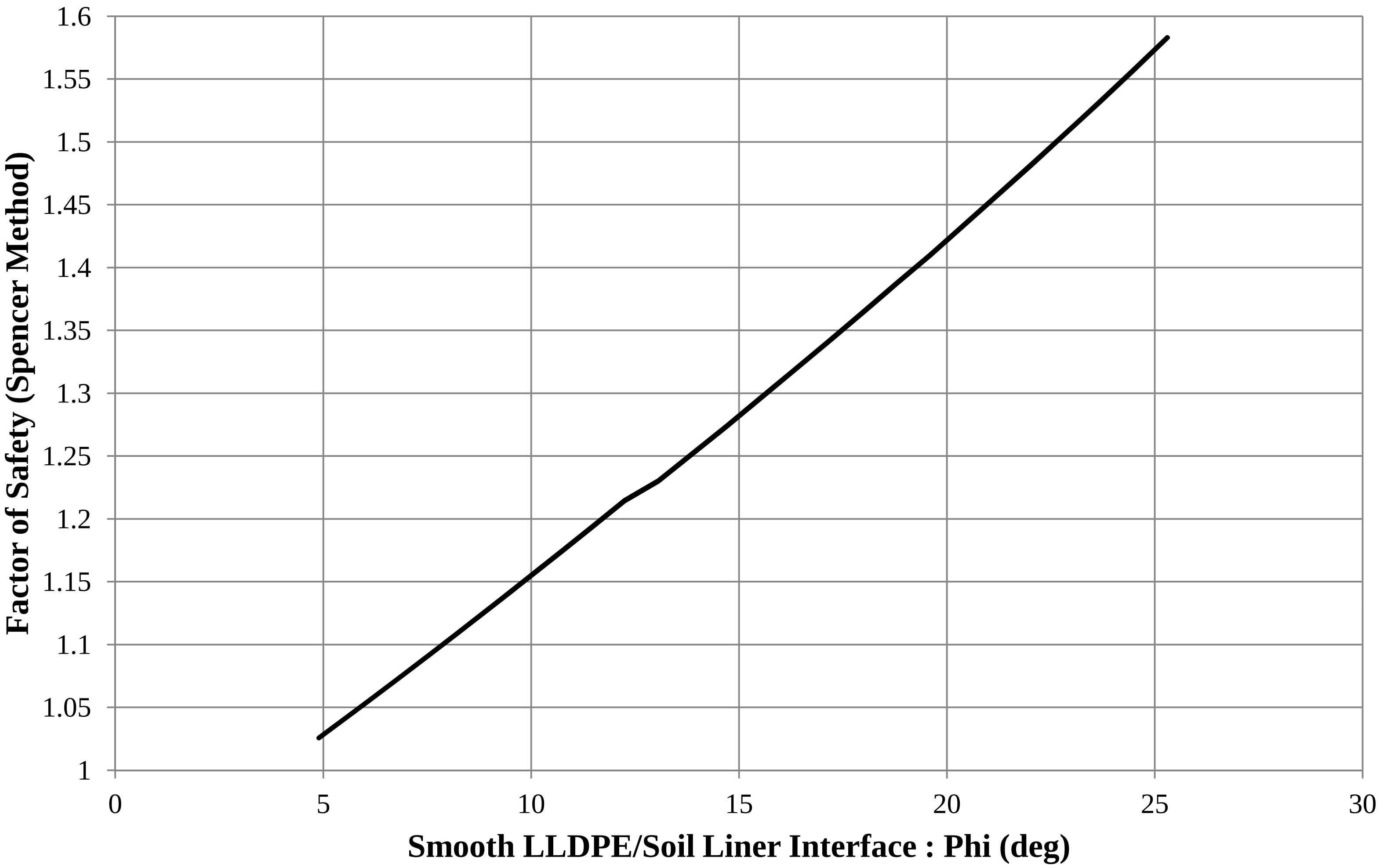
SLIDEINTERPRET 6.017

5/17/2012 4:07:29 PM



C1-5-c-s.slim

Scale: 1:1500



Golder Associates

Denver, Colorado

TITLE

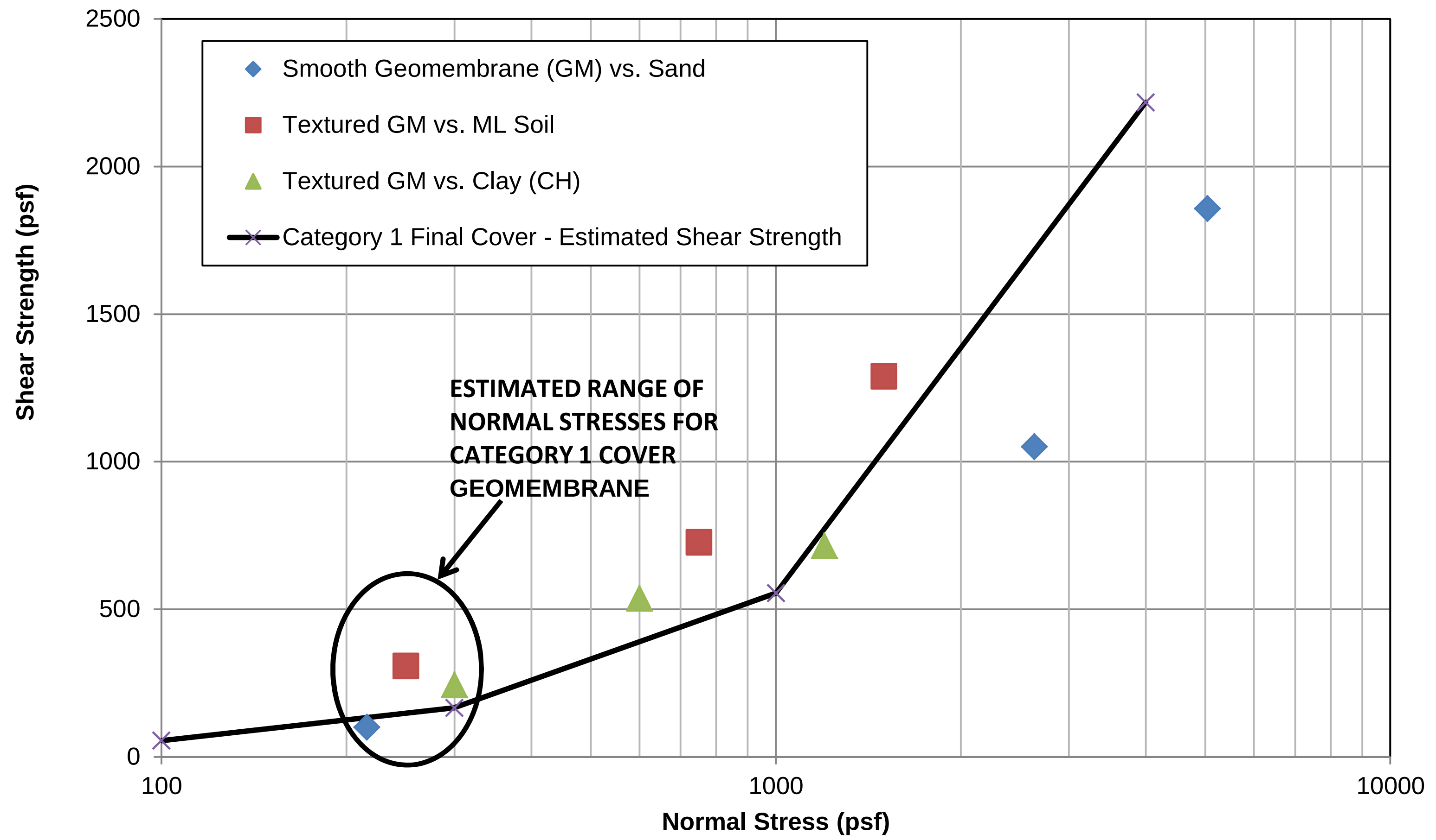
Sensitivity Plot
Design Section R-2

CLIENT/PROJECT

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

DRAWN	JP	DATE	May-12	JOB NO.	113-2209
CHECKED	GG	SCALE	AS SHOWN	DWG. NO.	N/A
REVIEWED	GG	FILE NO.	*N/A*	FIGURE NO.	N/A

ATTACHMENT 2
SELECTED INTERFACE FRICTION VALUES (GOLDER 2012)



Golder Associates

Denver, Colorado

TITLE

Interface Strength for Cover Design
Estimated Category 1 Cover Strength vs. Golder (2012) Database

CLIENT/PROJECT

POLYMET MINING CORPORATION
HOYT LAKES, MINNESOTA

DRAWN	GG	DATE	Oct-15	JOB NO.	113-2209
CHECKED	BRB	SCALE	AS SHOWN	DWG. NO.	
REVIEWED	BRB	FILE NO.		FIGURE NO.	FIGURE A-2-1

Attachment J

Foundation Settlement and Liner Strain Calculation

TECHNICAL MEMORANDUM

Date:	May 17, 2012	**Project No.:**	113-2209
To:	Tom Radue and Christie Kearney	**Company:**	Barr Engineering Company
From:	Gordan Gjerapic	**Email:**	ggjerapic@golder.com
cc:	Brent Bronson		

RE: **PRELIMINARY STOCKPILE FOUNDATION SETTLEMENT AND LINER STRAIN CALCULATIONS**

1.0 INTRODUCTION

This document summarizes the approach and results of preliminary foundation settlement and liner strain calculations for the proposed waste rock stockpiles at the PolyMet NorthMet site located near Babbitt, Minnesota. A geotechnical investigation sufficient to support a final design has not yet been completed due to both logistical and regulatory constraints. In particular, no site disturbance required to obtain additional data can occur until the permit to mine is approved. As a result, the analyses included herein are based on assumed properties that will need confirmation based on the results of a Phase II geotechnical investigation.

2.0 INPUT PARAMETERS

It was assumed that the stockpile foundations will be developed based on the following general sequence:

1. Excavate to bedrock within lowland areas, assuming a maximum depth of over-excavation of 20 feet, stockpiling organic soils and till material separately for future use as reclamation soils and structural fill, respectively.
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.
4. Construct the liner system dependent upon the reactivity category of the stockpile.

The minimum grade for foundation underdrains and the leachate collection overliner layer is limited to 0.5 percent. Consequently, the minimum construction liner grade for the stockpile settlement and liner strain calculations has been assumed to be 0.5 percent.

2.1 Material Properties

The available information on subsurface soils is insufficient to evaluate the variability of geotechnical conditions at the NorthMet site, especially within the lowland areas. Consequently, compression properties of highland materials (glacial tills) were estimated from laboratory data for a single test pit sample (TP#5, Sample #1, 0.5 to 4 feet) collected during the Phase I geotechnical investigation performed by Golder (2006). The selected compression properties for glacial till material (Figure 1) were assumed to be representative of subsurface soil conditions in the case where no structural fill is required to construct stockpile foundations.

It was assumed that the structural fill materials will exhibit properties similar to medium dense to dense sand, with a constrained modulus of approximately 10,000 pounds per square inch (psi) at an effective stress of 100 psi. The gravimetric moisture content of subgrade materials (glacial till and structural fill) was assumed to be 14 percent.

The following compressibility model was used for settlement calculations:

$$e = A\left[\sigma' + Z\right]^{B}, \tag{1}$$

where e stands for the void ratio, σ' denotes the vertical effective stress, and A, B, and Z are material parameters shown in Table 1. The employed compressibility model inherently assumes that all unsuitable materials (e.g., peat, organic soils, clays, etc.) in lowland areas are excavated and replaced with structural fill.

Table 1 Estimated Material Parameters

Material	Units	A	B	Z
Glacial till	(kPa)	1.0277	-0.1113	66.73
	(psf)	1.4414	-0.1113	1393.3
	(psi)	0.8289	-0.1113	9.679
Structural fill	(kPa)	0.4471	-0.0271	57.24
	(psf)	0.4854	-0.0271	1195.1
	(psi)	0.4243	-0.0271	8.3021

Compression curves developed for glacial till and structural fill materials used in the settlement calculations are shown in Figures 1 and 2.

2.2 Geometry and Loading Conditions

The thicknesses of subgrade materials (glacial till or structural fill) were estimated as a difference between the proposed liner grades and the estimated bedrock elevations. Surface loading was calculated based on the stockpile configurations at Year 20, assuming a waste rock dry density of 1.7 tons per cubic yard (t/yd^3) and a gravimetric moisture content of 8 percent.

2.3 Initial Conditions

The groundwater table was assumed to coincide with the bedrock surface during stockpile construction, i.e., it was assumed that the site is de-watered prior to fill placement. Pre-loading of subgrade materials was assumed to be equal to 10 psi due to construction equipment used for subgrade preparation.

3.0 CALCULATIONS

3.1 Foundation Settlements

Settlement calculations were based on determining the subgrade thickness prior to and after loading with the waste rock material. The height of the one-dimensional subgrade column (*H*) was calculated as follows:

$$H = H_s + \frac{e(0)[\sigma'(0)+Z]-e(H_s)[\sigma'(H_s)+Z]}{(1+B)\,\gamma_w\,G_s\,(1+w)} , \qquad (2)$$

where *w* is the gravimetric moisture content, H_s is the height of solids, *e*(0) and *σ'*(0) denote the void ratio and the effective stress at the base of the soil column, and $e(H_s)$ and $\sigma'(H_s)$ are the void ratio and the effective stress at the surface. The effective stress applied to the surface was set to 10 psi for the soil column prior to placement of the waste rock in order to account for equipment loading during construction. The effective stress at the surface of the soil column after placement of waste rock with a defined thickness, H_{WR}, was calculated as follows:

$$\sigma^{'}(H_s) = H_{WR}\,\gamma_{WR} , \qquad (3)$$

where Y_{WR} is the waste rock density (assumed as 136 pounds per cubic foot (pcf)). The effective stress at the base of the soil column was calculated as follows:

$$\sigma'(0) = \gamma_w\,G_s(1+w)H_s + \sigma'(H_s) , \qquad (4)$$

where Y_w is the density of water and G_s denotes the specific gravity of subgrade soils (assumed to be equal to 2.8). For a one-dimensional soil column, the height of solids, H_s, was calculated from Equation 2 with the column height, *H,* equal to the difference between the proposed liner grades and the corresponding estimated bedrock elevation.

3.2 Liner Strain

Foundation settlement calculations were determined using the grid spacing *L*. Using the maximum calculated settlement, δ, the maximum liner strain was conservatively estimated as follows:

$$\varepsilon = \frac{\sqrt{L^2 + \delta^2} - L}{L} = \sqrt{1 + \frac{\delta^2}{L^2}} - 1 \approx \frac{1}{2}\frac{\delta^2}{L^2} \tag{5}$$

4.0 RESULTS

The minimum initial liner grade employed for stockpile foundation construction is 0.5 percent according to project design criteria. Figures 4.1, 5.1, and 6.1 display the initial liner grades for the Category 2/3 Stockpile, Category 4 Stockpile, and Lean Ore Surge Pile, respectively. Figures 4.2, 5.2, and 6.2 display the calculated final liner grades based on the assumption that all subgrade materials are uniform and can be described using the properties for glacial till listed in Table 1. The change in liner grades between initial and final liner grades (e.g., between liner grades in Figures 4.1 and 4.2) is due to stresses exerted by the waste rock placement through the end of year 20. Critical reductions in liner grades (final post-settlement liner grades shallower than 0.2 percent) were not found.

Figures 4.3, 5.3, and 6.3 display the calculated final liner grades assuming structural fill as the subgrade soil material (rather than glacial till), with no compressible soils at depth. Assuming that the structural fill behaves as a moderately stiff to dense sand with the compression properties displayed in Figure 2, liner grades are likely to remain within tolerable limits.

The maximum foundation settlements and liner strains are shown in Tables 2 through 4.

Table 2 Maximum Settlements and Strains for Category 2/3 Stockpile

Subgrade	Maximum Settlement (ft)	Maximum Strain (%)
Glacial till	1.24	0.03
Structural fill	0.25	<0.01

Table 3 Maximum Settlements and Strains for Category 4 Stockpile

Subgrade	Maximum Settlement (ft)	Maximum Strain (%)
Glacial till	0.64	<0.01
Structural fill	0.13	<0.01

Table 4 Maximum Settlements and Strains for Lean Ore Surge Stockpile

Subgrade	Maximum Settlement (ft)	Maximum Strain (%)
Glacial till	0.36	<0.01
Structural fill	0.07	<0.01

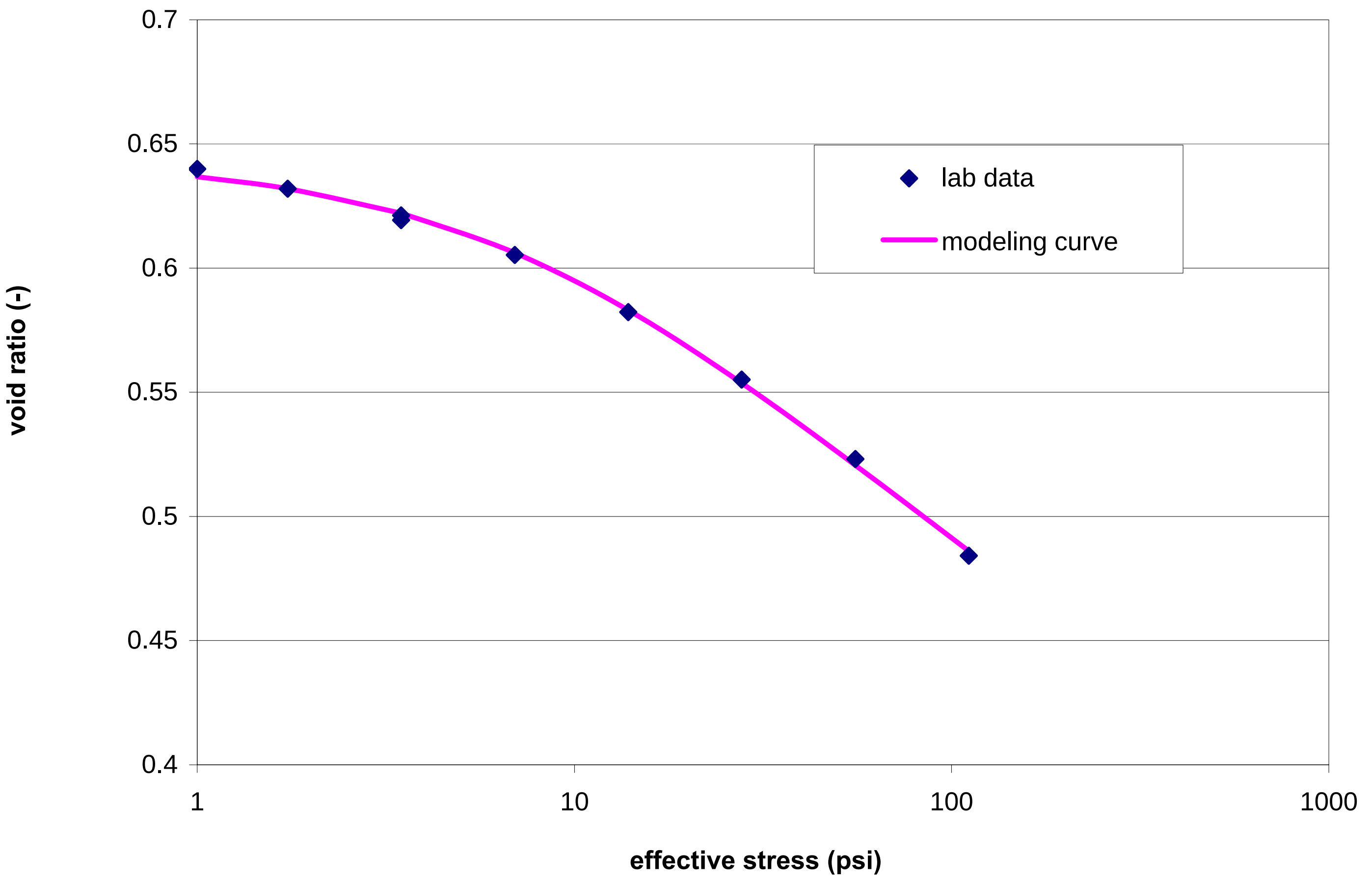
Large strains from foundation consolidation are not anticipated at the NorthMet stockpiles as the highland foundation soils are believed to be dominantly composed of relatively low-compressibility glacial moraine, colluvium, and weathered bedrock, which are not expected to experience large settlements. Engineered fills have also been designed to minimize the potential for settlement in lowland areas that have yet to be characterized. Note that the main reason that a linear low-density polyethylene (LLDPE) liner system was selected over a high-density polyethylene (HDPE) system is because of its greater flexibility and significantly more favorable biaxial stress-strain properties, which can accommodate unexpected foundation settlements. The documented allowable biaxial strain for LLDPE is in excess of 30 percent, while HDPE will only strain uniaxially to only 12 to 17 percent before yield failure occurs. Conservatively assuming a maximum strain for the LLDPE liner systems of 30 percent and the maximum predicted settlement strain from glacial till of 0.03 percent, the factor of safety against liner rupture resulting from settlement is approximately 1000.

