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Orvana Resources U.S. Corporation
Copperwood Project
Pre-Feasibility Study Report on Tailings Disposal Facility and Ancillary Structures

July 29, 2011

Orvana Resources U.S. Corporation
10199 Lake Rd.
Ironwood, MI 49938
Telephone: (906) 364-7577
Facsimile: (906) 364-7579

prepared by:

Knight Piésold and Co.

1580 Lincoln Street, Suite 1000
Denver, Colorado 80203-1512 USA
Telephone: (303) 629-8788
Facsimile: (303) 629-8789
E-mail: *denver@knightpiesold.com*

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Orvana Resources U.S. Corporation
Copperwood Project
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Tailings Disposal Facility and Ancillary Structures

Executive Summary

Introduction

Orvana Resources U.S. Corporation (Orvana) is planning to develop the Copperwood Project located at the western end of Michigan's Upper Peninsula, straddling Ironwood and Wakefield Townships in Gogebic County. The copper deposit and site are located approximately 10 miles north of Wakefield, Michigan, 1- to 2-miles southeast of Lake Superior, and 16 miles northeast of Ironwood, Michigan.

Mining at the site currently considers both conventional drill-and-blast and underground room–and-pillar methods. The copper bearing ore will be delivered to a nearby plant to be crushed, milled, and processed by flotation methods to recover the copper. The waste tailings will be pumped as slurry to a disposal facility located to the southeast of the process plant. During the planned 14.25-year mine life, approximately 32.3 Million dry tons (Mt) of tailings will be deposited within the Tailings Disposal Facility (TDF). This report presents a pre-feasibility study (PFS) level design of the TDF and ancillary structures.

Tailings Disposal Facility and Ancillary Structures

The PFS design of the TDF was based on a facility sizing and layout exercise, a mill and tailings circuit water balance, a geotechnical site investigation and associated soil and rock testing, hydrogeologic and geologic investigations, tailings samples testing, geotechnical stability analyses , and seepage and consolidation modeling which assumed both top and bottom drainage of the tailings mass. The storage capacity requirements were designed to meet the mine production schedule completed by Marston & Marston, Inc., and provided by Orvana on April 19, 2011.

The TDF will be developed in five stages over the life of the project, with the ultimate configuration designed to store the 32.3 Mt of tailings according to the current mine schedule. The ultimate Stage 5 facility footprint will extend approximately 2,200 yards (yd) in the east-west direction, 1,000 yd in the north-south direction, and will cover approximately 346 acres. The stage capacities and development schedule are summarized as follows:

Stage	Storage through Year	Storage Mass Mt	Dry Density t/yd^3 (2)	Storage Volume Myd^3 (2)
1	3	2.63	0.89	2.95
2	6	9.61	0.97	9.89
3	9	17.07	1.01	16.84
4	12	24.56	1.04	23.53
5	16(1)	32.27	1.07	30.32

1. Tailings deposition is planned to start in November of Year 1, and conclude in January of Year 16. Years 1 and 16 are therefore short years and the overall life of operations will be approximately 14.25 years.
2. Million cubic-yards (Myd^3), tons per cubic yard (t/yd^3)

The TDF site is in an area of variable but generally quite deep, very low-permeability till. Tailings will be contained partially below grade in a basin excavated into the till and partially above grade behind a zoned earthfill embankment constructed by the conventional downstream method. At full build out the

embankment will range in height from approximately 17 to 140 feet (ft). The embankment has been designed as a water retention structure due to the soft and wet nature of the tailings to be stored, and the large size of the operational water pond (supernatant pond) that will be contained in the TDF above the tailings. The embankment crest elevation for each stage of TDF development was selected based on the tailings and water storage requirements, including a 3-ft freeboard allowance, and accounts for an estimated tailings beach slope of minus 0.25 percent from the southeast to northwest corner of the facility.

The embankment will include a 40-ft-wide upstream Seal Zone to reduce seepage and a large Downstream Shell for stability. A 5-ft-wide filter and drain (Chimney Drain) will be constructed between these zones to intercept any small amounts of seepage passing through the Seal Zone, and to transport the seepage to a collection system at the base of the embankment. This drain will act in conjunction with a partial drainage blanket below the Downstream Shell and mid-height finger drains constructed within the Downstream Shell to limit the build-up of a phreatic level within the embankment downstream of the Seal Zone. The upstream side of the Seal Zone will be armored with riprap protection to limit erosion that could otherwise result from direct precipitation and wave action on the TDF supernatant pond.

Under the embankment and within the TDF basin, topsoil and unsuitable materials will be removed and stockpiled to establish a suitable working construction surface. Within the basin, predominantly during Stages 1 and 2, glacial till will be excavated to provide fill material for embankment construction and to provide additional tailings storage capacity such that the size of the ultimate embankment will be reduced. The Stages 1 and 2 TDF embankment configurations have been overbuilt to allow for excess material to be excavated and recovered before this source of material is buried by tailings. This removes the need for stockpiling and double-handling.

After excavation and grading, the basin surface will be scarified to remove any local lenses of silt and compacted to form a dense and low-permeability base. The TDF basin would then be prepared according to one of three liner systems evaluated as follows:

- Case 1 (In-situ Soil Liner) – In this alternative, no additional work would be conducted within the TDF basin. The containment of solutions within the TDF would rely on the natural in-situ, low-permeability glacial till material.
- Case 2 (Full Drainage Blanket) – In this alternative, the containment of solutions within the TDF would rely on a layer of drainage aggregate placed over the scarified and re-compacted (prepared) surface of the in-situ glacial till in the TDF basin floor. The drainage blanket would act to reduce the hydraulic head on the till during operations. Layers of filter fabric would be used to separate the drainage material from the underlying till and overlying tailings.
- Case 3 [Tailings Storage Facility (TSF) Prescriptive Liner] – This alternative is modeled after the prescriptive liner for a TSF under *Michigan's Nonferrous Metallic Mining Regulations, Part 632, R425.409 Treatment and containment of reactive material*. In this alternative, the containment of solutions within the TDF would rely on a layer of 60 mil geomembrane placed over the prepared glacial till, with a layer of drainage aggregate placed over the lowest portion of the TDF basin floor.

The three liner systems were compared based on their abilities to reduce seepage from the facility and through the foundation, and Case 2 was found to perform the best. It can be expected to reduce the seepage flux from through the underlying foundation of the TDF by nearly two orders of magnitude (if the drain is kept open) when compared to the other two cases. If the Case 2 drain is closed after final reclamation and consolidation of the tailings mass the seepage flux from the TDF would eventually stabilize to the same order of magnitude as the Cases 1 and 3 liner systems.

Tailings will be deposited into the TDF as slurry from designated offtakes on a pipeline routed around the south and east sides. The tailings solids will settle out in the facility to form a stored deposit and some of the water entering with the slurry will be retained in the inter-particle voids of the deposit. The remainder of the water will drain into the underlying drainage blanket, evaporate from the top surface or report to a

supernatant pond in the northwest corner of the TDF. Water in the supernatant pond will be removed from the TDF by decant towers installed along the upstream face of the embankment in the northwest corner and conveyed to a decant sump downstream of the dam from where it will be pumped to the mill for re-use in the process or to a treatment plant prior to discharge. Some portion of the reclaimed water may also require treatment before re-use in the mill. Flocculent is being considered for addition to the tailings just prior to deposition to enhance liquid/solids separation and increase the density of the tailings in the deposit. Flocculent would be added to the slurry in a liquid form and recovered water from this addition would also be decanted to the decant sump for pumping back to the flocculent circuit. The flocculent circuit has been considered as a closed loop with constant inflows and outflows and therefore for this design these waters were not included in the process water balance.

An overflow pond will be installed adjacent to the decant sump to receive water from the sump if the pumps go down due to power outages. Backup emergency power will be required to keep these periods short. The decant sump overflow pond will be geomembrane lined and has been configured to store approximately 46,000 ft^3 of water, which accounts for roughly 2-hr of unregulated inflow from the TDF in addition to direct precipitation from the 100-yr/24-hr storm event. A 1 ft freeboard allowance has been provided for above this.

Conceptual Closure

Conceptual closure and reclamation provisions for the TDF have been accounted for. They include a mechanically-placed (in winter), sloped soil cap over the final tailings surface consisting of (from bottom to top):

- A filter fabric and geogrid for material separation and tensile strength at the tailings surface,
- A capillary break layer to limit the upward migration of salts or other constituents from the tailings,
- An initial soil grading layer,
- A low-permeability rainfall shedding layer, and
- An upper topsoil layer that will be vegetated.

A spillway with an armored inlet apron, control section and outlet channel will be constructed near the southwest corner of the closed TDF to convey runoff from the surface of the closure cap out of the TDF. The spillway channel will discharge into a retention/detention basin to dissipate energy prior to releasing water to the environment.

Pre-Feasibility Cost Estimate

PFS level estimates were developed for the capital expenditure (CAPEX) and operating expenditure (OPEX) costs associated with the TDF, its decant system with sump and overflow pond, and the conceptual closure plan for the TDF. CAPEX cost estimates were included for each of the three liner systems evaluated within this report, and all costs were developed for the life of the project based on a time schedule that matches the current mine production plan.

In interpreting these cost estimates, the following should be noted:

- The cost estimates are presented in 2011 US$ with no escalation or time value of money factors applied for out-year costs.
- The design and costs associated with the tailings delivery and deposition system, flocculent addition to the tailings slurry stream, reclaim water pumping from the decant sump and overflow pond, surface water diversions around the ultimate TDF and the development and/or maintenance of stockpiles and/or borrow areas were not included in Knight Piésold's work scope, and are assumed to be provided by others.
- Geosynthetics for the TDF and decant pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.

- Pipework quantities associated with the TDF account for drains and the decant system and have been increased 5 percent over neat line quantities to account for waste.
- Operating costs were assumed to be the same regardless of liner system.
- Groundwater levels and quality will be monitored for approximately 1 year prior to the start of operations.
- Monitoring and testing will continue throughout the closure period, although additional monitoring and testing may be required beyond this period.
- Costs do not include for engineering design or construction supervision and quality assurance/quality control (QA/QC).
- The cost estimates presented herein are considered to be within a ±25 percent level of accuracy, which is commensurate with a PFS level design.
- No contingencies have been included at this time; however, a 25 percent contingency is recommended for this level of design.

While the level of accuracy specifically speaks to the confidence level associated with, and the detail of, the design, contingencies are typically included to account for uncertainties associated with unit rates, as well as potential changes that may be implemented as the project designs progress.

The staged PFS CAPEX cost estimates associated with the three liner systems for the Copperwood TDF and ancillary structures are summarized as follows:

Case 1 (In-Situ Soil Liner)

Stage 1 Years 0 - 2	Stage 2 Years 3 - 5	Stage 3 Years 6 - 8	Stage 4 Years 9 - 11	Stage 5 Years 12 - 14	Closure Years 16 - 19	Total
$22,510,020	$9,433,034	$10,870,884	$10,606,574	$9,921,278	$18,469,603	$81,811,393

Case 2 (Full Drainage Blanket)

Stage 1 Years 0 - 2	Stage 2 Years 3 - 5	Stage 3 Years 6 - 8	Stage 4 Years 9 - 11	Stage 5 Years 12 - 14	Closure Years 16 - 19	Total
$24,279,803	$11,404,712	$10,683,734	$9,814,525	$9,075,316	$18,469,603	$83,727,694

Case 3 (TSF Prescriptive Liner)

Stage 1 Years 0 - 2	Stage 2 Years 3 - 5	Stage 3 Years 6 - 8	Stage 4 Years 9 - 11	Stage 5 Years 12 - 14	Closure Years 16 - 19	Total
$27,401,175	$13,177,356	$11,912,450	$10,606,574	$9,921,278	$18,469,603	$91,488,436

OPEX costs were estimated for: 1) monitoring and reporting of instrumentation and groundwater wells; 2) decant system operation and closure; and 3) decant sump and overflow pond maintenance.

The annual PFS OPEX cost estimate is summarized as follows:

Year 0	Year 1	Years 2 - 15	Year 16	Years 17 - 19	Total
$36,667	$234,667	$308,000	$227,333	$220,000	$5,470,667

Recommendations

The following bullet points present the recommendations for future studies and design refinements for the Copperwood TDF as related to Knight Piésold's work scope.

- Additional Site Investigations and Monitoring
  - Ongoing Monitoring of Site Groundwater Levels
    - Groundwater levels and pressures in the till and bedrock beneath the proposed TDF are not well known but measurements should be made in the standpipe piezometers installed in the 2011 geotechnical investigation to determine them. While the flows are likely to be low in the till as a result of its low hydraulic conductivity, the pressure regimes should be defined in order to avoid problems with quick conditions developing in the base of the excavation for the TDF. It is suspected that the bedrock is acting as an aquifer confined under the till and it is possible that once the excavation is carried out, if its bottom is close enough to the bedrock, upward flows may occur into the excavation. The solution would be to raise the bottom of the excavation.
    - Based on the data from the existing installations and any suspected gaps, additional installations and monitoring programs may be required to establish a reliable groundwater model for use in properly siting the planned TDF and its base excavation.
  - On-Site Borrow for Riprap and/or Filter/Drain Material
    - Riprap and filter/drain material represent significant costs to the project. It is known that these materials are commercially available in close proximity to the Copperwood site but it may be possible to identify on-site borrows areas for sourcing these materials that will reduce the overall construction costs.
- Additional Materials Testing
  - Triaxial Testing for Embankment Stability Parameters
    - It is possible that the triaxial testing may not have been conducted at a slow enough rate of loading to allow for the best selection of effective stress parameters. Additional undisturbed samples should be acquired and tested to confirm or modify the parameters for use in the TDF embankment stability analyses.
    - Testing should be conducted on remolded samples produced from moisture-density testing to better represent the fill materials.
  - Construction Pore Pressures
    - The consolidation tests on the till indicate that its time rate of consolidation is quite slow, which is consistent with its low hydraulic conductivity. Such a material may contain significant excess pore pressures when loaded and compacted, and this indicates that it will be important to monitor pore pressures during construction. The final design of the TDF should investigate limits on the rate of construction and the number and positions of embankment drains adopted.
  - Geotextile Compatibility Testing
    - A variety of non-woven geotextiles should be evaluated to determine their compatibility with the Copperwood tailings, and more specifically their effectiveness in limiting the passage of tailings solids through their openings. Non-woven geotextile will be placed over the basin underdrain blanket and around the decant towers to limit the ingress of solids into either system.
  - Drainage Material Testing – for conductivity and durability
    - The potential candidate drainage materials should be tested for hydraulic conductivity and durability (if aggregate material) to assess how they will function over the life of the project.
- Tailings Disposal Facility Design Items
  - Tailings Underdrain Retardant Layer
    - It will be necessary to restrict the flows in the blanket underdrain under the TDF during the initial period of operations when the supernatant pond is in contact with the drain in order to prevent

the decant sump from being overwhelmed. Once the drain is covered with tailings, the tailings will limit the rate of inflow from the supernatant pond to an appropriate level. The retarding layer may include placing a lower permeability material over the underdrain or placing a series of low-height berms in the basin to more rapidly develop a tailings cover.

- Drainage Aggregate/Sand Filter Criteria
  - The material planned to for use in the TDF embankment drains should be evaluated to assess how well it meets filter criteria for placement adjacent to the embankment Seal Zone and Downstream Shell materials.
- Alternative Tailings Disposal
  - The TDF design has been developed assuming the storage of 100 percent of the tailings from the mine at surface. However, the footprint of the TDF could be significantly reduced if some of the tailings can be used as backfill for the underground mine. The reduction of the tailings stored at surface would reduce the required dike construction, surface water diversions, and wetlands impact and thus the total construction and closure costs of the facility. Further engineering studies would be required on potential methods to thicken or filter the tailings in order to produce a suitable material for backfill. The technical feasibility of this alternative would need to be assessed including a tradeoff study of the reduced footprint of the TDF and wetlands implications, construction costs, and operating costs associated with a thickened or filtered tailings plant.

- Decant System and Overflow Pond Design Items
  - Decant Structure Drain Pipe
    - It may be possible to eliminate a 12-in-diameter perforated CPT (Type SP) drain pipe that has been included for enhanced drainage in the decant structure aggregate surround material.
  - Flocculent Analysis
    - As determined through sample preparation for consolidation testing, flocculent addition equal to 150 percent of the incoming tailings slurry flow was required for the sample to exhibit fully flocculated behavior. This is large and should be investigated with a view towards reducing the volume through additional product analysis and testing.
  - Evaluation of Decant Sump Overflow Pond
    - The decant sump overflow pond will need to be re-evaluated based on any changes to the flocculent addition strategy and consideration for multiple usages (i.e., power outages) during each winter.
- Closure Design
  - Tailings Strength to Support Closure Surface
    - For this stage of design, the conceptual closure plan envisages mechanical placement of the cap materials with an estimated thickness between 2 and 27 ft (13 ft average). Testing and modeling of the consolidated tailings strength to support this load should be conducted during future design stages.
  - Closure Surface Slope
    - A 0.25 percent slope was utilized on the closure surface to mimic the slope of the tailings surface; however, this may be unrealistic to construct and maintain with positive drainage. Closure quantities and associated costs should be investigated to consider a range of closure surface slopes from 0.25 to 1 percent.
  - Closure Spillway Location
    - The closure spillway is currently planned to be constructed in the TDF southwest corner in order to reduce the drop height to convey flows to the existing ground surface. In order to slope the closure surface to the southwest corner, a substantial amount of fill material is required (13 ft average). A cost trade-off should be conducted to compare the current closure plan, in

addition to the costs to provide more slope to the closure surface, with the concept of sloping the surface to the northwest corner of the TDF and construction of the outlet spillway.

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Section 1.0 - Introduction

1.1 General

Orvana Resources U.S. Corporation (Orvana) is planning to develop the Copperwood Project located at the western end of Michigan's Upper Peninsula, straddling Ironwood and Wakefield Townships in Gogebic County. The copper deposit and site are located approximately 10 miles north of Wakefield, Michigan, 1- to 2-miles southeast of Lake Superior, and 16 miles northeast of Ironwood, Michigan.

Mining will be by underground room and pillar methods. The copper bearing ore will be delivered to a nearby plant to be crushed, milled, and processed by flotation methods to recover the copper. The waste tailings will be pumped as slurry to a disposal facility located to the southeast of the process plant. During the planned 14.25-year mine life, approximately 32.3 Million tons (Mt) of tailings will be deposited within the Tailings Disposal Facility (TDF).

Orvana has retained Knight Piésold and Co (Knight Piésold) to develop the pre-feasibility study (PFS) level design of the TDF and ancillary structures. This PFS design is presented herein in addition to the PFS level quantities and cost estimates. It is understood that this report will be utilized by Orvana in an overall project PFS report which may be used in the project permitting process.

1.2 Previous Work

Previous design work and site investigations have been performed at the Copperwood site. Information from these reports was used to develop the PFS design herein where applicable.

These reports include, but may not be limited to, the following:

- *Geotechnical Site Characterization Report, Copper Range Company's White Pine Mine Tailings Impoundments, White Pine, Michigan*, prepared by Golder Associates Inc., April 6, 1998.
- *Site Visit Memo Copperwood Project*, memorandum prepared by AMEC Americas Limited (AMEC), September 11, 2009.
- *Copperwood Project, Ironwood Township, Gogebic County, MI – Environmental Impact Assessment, Draft Summary Report*, November 2009, prepared by AECOM, November 25, 2009.
- *3rd Set of Laboratory Testing for Proposed Copperwood Mine Project, Wakefield Township, Michigan*, prepared by Coleman Engineering Company, May, 2010.
- *Orvana Minerals US Corp Copperwood Project, Michigan, Tailings Scoping Study*, prepared by Crescent Park Consulting Ltd, June 13, 2010.
- *Preliminary Economic Assessment of the Copperwood Project, Upper Peninsula, Michigan, USA*, prepared by K D Engineering, September 24, 2010.
- *Glacial Overburden Material at Copperwood*, memorandum prepared by AECOM, November 3, 2010.
- *Report of Supplemental Subsurface Exploration for Proposed Copperwood Mine Project, Wakefield Township, Michigan*, prepared by Coleman Engineering Company, April 2011.

1.3 Scope of Report

This report presents the PFS design of the TDF, decant structure, decant sump and overflow pond. It also presents the tailings management and deposition plans, and the conceptual closure plan of the TDF. Associated PFS level design drawings are included. Finally the report includes estimated capital expenditure (CAPEX) and operating expenditure (OPEX) costs for the TDF. It does not include for the design of, or costs associated with, the tailings delivery or deposition pipes and pumps, or the pipes and pumps associated with conveying decanted and/or seepage waters from the TDF decant sump to the plant for re-use in the process. These systems were by others.