5.0 CONCLUSIONS

Waste rock loading may increase or decrease the slope gradients as illustrated in Figure 3 (potentially even resulting in depressions or negative gradients depending upon the actual site conditions). For example, loading Case A in Figure 3 depicts liner grade reduction caused by decreasing waste rock height in the direction of decreasing liner elevations. Similarly, the loading Case B in Figure 3 depicts steepening of the liner grades caused by increasing waste rock height in the direction of decreasing liner elevations. This trend of liner grade reduction/increase may be exacerbated if the subgrade soil thickness increases in the same direction as the waste rock height.

Settlement calculations indicate that subgrade soils with the compression index below approximately 0.1 are likely to perform favorably under the assumed loading conditions.

FIGURES



Golder Associates

Denver, Colorado

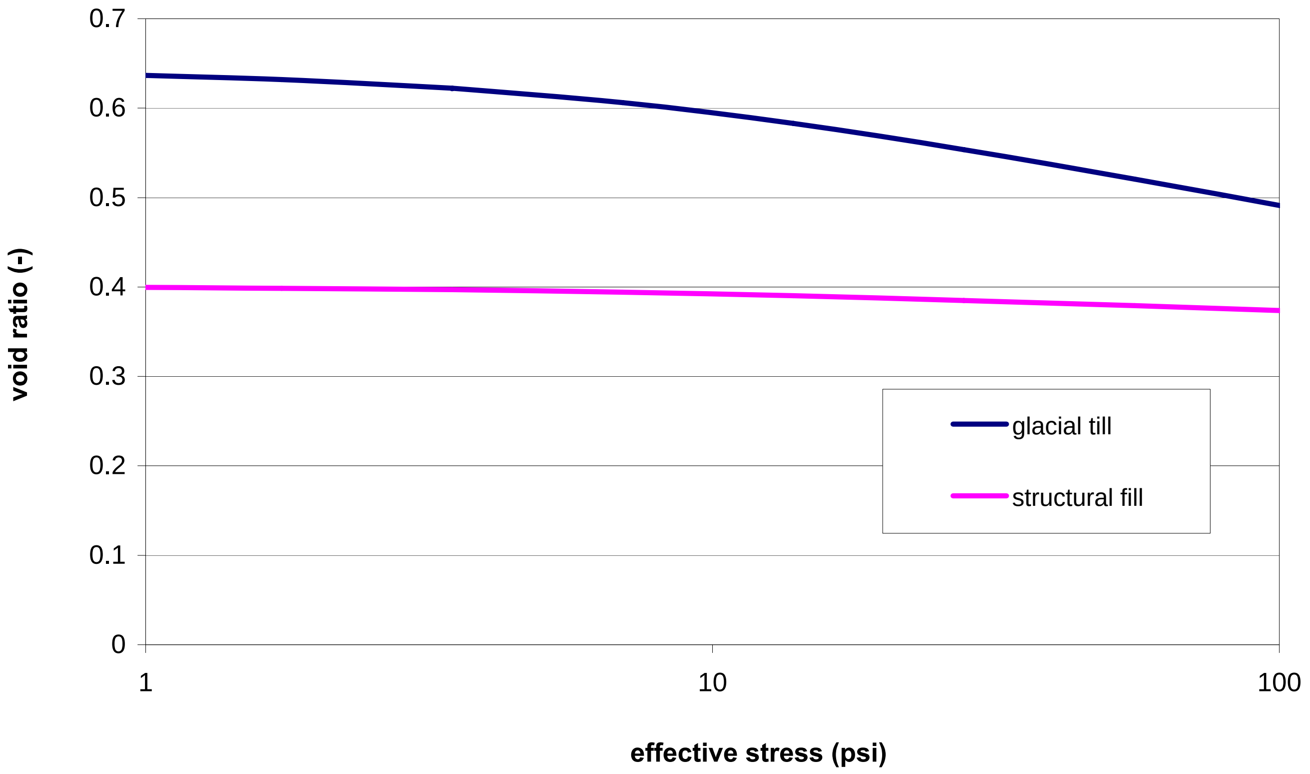
TITLE

Glacial Till Compressibility
Laboratory Data vs. Modeling Curve

CLIENT/PROJECT

POLYMET MINING CORPORATION
HOYT LAKES, MINNESOTA

DRAWN	**GG**	DATE	**May-12**	JOB NO.	**113-2209**
CHECKED	**BRB**	SCALE	**AS SHOWN**	DWG. NO.	
REVIEWED	**BRB**	FILE NO.		FIGURE NO.	**FIGURE 1**



Golder Associates

Denver, Colorado

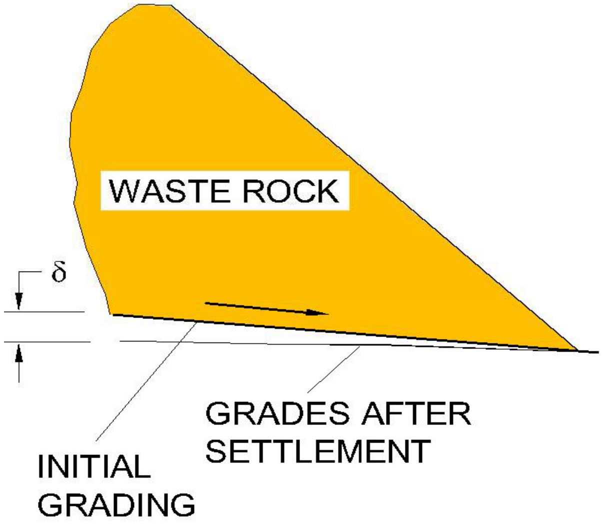
TITLE

Compressibility Data for Settlement Modeling

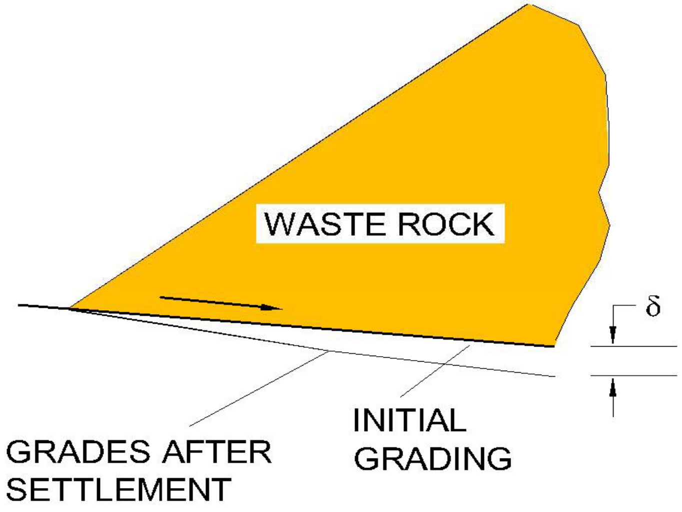
CLIENT/PROJECT

POLYMET MINING CORPORATION
HOYT LAKES, MINNESOTA

DRAWN	**GG**	DATE	**May-12**	JOB NO.	**113-2209**
CHECKED	**BRB**	SCALE	**AS SHOWN**	DWG. NO.	
REVIEWED	**BRB**	FILE NO.		FIGURE NO.	**FIGURE 2**



LOADING CASE A:
WASTE ROCK HEIGHT INCREASES W/
INCREASING LINER ELEVATIONS



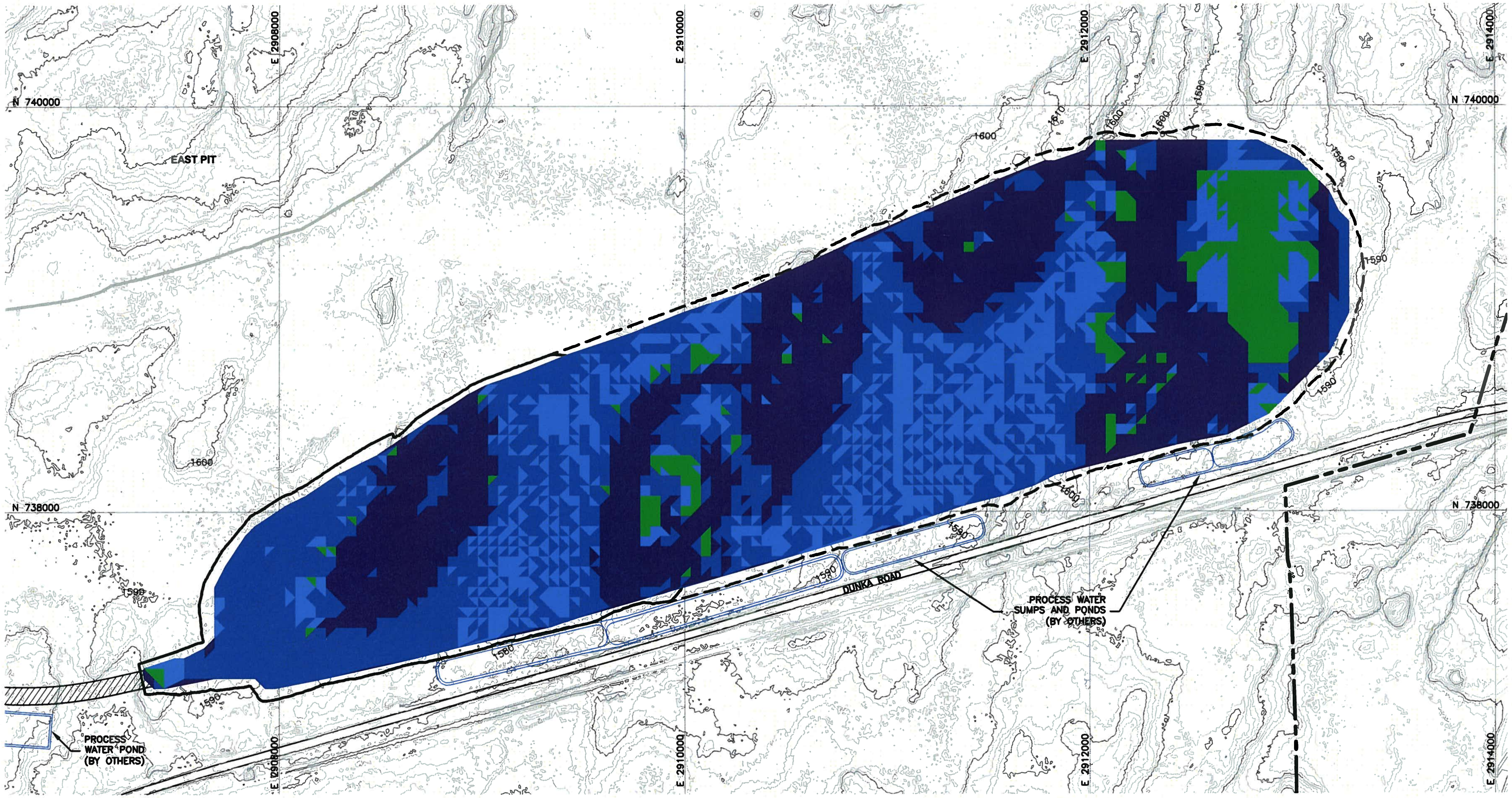
LOADING CASE B:
WASTE ROCK HEIGHT INCREASES W/
DECREASING LINER ELEVATIONS

Golder Associates
Denver, Colorado

TITLE
Liner Grade Changes Due to Waste Rock Loading

CLIENT/PROJECT
POLYMET MINING CORPORATION
HOYT LAKES, MINNESOTA

DRAWN	**GG**	DATE	**May-12**	JOB NO.	**113-2209**
CHECKED	**BRB**	SCALE	**AS SHOWN**	DWG. NO.	
REVIEWED	**BRB**	FILE NO.		FIGURE NO.	**FIGURE 3**



0 300 600
SCALE IN FEET

LEGEND

LINER GRADES:

- 🟥 0.0 TO 0.1 PERCENT
- 🟧 0.1 TO 0.2 PERCENT
- 🟨 0.2 TO 0.3 PERCENT
- 🟩 0.3 TO 0.4 PERCENT
- 🟩 0.4 TO 0.6 PERCENT
- 🟦 0.6 TO 1.0 PERCENT
- 🟦 1.0 TO 2.0 PERCENT
- ⬛ > 2.0 PERCENT

- PROJECT BOUNDARY
- YEAR 11 PIT BOUNDARIES (SEE NOTE 1)
- YEAR 1 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
- YEAR 11 AND ULTIMATE WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
- ▨ HAUL ROADS
- PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

CATEGORY 2/3 STOCKPILE
INITIAL LINER GRADES

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS

ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS – NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED:

GOLDER PROJECT NO.: 113-2209

SCALE: AS SHOWN

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

Golder Associates

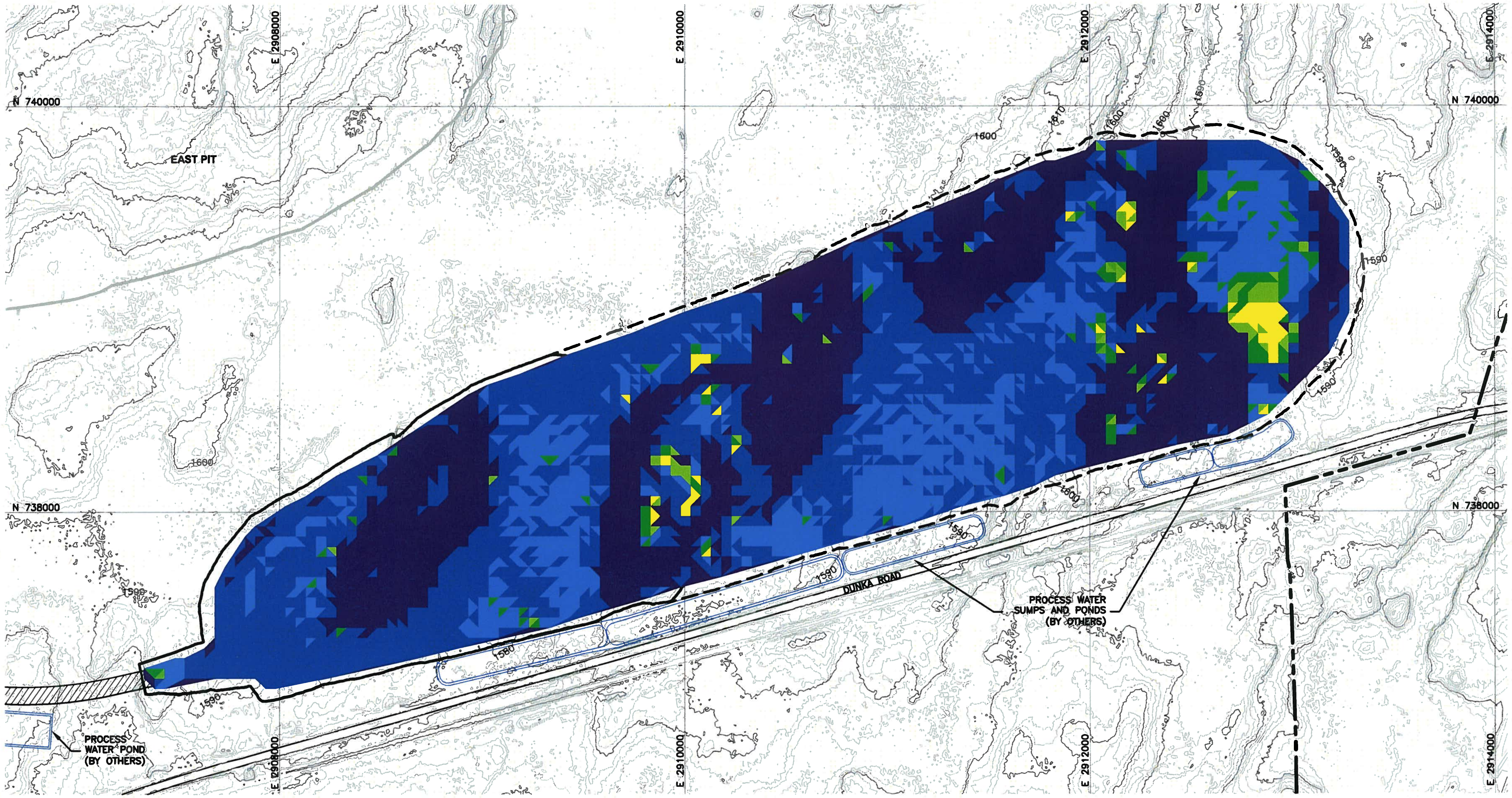
GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

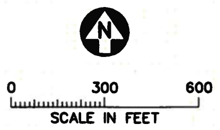
DWG. NO. 4.1

REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D007.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 11:08 AM

INCHES 1 2





LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟪	> 2.0 PERCENT

— — — —	PROJECT BOUNDARY
———	YEAR 11 PIT BOUNDARIES (SEE NOTE 1)
———	YEAR 1 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
— — —	YEAR 11 AND ULTIMATE WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
▨	HAUL ROADS
———	PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

CATEGORY 2/3 STOCKPILE
LINER GRADES AFTER COMPRESSION
GLACIAL TILL FOUNDATION

POLYMET
MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		
PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.		