More specifically, the PFS level design as reported herein includes the following:

- Tailings Disposal Facility Siting, Staging, and Layout Design - The TDF was sited to account for land use restrictions, mine plan limits and preferences provided by Orvana. The TDF has been designed for development in five principal 3-year stages.
- Tailings Disposal Facility Impounding Embankment – A zoned earthfill structure with a maximum height of approximately 140 feet (ft) above the original ground surface at its full build out arrangement (five stages), with a 40-ft-wide Seal Zone on the upstream face constructed from the low-permeability (k ~ 2 x 10-8 cm/s) in-situ glacial till, a filter and drain against the downstream side of the Seal Zone and a structural shell downstream of this for support (seepage and stability analyses are included on this embankment).
- Tailings Disposal Facility Liner System - The TDF liner system, for containment of deposited materials and direct precipitation, was evaluated for three different liner systems:
  - Case 1 (In-situ Soil Liner),
  - Case 2 (Full Drainage Blanket), and
  - Case 3 [Tailings Storage Facility (TSF) Prescriptive Liner].

  The three liner systems, described further in Section 5.4, were compared based on their abilities to mitigate seepage fluxes from the facility.
- Supernatant Pool Decant System - A decant system will be installed in the northwest corner of the TDF to recover and remove water from the TDF. Decanted water will be returned to the process plant, or be treated for discharge. The design of this system includes decant towers, for water removal from the supernatant pond on the surface of the tailings, a water conveyance outlet pipe under the TDF impounding embankment to a decant receptor sump, the decant sump, and a temporary overflow pond.
- Tailings Management and Deposition Plan – This plan presents the tailings placement and deposition management procedures through the life of mine during winter and summer.
- Conceptual Closure Plan - Closure and reclamation provisions of the TDF have been accounted for as part of the PFS design. They include a sloped soil cap over the ultimate, consolidated tailings surface and an armored spillway with outlet channel to convey storm water runoff from the closure cap surface.
- Pre-Feasibility Level Cost Estimate – PFS level cost estimates are included for the TDF components described above. Unit cost rates in the estimate were based on information provided from Coleman Engineering Company (Coleman), in consultation with local contractors in Michigan's Upper Peninsula, and from Knight Piésold's experience with similar projects. While the TDF was designed to be developed in five 3-year stages, where deemed appropriate, annual costs were developed realizing Orvana may prefer to conduct smaller and more frequent increments of construction

1.4 Limitations and Disclaimer

This report titled *Orvana Resources U.S. Corporation, Copperwood Project, Prefeasibility Study Report on Tailings Disposal Facility and Ancillary Structures* has been prepared by Knight Piésold and Co. (Knight Piésold) for the exclusive use of Orvana Resources U.S. Corporation (Orvana). No other party is an intended beneficiary of this report or the information, opinions, and conclusions contained herein. Any use by any party other than Orvana of any of the information, opinions, or conclusions is the sole responsibility of said party. The use of this report shall be at the sole risk of the user regardless of any fault or negligence of Orvana or Knight Piésold.

The information and analyses contained herein have been completed to a level of detail commensurate with the objectives of the assignment and in light of the information made available to Knight Piésold at the time of preparation. This report and its supporting documentation have been reviewed and/or checked for conformance with industry-accepted norms and applicable government regulations. Calculations and computer simulations have been checked and verified for reasonableness, and the content of the report has been reviewed for completeness, accuracy, and appropriateness of conclusions. To the best of the information and belief of Knight Piésold, the information presented in this report is accurate to within the limitations specified herein.

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1.5 Contributors and Contacts

This report was prepared, reviewed, and approved by the undersigned.

Prepared by:

Jason T. Reiva, P.E.(Colorado)
Sr. Engineer/Scientist II

Reviewed by:

Thomas F. Kerr, P.E. (Michigan)
President

Approved by:

Thomas F. Kerr, P.E. (Michigan)
President

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Section 2.0 - Tailings Disposal Facility Description

The TDF will be built on the south end of the Copperwood Project site, within Sections 6, 7, and 8. This site was chosen due the favorable topography, low-permeability underlying soil conditions, and close proximity to the mine and process facilities. Its northern extent was constrained by the planned underground mine development, with the TDF being limited to extending 30 ft north of the ore sub-crop line proposed for the mine by Marston & Marston, Inc. (Marston). Tailings will be contained behind an embankment constructed by the conventional, downstream method that is proposed to be built in five stages over the life of the project. At full build-out in Stage 5, the facility will extend about 2,200 yd in the east-west direction and 1,000 yd in the north-south direction, and will cover about 346 acres. A general layout of the TDF can be seen on Drawing 120.

The ultimate TDF embankment will range in height from approximately 17 to 140 ft, in the southeast and northwest corners, respectively. The embankment has been designed as a water retention structure due to the soft and wet nature of the tailings to be stored, and due to the large size of the operational water pond (supernatant pond) that will be contained above the tailings. Provisions have also been included in the process water balance (Section 6.0) to temporarily store excess water in the TDF for supply to the Plant during drier winter periods. The dam crest elevations for the different stages have typically been selected based on the tailings and water storage requirements, including a 3-ft freeboard, and account for an estimated tailings beach slope of minus 0.25 percent from the southeast to northwest corner of the facility.

The zoned earthfill embankment will be comprised of an upstream Seal Zone to reduce seepage and a large Downstream Shell for stability. A 5-ft-wide filter and drain (chimney drain) will be constructed between these zones to intercept any small amounts of seepage passing through the Seal Zone, and to transport the seepage to a collection system at the base of the embankment. This drain will act in conjunction with a partial drainage blanket below approximately two-thirds of the Downstream Shell to limit the build-up of a phreatic level within the embankment structural zone. The upstream Seal Zone will be faced with a riprap protection layer, to limit the erosion of the fine-grained soil that could otherwise result from direct precipitation and potential wave action on the TDF supernatant pond. To the maximum extent possible, the embankment will be constructed from on-site or near-site materials. Materials for the Seal Zone and Downstream Shell will be sourced from the overburden soil on site, consisting mostly of lean clays that are termed glacial till. The embankment drains, basin drainage blanket, and pipe surround materials will consist of clean aggregates of different particle sizes and will be supplied from nearby quarry and processing sites. It is envisaged that riprap will be supplied either from an on-site or nearby quarry. A typical cross section of the TDF embankment can be seen on Drawing 150.

Below the embankment, and within the TDF basin, topsoil and unsuitable materials will be removed and stockpiled to establish a suitable working construction surface. Predominantly during Stages 1 and 2, glacial till within the TDF basin will be excavated to provide fill material for embankment construction, and to provide additional tailings storage capacity such that the size of the ultimate embankment will be reduced. Specific to the Stages 1 and 2 configurations, the TDF embankment has been overbuilt to account for the excess amount of material excavated from within the TDF basin. The excess cut material during the initial stages reduces the amount of borrow material required for construction of the later-stage embankments, while the Stages 1 and 2 embankment overbuilds eliminate the need for stockpiling and double-handling.

The TDF liner system was evaluated for three different alternatives:

- Case 1 (In-situ Soil Liner) – In this alternative, the containment of solutions within the TDF would rely on the natural in-situ, low-permeability glacial till material. This liner system is described further in Section 5.4.1.

- Case 2 (Full Drainage Blanket) – In this alternative, the containment of solutions within the TDF would rely on a layer of drainage aggregate placed over the scarified and re-compacted (prepared) surface of the in-situ glacial till in the TDF basin floor. The drainage blanket would serve to reduce the hydraulic head acting on the till to approximately 1 ft during operations. Layers of filter fabric would be used to separate the drainage material from the underlying till and overlying tailings. This liner system is described further in Section 5.4.2.
- Case 3 (TSF Prescriptive Liner) – This alternative is modeled after the prescriptive liner for a TSF under *Michigan's Nonferrous Metallic Mining Regulations, Part 632, R425.409 Treatment and containment of reactive material*. In this alternative, the containment of solutions within the TDF would rely on a layer of 60 mil geomembrane placed over the prepared glacial till, with a layer of drainage aggregate placed over the lowest portion of the TDF basin floor. This liner system is described further in Section 5.4.3.

The three liner systems were compared based on their abilities to reduce seepage from the facility and through the foundation, and Case 2 was found to perform the best. It can be expected to reduce the seepage flux from through the underlying foundation of the TDF by nearly two orders of magnitude (if the drain is kept open) when compared to the other two cases. If the Case 2 drain is closed after final reclamation and consolidation of the tailings mass, the seepage flux from the TDF would eventually stabilize to the same order of magnitude as the Cases 1 and 3 liner systems. Notwithstanding this, CAPEX estimates are included in this report for all three liner systems.

Supernatant water will be removed from the TDF by decant towers installed along the upstream face of the embankment, in the northwest corner of the facility, and conveyed to a decant sump downstream of the dam. Water will be pumped from the decant sump to the mill for re-use in the process or to the treatment plant for treatment and discharge. Some portion of the reclaim water may require treatment before reuse in the mill. Water from flocculent addition at the tailings slurry inlet to the TDF will also be decanted and report to the decant sump for pumping back to the flocculent circuit; however, the flocculent circuit has been considered as a closed loop and therefore these waters have not been included in the process water balance.

An overflow pond adjacent to the decant sump has also been included in the PFS design. This geomembrane-lined pond will receive water from the decant sump if the pumps are down due to power outages. Backup emergency power will be required to keep these periods short. The decant sump overflow pond has been configured to store approximately 46,000 ft^3, accounting for roughly 2 hours of the incoming flow, in addition to the direct precipitation from the 100-yr/24-hr storm event and 1 ft of freeboard.

Staged development of the TDF, including basin excavation, can be seen on Drawings 140 through 148. The TDF decant system is presented on Drawing 160.

Conceptual closure and reclamation provisions for the TDF have been accounted for in the PFS design. They include a mechanically-placed, sloped soil cap over the final tailings surface consisting of (from bottom to top):

- A filter fabric and geogrid for material separation and tensile strength at the tailings surface,
- A capillary break layer,
- An initial soil grading layer,
- A low-permeability rainfall shedding layer, and
- An upper topsoil layer that will be vegetated.

An armored spillway with outlet channel will be constructed through the TDF embankment, near the southwest corner of the facility, to convey storm water runoff from the surface of the closure cap. It is currently envisioned that the spillway and channel will outlet into a retention/detention basin prior to

discharging into the Namebinag Creek. A retention/detention basin near this location has been included in Coleman's 2011 design of the mine access road; however, this structure may need to be improved at closure to accommodate additional flow from the reclamation surface.

The conceptual closure plan is presented on Drawing 190.

Section 3.0 - Site Conditions

3.1 Location, Area Restrictions, and Land Use

The following are selected excerpts from the *Environmental Impact Assessment, Draft Summary Report, November 2009*, completed by AECOM Technologies (AECOM), describing the project location and land uses.

> *The Copperwood Project is located in the western portion of Gogebic County, Michigan. The project is centered on Section 1, T49N, R46W, in Ironwood Township. The project also includes portions of the surrounding sections, including Sections 2, 11, and 12 of T49N, R46W, Sections 6 and 7 of T49N, R45W, and Sections 35 and 36 of T50N, R46W. The central portion of the project is at the location of the historic test mining operation, which left a small pile (approximately 2.5 acres) of mined rock at the surface, surrounding an abandoned shaft and building foundation.*
>
> *The project is located approximately 2.3 miles east of the mouth of the Black River, and 2.9 miles southwest of the mouth of the Presque Isle River. The center of the site (at the location of the historic mine/rock pile) is located approximately 1 mile southeast of Lake Superior, if measured perpendicular to the shoreline. The nearest communities are Wakefield and Bessemer, located along US highway 2, approximately 15 miles to the south of the site. The villages of Thomaston and Connorville are located along County Road (CR) 519, approximately 12 and 9 miles (respectively) to the south-southeast of the project site.*
>
> *The project site is located within a remote, forested portion of Gogebic County. Access to the historic mine/rock pile area is through a private, gated road off of CR 519 (also known as Presque Isle Road) in the northwest corner of Section 8, T49N, R45W. This road is one of many historic railroad grades which cross the area, and are now used predominantly as access roads for logging activities. These roads are in generally good condition, although only constructed as one-lane dirt roads.. The historic mine/rock pile area of the project site is approximately 2.7 miles to the west and north from the gated access off of CR 519.*

The proposed TDF site is located within Sections 6, 7, and 8 and is approximately 1 mile southeast of the historic mine/rock pile.

The main drainages in the area of the TDF site are Namebinag Creek to the west, and Lehigh and Gipsy Creeks which run through or partially through the site, and which will be diverted around the TDF. The TDF has been set back from Namebinag Creek by approximately 150 ft.

The North Country National Scenic Trail (NCNST) is located south of the proposed TDF location. The location of the TDF in relation to the NCNST, in addition to wetlands mitigation, will be important aspects of the Copperwood Project; however, these are not covered within the work scope of this PFS report and are addressed in AECOM's environmental impact assessment report.

3.2 General Climatological Site Characterization

The Copperwood Project site can be characterized as having a continental climate with seasonally cold winters and warm summers. Precipitation is generally evenly distributed throughout the year and occurs as rainfall in spring and summer, and snowfall during the winter. A moderate amount of evaporation typically occurs during the non-winter months (April through October).

A search of the Michigan State Climatologist's database, the Midwestern Climate Center database, and the National Climatic Data Center found that nearby weather stations with long-term records include Ironwood, Ontonagon, and the Bergland Hydro Plant. These data were obtained and analyzed, together

with daily precipitation and temperature data from the mine site weather station from June to October 2009 and from April to September 2010. Based on a review of the location, elevation, and data from the three nearby stations, the Ontonagon station appears to provide a good representation of the climatic conditions at the mine site as provided by the on-site station. Data from October 1977 to December 2010 from the Ontonagon station were used to represent precipitation as well as mean monthly minimum and mean monthly maximum air temperatures at the site. The following bullets summarize the key findings of the climatic analysis, based on the Ontonagon station data:

- The design 100-yr/24-hr annual storm event was determined to be 4.25 inches.
  - Utilized for the design of the decant sump overflow pond based on a "low-hazard potential" dam classification according to the Natural Resources and Environmental Protection Act, 1994 PA 451, Part 315, Dam Safety.
- The design 72-hr/one-half Probable Maximum Precipitation (half-PMP) storm event was determined to be 16.4 inches, likely to occur in August.
  - Utilized for the design of the TDF supernatant pond based on a "high-hazard potential" dam, greater than 40 ft in height, classification according to the Natural Resources and Environmental Protection Act, 1994 PA 451, Part 315, Dam Safety.
- The average annual precipitation for the site was found to be 33.02 inches.
- The average maximum temperature for July was found to be 79.2 degrees Fahrenheit (^{o}F), while the average minimum temperature for July was found to be 54.7 ^{o}F.
- The average maximum temperature for January was found to be 25.1 ^{o}F, while the average minimum temperature for January was found to be 8.3 ^{o}F.
- The average annual potential evaporation was found to be 36.47 inches.
- The average annual evaporation from exposed tailings areas was found to be 16.82 inches.
- The average annual pond evaporation was found to be 23.71 inches.

Rain-on-snow events may result in higher total runoff values than runoff due to rainfall on bare ground. To address this possibility, snowmelt due to rainfall was estimated using equations developed by the U.S. Army Corps of Engineers (USACE, 1998). Rain-on-snow events are assumed only to occur from October through May of each year. The maximum precipitation associated with the 72-hr/half-PMP storm event has been modeled to occur during the month of August (16.4 inches). This monthly 72-hr/half-PMP precipitation, occurring as rainfall alone, exceeds the modeled monthly maximum rain-on-snow event (13.0 inches occurring in March) which combines the 72-hr/half-PMP precipitation with the associated amount of snowmelt that would occur during that storm event. Therefore, the 72-hr/half-PMP storm event, neglecting rain-on-snow conditions, governs the design.

Details of the development of these data are provided in the Knight Piésold memorandum titled, *Copperwood Project, Climatic Data Analysis, Revision 0*, dated June 15, 2011. This document has been included in its entirety in Appendix A.

3.3 Geology and Hydrogeology

Summary information in this section was obtained primarily from AECOM's preliminary draft document titled *Copperwood Project, Ironwood Township, Gogebic County, MI, Environmental Impact Assessment, Draft Summary Report(Draft Summary Report)*, prepared in November, 2009. Detailed material descriptions developed during the 2011 geotechnical site investigation are presented in Section 3.4.

3.3.1 Major Geologic Units

3.3.1.1 Bedrock

Bedrock beneath the project site was examined in more than 100 borings (both environmental and exploration) advanced in 2008 and 2009 by AECOM; although these borings were conducted on a more widespread basis for the previously considered mine site slightly northwest of the currently proposed TDF location. A total of 11 additional borings, specific to the current TDF site, were completed by Coleman as part of the 2011 geotechnical site investigation described in Section 3.4, under the direction of Knight Piésold. The top of the bedrock surface is variable, reflecting the presence of transitional materials including boulders, likely dislodged and transported by glacial movement, and a zone of weathered bedrock at the surface. The bedrock generally slopes downward to the northwest in the same general direction as, but at a steeper slope than, the overlying ground surface. This typically results in larger depths of glacial overburden under the northern side of the TDF, and shallower depths under the southern side. Bedrock is exposed at the ground surface to the southeast of the proposed TDF site, and in localized areas within the Namebinag Creek.

The following geologic description is comprised of excerpts from AECOM's 2009 *Draft Summary Report*:

> *Bedrock beneath the site is composed of sedimentary rocks of the Keweenawan Supergroup of middle-proterozoic age. The thick sequence of Keweenawan Supergroup volcanic and sedimentary rocks are associated with the ~1.1 Ga midcontinent rift system. The rocks of the Keweenawan Supergroup in western Gogebic County include, from oldest to youngest, the Bessemer Quartzite, Siemens Creek Formation, Kallander Creek Formation, the Portage Lake Volcanics, Porcupine Volcanics, Copper Harbor Conglomerate, Nonesuch Shale, Freda Sandstone, and the Jacobsville Sandstone (Cannon, et. al. 1992). Of these units, only the Copper Harbor Conglomerate and the Nonesuch Shale are present beneath the project site.*
>
> *The Nonesuch Shale is a succession of gray-black siltstone, shale and sandstone, deposited in a reducing lacustrine environment within a short-lived stratified lake within the rift valley (Cannon e. al., 1992). The basal beds of the Nonesuch Shale and locally the top of the Copper Harbor Conglomerate are mineralized with copper and silver throughout the region. The mineralized zone lies at the base of the Nonesuch Shale and is stratigraphically equivalent to the mineralized zone at the White Pine Mine located in western Ontonagon County. Historical and recent drill holes indicate that the copper-mineralized zone is from approximately 4.5 feet 12 feet thick, with average copper grades between 1.0% and 2.2%. Mineralization within the shale consists of fine-grained chalcocite.*
>
> *Copper Harbor Conglomerate underlies the Nonesuch Shale at the project site. The Copper Harbor Conglomerate is a red-brown sequence of volcanogenic clastic sediments, which become generally finer grained up-section (i.e. fining upward sequence). The Copper Harbor Conglomerate is composed of sandstone and conglomerate facies. The sandstones are lithic graywackes, and the conglomerate is composed of clasts of silicic and mafic volcanic rocks (Bornhorst, et. al., 1994).*

3.3.1.2 Glacial Overburden

Also paraphrased from AECOM's 2009 *Draft Summary Report*:

> (The glacial overburden consists) *primarily of a reddish-brown glacial till. The material was described in the field during the soil boring program as several variations of a silty clay. Slight variations in the observed portions of silt, clay, and sand, brought about descriptions ranging from silt, clay, silty clay, clayey silt, silty sand, and sandy silt. The till was found to contain trace (1-9%) to little (10-19%) to some (20-34%) amounts of sand and gravel.*

Gravel size particles in the till are predominantly comprised of dark, reddish-brown sandstone likely from the Freda Sandstone, a unit which overlies the Nonesuch Shale and was eroded by the glaciers in the vicinity of the site.

> (The glacial overburden) *was described as a massive matrix-supported diamicton. A diamicton is a descriptive term for poorly sorted deposits composed of gravel clasts within a finer-grained matrix, and is an important term in the description of glacial sediments. Based on the lack of structure observed within the material, a possible classification of the site glacial materials is a subglacial diamicton (Kemmis, 2008), meaning that it was deposited beneath the glacial ice.*

The section of site glacial overburden was generally described as "slightly coarser with depth, being more clay-rich at the surface and more silt-rich at depth." Specific to the current TDF location, the glacial till thickness was estimated to vary from approximately 20 to 120 ft across the site. While the thickness of the material may vary across the site, AECOM has suggested that it was found to be present and consistent over an area of several square miles surrounding the project.

> *Layers of coarser (non-cohesive) material were observed throughout the site in various borings. These soil types generally consisted of fine to medium sand with varying amounts of silt and clay. Granular deposits appear to be thin and isolated. No granular deposits thicker than 10 feet were observed at the site. In fact, the average thickness of the granular deposits is less than 1 to 3 feet thick. The cleanest (i.e. well sorted) sand layer within the glacial materials was observed at boring CW-08-12, at a depth between 62 and 72 feet below ground surface. These granular deposits, when encountered, do not appear laterally extensive, and for the most part, cannot be correlated between adjacent borings. These deposits are considered to be intra-till sands or subglacial meltwater deposits. Based on descriptions of the glacial section by Hack (1965), these coarser-grained deposits may represent lacustrine deposits deposited within lakes which existed between different glacial advances, but no clear evidence was observed to support a lacustrine origin of these layers.*

AECOM has also identified several shoreline features across the site, believed to have been formed by glacial Lake Duluth.