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED:

GOLDER PROJECT NO.: 113-2209

SCALE: AS SHOWN

Golder Associates

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

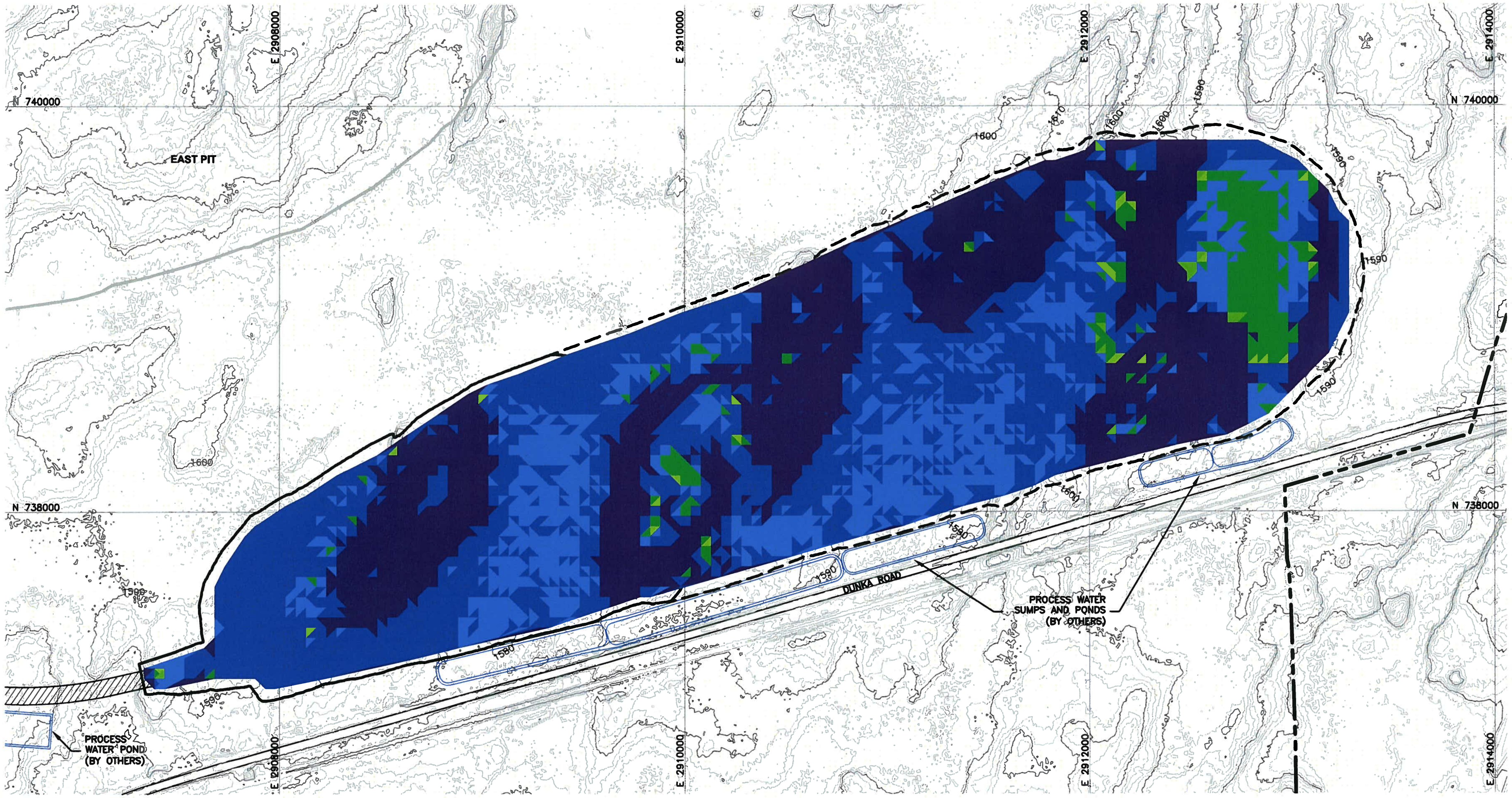
DWG. NO. 4.2

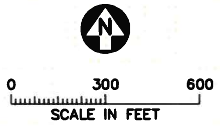
REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\113220909008.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 11:11 AM

INCHES 1 2

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\11322090009.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 11:15 AM





LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟦	> 2.0 PERCENT

▬ ▬ ▬	PROJECT BOUNDARY
───	YEAR 11 PIT BOUNDARIES (SEE NOTE 1)
───	YEAR 1 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
– – –	YEAR 11 AND ULTIMATE WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
▨	HAUL ROADS
───	PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

CATEGORY 2/3 STOCKPILE
LINER GRADES AFTER COMPRESSION
STRUCTURAL FILL FOUNDATION

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED: SS

GOLDER PROJECT NO.: 113-2209

SCALE: AS SHOWN

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

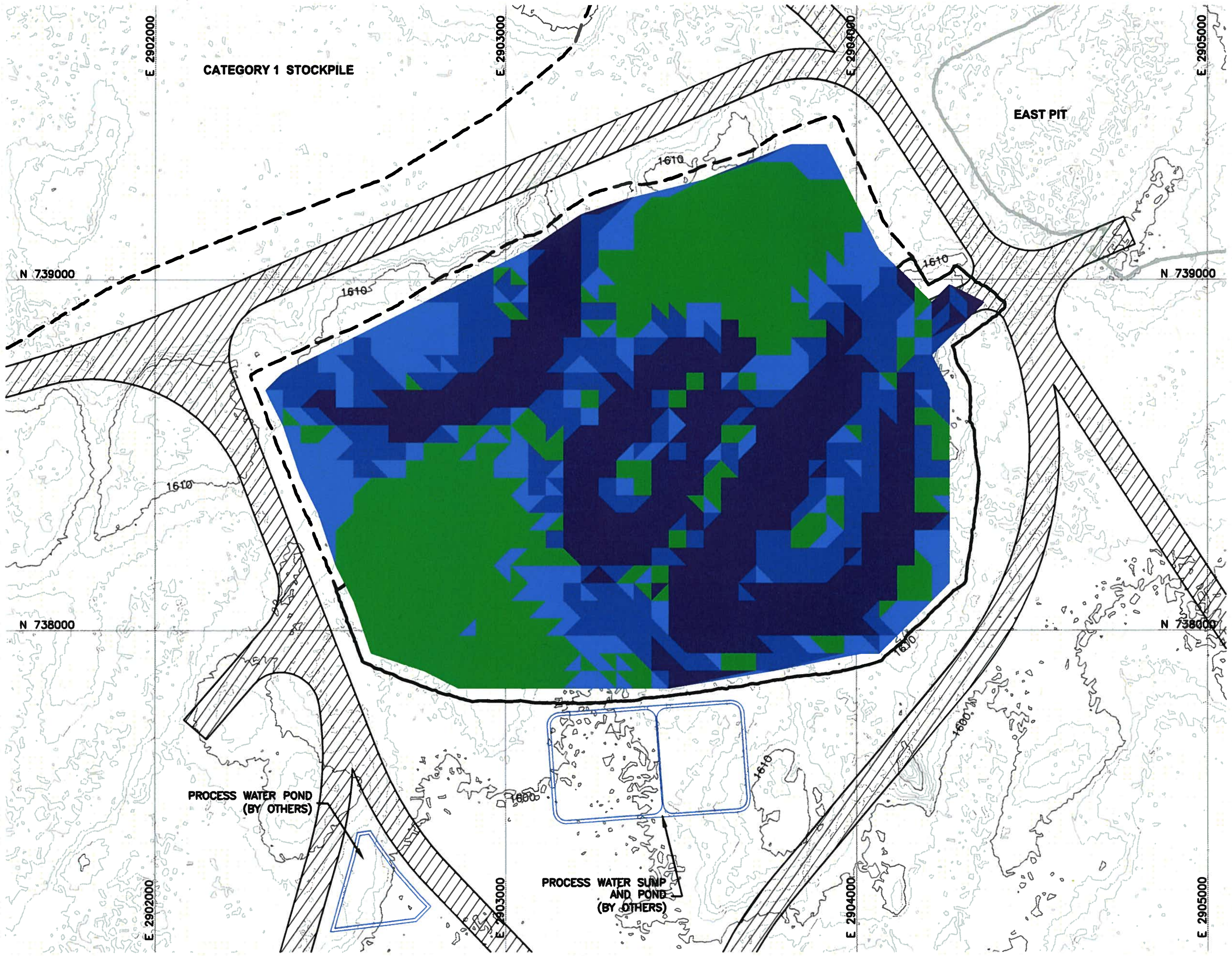
Golder Associates

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. 4.3

REV A

INCHES 1 2



0 200 400
SCALE IN FEET

LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟪	> 2.0 PERCENT

— - - —	PROJECT BOUNDARY
———	YEAR 1 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
- - - - -	YEAR 11 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
▨	HAUL ROAD
———	YEAR 2 PIT BOUNDARIES (SEE NOTE 1)
———	PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

CATEGORY 4 STOCKPILE
INITIAL LINER GRADES

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		
PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.		

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED:

GOLDER PROJECT NO.: 113-2209

SCALE: AS SHOWN

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

Golder Associates

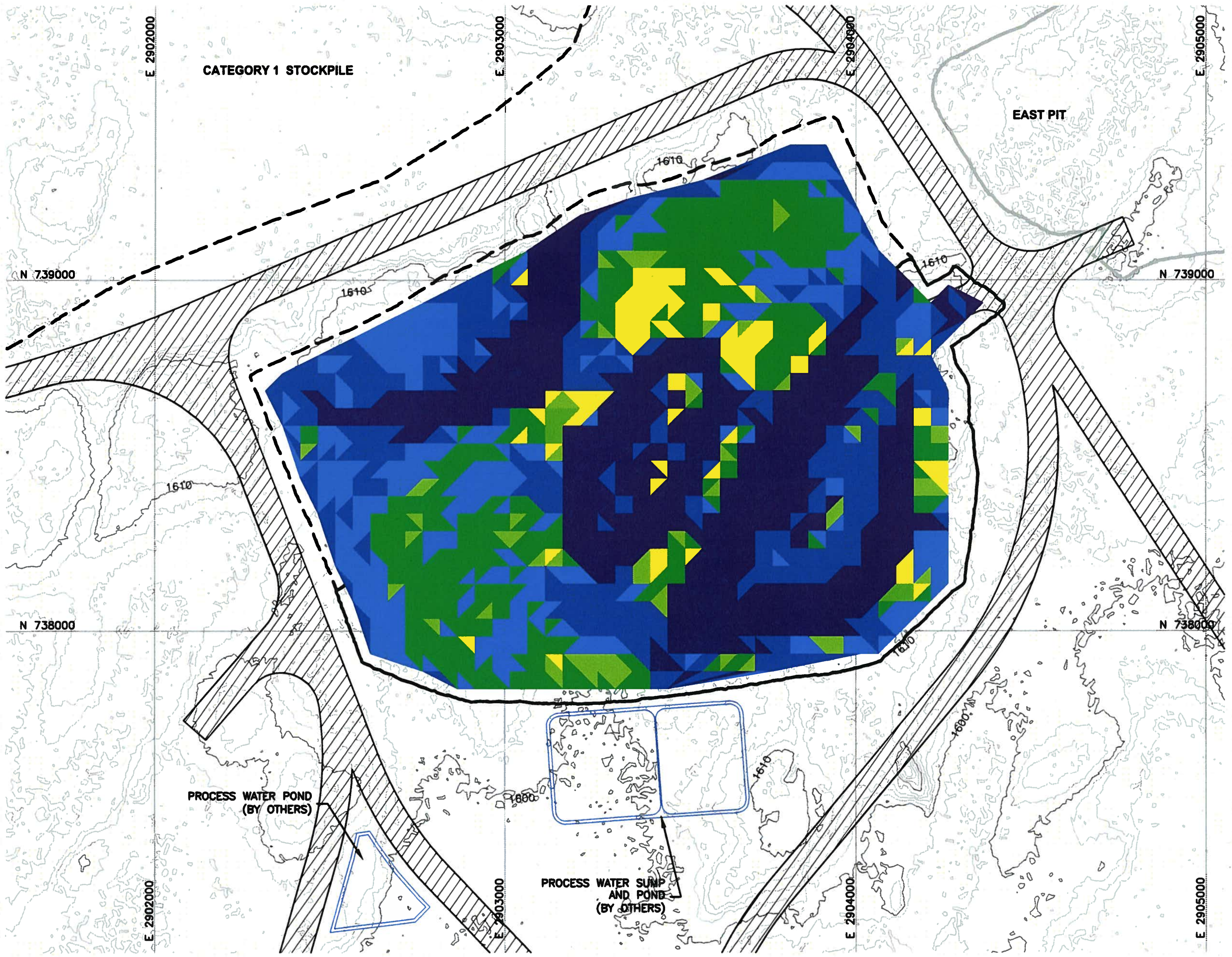
GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. 5.1

REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D004.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 11:00 AM

INCHES 1 2



0 200 400
SCALE IN FEET

LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟪	> 2.0 PERCENT

— - - —	PROJECT BOUNDARY
———	YEAR 1 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
— — —	YEAR 11 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)
▨	HAUL ROAD
———	YEAR 2 PIT BOUNDARIES (SEE NOTE 1)
———	PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

CATEGORY 4 STOCKPILE
LINER GRADES AFTER COMPRESSION
GLACIAL TILL FOUNDATION

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS

ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED: -

GOLDER PROJECT NO.: 113-2209

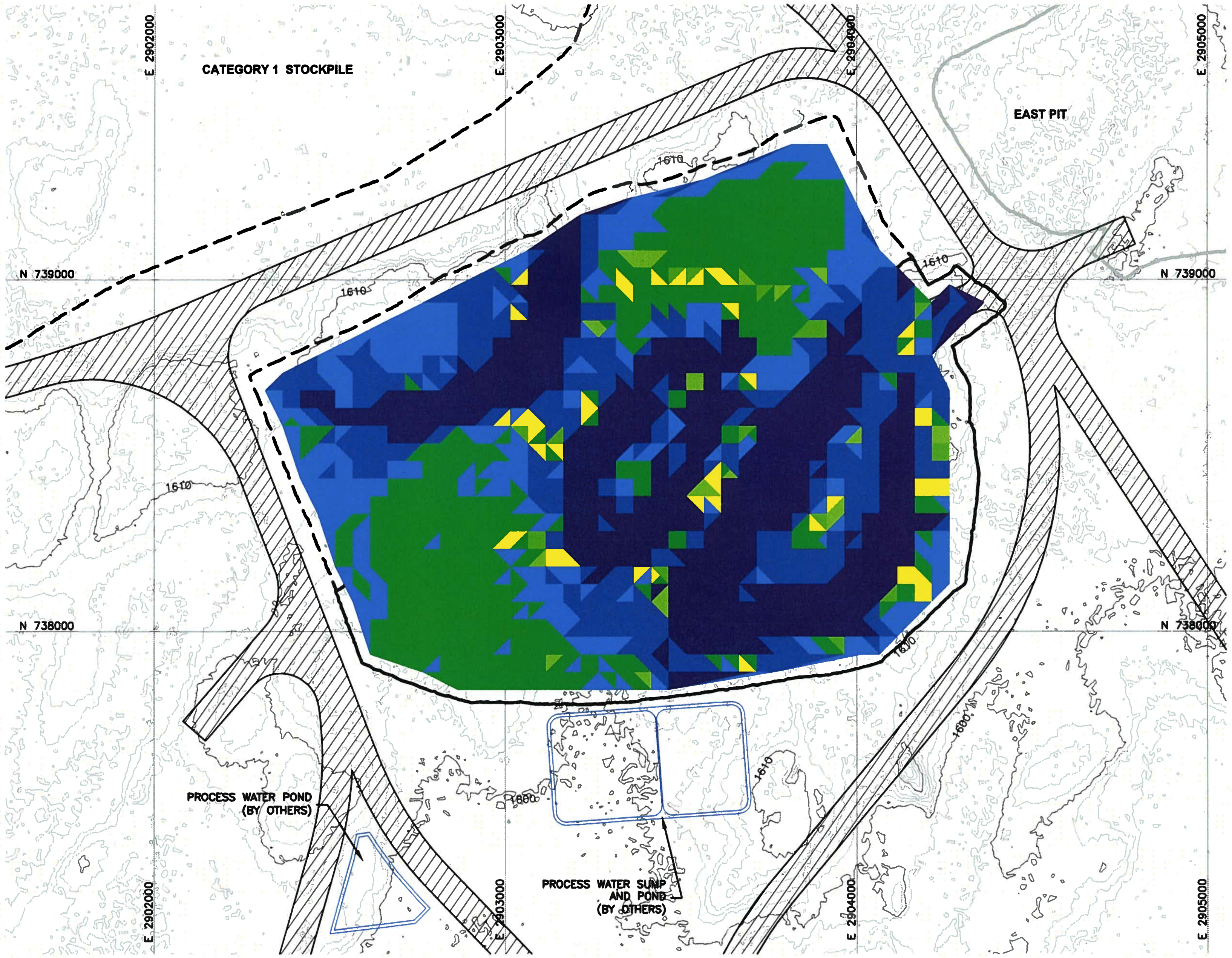
SCALE: AS SHOWN

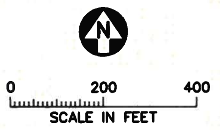
DWG. NO. 5.2

REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D005.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 11:02 AM

INCHES 1 2





LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟪	> 2.0 PERCENT

PROJECT BOUNDARY

YEAR 1 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)

YEAR 11 WASTE ROCK STOCKPILE LINER OUTLINES (SEE NOTE 2)

▨ HAUL ROAD

YEAR 2 PIT BOUNDARIES (SEE NOTE 1)

PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

CATEGORY 4 STOCKPILE
LINER GRADES AFTER COMPRESSION
STRUCTURAL FILL FOUNDATION

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS

ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		

PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED: -

GOLDER PROJECT NO.: 113-2209

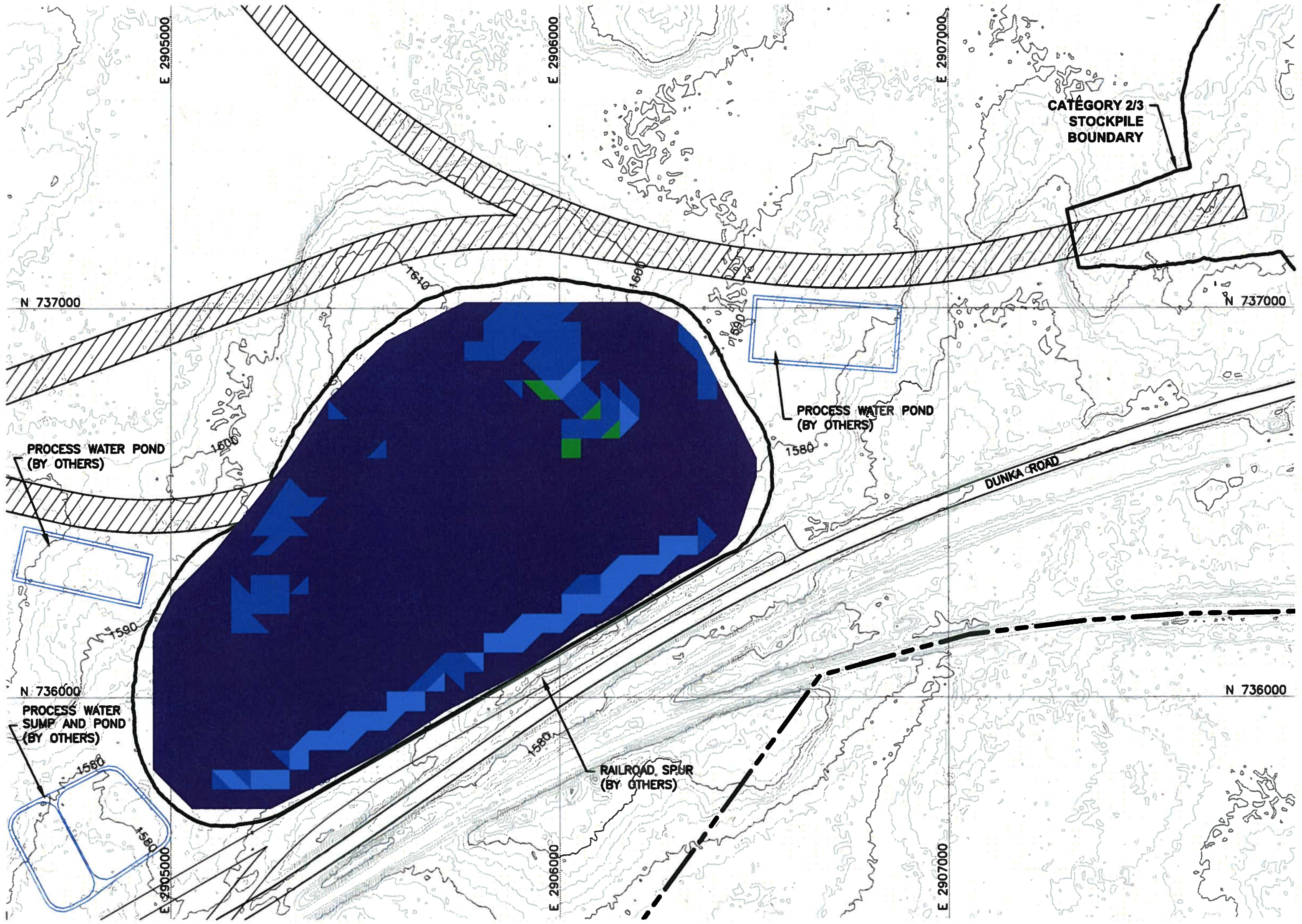
SCALE: AS SHOWN

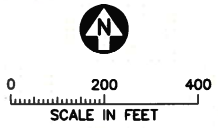
DWG. NO. 5.3

REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D006.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 11:04 AM

INCHES 1 2





LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟦	> 2.0 PERCENT

— — —	PROJECT BOUNDARY
——	YEAR 1 ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
▨	HAUL ROADS
——	PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS MINNESOTA STATE PLANE.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

ORE SURGE PILE
INITIAL LINER GRADES

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		
PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.		

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

SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

DRAWN: JP

CHECKED:

GOLDER PROJECT NO.: 113-2209

SCALE: AS SHOWN

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

Golder Associates

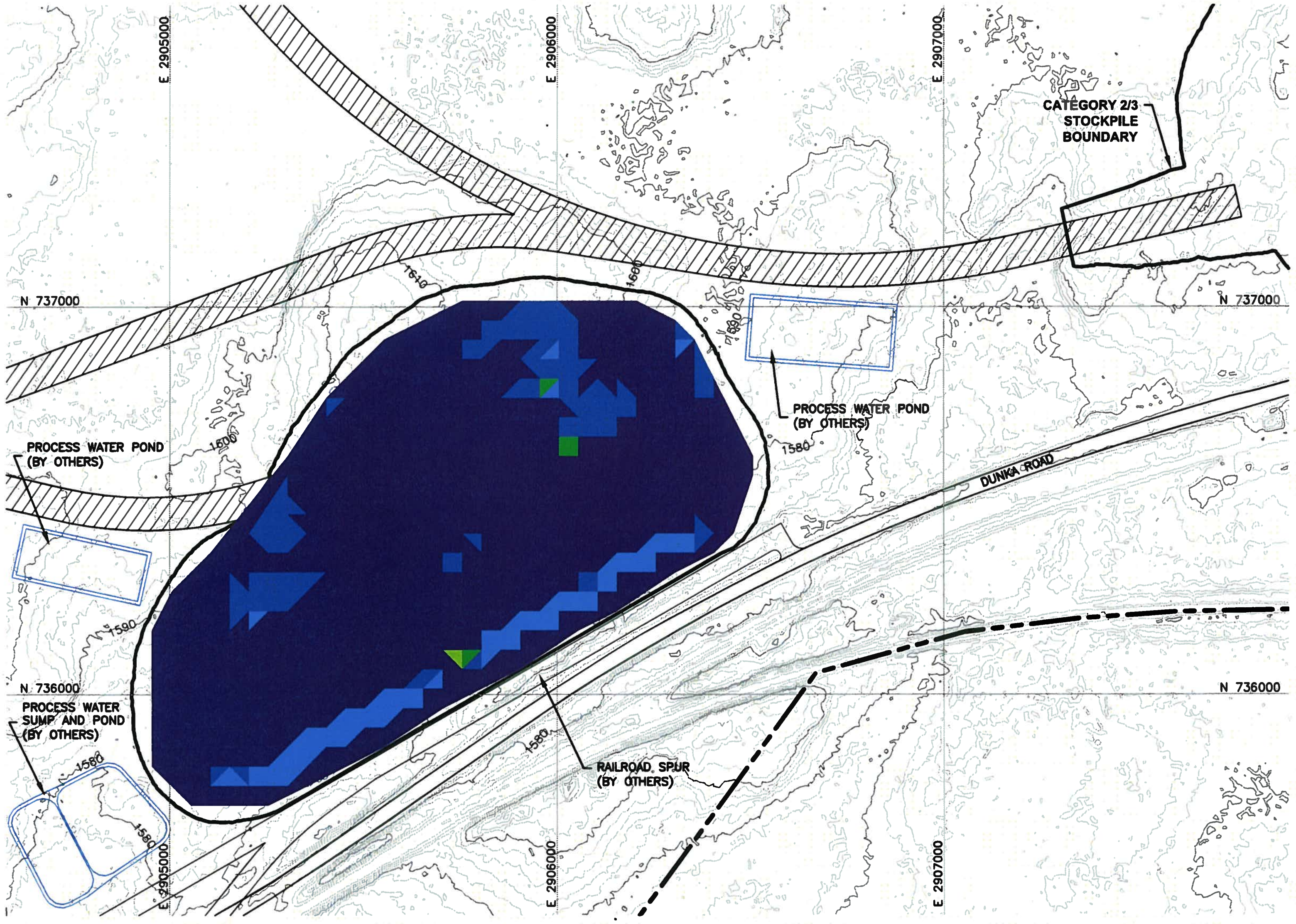
GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. 6.1

REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D001.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 10:52 AM

INCHES 1 2



0 200 400
SCALE IN FEET

LEGEND

LINER GRADES:

🟥	0.0 TO 0.1 PERCENT
🟧	0.1 TO 0.2 PERCENT
🟨	0.2 TO 0.3 PERCENT
🟩	0.3 TO 0.4 PERCENT
🟩	0.4 TO 0.6 PERCENT
🟦	0.6 TO 1.0 PERCENT
🟦	1.0 TO 2.0 PERCENT
🟦	> 2.0 PERCENT
▬ ▬ ▬ ▬	PROJECT BOUNDARY
▬▬▬▬	YEAR 1 ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
▨	HAUL ROADS
───	PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS MINNESOTA STATE PLANE.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

PLANT DRAWING NUMBER:

ORE SURGE PILE
LINER GRADES AFTER COMPRESSION
GLACIAL TILL FOUNDATION

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

Golder Associates

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		
PERMIT DRAWINGS – NOT APPROVED FOR CONSTRUCTION.		

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

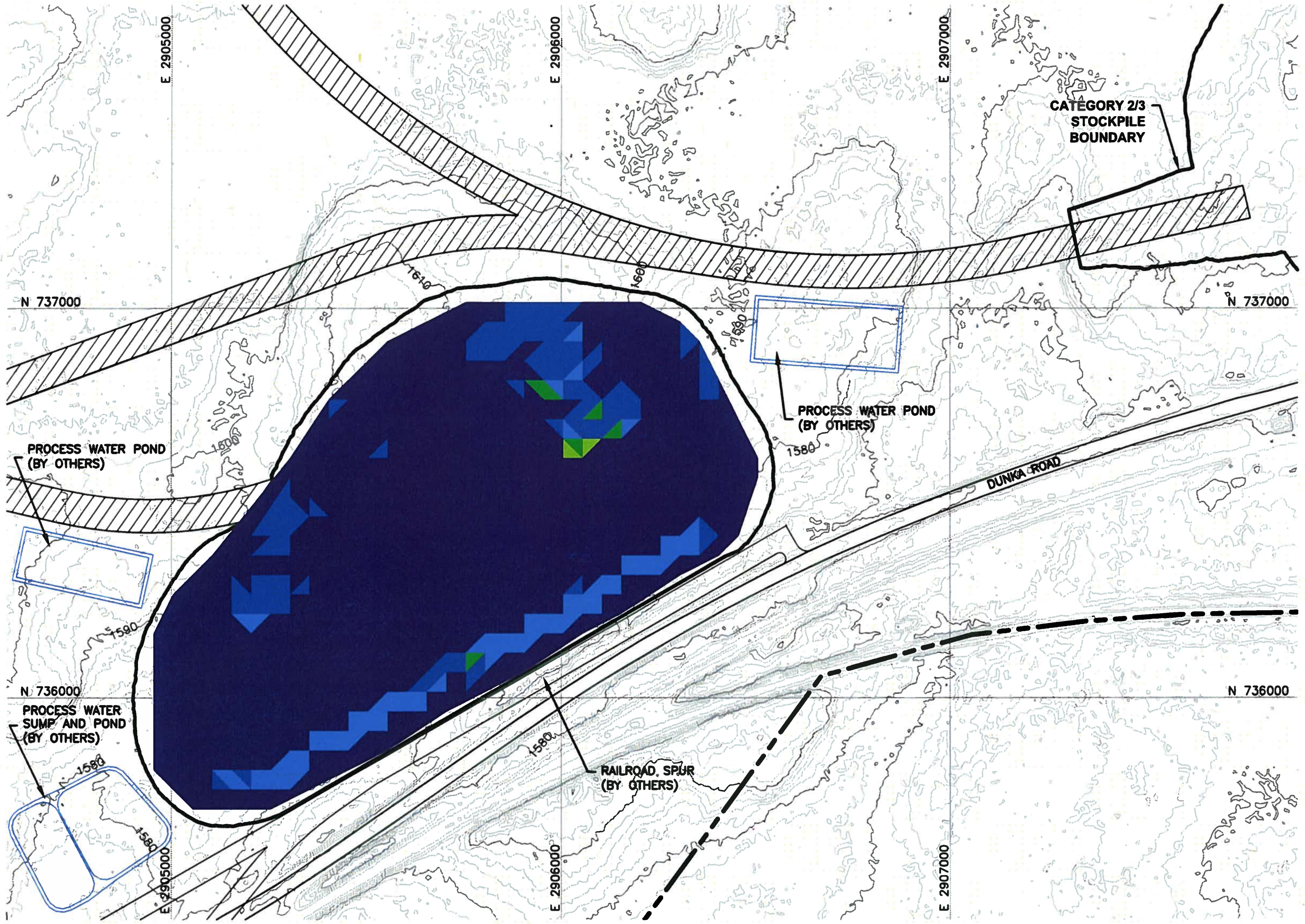
SIGNATURE ______
PRINTED NAME ______
DATE ______ REG. NO. ______

DRAWN: JP
CHECKED:
GOLDER PROJECT NO.: 113-2209
SCALE: AS SHOWN

DWG. NO. 6.2
REV A

CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D002.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 10:55 AM

INCHES
1
2



LEGEND

LINER GRADES:

🟥 0.0 TO 0.1 PERCENT
🟧 0.1 TO 0.2 PERCENT
🟨 0.2 TO 0.3 PERCENT
🟩 0.3 TO 0.4 PERCENT
🟩 0.4 TO 0.6 PERCENT
🟦 0.6 TO 1.0 PERCENT
🟦 1.0 TO 2.0 PERCENT
🟦 > 2.0 PERCENT

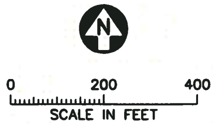
— — — PROJECT BOUNDARY
——— YEAR 1 ORE, WASTE ROCK STOCKPILE OUTLINES (SEE NOTE 2)
▨ HAUL ROADS
——— PROCESS WATER SUMP/POND (BY OTHERS)

NOTES

1. OPEN PIT AND HAUL ROAD LAYOUTS PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS MINNESOTA STATE PLANE.
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).



CADD USER: Parks, Jean FILE: N:\11\113-2209_D SLOPES\1132209D003.DWG PLOT SCALE: 1:2 PLOT DATE: 5/16/2012 10:57 AM

INCHES 1 2

VER NO	DATE	DESCRIPTION
A	12/02/11	ISSUED FOR REVIEW FOR INCLUSION IN ROMP

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING		
FOR CONSTRUCTION		
PERMIT DRAWINGS - NOT APPROVED FOR CONSTRUCTION.		

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

SIGNATURE ____________
PRINTED NAME ____________
DATE ______ REG. NO. ______

DRAWN: JP
CHECKED:
GOLDER PROJECT NO.: 113-2209
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

ORE SURGE PILE
LINER GRADES AFTER COMPRESSION
STRUCTURAL FILL FOUNDATION

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

Golder Associates

GOLDER ASSOCIATES INC.
44 UNION BOULEVARD, SUITE 300
LAKEWOOD, CO USA 80233
Ph: (303) 980-0540
Fax: (303) 985-2080
www.golder.com

DWG. NO. 6.3
REV A

Attachment K

Liner Survivability Evaluation

APPENDIX K

GEOMEMBRANE LINER SURVIVABILITY

Golder Associates Inc. (Golder) has prepared this appendix presenting results of liner load testing conducted for other high stress applications demonstrating the survivability of 80 mil linear low density polyethylene (LLDPE) geomembrane, as proposed for use as the primary liner for waste rock stockpiles containing Categories 2, 3, and 4 waste rock at PolyMet's NorthMet Project. Confirmatory laboratory testing will need to be conducted for the proposed liner system once actual construction materials (i.e., drainage gravel, soil liner, and subgrade soils) become available to facilitate the testing.

BACKGROUND

The liner system designs for the NorthMet Project incorporate a risk-based approach depending on the reactivity category of the waste rock. Use of geomembrane liner, specifically 80 mil LLDPE, is proposed for use at the following facilities:

- Category 2/3 Waste Rock Stockpile: A compacted subgrade (i.e., soil liner 3) overlain by an 80 mil LLDPE geomembrane liner and an overliner drainage layer. The upper one foot of the prepared subgrade shall have a maximum permeability of $1x10^{-5}$ centimeters per second (cm/s).
- Category 4 Waste Rock Stockpile and Ore Surge Pile: A minimum of one foot of compacted soil liner 2 with a maximum permeability of $1x10^{-6}$ cm/s overlain by an 80 mil LLDPE geomembrane liner and an overliner drainage layer.

Per the project design criteria, the maximum depth over liner for Category 2, 3, and 4 waste rock is 200 feet. The average dry density of waste rock is 1.7 tons per cubic yard, which corresponds to a maximum stress applied at the liner by overlying waste rock of approximately 175 pounds per square inch (psi).

The geomembrane liner will be overlain by a drainage layer comprised of a minimum of 2 feet of minus one and one-quarter inch (-1 ¼ in) crushed rock or native gravelly materials. At this time, it is anticipated that the drainage layer will have a minimum permeability of $1x10^{-2}$ cm/s under the anticipated design loading conditions. Once drainage material meeting the project specifications becomes available for laboratory testing (anticipated during the Phase II investigation), confirmatory testing will need to include consolidation-permeability testing of the overliner materials.

OBJECTIVE

The purpose of a liner load testing program is to evaluate the site-specific survivability of various liner systems under anticipated loading conditions. Further, the purpose of liner load testing is to demonstrate that the proposed liner system can maintain hydraulic containment even with waste rock depths that are greater than the designed ultimate height of the proposed facilities.

In the absence of actual liner load tests conducted for this project, Golder has prepared a compilation of liner load test results from other projects which utilize a similar liner system design as that

GEOMEMBRANE LINER SURVIVABILITY

Golder Associates Inc. (Golder) has prepared this appendix presenting results of liner load testing conducted for other high stress applications demonstrating the survivability of 80 mil linear low density polyethylene (LLDPE) geomembrane, as proposed for use as the primary liner for waste rock stockpiles containing Categories 2, 3, and 4 waste rock at PolyMet's NorthMet Project. Confirmatory laboratory testing will need to be conducted for the proposed liner system once actual construction materials (i.e., drainage gravel, soil liner, and subgrade soils) become available to facilitate the testing.

BACKGROUND

The liner system designs for the NorthMet Project incorporate a risk-based approach depending on the reactivity category of the waste rock. Use of geomembrane liner, specifically 80 mil LLDPE, is proposed for use at the following facilities:

- Category 2/3 Waste Rock Stockpile: A compacted subgrade (i.e., soil liner 3) overlain by an 80 mil LLDPE geomembrane liner and an overliner drainage layer. The upper one foot of the prepared subgrade shall have a maximum permeability of $1x10^{-5}$ centimeters per second (cm/s).
- Category 4 Waste Rock Stockpile and Ore Surge Pile: A minimum of one foot of compacted soil liner 2 with a maximum permeability of $1x10^{-6}$ cm/s overlain by an 80 mil LLDPE geomembrane liner and an overliner drainage layer.

Per the project design criteria, the maximum depth over liner for Category 2, 3, and 4 waste rock is 200 feet. The average dry density of waste rock is 1.7 tons per cubic yard, which corresponds to a maximum stress applied at the liner by overlying waste rock of approximately 175 pounds per square inch (psi).