The site overburden has been compared to subglacial deposits that have elsewhere been described as "drumlinized and fluted glacial deposits" (after Peterson, et. al., 1986). These landforms are streamlined features that are typically formed in till by the movement of the overlying glacier (drumlin) and by processes including subglacial flow of meltwater (fluting). While drumlins and fluted landforms were not observed at the project site AECOM suggested that the fluted features may have been the cause of the distinct drainage patterns exhibited at the Copperwood site.

AECOM previously considered subdividing the site glacial deposits into three subunits, as has been done elsewhere in the region (Hack, 1965, reported in AECOM); AECOM also developed geologic cross-sections for the site that contain three subdivided till layers. However, more recently, in AECOM's memorandum titled *Glacial Overburden Material at Copperwood*, dated November 3, 2010, AECOM identified the upper till unit of Hack (1965) as most closely matching the entire site glacial section.

> *The upper unit is described as a clayey till that is much less stony than either of the lower units. This reference (which was identified by AECOM after the drilling program was completed), closely matches the glacial section described by AECOM geologists.*

The AECOM geologic cross-sections from 2009 are therefore not further used in this study. Also from AECOM's 2010 memorandum, it suggests a final conclusion that the overburden material at Copperwood is of sub-glacial till origin.

It is unlikely that the Copperwood material is a water-laid till (rain-out deposit or debris flow into glacial lake) because it lacks vague horizontal layering and multiple coarsening or fining sequences and it covers much larger areas than water-laid till.

Significance of Sub-glacial Till
We (AECOM, 2010) *think that the sub-glacial till origin to be correct as well as an advantage for site permit approval because:*

- *Sub-glacial till is more uniform over larger areas and greater thicknesses than lacustrine deposits,*
- *Sub-glacial till is massive, lacking the bedding that lacustrine deposits have which lowers shear strength and increases bulk hydraulic conductivity,*
- *Sub-glacial till is overconsolidated, and hence denser, resulting in lower hydraulic conductivity, higher bearing capacity, and* greater shear strength.

It is noted that the extremely fine-grained and relatively well-sorted character of the subglacial till has led to confusion in the past. For example, a recent U.S. Geological Survey publication (Hoard and Westjohn, 2001) describes how a thick (>50 ft in thickness) layer of dense, clay-rich basal lodgment till (i.e., ground moraine) was previously mapped as lacustrine sediments on the State Quaternary geologic map (Farrand and Bell, 1982).

3.3.2 Hydrogeology

The following description of site hydrogeologic units was developed from available summary information (AECOM, 2009, 2010), some of which has been updated through April of 2011.

3.3.2.1 Groundwater Occurrence and Hydrogeologic Units

Groundwater has been classified into three subsurface hydrogeologic units, which correspond to the geologic units encountered on-site at Copperwood: glacial overburden, Nonesuch Shale, and Copper Harbor Conglomerate. These units are discussed below together with an assessment of their characteristic hydraulic conductivities.

3.3.2.1.1 Glacial Overburden

Most groundwater within the glacial overburden is believed to be contained within poorly connected pore spaces within the fine matrix of the diamicton/till. Porosity is believed to range between 25 and 45 percent, based on textbook values. No fractures or deformation zones were observed in the till. Thin layers of more sandy materials are estimated to comprise less than 3 percent of the overall glacial overburden.

AECOM's baseline investigation has reported variable hydraulic conductivity values for the glacial till deposits that range from 1.67×10^{-8} to 1.86×10^{-2} centimeters per second (cm/s), with a geometric mean value of 1.91×10^{-5} cm/s based on 25 field measurements. While isolated deposits of coarser materials within the glacial till have been identified, and may be the cause of the higher hydraulic conductivity values, there does not appear to be hydraulic connectivity between the coarser deposits.

The geometric mean hydraulic conductivity suggested by AECOM was based on a larger scale of testing conducted for the entire Copperwood site, circa 2009. Systematically lower hydraulic conductivity values were measured during the 2011 geotechnical site investigation, described in Section 3.4, in the area beneath the currently proposed TDF. Sixteen field measurements and three laboratory measurements yielded values ranging from 5.9×10^{-9} to 9.8×10^{-8} cm/s, with a geometric mean value of 2×10^{-8} cm/s.

3.3.2.1.2 Nonesuch Shale and Copper Harbor Conglomerate

Groundwater within the Nonesuch Shale and Copper Harbor Conglomerate hydrogeologic units appears to be confined, based on measurements of potentiometric surfaces above the top of the rock (AECOM, 2009). Groundwater within these formations is confined by the overlying low-permeability glacial till; with the groundwater likely being contained within fractures in the Nonesuch Shale, and in both fractures and some open pore spaces within the Copper Harbor Conglomerate.

AECOM (2009) reported the measured hydraulic conductivity of the Nonesuch Shale to be between 9.32×10^{-8} and 7.44×10^{-4} cm/s, based on nine field measurements; with a geometric mean value of 4.51×10^{-6} cm/s. Eight field measured hydraulic conductivity values in the Copper Harbor Conglomerate ranged from 6.20×10^{-8} to 6.54×10^{-3} cm/s, with a geometric mean value of 4.07×10^{-6} cm/s.

3.3.2.2 Depth to Groundwater, Elevations, Gradients and Flow

The depth to groundwater varies beneath the project area and by geologic unit. Depth to groundwater measurements from the regional wells installed by AECOM suggest water levels within the glacial overburden ranging from at or near ground surface, to as much as 30 to 50 ft below ground surface. Within the Copper Harbor Conglomerate, the depth to groundwater is suggested to vary between 2 and 70 ft below ground surface, while the depth to groundwater in the Nonesuch Shale is likely between about zero and 100 ft.

As part of their work on the project, AECOM has prepared groundwater elevation (potentiometric surface) maps for the overall site. These maps were updated in April, 2011 to include additional monitoring wells completed in the southern part of the project area. Measured groundwater elevations in the glacial overburden were found to vary from about 900 feet above mean sea level (ft amsl) in the south, near the proposed TDF, to 640 ft amsl near the shoreline of Lake Superior. In the Copper Harbor Conglomerate, measured groundwater elevations ranged from about 800 ft amsl in the southern portion of the project area to 725 ft amsl near the contact with the Nonesuch Shale. Within the Nonesuch Shale, measured groundwater elevations ranged from about 790 ft amsl in the southeastern part of the project area to about 600 ft amsl at the Lake Superior shoreline. It should be noted that some of these readings indicated groundwater levels above the existing ground. It is uncertain whether these readings might be attributed to pressurized conditions due to overlying materials, and it has been suggested that the groundwater conditions at the proposed TDF location be reviewed during future stages of the design.

In all cases, groundwater flow directions indicated by the potentiometric surface maps are generally to the northwest. Local variations in the potentiometric surfaces indicate flow components ranging from the northwest to the north in the Copper Harbor conglomerate, and from the northwest to the west in the Nonesuch Shale.

AECOM (2009, 2011) prepared the following analysis of groundwater gradients within the subsurface hydrogeologic units:

- Glacial Overburden: 0.0210 average horizontal ft per ft (dimensionless),
- Nonesuch Shale: 0.0244 average horizontal, and
- Copper Harbor Conglomerate: 0.0256 average horizontal.

Using the geometric mean values for hydraulic conductivity in the respective hydrogeologic units, suggested by AECOM, the anticipated groundwater movements due to the above noted gradients are shown on the following page.

Hydrogeologic Unit	Hydraulic Conductivity cm/s	Gradient ft/ft	Average Groundwater Movement (Darcian Velocity)		
			cm/s	ft/day	inches/yr
Glacial Overburden	1.91×10^{-5}	0.021	$4.01 \times 10E^{-7}$	1.14×10^{-3}	5.0
Nonesuch Shale	4.51×10^{-6}	0.0244	1.10×10^{-7}	3.12×10^{-4}	1.4
Copper Harbor Conglomerate	4.07×10^{-6}	0.0256	1.04×10^{-7}	2.95×10^{-4}	1.3

These values, also known as Darcian velocities, are the product of hydraulic conductivity and the respective gradient. These should not be considered as actual velocities, but rather the total seepage flux per unit area. When converted to inches per year, the specific seepage fluxes are also comparable to volumes of groundwater flow that may be expected from annual recharge, on a unit area basis, as described in Section 3.3.3.

The groundwater pore velocity is obtained by dividing the specific seepage, Darcian velocity, by the effective porosity of the material. Using textbook values assumed for effective porosity in the respective hydrogeologic units, the following presents an analysis of the average linear horizontal groundwater pore velocity:

Hydrogeologic Unit	Average Groundwater Movement (Darcian Velocity)		Porosity	Average Linear Pore Velocity	
	ft/day	inches/yr		ft/day	inches/yr
Glacial Overburden	1.14×10^{-3}	5.0	0.5	2.28×10^{-3}	10.0
Nonesuch Shale	3.12×10^{-4}	1.4	0.05	6.24×10^{-3}	27.3
Copper Harbor Conglomerate	2.95×10^{-4}	1.3	0.1	2.95×10^{-3}	12.9

These figures indicate that groundwater movements beneath the site are very slow.

3.3.3 Possible Effects of Mine Development

In general, the major foreseeable effects of mine development to groundwater resources will be to alter the groundwater flow regime in the area of the underground mine due to mine dewatering. The TDF will also alter the groundwater recharge occurring over the facility footprint and replace it with seepage from the TDF. The latter effect is expected to be relatively minor due to the very low hydraulic conductivity of the glacial till overburden, as described in Section 3.3.2.1.1, which currently limits the amount of infiltration occurring and will limit the amount of seepage from the TDF. However, the effects will also be dependent upon the type of liner installed at the base of the TDF. As mentioned previously, and described further in Section 5.4, three liner systems were contemplated and evaluated, as follows:

- Case 1 (In-situ Soil Liner)
- Case 2 (Full Drainage Blanket)
- Case 3 (TSF Prescriptive Liner)

To assess the potential seepage impacts, steady-state, Darcian unit area fluxes for each liner configuration have been calculated in a 1D columnar approach with the following assumptions made for the materials:

- 35 ft thickness of native, in-situ glacial till with an average hydraulic conductivity of 2 x 10^{-8} cm/s as determined from the recently completed testing described in section 3.4 (all three cases),
- 1 to 3 ft thickness (Case 2 and Case 3 respectively) of engineered (recompacted) clay with average hydraulic conductivity of 1 x 10^{-7} cm/s,
- Geomembrane liner of 60 mil (1.5 mm) thickness with assumed hydraulic conductivity of 1 x 10^{-11} cm/s (Case 3 only),
- Drainage layer that reduces the average head to 1 ft over the geomembrane of head over perforated pipe network (Case 2 only), and
- Average 78 ft thickness of tailings (average depth for the TDF at full development) assumed to exert hydrostatic pressure-head on liner representing the long-term, steady state pressure exerted by the tailings, unless drainage layer is present (Case 2) in which case the head is reduced to 1 ft.