The geomembrane liner will be overlain by a drainage layer comprised of a minimum of 2 feet of minus one and one-quarter inch (-1 ¼ in) crushed rock or native gravelly materials. At this time, it is anticipated that the drainage layer will have a minimum permeability of $1x10^{-2}$ cm/s under the anticipated design loading conditions. Once drainage material meeting the project specifications becomes available for laboratory testing (anticipated during the Phase II investigation), confirmatory testing will need to include consolidation-permeability testing of the overliner materials.

OBJECTIVE

The purpose of a liner load testing program is to evaluate the site-specific survivability of various liner systems under anticipated loading conditions. Further, the purpose of liner load testing is to demonstrate that the proposed liner system can maintain hydraulic containment even with waste rock depths that are greater than the designed ultimate height of the proposed facilities.

In the absence of actual liner load tests conducted for this project, Golder has prepared a compilation of liner load test results from other projects which utilize a similar liner system design as that proposed for the NorthMet Project. In general, the stresses tested to were greater than those anticipated for the NorthMet Project.

TEST RESULTS

Table K-1 provides a compilation of liner load test characteristics and results from several projects from Golder's database which utilized LLDPE geomembrane for high stress applications. The project names have been removed to provide anonymity.

Appendices K-1 through K-3 of this Appendix provide test summaries and photos from the liner load tests discussed in Table K-1. In general, the LLDPE geomembrane liners in the above tests exhibited minor indentations and scratches, but did not show any signs of failure or puncture under visual observation, nor were pinhole leaks detected during vacuum testing. Therefore, the use of 80 mil LLDPE geomembrane as proposed for the NorthMet Project is expected to perform well. It should be noted that the anticipated loading conditions for the NorthMet Project are generally less than those in the presented test work.

FUTURE TEST WORK

As part of the Phase II geotechnical investigation program in support of design work for the NorthMet Project, specifically design of the liner system and overliner drainage network, the following confirmatory laboratory testing is required using the site specific materials specified for construction:

- Consolidation/permeability testing of overliner drainage materials to confirm permeability of the material under the design loading conditions, as well as the ability of the material to resist crushing under load;

- Liner load testing of the proposed liner systems with the specified overliner and underliner materials to confirm survivability of the proposed geomembrane liner under the anticipated design loading conditions; and

- Interface shear testing of the proposed liner systems to evaluate the strength characteristics of the liner system for use in stability evaluations.

In order to facilitate current design work for the NorthMet Project, necessary design parameters have been assumed for use in the analyses based on Golder's recent experience with design of similar facilities.

TABLE K-1

LINER LOAD TEST CONDITIONS AND RESULTS FROM HIGH STRESS APPLICATIONS

Project	Liner System			Load Applied (psi)	Test Results
	Underliner	Geomembrane Liner	Overliner		
Project 1 (4 tests)	Clayey gravel with sand (GC)	Single-sided textured 80 mil LLDPE	2-inch minus overliner	450	PASS (Appendices K-1-1)
	Clayey sand with gravel (SC)	Single-sided textured 80 mil LLDPE	2-inch minus overliner	450	PASS (Appendices K-1-2 and K-1-3)
	Clayey gravel with sand (GC)	Single-sided textured 80 mil LLDPE	1-1/2-inch minus overliner	850	PASS (Appendix K-1-4)
Project 2 (3 tests)	Lean clay (CL)	Smooth 80 mil LLDPE	1-1/4-inch minus overliner (GP) (3 different sources)	175	PASS (Appendices K-2-1, K- 2-2, and K-2-3)
Project 3 (5 tests)	Clayey gravel (GC)	Smooth 80 mil LLDPE	1-1/2-inch minus overliner	350	PASS (Appendix K-3)
	Clayey gravel (GC)	Smooth 60 mil LLDPE	1-1/2-inch minus overliner	350	
	1-1/2-inch minus gravel	Smooth 80 mil LLDPE	1-1/2-inch minus overliner	350	
	Clayey gravel (GC)	Smooth 80 mil LLDPE	1-1/2-inch minus overliner	350	
	1-1/2-inch minus gravel	Smooth 100 mil LLDPE	1-1/2-inch minus overliner	350	

APPENDIX K-1

PROJECT #1 LINER LOAD TESTING

K-1-1

TEST #1

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #1**

JOB NUMBER: **NA**

BORING NUMBER

DATE: **2/12/2003**

SAMPLE NUMBER Liner Load Test

DEPTH (ft)

Underliner (Bedding) Source:

Underliner Classification: Clayey gravel with sand GC

Atterberg Limits: 33, 15, 18

Maximum Dry Density (pcf): 118.8

Optimum Moisture: 13.5

Overliner Material Source: Site Supplied

Overliner Classification: -2" gravel

Atterberg Limits:

Dry Density (pcf): 90.3

Geosynthetic Manufacturer/Supplier: Site supplied

Liner Type	**Ave. Liner Thickness (mls)**	**Duration of Test (hrs.)**	**Underliner Compaction %**	**Moisture %**	**Load Applied (psi)**	**Change in total sample height (in)**	**Test Results**	
							Visual	**Vacuum**
LLDPE Single-sided textured	81.00	24	95	10.25	450	1.262	pass	pass

General Test Notes:

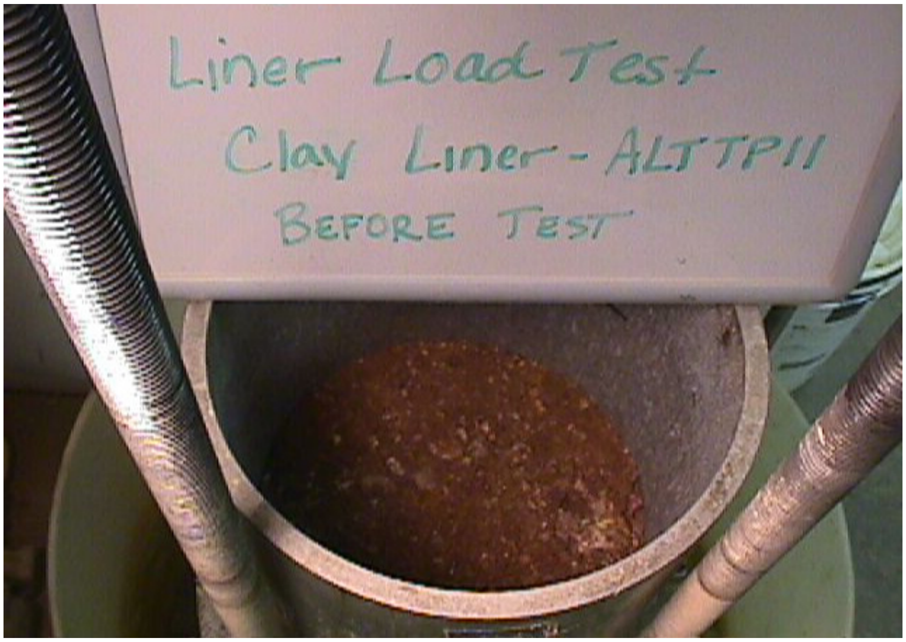
Test was conducted using a 10" diameter cell. The liner was placed on top of 4.0 inches of
bedding soil, then covered with 6.3 inches of overliner material. Approximately 10
rocks were hand placed directly on the liner prior to placement of remaining overliner material.
A hydraulic jack was used to apply a load of 450 psi to the sample at 50 psi increments.
The load was maintained for 24 hours. Dial gages were used to monitor deformation of the sample.
At the conclusion of the test, the liner was inspected and tested for punctures both visually
and by application of a vacuum. The vacuum pressure was 70 mmHG.

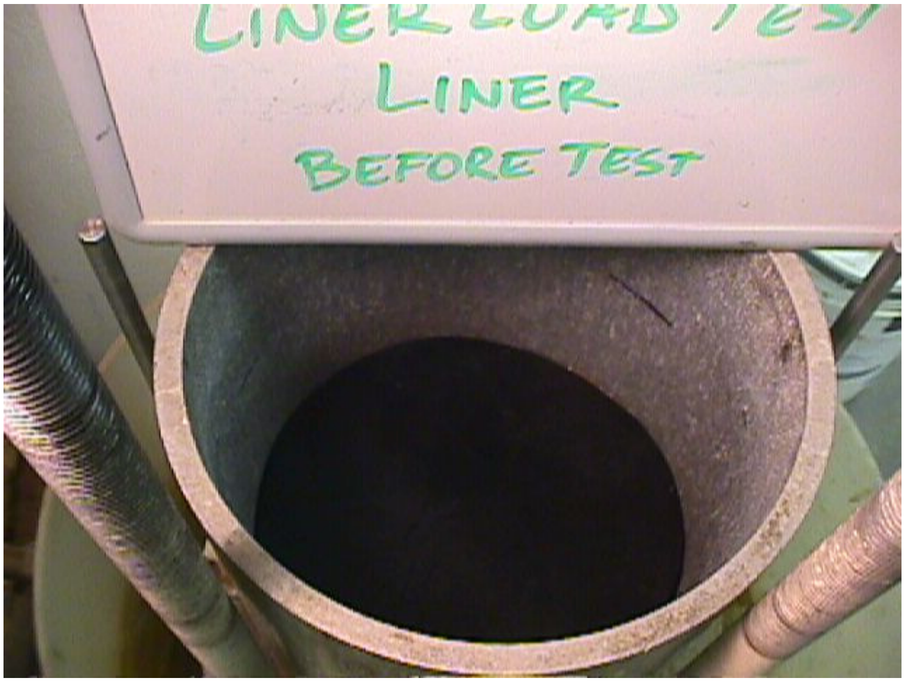
Liner observations: No severe damage. No punctures. One deep dimple noted.
Numerous small dimples and scratches.

Clay liner was remolded to 95% of maximum dry density and -3% of optimum moisture.
3% bentonite was added to the clay underliner.
Overliner was poured into cell in 4 lifts. It was not compacted between lifts.

Date: 2/12/03
Tech: NG
Review: MB

Liner Load Testing Photo Log



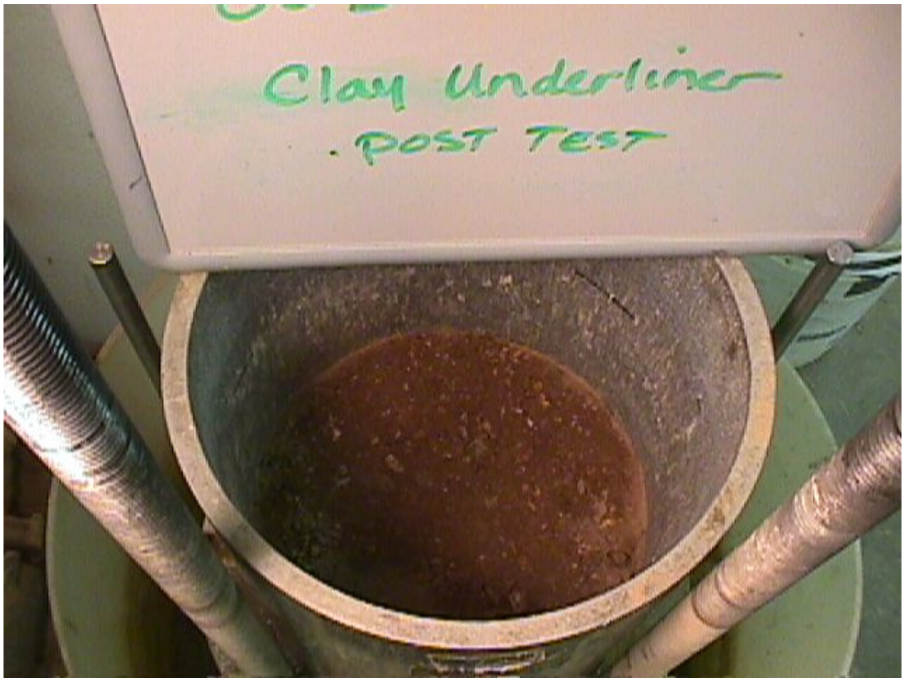



LINER LOAD TEST
OVERLINER
BEFORE TEST


OVERLINER
POST TEST


LINER
POST TEST

K-1-1



K-1-2

TEST #2

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #1**

JOB NUMBER: **NA**

BORING NUMBER

DATE: **12/31/2002**

SAMPLE NUMBER Liner Load Test

DEPTH (ft)

Underliner (Bedding) Source:

Underliner Classification: Clayey sand with gravel (SC)

Atterberg Limits: 41, 15, 26

Maximum Dry Density (pcf): 115.3 (rock corrected)

Optimum Moisture: 12.9

Overliner Material Source: Site supplied

Overliner Classification: -2.0" gravel

Atterberg Limits:

Dry Density (pcf): 90.0

Geosynthetic Manufacturer/Supplier: Site supplied

Liner Type	Ave. Liner Thickness (mls)	Duration of Test (hrs.)	Underliner Compaction %	Moisture %	Load Applied (psi)	Change in total sample height (in)	Test Results	
							Visual	Vacuum
LLDPE Single-sided textured	81.3	24	95	9.9	450	1.540	PASS	PASS

General Test Notes:

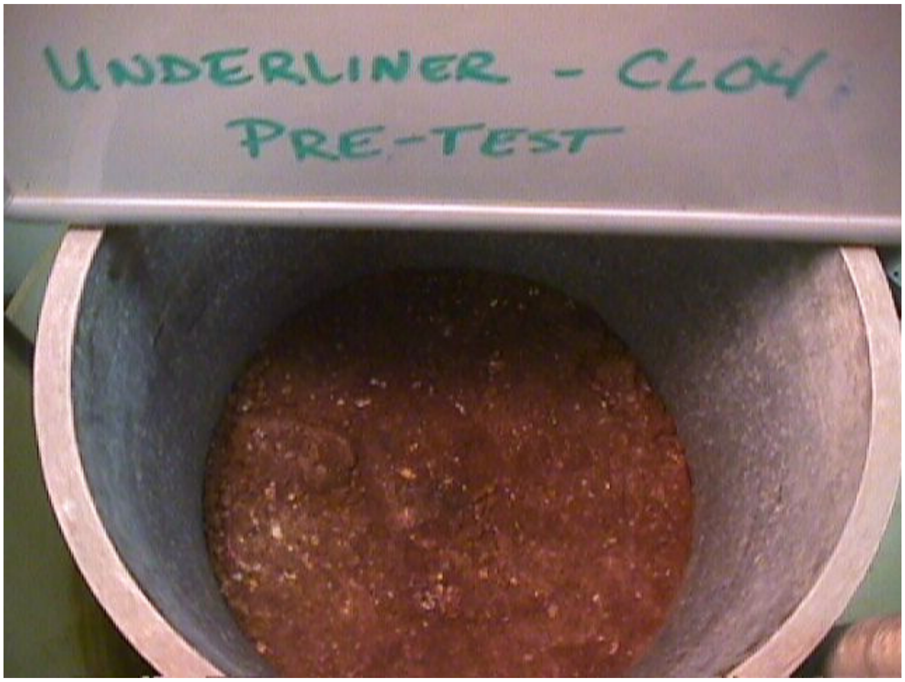
Test was conducted using a 10" diameter cell. The liner was placed on top of 4.0 inches of bedding soil, then covered with approximately 6.5 inches of overliner material. Approximately 10 rocks were hand placed directly on the liner prior to placement of remaining overliner material. A hydraulic jack was used to apply a load of 450 psi to the sample. The load was maintained for 24 hours. Dial gages were used to monitor deformation of the sample.
At the conclusion of the test the liner was inspected and tested for punctures both visually and by application of a vacuum. The vacuum pressure was 70 mmHG.

Liner observations: No severe damage. No punctures. One deep dimple noted.
Numerous small dimples and scratches.

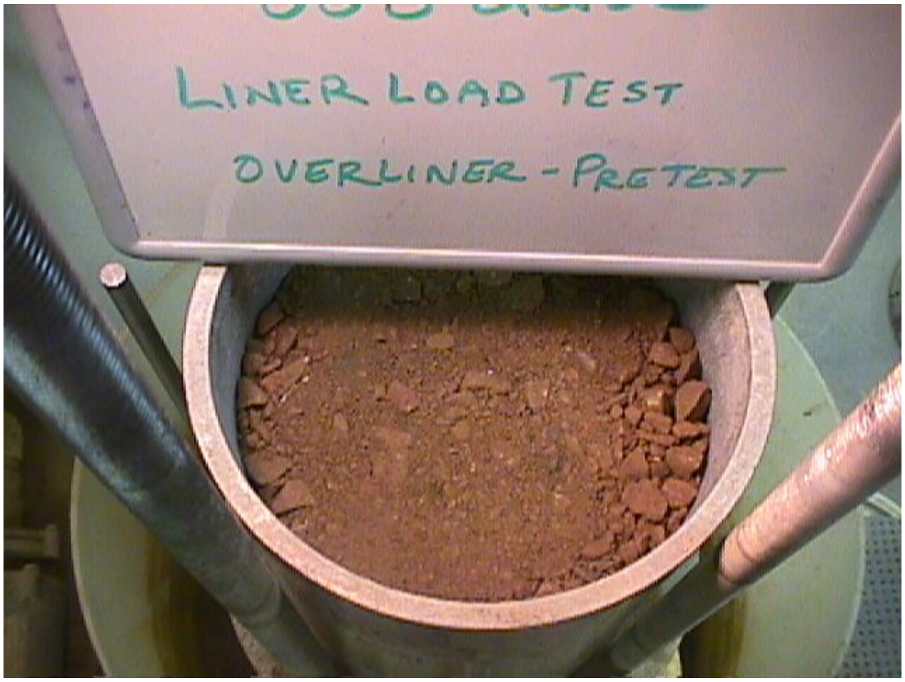
Clay liner was remolded to 95% of maximum dry density and -3% of optimum moisture.
Overliner was poured into cell in 4 lifts. It was not compacted between lifts.

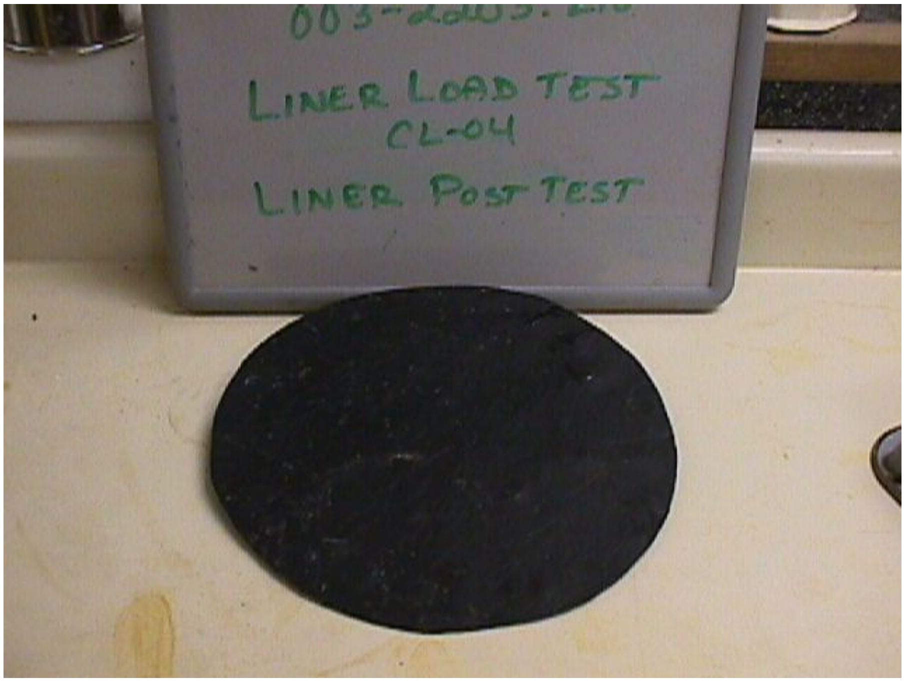
Date: 12/31/02
Tech: NG

Liner Load Testing Photo Log

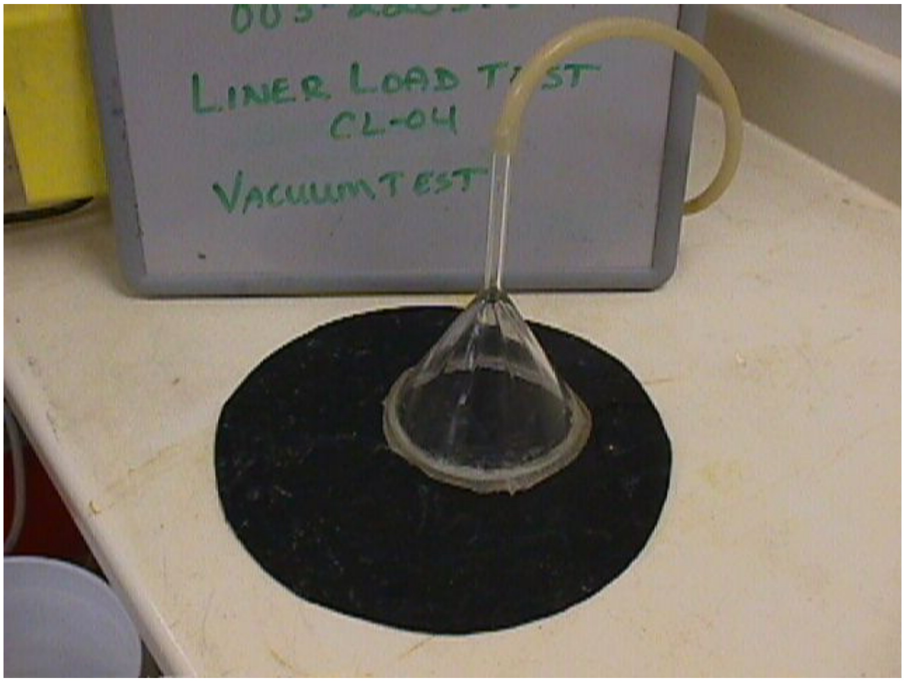



LINER LOAD TEST
LINER - PRETEST


LINER LOAD TEST
OVERLINER - PRETEST


LINER LOAD TEST
CL-04
LINER POST TEST

K-1-2



K-1-3

TEST #3

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #1**

JOB NUMBER:

BORING NUMBER

DATE: **2/23/2003**

SAMPLE NUMBER Liner Load Test

DEPTH (ft)

Underliner (Bedding) Source:

Underliner Classification: Clayey sand with gravel SC

Atterberg Limits: 31,14,17

Maximum Dry Density (pcf): 122.2

Optimum Moisture: 11.5

Overliner Material Source: Site Supplied

Overliner Classification: -2" gravel

Atterberg Limits:

Dry Density (pcf): 87.5

Geosynthetic Manufacturer/Supplier: Site supplied

Liner Type	Ave. Liner Thickness (mls)	Duration of Test (hrs.)	Underliner Compaction %	Moisture %	Load Applied (psi)	Change in total sample height (in)	Test Results	
							Visual	Vacuum
LLDPE Single-sided textured	80.83	48	95	9.92	450	1.378	pass	pass

General Test Notes:

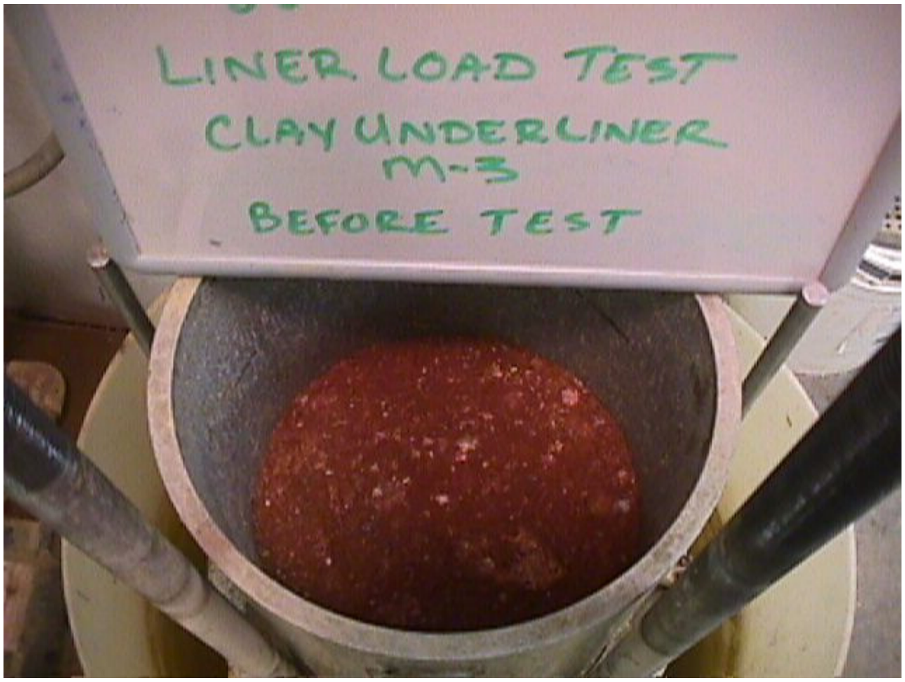
Test was conducted using a 10" diameter cell. The liner was placed on top of 4.0 inches of
bedding soil, then covered with 5.0 inches of overliner material. Approximately 10
rocks were hand placed directly on the liner prior to placement of remaining overliner material.
A hydraulic jack was used to apply a load of 450 psi to the sample at 50 psi increments.
The load was maintained for 48 hours. Dial gages were used to monitor deformation of the sample.
At the conclusion of the test, the liner was inspected and tested for punctures both visually
and by application of a vacuum. The vacuum pressure was 70 mmHG.

Liner observations: No severe damage. No punctures. Two deep dimples noted.
Numerous small dimples and scratches.

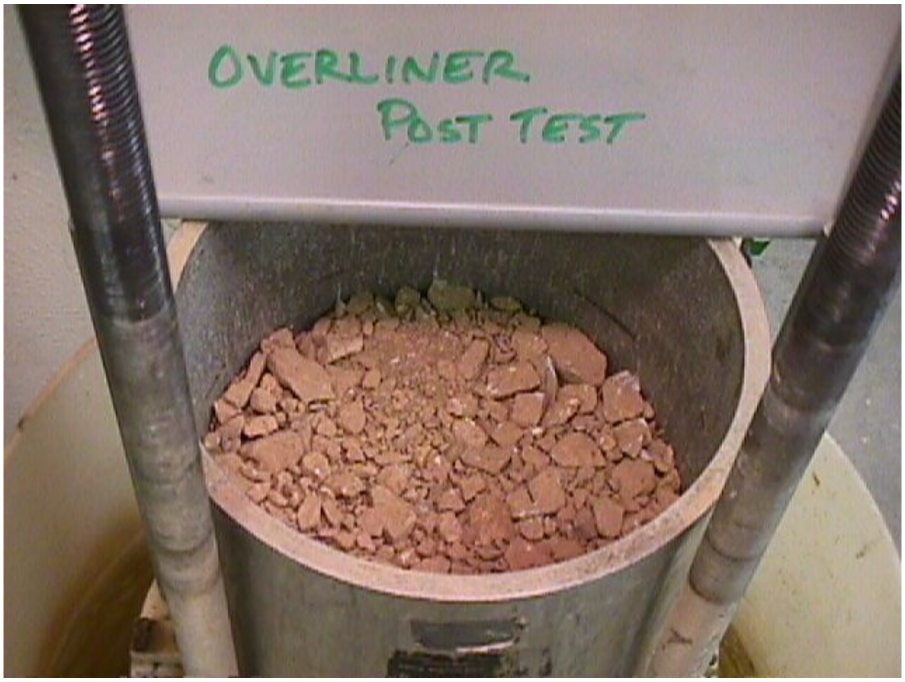
Clay liner was remolded to 95% of maximum dry density and -3% of optimum moisture.
3% bentonite was added to the clay underliner.
Overliner was poured into cell in 4 lifts. It was not compacted between lifts.

Date: 2/23/03
Tech: NG
Review: MB

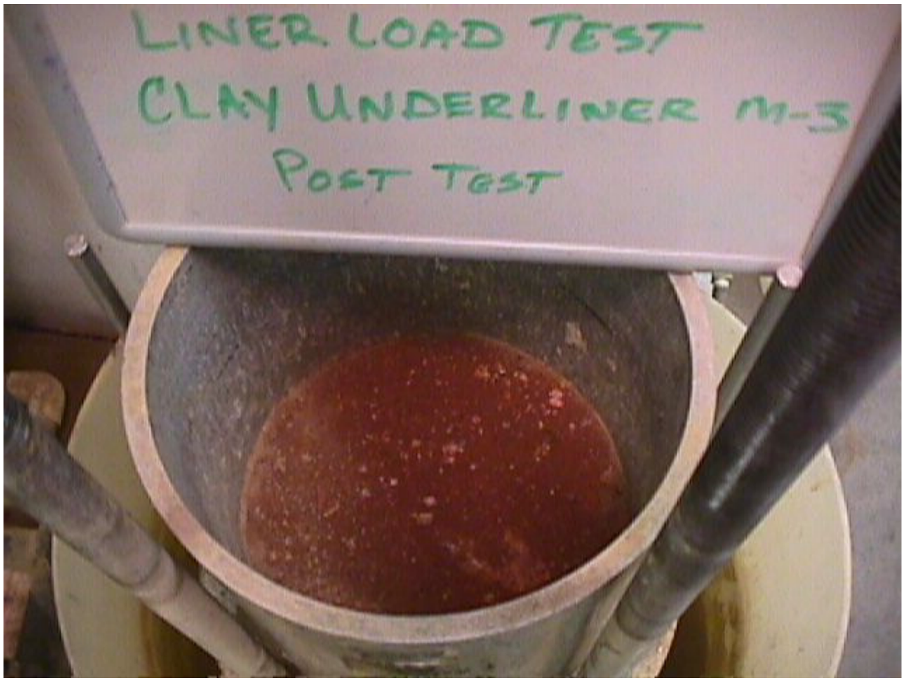
Liner Load Testing Photo Log




LINER LOAD TEST
OVERLINER
BEFORE TEST


OVERLINER
POST TEST


LINER
POST TEST


LINER LOAD TEST
CLAY UNDERLINER M-3
POST TEST

K-1-4

TEST #4

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #1**

JOB NUMBER:

BORING NUMBER

DATE: **4/12/2004**

SAMPLE NUMBER 80 mil SST LLDPE Liner

DEPTH (ft)

Underliner (Bedding) Source: Site supplied

Underliner Classification: GC

Atterberg Limits: LL=39, PL=20, PI=19

Maximum Dry Density (pcf): 114.6

Optimum Moisture: 13.1

Overliner Material Source: Site supplied

Overliner Classification: --

Atterberg Limits: --

Dry Density (pcf): 77.4

Geosynthetic Manufacturer/Supplier: Site supplied

Liner Type	Ave. Liner Thickness (mls)	Duration of Test (hrs.)	Underliner Compaction %	Moisture %	Load Applied (psi)	Change in total sample height (in)	Test Results	
							Visual	Vacuum
80 mil Smooth/Textured	83.50	53	96.6	12.0	850	3.410	Pass	Pass

General Test Notes:

Test was conducted using a 12" diameter cell. The liner was placed on top of 4.0 inches of soil liner material, then covered with approximately 9.4 inches of overliner material. Approximately 10-1 rocks were hand placed directly on the liner prior to placement of remaining overliner material. A hydraulic jack was used to apply a load of 850 psi to the sample over a period of 53 hours. The load was maintained for 28 hours. A dial gage was used to monitor deformation of the sample. At the conclusion of the test the liner was inspected and tested for punctures both visually and by application of a vacuum. The vacuum pressure was 70 mmHG.

Liner observations: No severe damage. No punctures.
Numerous small dimples and scratches.

Clay liner was remolded to 96.6% of maximum dry density and 1.1% of optimum moisture.
Overliner was placed into cell in 4 lifts. It was not compacted between lifts.

Date: 4/13/04
Tech: JR
Review: MB

APPENDIX K-2

PROJECT #2 LINER LOAD TESTING

K-2-1

TEST #1

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #2**

JOB NUMBER:

DATE: **4/25/2006**

Underliner (Bedding) Source: Soil Liner

Underliner Classification: CL

Maximum Dry Density (pcf): 97.9

Atterberg Limits: LL-33, PL-23, PI-10

Optimum Moisture: 23.7

Overliner Material Source: Ore

Overliner Classification: GP

Dry Density (pcf): 103.2

Atterberg Limits: --

Geosynthetic Manufacturer/Supplier: GSE

Liner Type	**Ave. Liner Thickness (mls)**	**Duration of Test (hrs.)**	**Underliner Compaction %**	**Moisture %**	**Load Applied (psi)**	**Change in total sample height (in)**	**Test Results**	
							Visual	**Vacuum**
LLDPE S/S	80.93	24	95	23.3	175	0.833	PASS	PASS

General Test Notes:

Test was conducted using a 10" diameter cell. The 80 mil smooth/smooth LLDPE liner was placed on top of 4.0 inches of underliner soil, then covered with approximately 6.9 inches of overliner material. Per specifications, two 1/2" rock protrusions were placed in the underliner soil. Approximately 3 rocks were hand placed with points downward on the liner prior to placement of remaining overliner material. A hydraulic jack was used to apply a load of 175 psi to the sample over a period of 17.3 hours. The load was maintained for 24 hours. Dial gages were used to monitor deformation of the sample. At the conclusion of the test, the liner was inspected and tested for punctures both visually and by application of a vacuum. The vacuum pressure was approximately 450 mmHG.

Liner observations: No punctures were present but several dimples and scratches.

Underliner was remolded to 95.7% of maximum dry density at optimum moisture. Overliner was loosely placed and slightly tamped.

Date: 4/26/06
Tech: RT
Review: MB

Liner Load Testing Photo Log

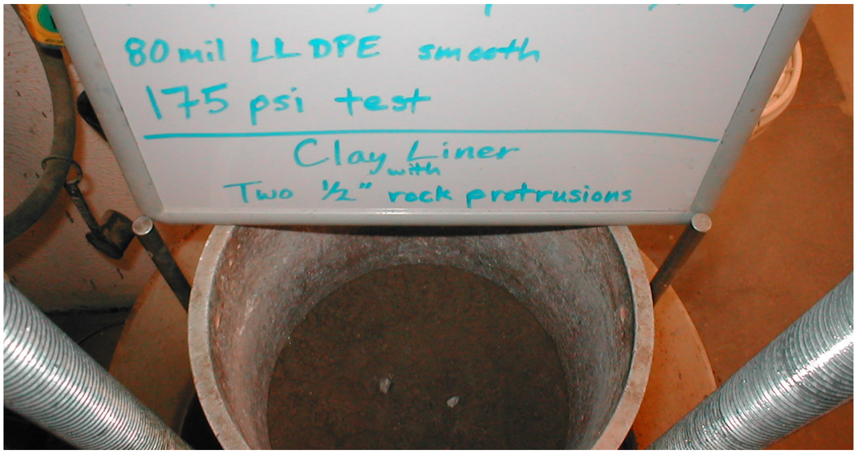


Figure 1 – Clay liner with rock protrusions, pre-test.

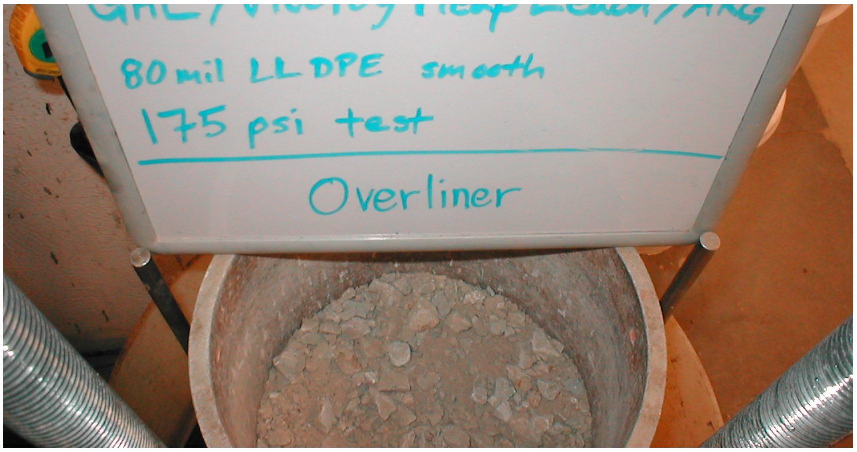


Figure 2 - Ore, post-test.

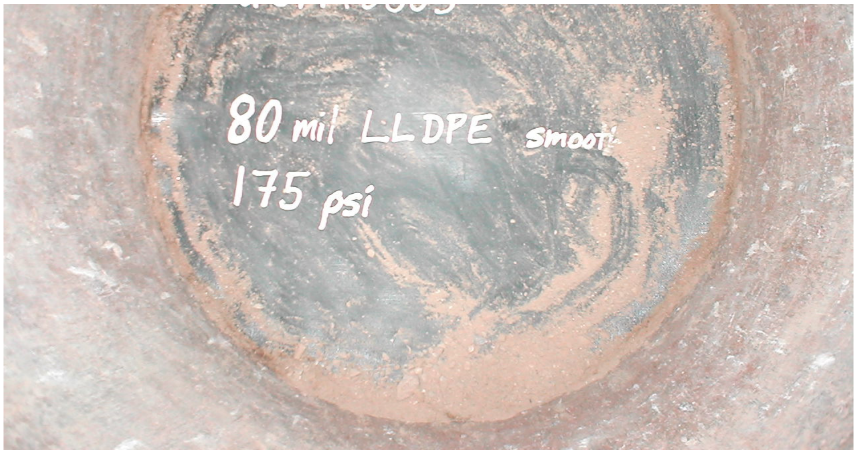


Figure 3 – 2.0 mm LLDPE, post-test.