The calculations involved first determining the average vertical permeability (i.e., the harmonic mean of hydraulic conductivity values given above) of each column and then the vertical gradient and flux rate from the base of the tailings to the base of the 35 ft of in-situ, native clay. Calculated bottom flux rates are shown on Figure 3.1. Due to low in-situ permeability of the in-situ clay, the addition of a geomembrane liner achieves only a 25 percent reduction in bottom flux. However, the installation of a drainage layer over the clay to reduce the head on the clay to 1 ft, without a geomembrane, reduces calculated bottom flux by nearly two orders of magnitude.

Liner System Case	Calculated Flux Rate inches/yr
Case 1	0.42
Case 2 (drain open)	0.007
Case 2 (drain closed)	0.55
Case 3	0.55

The calculated bottom flux rates for seepage from the TDF may be directly compared to the values of natural groundwater flux under the TDF determined in Section 3.3.2.2. It is noted that the groundwater flux rate of 5.0 in/yr for the glacial overburden is presently considered a high value based on the relatively high average permeability assumed (AECOM, 2009). However, both bedrock units (i.e., Nonesuch Shale and Copper Harbor Conglomerate) have calculated groundwater flux rates of about 1 in/yr, which at about 3 percent of annual precipitation in the region are considered reasonable.

Possible effects to groundwater quality may be qualitatively estimated by comparing the calculated bottom flux rates to a groundwater flux rate of 1 in/yr. The drainage layer (Case 2) is the only liner configuration that will reduce bottom flux to achieve substantial dilution with respect to the underlying groundwater flux.

While the columnar model estimates the unit flux rates out of the TDF based on the steady state assumptions listed above, including an average hydrostatic pressure-head of 78 ft for all but the Case 2 (drain open) liner system, modeling was also conducted on the conceptual closure cover to estimate the potential long-term infiltration into the facility. Based on that modeling, presented in Section 5.10.2, the average annual seepage flux through the TDF conceptual closure cap was estimated as 0.21 ± 0.01 inches. Comparing this with the flux rate modeling using the columnar approach it can be seen that the unit flux rate from the bottom of the TDF will be controlled by the amount of infiltration through the closure cap for the Case 1, Case 2 (drain closed), and Case 3 liner systems.

3.4 Geotechnical Site Investigation

3.4.1 General

The foundation materials beneath the TDF site consist of glacial till typically underlain by the Copper Harbor Conglomerate formation bedrock. The Nonesuch Shale formation contains the ore body host rock, but is located to the north-northwest of the TDF. A geotechnical investigation of the area under and closely surrounding the TDF site was conducted in early 2011 as part of this PFS to support the design of the TDF. This investigation was completed by Coleman under the direction and partial supervision of Knight Piésold. The investigation consisted of excavating test pits and drilling geotechnical boreholes to visually inspect and sample the subsurface materials and carrying out certain in-situ and laboratory tests to evaluate their geotechnical properties. The information gathered was supplemented with information obtained during previous site investigations by Coleman and regional information by AECOM. Details of the 2011 site investigation, including detailed logs of the test pits and boreholes, and the results from the in-situ and laboratory testing, are presented in Appendix B.

3.4.2 Glacial Till

The glacial till overburden material encountered during the site investigation appears to be largely homogeneous, and was estimated to vary in thickness from 20 to 120 ft, over the proposed TDF site. A majority of this material classifies as a lean clay (CL) with some silt and sand, and occasionally trace gravel, according to the Unified Soil Classification System (USCS). Several localized pockets of silty sand (SM) were identified, but they range in thickness from less than 1 ft to 2 ft and do not appear to be continuous.

The in-situ and laboratory testing of the on-site materials generally involved the following:

- Index testing (Atterberg limits, natural moisture content, specific gravity),
- Moisture-density testing (both Standard and Modified Proctor tests),
- Permeability testing,
- Compressibility testing,
- Shear strength testing, and
- In-situ SPT testing.

3.4.2.1 Index Testing

The glacial tills were found to have liquid limits between 25 and 40 (average 29.5), plasticity indices between 10 and 20 (average 15.1), and in-situ moisture contents between 5 and 20 (average 13.3). The samples with lower moisture contents were generally from higher elevations in a drier, near surface crust of the till, while the samples with higher moisture contents were generally from lower levels within the till. These index tests were performed on both disturbed and undisturbed samples. The solids within the soil were determined to have specific gravity of approximately 2.64, which is consistent with this type of material.

3.4.2.2 Moisture Density Testing

Both Standard and Modified Proctor tests were performed on bulk, disturbed samples from the test pits to estimate moisture-density relationships and to evaluate potential construction materials for the TDF embankment. The two separate testing procedures were utilized to determine the effect of different compaction efforts. The Modified Proctor test imparts a much higher compactive effort, compared to the Standard Proctor test, and resulted in an average Optimum Moisture Content (OMC) of 8.6 percent, and an average Maximum Dry Density (MDD) of 134.2 pounds per cubic foot (pcf). Standard Proctor testing of the materials resulted in averages of 11.6 percent for the OMC and 122.5 pcf for the MDD. The OMC for both the Standard and Modified Proctor tests were determined to be below the average natural

moisture content and well below the higher moisture contents of the till. This suggests that, during construction, some drying of the material will be required before it is placed as fill into the TDF embankment. Placement and compaction of material significantly wet of optimum can be problematic due to the increased potential for pore-pressures to build up in the fill, which could lead to embankment instability.

3.4.2.3 Permeability Testing

Permeability testing was performed on the glacial till material using several techniques. In-situ testing was performed using down-hole falling head tests in standpipe piezometers installed within the boreholes, and laboratory testing was carried out using flexible-wall, constant head permeability methods in the triaxial cell. The test results suggest that the permeability of the material below the TDF site ranges between approximately 1×10^{-7} and 1×10^{-9} cm/s. The geometric mean of the laboratory testing was 5.1×10^{-9} cm/s, while the geometric mean of the in-situ testing was 1.5×10^{-8} cm/s. Most likely the laboratory test results were lower because they do not account for small field discontinuities that the in-situ tests typically will. These results show that the TDF foundation and embankment fill material can be expected to have low hydraulic conductivities. While this will be beneficial for seepage control from the TDF, these materials will have higher potential to develop excess pore pressures when compacted for construction of the TDF embankment or in the foundation under the embankment. This will need to be monitored during construction to mitigate the potential for undrained slope instability.

3.4.2.4 Compressibility Testing

The compressibility characteristics of the till materials at the TDF site were estimated by Oedometer testing. This test provides several compressibility parameters, including the coefficient of consolidation (a measure of the rate of compression) and coefficient of compressibility (a measure of the amount of compression). The coefficient of permeability can also be calculated from these two parameters.

At low stresses in the Oedometer tests, the average values for the coefficient of consolidation and coefficient of compressibility were found to be 1.7×10^{-3} cm^2/s and 6.7×10^{-5} 1/kPa, respectively. At high stresses, these averages were found to be 1.6×10^{-3} cm^2/s and 5.1×10^{-5} 1/kPa, respectively. Over these same stresses the calculated coefficient of permeability was found to be 1.6×10^{-8} and 1.9×10^{-9} cm/s, which is in good agreement with the previously stated permeability testing. Along with these material properties, the compression index was calculated over the entire stress range of the testing, and resulted in an average of 0.15. The overconsolidation ratio (OCR) of the samples was estimated to range between 2.4 and 1.7, with an average of 2.0. These values are consistent with materials which are slightly overconsolidated. These results indicate that the time rate of consolidation of the till is quite slow but the amount of compression can be significant. This is consistent with a material that can generate excess pore pressures when loaded and compacted, and confirms that monitoring of these pore pressures during construction will be important. The final design of the TDF should investigate limits on the rate of construction.

3.4.2.5 Shear Strength Testing

Shear strength parameters of the glacial till were estimated using three different testing techniques, as follows:

- Unconsolidated, undrained (UU) triaxial testing,
- Isotropically consolidated, undrained (ICU) triaxial testing with pore pressure measurements, and
- Direct shear testing.

All three tests were performed under saturated conditions on undisturbed samples obtained from thin wall Shelby tubes extracted from the boreholes, and on block samples from the test pits.

3.4.2.5.1 UU Testing

This test is carried out in the triaxial cell at a rapid rate of loading with no drainage of the sample. The sample is not consolidated prior to shearing and pore pressures are not measured. The results give an estimate of the undrained (total stress) shear strength parameters for the material.

From the test results, it was observed that the undrained shear strength varies with depth. To more accurately model stability behavior of the TDF, three layers were assumed and undrained shear strengths were estimated based on the test results. The top 5 ft of material was assumed to be desiccated, and was assigned an undrained shear strength of 153 kPa [1.6 tons per square foot (t/ft^2)]. Below this, a 30-ft-thick layer was modeled with an undrained shear strength of 120 kPa (1.25 t/ft^2). Below the depth of 35 ft, the undrained shear strength was estimated to be 153 kPa (1.6 t/ft^2).

3.4.2.5.2 ICU Testing

This test is carried out in the triaxial cell after the sample is consolidated to a predetermined stress level. Loading is then applied under undrained conditions but the pore pressures created in this loading stage are measured. The results give an estimate of both undrained (total stress) and drained (effective stress) shear strength parameters. On average, these tests estimated the undrained shear strength parameters to be approximately 127.4 kPa and 21 degrees, and the drained shear strength parameters to be 0 kPa and 29 degrees, for the associated cohesion and friction angles, respectively. It should be noted that one sample classified as silty sand (SM), and was estimated to have considerably higher shear strength parameters than the tests classifying as a lean clay (CL). This one sample is considered to be only representative of small, localized, and isolated zones of slightly coarser material.

The majority of the till material was found to classify as a lean clay (CL). These lean clays are estimated to have an effective friction angle of approximately 25 degrees from the results of the shear strength testing; however, the rate of loading in the ICU triaxial tests was quite high considering the low-permeability of the material and this could result in a slight under-estimate of the strength of the material. To investigate this, the correlation between the friction angle of a normally consolidated clay and its plasticity index, proposed by Mitchell (1976), was also used to estimate the effective shear strength of the glacial till. This correlation resulted in effective friction angles between 27 and 32 degrees.