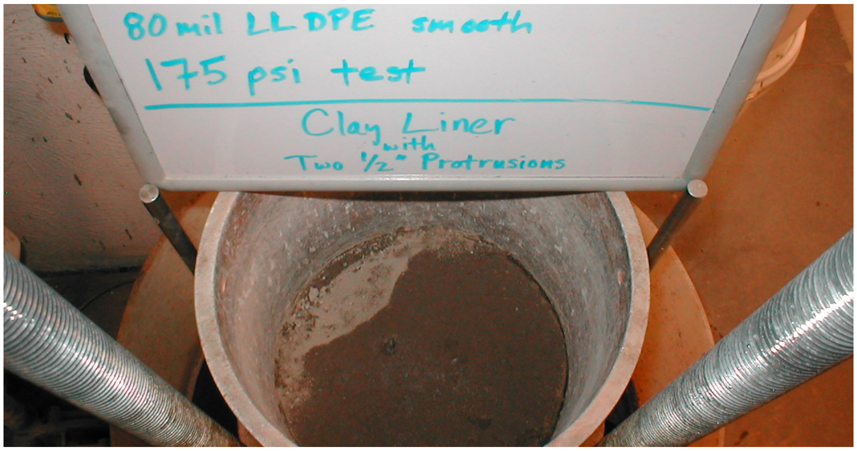


Figure 4 – Clay liner, post-test.

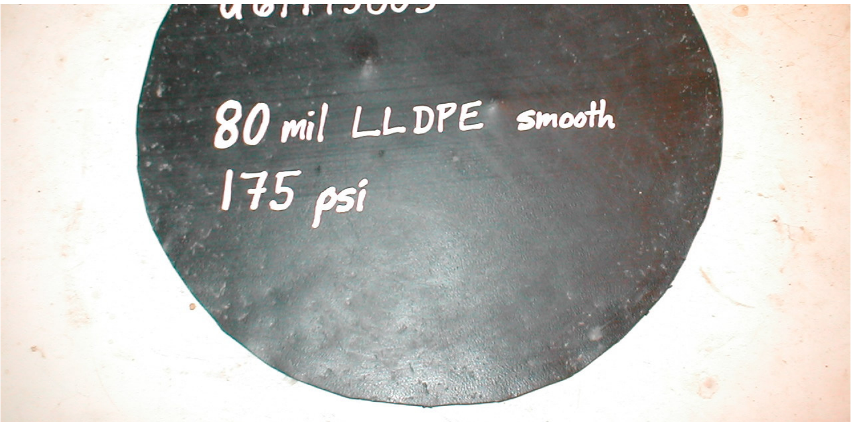


Figure 5 – 2.0 mm LLDPE, visual inspection.

K-2-2

TEST #2

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #2**

JOB NUMBER:

DATE: **7/5/2006**

Underliner (Bedding) Source: Soil Liner

Underliner Classification: CL

Atterberg Limits: LL-33, PL-23, PI-10

Maximum Dry Density (pcf): 97.9

Optimum Moisture: 23.7

Overliner Material Source: Bolsa #1

Overliner Classification: GP

Atterberg Limits: --

Dry Density (pcf): 98.2

Geosynthetic Manufacturer/Supplier: GSE

Liner Type	Ave. Liner Thickness (mls)	Duration of Test (hrs.)	Underliner Compaction %	Moisture %	Load Applied (psi)	Change in total sample height (in)	Test Results	
							Visual	Vacuum
LLDPE S/S	77.83	24	95	24.2	175	0.701	PASS	PASS

General Test Notes: Test was conducted using a 10" diameter cell. The 80 mil smooth/smooth LLDPE liner was placed on top of 3.5 inches of underliner soil, then covered with approximately 6.0 inches of overliner material. Per specifications, two 1/2" rock protrusions were placed in the underliner soil. Approximately 20 rocks were hand placed with points downward on the liner prior to placement of remaining overliner material. A hydraulic jack was used to apply a load of 175 psi to the sample over a period of 17.6 hours. The load was maintained for 24 hours. Dial gages were used to monitor deformation of the sample. At the conclusion of the test, the liner was inspected and tested for punctures both visually and by application of a vacuum. The vacuum pressure was approximately 450 mmHG.

Liner observations: No punctures were present but several dimples and scratches.

Underliner was remolded to 94.7% of maximum dry density at optimum moisture. Overliner was loosely placed and slightly tamped.

Date: 7/7/06

Tech: MS

Review: MB

Liner Load Testing Photo Log

Figure 1 – Clay liner with rock protrusions, pre-test.

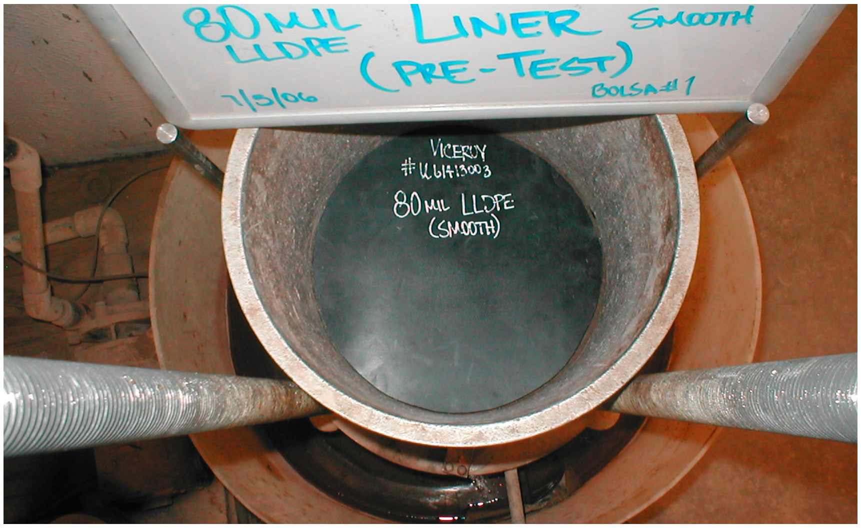


Figure 2 – 2.0 mm LLDPE geomembrane, pre-test.

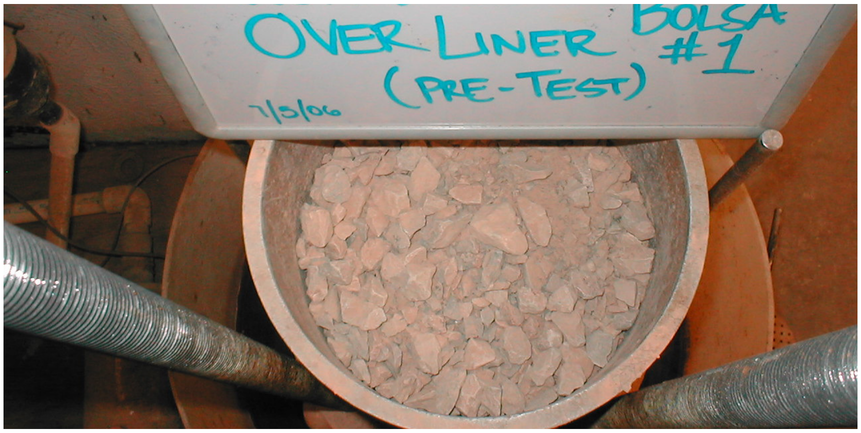


Figure 3 – Overliner (Bolsa #1), pre-test.

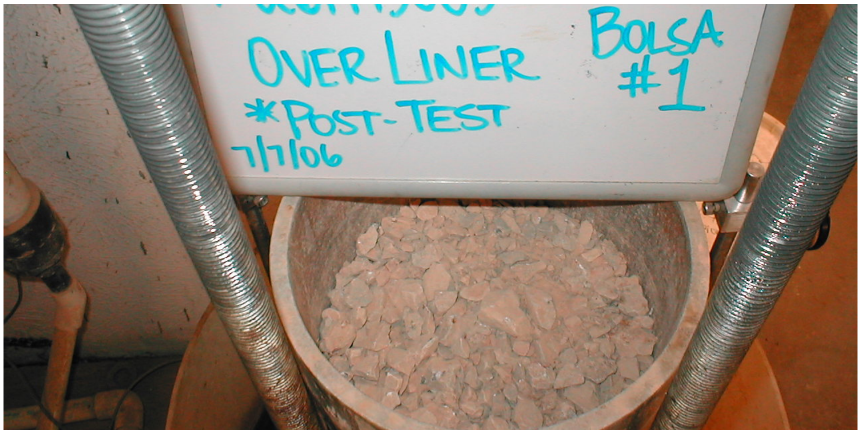


Figure 4 – Overliner (Bolsa #1), post-test.

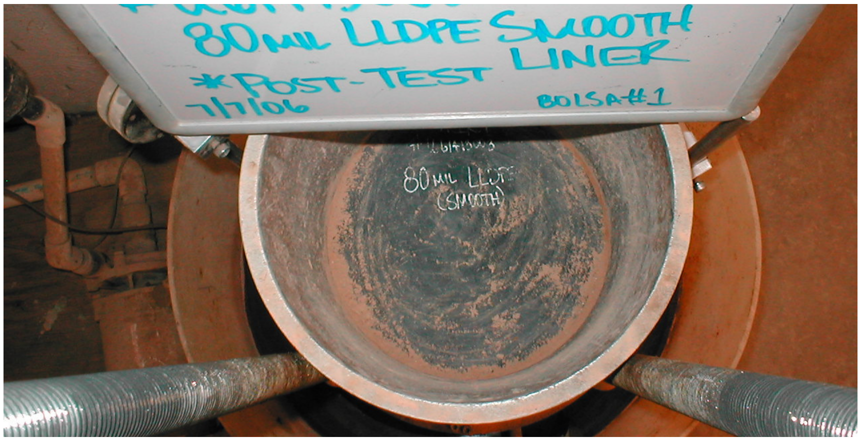


Figure 5 – 2.0 mm LLDPE, post-test.

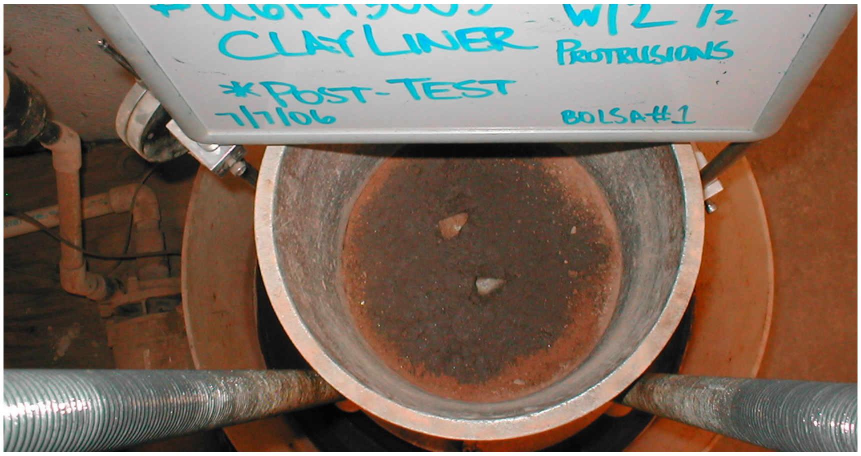


Figure 6 – Clay liner, post-test.

Figure 7 – 2.0 mm LLDPE, visual inspection.

K-2-3

TEST #3

GEOMEMBRANE LINER LOAD TEST SUMMARY

JOB NAME: **PROJECT #2**

JOB NUMBER:

DATE: **7/10/2006**

Underliner (Bedding) Source: Soil Liner

Underliner Classification: CL

Atterberg Limits: LL-33, PL-23, PI-10

Maximum Dry Density (pcf): 97.9

Optimum Moisture: 23.7

Overliner Material Source: Bolsa #2

Overliner Classification: GP

Atterberg Limits: --

Dry Density (pcf): 94.0

Geosynthetic Manufacturer/Supplier: GSE

Liner Type	Ave. Liner Thickness (mls)	Duration of Test (hrs.)	Underliner Compaction %	Moisture %	Load Applied (psi)	Change in total sample height (in)	Test Results	
							Visual	Vacuum
LLDPE S/S	80.17	24	95	23.7	175	0.566	PASS	PASS

General Test Notes: Test was conducted using a 10" diameter cell. The 80 mil smooth/smooth LLDPE liner was placed on top of 3.5 inches of underliner soil, then covered with approximately 6.2 inches of overliner material. Per specifications, two 1/2" rock protrusions were placed in the underliner soil. Approximately 15 rocks were hand placed with points downward on the liner prior to placement of remaining overliner material. A hydraulic jack was used to apply a load of 175 psi to the sample over a period of 18.3 hours. The load was maintained for 24 hours. Dial gages were used to monitor deformation of the sample. At the conclusion of the test, the liner was inspected and tested for punctures both visually and by application of a vacuum. The vacuum pressure was approximately 450 mmHG.

Liner observations: No punctures were present but several dimples and scratches.

Underliner was remolded to 95.1% of maximum dry density at optimum moisture. Overliner was loosely placed and slightly tamped.

Date: 7/12/06

Tech: MS

Review: MB

Liner Load Testing Photo Log

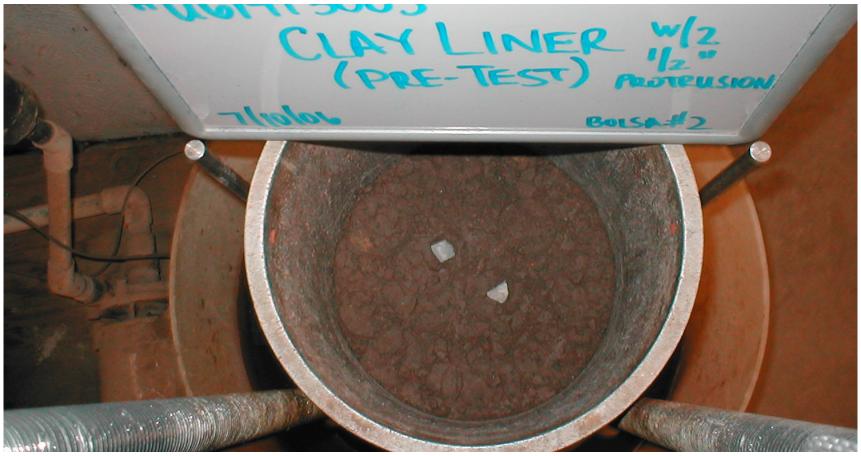


Figure 1 – Clay liner with rock protrusions, pre-test.

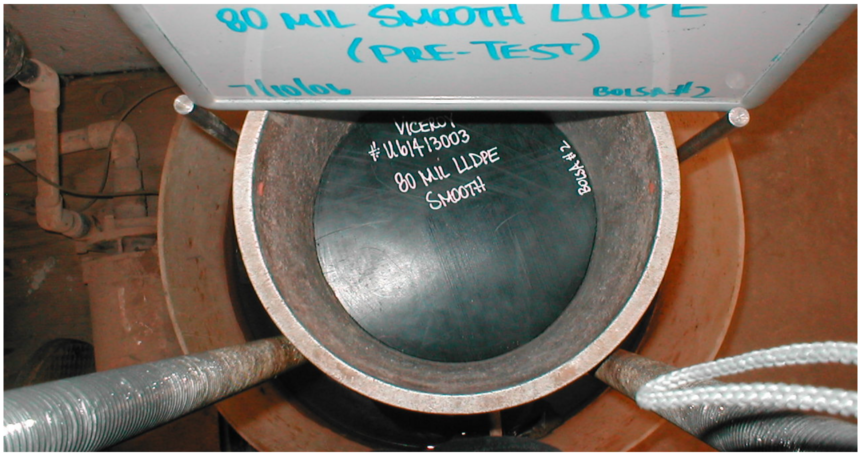


Figure 2 – 2.0 mm LLDPE geomembrane, pre-test.

Figure 3 – Overliner (Bolsa #2), pre-test.

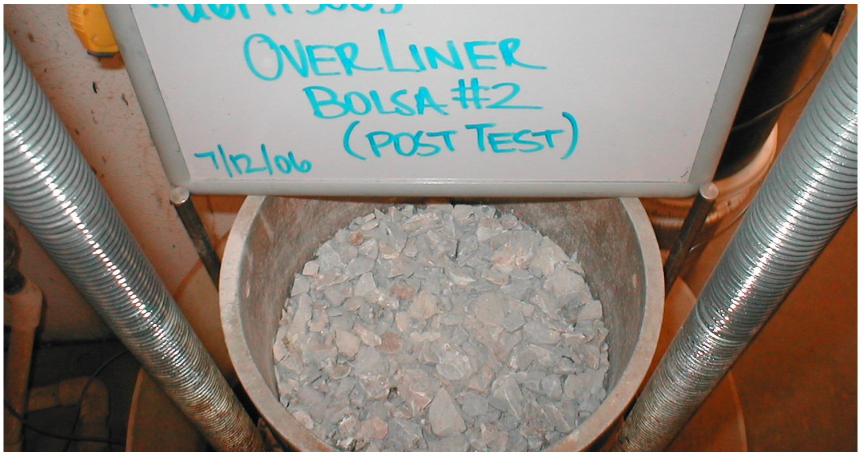


Figure 4 – Overliner (Bolsa #2), post-test.

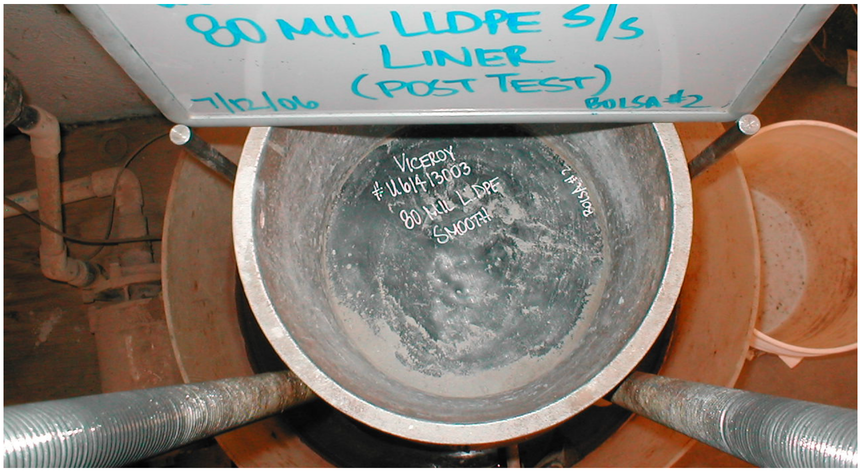


Figure 5 – 2.0 mm LLDPE, post-test.

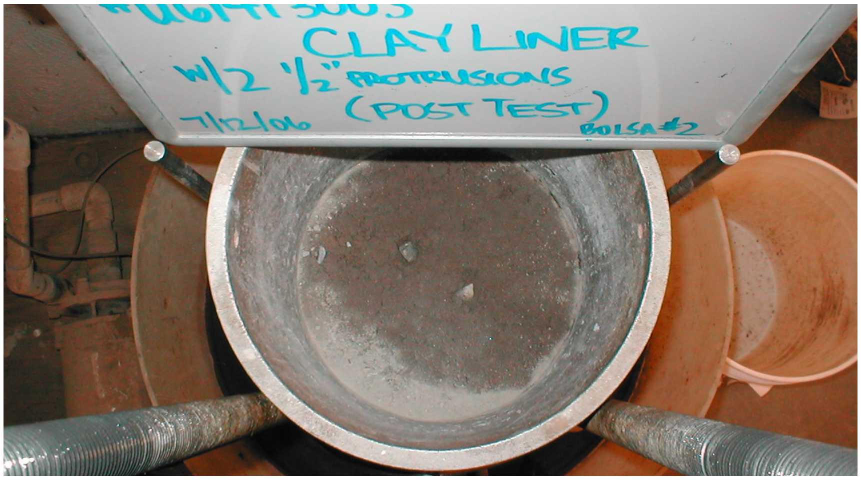


Figure 6 – Clay liner, post-test.

Figure 7 – 2.0 mm LLDPE, visual inspection.

APPENDIX K-3

PROJECT #3 LINER LOAD TESTING

PROJECT #3

LINER LOAD TESTING

	MOISTURE %	DENSITY pcf	RESULT	Starting Sample Height (in)	CHANGE IN HEIGHT (in)			Final Sample Height (in)
					50 psi	150 psi	350 psi	
Test #1								
4.0 inches Liner Bedding Soil - GA1-TP-30	8.9	123.0						
80-mil LLDPE geomembrane			**PASS**	10.785	0.173	0.492	0.789	9.996
6.5 inches (14997.0g) Drain Cover Fill -1 $^{1}/_{2}$"	0.1							
Test #2								
4.0 inches of Liner Bedding Soil - GA-1-TP-33	10.6	120.3						
60-mil LLDPE geomembrane			**PASS**	11.396	0.385	0.716	1.120	10.278
4.0 inches (7863.8 g) Drain Cover Fill -1 1/2"	0.1							
80-mil LLDPE geomembrane			**PASS**					
3.5 inches (7182g) Drain Cover Fill -1 1/2"	0.1							
Test #3								
4 inches of Liner Bedding Soil - GA-1-TP-33	10.8	120.2						
80-mil LLDPE geomembrane			**PASS**	11.595	0.229	0.549	0.939	10.656
4.5 inches (9535.3 g) Drain Cover Fill -1 1/2"	0.1							
100-mil LLDPE geomembrane			**PASS**					
3.0 inches (6367.1g) Drain Cover Fill -1 1/2"	0.1							

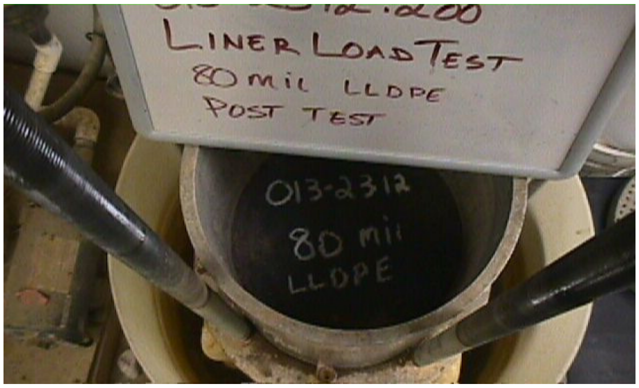
K-3-1

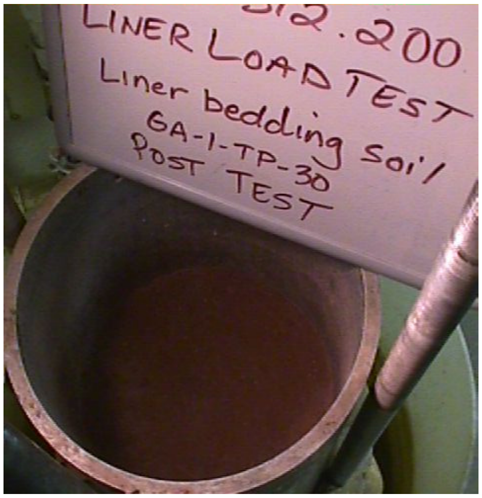
TEST #1

Liner Load Test #1
Load Testing

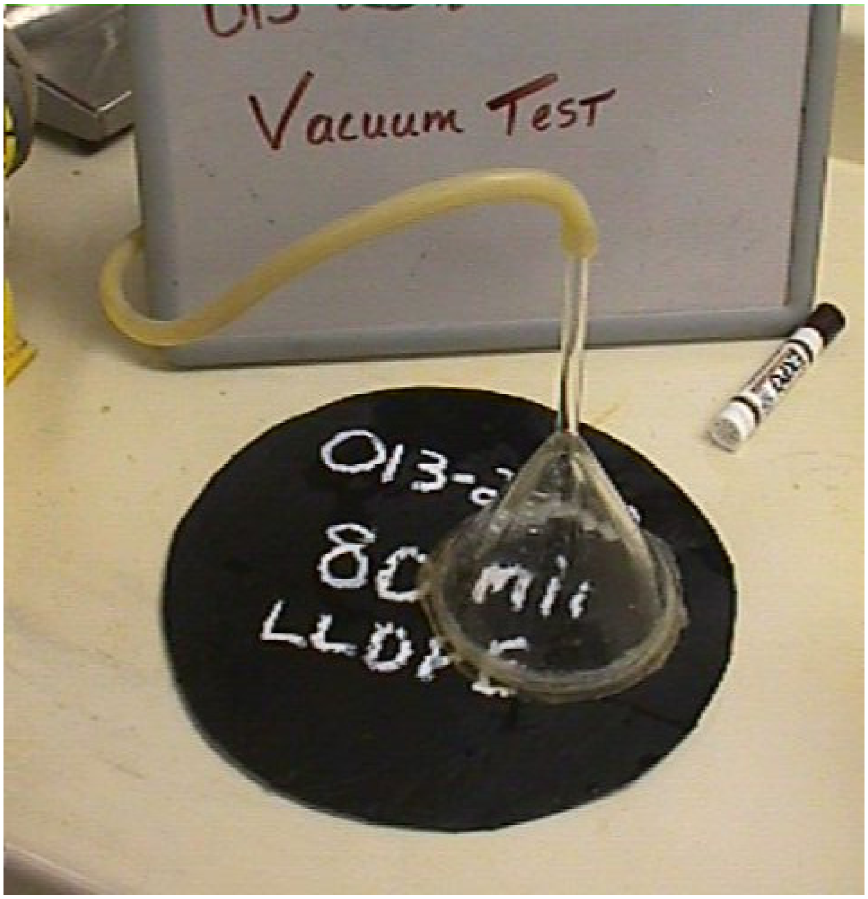
Golder Associates

Liner Load Test #1
Post-Test





Liner Load Test #1
Vacuum Testing

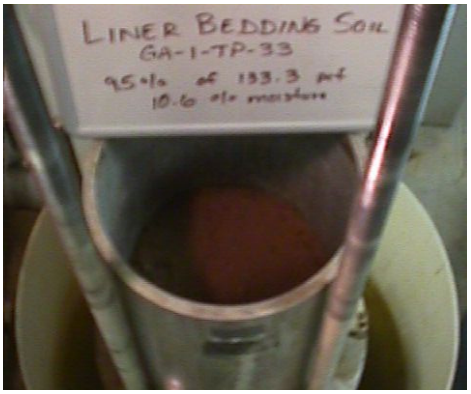


Golder Associates

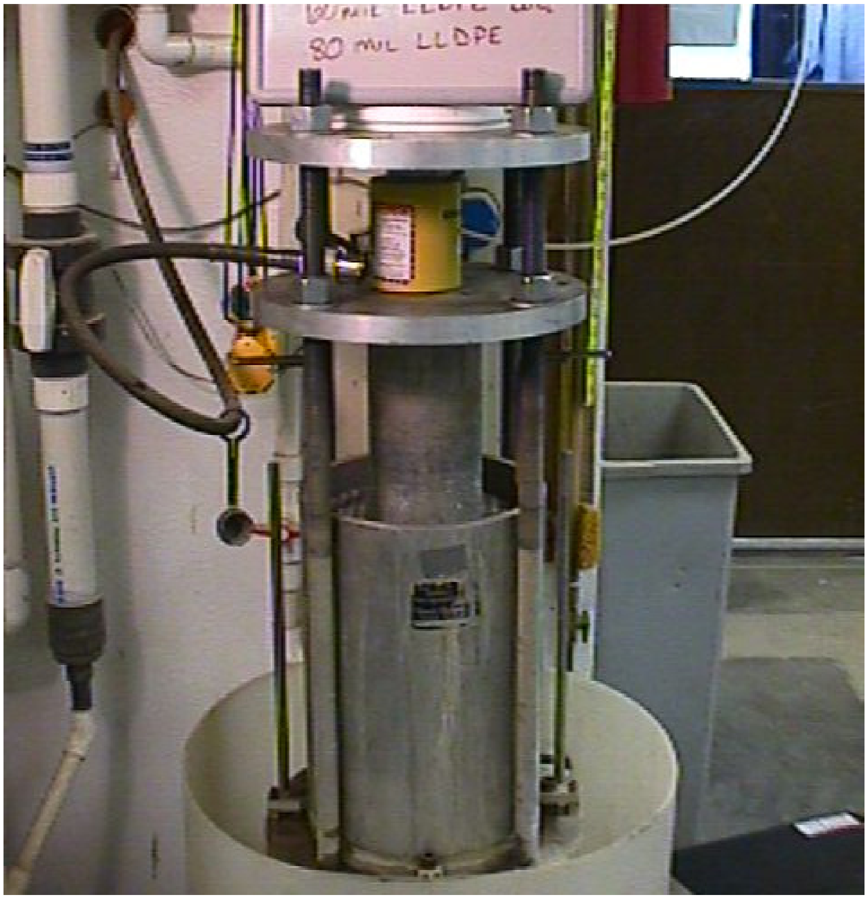
K-3-2

TEST #2

Liner Load Test #2
Sample Set-Up

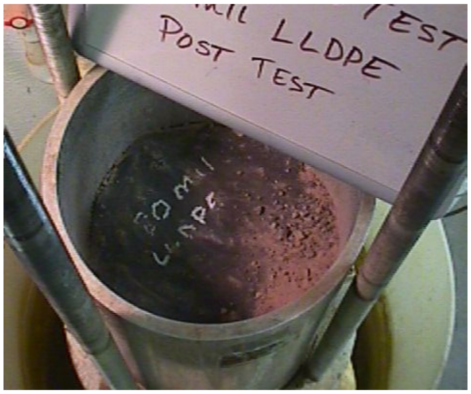


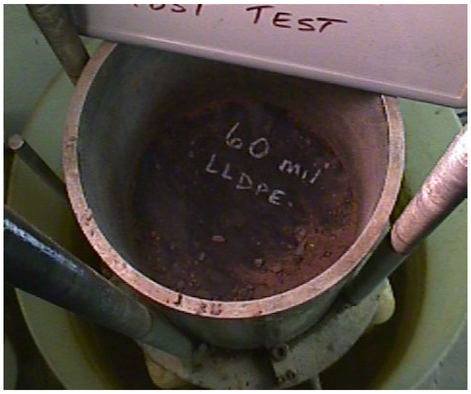
Liner Load Test #2
Load Testing



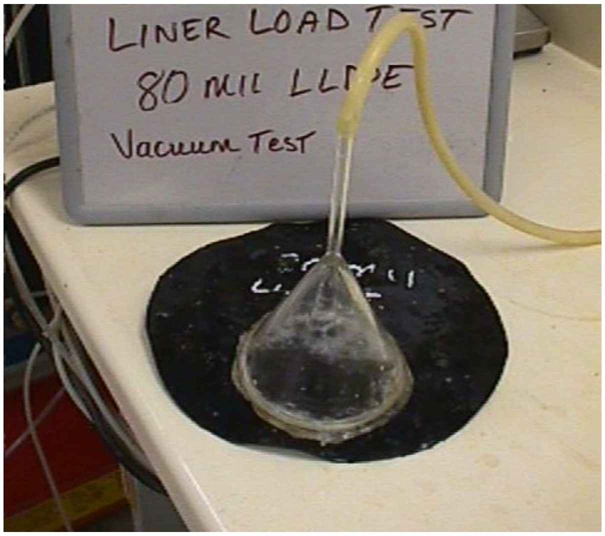
Golder Associates

Liner Load Test #2
Post-Test





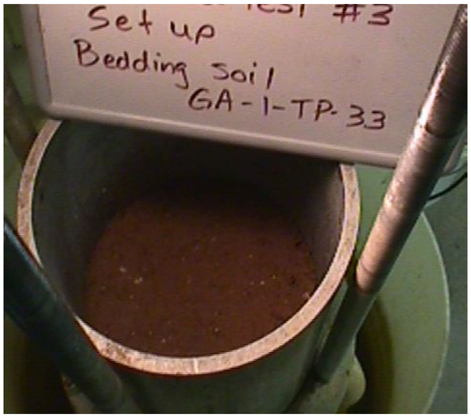
Liner Load Test #2
Vacuum Testing

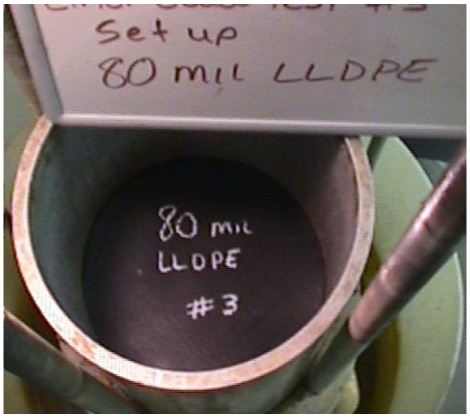


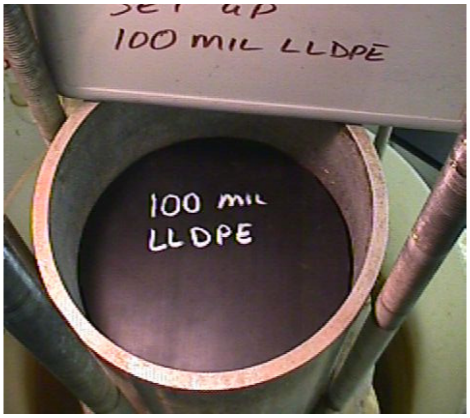
K-3-3

TEST #3

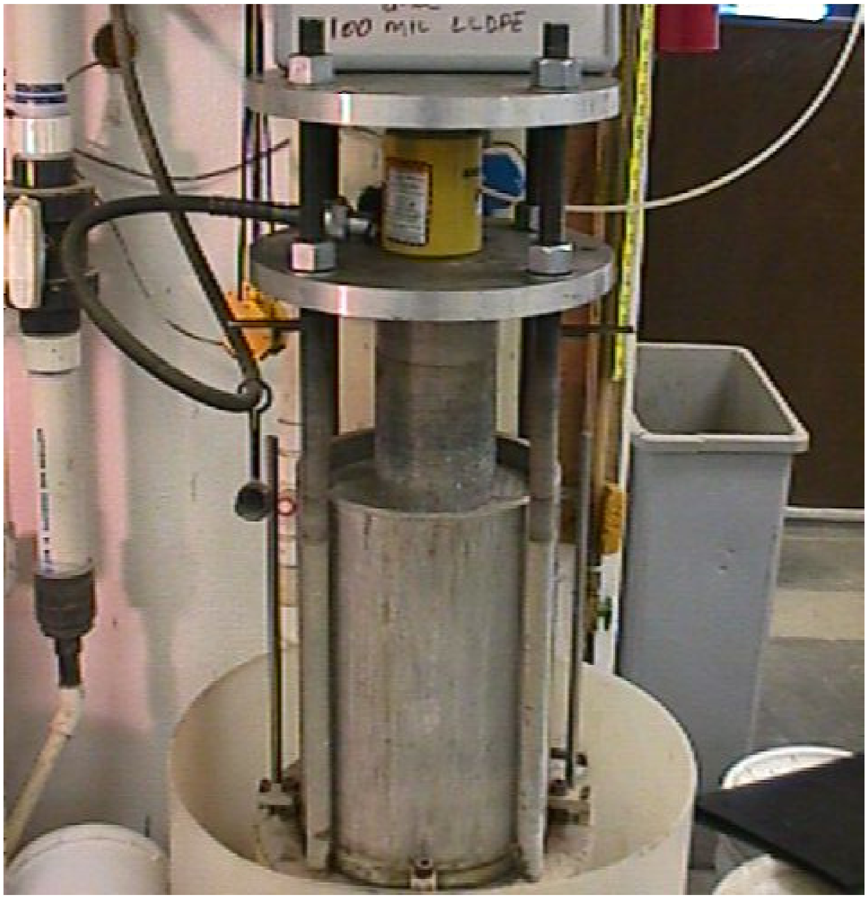
Liner Load Test #3
Sample Set-Up





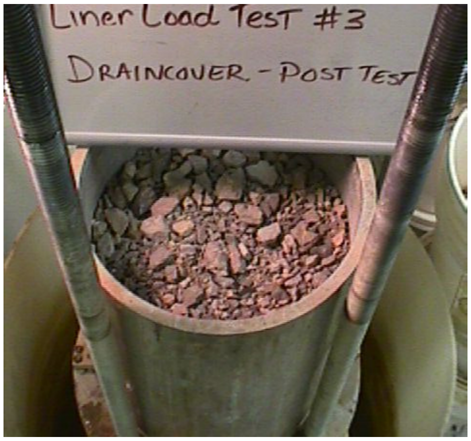


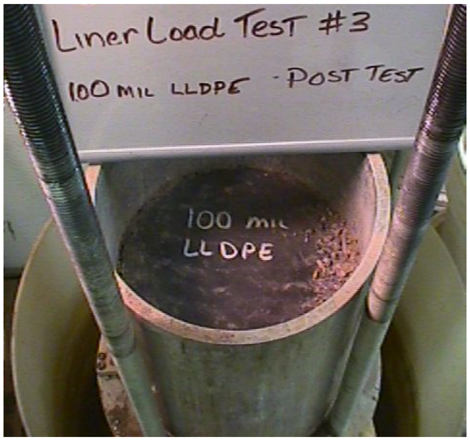
Liner Load Test #3
Load Testing

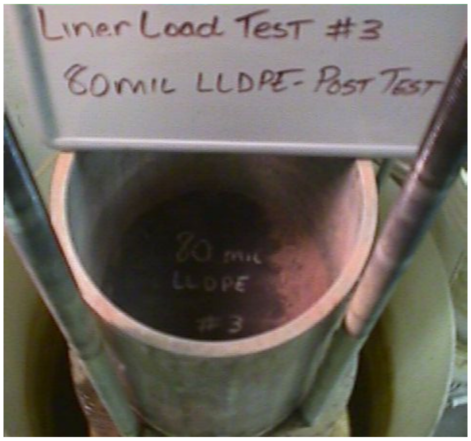


Golder Associates

Liner Load Test #3
Post-Test







Liner Load Test #3
Vacuum Testing