It should be noted that the in-situ clays are slightly over-consolidated, but this correlation can still be considered reasonable. For the purposes of the TDF stability analyses, discussed in Section 7.0, an effective friction angle of 30 degrees was assumed to be appropriate for the glacial till material. Additional ICU triaxial testing, focusing on shearing the samples at a lower rate of loading, is recommended during detailed design.

3.4.2.5.3 Direct Shear Testing

Direct shear testing measures the resistive strength along a pre-defined horizontal plane. The glacial till material at the Copperwood site was tested to investigate the strength along potential slip surfaces. In this test, no pore pressure readings are taken and only undrained material strengths are determined. These tests resulted in an average cohesion of 25.6 kPa and an average undrained (total stress) friction angle of 25.4 degrees, which is close to but slightly higher than the 21 degree value determined from the ICU triaxial test.

3.4.2.6 In-Situ SPT Testing

In-situ Standard Penetration Tests (SPTs) were performed in the boreholes to evaluate the consistency of the subsurface materials beneath the proposed TDF footprint. SPT testing measures downhole resistance to the advancement of a split-spoon sampler due to successive impacts from a falling weight. The number of impacts (blow counts, N-values), to move the sampler the last 12 inches of an 18-inch run, are used to correlate strength and consistency parameters of the in-situ soil. The SPT tests conducted showed that N-values generally increased with depth, which indicates that the undrained strength of the till also likely increases with depth. This is consistent with the UU test results. The SPT test results

indicate that the till is medium dense, which is consistent with the slightly overconsolidated condition described earlier.

Typical SPT blow count profiles, with depth, can be seen on Drawings 132 and 134.

3.4.3 Bedrock

Bedrock below the TDF site is of the Copper Harbor Conglomerate formation. This material has been described as a sedimentary rock containing many rounded pebbles cemented together by finer materials. These particles are often durable igneous rock. In-situ packer testing was performed in the bedrock to estimate its coefficient of permeability, and resulted in an average value of 1.2×10^{-6} cm/s. It should be noted that this is approximately two orders of magnitude greater (more free-draining) than that of the overburden till.

As stated previously, the other bedrock formation in vicinity of the proposed TDF is the Nonesuch Shale, which is mainly located to the north-northwest of the TDF site. No boreholes from the 2011 geotechnical site investigation intersected the Nonesuch Shale formation.

Section 4.0 - Design Criteria

This section outlines the criteria used for the PFS design of the Copperwood Project TDF and ancillary structures.

The main design criteria used in developing the TDF and ancillary structures were as follows:

- Staged TDF configurations generally account for input from Orvana, the current mine production plan from Marston, and two-sided consolidated tailings dry densities determined from laboratory testing. The staged TDF tailings storage capacities are summarized as follows:

Stage	Storage through Year	Storage Mass Mt	Dry Density tons/yd^3 (2)	Storage Volume Myd^3 (2)
1	3	2.63	0.89	2.95
2	6	9.61	0.97	9.89
3	9	17.07	1.01	16.84
4	12	24.56	1.04	23.53
5	16(1)	32.27	1.07	30.32

1. Tailings deposition is planned to start in November of Year 1, and conclude in January of Year 16. Years 1 and 16 are therefore short years and the overall life of operations will be approximately 14.25 years.
2. Million cubic-yards (Myd^3), tons per cubic yard (t/yd^3)

- 0.25 percent tailings slope,
- 2.5H:1V (horizontal to vertical) exterior slopes for the TDF impounding embankment,
- 2H:1V interior slopes for the TDF impounding embankment,
- 40 ft minimum crest width for the TDF impounding embankment,
- Approximate offset distances from existing or planned site features, which limited the extents of the TDF:
  - 200 ft from Section 5,
  - 150 ft from the apparent crests of the two major surrounding stream beds (Namebinag Creek to the west and a tributary of Gipsy Creek to the east),
  - 250 ft from the NCNST,
  - 30 ft from the sub-crop delineation boundary of the underground mine.
- Excavation into the glacial till within the TDF basin was conducted based on borehole results from the 2011 geotechnical site investigation, described in Section 3.4, to enable reduction in the ultimate TDF embankment height, and yet still maintain in-situ low-permeability material for containment. The basin excavation surface was developed as follows:
  - No excavation on the southern side and in the southwestern corner of the TDF basin in the areas of boreholes BH04, BH11, and BH12,
  - 12 ft at the location of AECOM monitoring well MW-10-120,
  - 20 ft in the southeast corner of the ultimate TDF basin and in the locations of boreholes BH01, BH05, and AECOM monitoring well CW-08014,
  - 25 ft in the location of AECOM monitoring well MW-10-134,
  - 30 ft in the location of borehole BH06, and

- 35 ft in the location of borehole BH09

The above, and additional, design criteria details are presented in Table 4.1. The current mine production schedule, completed by Marston, is presented in its entirety in Table 4.2.

Section 5.0 - Pre-Feasibility Design of Tailings Disposal Facility

5.1 General Arrangement and Staged Development Plans

5.1.1 General Arrangement

The Copperwood TDF has been designed to account for the subsurface conditions encountered at the site, anticipated fill materials, water and tailings storage requirements, and the physical characteristics of the tailings.

The TDF will be located in the southeast portion of the Copperwood Project site, within Sections 6, 7, and 8. It will be developed in five stages over the life of the project, with the ultimate configuration designed to store approximately 14.25 years and 32.3 Mt of tailings production. The Stage 5 facility footprint will extend approximately 2,200 yds in the east-west direction, 1,000 yds in the north-south direction, and will cover approximately 346 acres. The TDF overall site plan is presented on Drawing 120 while the current mine production schedule is presented in Table 4.2.

The TDF has been designed such that each stage will accommodate approximately three years of tailings production from the current mine plan. The impounding TDF embankment will be constructed using conventional downstream methods, meaning the upstream toe will remain fixed while the downstream toe will progressively advance downstream as the embankment height increases. The embankment crest elevations for each stage were estimated using the current mine production schedule and the storage capacity curves developed for the TDF basin. The TDF storage capacity versus embankment elevation and time curve, assuming the tailings surface is sloped at minus 0.25 percent from the southeast to northwest corner of the TDF, is presented on Figure 5.1. Figure 5.2 presents a comparative storage capacity curve which considers a horizontal tailings beach. Both filling curves assume the TDF basin floor is constructed with a full drainage blanket, the Case 2 liner system described further in Section 5.4, thereby providing two-sided drainage for consolidation of the tailings mass.

5.1.2 Stage 1 Tailings Disposal Facility

The Stage 1 TDF will consist of a significant excavation in the till within the facility basin and placement of this material into the initial impounding embankment around the west, north, and east sides of the TDF. The depth of till material available for excavation typically increases from south to north across the site. The amount of targeted excavation from the Stage 1 basin exceeds that required for embankment construction, on a straight cut-to-fill basis, to store the Stage 1 (first 3 years) tailings production; however, the Stage 1 TDF was designed to be overbuilt to elevation 930 ft in agreement with Orvana. The objective of the basin excavation was to generate more tailings capacity and recover a greater amount of fill material when it is available in order to reduce the overall amount of embankment fill and the amount of external borrow required for the overall TDF development.

The Stage 1 embankment will be constructed from the basin excavation material as well as approximately 300,000 yd^3 (per Marston) to be generated from the mine opening box-cut. Additional material requirements for the Stage 1 TDF will include imported drainage aggregate for the embankment drains and blanket underdrain covering the prepared basin floor as well as riprap material for erosion protection on the embankment upstream face.

In addition to the basin and embankment components, the Stage 1 TDF will include the TDF decant structure, outlet pipe, and decant sump and overflow pond. The decant structure will remove water from the supernatant pond on the surface of the tailings for recycle back to the process and/or in the latter years of the mine life for water treatment and release.

The Stage 1 TDF footprint will cover approximately 161 acres, around which a 20-ft-wide perimeter road will be constructed. Stage 1 will be constructed during the project pre-production period such that it will

be available for the start of tailings deposition in Year 1 of the current mine production schedule. The Stage 1 TDF layout is presented on Drawing 140.

5.1.3 Stage 2 Tailings Disposal Facility

Similar to the Stage 1 TDF, the Stage 2 expansion will involve an excavation into the bottom of the tailings basin to generate more storage capacity and provide fill for the embankment. In Stage 2 this excavation will also be in excess of that required for a straight cut-to-fill balance required to store the second three years of tailings. The Stage 2 expansion will be on the uphill side and to the immediate south of the Stage 1 TDF and will involve expanding the blanket drain on the basin floor over the increased TDF area. The embankment will be extended around the east and west sides of the TDF at elevation 930 ft but the majority of the Stage 2 construction will consist of fill placement on the downstream side of the Stage 1 embankment to elevation 875 ft. The embankment drains will be extended through this downstream fill. A raise to the TDF decant structure will not be required since the crest elevation of the embankment will not change.

At the end of Stage 2, the majority of the ultimate TDF basin, including the extension of the basin drainage blanket and collection pipes, will have been developed. The Stage 2 layout is presented on Drawing 142.

The expanded Stage 2 TDF will cover approximately 282 acres, around which the 20-ft-wide perimeter road will be extended. Stage 1 will be constructed during the third year of operations such that it will be available for the start of year 4 of the current mine production schedule.

5.1.4 Stages 3 through 5 Tailings Disposal Facility

Stages 3 through 5 of the TDF will consist largely of downstream raises to the TDF embankment. The Stage 3 facility will include a small amount of cut from the final (southeast) area of the basin to be expanded into, but the majority of the fill required for the embankment in Stages 3 through 5 will be sourced from exterior borrow areas. Stages 3 through 5 will also involve extensions to the embankment drains and basin drains where applicable. Additionally during each of these stages, the TDF decant structure will be raised. The expanded Stage 3 TDF will cover approximately 321 acres, while Stage 4 and Stage 5 TDF configurations will cover approximately 346 acres. The layouts for the Stages 3 through 5 TDF are presented on Drawings 144 thru 148.

5.2 Tailings Characteristics

This section describes the tailings production rate from the current Copperwood Project mine schedule, and the tailings physical and geotechnical characteristics as determined from laboratory testing. This information was used as a basis for the TDF PFS design.

5.2.1 Tailings Production

Based on the current mine schedule completed by Marston, the Copperwood tailings will be produced at a variable rate over the project life. Tailings will be produced from the mill at a rate of 2.5 Mt per year after Year 4 of operations, excluding the shortened Year 16 which will produce 0.1 Mt, but prior to that will follow a ramp up rate as follows:

- Year 1 – 0.1 Mt
- Year 2 – 0.7 Mt
- Year 3 – 1.8 Mt
- Year 4 – 2.0 Mt

It is assumed that mine production will occur 365 days per year over the approximate 14.25 year mine life (end of Year 1 to the beginning of Year 16), and will result in approximately 32.3 Mt of tailings for disposal. Tailings will exit the plant as slurry with an approximate 50 percent solids content. If necessary, owing to the fine particle sizes of the tailings as described later in this section, the slurry will be dosed with a flocculent to accelerate initial settling in the TDF and to clarify the supernatant water. Tailings delivery, including flocculation and deposition, is discussed further in Section 5.7.

5.2.2 Tailings Physical and Geotechnical Testing

During the course of the PFS, a comprehensive testing program was conducted on three tailings samples provided by Orvana as being representative of the material that may be produced over the life of the project. The samples received, suffixed with the metallurgical test from which they were generated, included:

- WPC-1,
- WPC-2, and
- WPC-4.

Each sample was tested for physical and geotechnical characteristics to evaluate the anticipated behavior under deposition and to estimate the densities and rates of consolidation that may be achieved within the TDF. Basic index testing of the tailings samples included determination of particle size distributions, Atterberg limits, specific gravity, and as received solids contents. Sedimentation, classical consolidation testing (Oedometer testing), and Seepage Induced Consolidation (SIC) testing, were also performed on the WPC-1, and WPC-4 samples, with the WPC-4 sample tested under both flocculated and unflocculated conditions. The results of this testing were used as input to the proposed deposition plan and to size the staged configurations of the TDF over the life of the project. The chemical characteristics of the tailings solids, pore water, and leachate have been investigated and reported by others and are not provided herein.

The index test results indicate that the tailings can be classified as a lean clay (CL) according to the Unified Soil Classification System (USCS). The tailings samples were found to have 100 percent of their particles passing the No. 200 sieve (fines), which is quite fine-grained for copper tailings. The material was also found to have a liquid limit of 33 and a plasticity index of 13, confirming the presence of clay mineralogy and thus supporting the flocculent addition to assist in liquid/solids separation. The material specific gravity was determined to be 2.8.

Sedimentation testing was conducted in 1 liter cylinders to estimate the settled tailings density under low effective stress conditions for three classic deposition conditions, comprising the following:

- Undrained, representing subaqueous deposition without bottom drainage where, during the laboratory testing, decant water is not removed from the top of the tailings in the test cylinder, and bottom drainage is not allowed.
- Drained, representing removal of water during deposition through progressive decantation off the top of the tailings column and continuous drainage from the bottom of the sample.
- Settling and Air Drying, representing rotational thin layer deposition with air drying between the deposition cycles. Decant water is removed from the surface of the tailings as it is released from the solids and air drying is allowed to de-saturate the tailings. This allows the development of soil suctions that increase the effective stress and tailings density.

Additional sedimentation and low-stress consolidation tests were conducted in a manner similar to the drained settling test. However, during this test the bottom drain was initially held closed such that initial sedimentation would occur without bottom drainage; this can be viewed as somewhat representative of deposition conditions during the initial stages of operating the TDF. Once initial settlement was

completed, the bottom drain was opened causing a seepage force to develop through the sample, thereby inducing consolidation under low effective stress.

Conventional Oedometer testing was also performed on the tailings samples to evaluate the consolidation characteristics of the material at high effective stresses. This test was performed by depositing the slurry into a conventional thick-walled ring with a porous platen on the top and bottom of the sample. Uniform but progressively increasing loads were then applied and the sample was allowed to consolidate under each load; with measurements made of the time rate and amounts of consolidation under each load.

The SIC test is a state-of-the-art laboratory test that quantifies the non-linear, large-strain consolidation characteristics of soft soils, such as tailings slurries, and covers the full range of effective stresses from low to high. The advantage of this test is the precise control and measurement capabilities at all stress levels. The first step in the test involved applying a seepage force across the sample to represent loading at very low effective stress. This force is incrementally increased to quicken the rate at which the sample consolidates. Once the sample has consolidated under a prescribed seepage-induced stress, the loading mechanism is switched to a pneumatic piston, and the test is continued at higher stress levels, similar to the Oedometer test. Under these applied loads, permeability measurements can be made by inducing a low-flow across the sample. The data from the SIC test is reduced using a software package called SICTA (Seepage Induced Consolidation Testing Analysis), which uses two power functions to represent the void ratio vs. effective stress and void ratio vs. permeability relationships of the sample.

The settlement and sedimentation, low-stress consolidation, high-stress consolidation, and SIC testing results are presented in Appendix D. Relatively good agreement was achieved between the low-stress consolidation, high-stress consolidation, and seepage induced consolidation testing in terms of the void ratio versus effective stress and void ratio versus hydraulic conductivity relationships. The coefficient of volume compressibility (m_v) was found to range from approximately 2×10^{-4} to 4×10^{-6} (1/kPa) and the hydraulic conductivity was found to range from approximately 5×10^{-6} to 1×10^{-8} cm/s. These material properties suggest that the tailings will be highly compressible, and that the time rate of consolidation will be relatively slow due to the low hydraulic conductivities estimated, over the range of stresses expected.

From the laboratory testing and consolidation modeling, a predicted dry density profile for the tailings deposit was developed using the SIC test results on the WPC-4 tailings that assumed the addition of a second dose of flocculent at the point of deposition. The calculation also assumed that the tailings deposit will be drained at its base and this will involve the installation of a drainage blanket under the tailings, which is the current design. This density profile together with the depth versus capacity characteristics of the TDF and the rate of tailing discharge into the TDF were then used to estimate the staged embankment crest elevations over the life of the project. Additionally, the same modeling procedure was performed considering no underdrainage to quantitatively assess the benefit of its installation. The result of this modeling is shown in Figure 5.3 as the average density vs. tailings surface height profile. From this plot, it can be seen that the current TDF configuration will only hold approximately 13.9 years of the tailings production if an underdrain is not installed within the basin.

5.3 Embankment Configuration

The TDF impounding embankment has been designed as a zoned, water containment dam that will be constructed using the conventional downstream method. In this method the upstream toe remains fixed while the centerline and downstream toe progressively advance to the downstream as the embankment height increases. A typical section of the stage-developed embankment is shown on Drawing 150. The embankment will consist of four general zones:

- Seal Zone (Zone 1) – This zone will be comprised of moisture conditioned and well compacted low-permeability glacial till from the site to reduce seepage through the embankment,
- Chimney Drain (Zone 2) – This zone will be comprised of relatively high-permeability filter and drainage materials that will serve as a hydraulic break between the Seal Zone and Downstream Shell and to

collect small amounts of seepage that pass through the Seal Zone. It will also protect the downstream side of the Seal Zone from internal erosion,

- Downstream Shell (Zones 3 and 4) – The Downstream Shell will provide structural stability to the embankment. It has been designed with upstream and downstream zones that will be constructed from the local glacial till material but with different compaction efforts in order to reduce the cost to the project.

In addition to these four embankment zones, a riprap layer will be installed on the upstream face of the embankment to protect the Seal Zone from erosion due to direct precipitation and wave action on the surface of the supernatant pond. Partial drainage blankets, of the same relatively high-permeability material as the Chimney Drain, will be constructed at the base of the embankment Downstream Shell for stability reasons to lower any phreatic level or construction related pore pressures that may develop in this zone. Localized mid-height finger drains will also be installed in portions of the Downstream Shell where the embankment ultimate height will be greater than 100 ft to assist in reducing construction related pore pressures. The mid-height and base drains will serve to reduce the seepage path lengths in the fill for more rapid dissipation of excess pore pressures that could develop during construction of the embankment. The mid-height drains, where installed, would be located approximately 60 to 70 ft above the base of the embankment. The embankment drains are discussed further in Section 5.5.

The embankment will be founded on in-situ till and foundation preparation will include topsoil and unsuitable materials removal followed by rough grading and proof rolling of the graded surface.

The upstream Seal Zone (Zone 1) and Downstream Shell (Zones 3 and 4) will be constructed from till excavated from within the tailings basin, or from similar till from nearby and on-site borrow sources. This material is anticipated to be relatively fine-grained and clayey with in-situ moisture contents greater than optimum. Some drying of these materials will be desirable but placement will most likely remain at least slightly wet of optimum (Section 3.4.2.2). While these embankment zones will be constructed with similar and likely consistent materials, the lift thicknesses and compaction efforts will differ by zone. Currently it is envisioned that the materials placed into Zones 1, 3, and 4 will be placed and compacted in lifts not to exceed 1, 2, and 4 ft, respectively and the compaction efforts will be established from the results of test pads carried out just prior to construction.

The riprap and drainage materials will be obtained from local sources. Filter and drainage sand will likely be obtained from regional commercial suppliers; a couple of which, Connors Pit and Lakes Pit, provided samples for geotechnical testing.

These materials were tested for specific gravity and particle size distribution in Knight Piésold's geotechnical laboratory. An average specific gravity of 2.7 was estimated from the laboratory testing. The particle size distribution testing shows that these materials classify as a uniformly graded sand (SP) according to the USCS. The Connors Pit samples (CP1 and CP2) were shown to contain approximately 5.5 and 4.5 percent passing the #200 sieve, while the Lakes Pit sample (LP1) contained a higher amount of fines with roughly 8.3 percent passing the #200 sieve. Typically drainage material is specified to contain less than 5 percent fines to reduce the amount of material that might interfere with process operations. Material permeability and soundness were not investigated at this time, but should be evaluated during future stages of the project.

Dependent on potential environmental restrictions, riprap may be produced from either on-site or off-site quarries in the Copper Harbor Conglomerate. A few outcrops at the south end of the site appear to be viable sources; however, an investigation of the outcrops is needed to confirm if sufficient quantity is available. This, together with testing of the rock for durability and hardness, should be done in the detailed design phase of the TDF.

The ultimate and intermediate stages of the TDF embankment were designed with 40 ft crest widths, downstream slopes of 2.5H:1V (horizontal:vertical), and upstream slopes of 2H:1V. The flatter

downstream slope was required for long term stability and access during reclamation. The steeper upstream slope was allowed because it will be buttressed by the tailings and will not be reclaimed.

5.4 Basin Preparation and Arrangement

The TDF interior basin will be fully developed in Stages 1 through 3. Basin preparation will initially include removal and stockpiling of topsoil and unsuitable materials and the removal of vegetation. The locations and designs of these stockpile facilities have not yet been defined and will be completed during futures stages of the project. Subsurface till will be excavated to defined lines and grades to increase the storage capacity of the TDF and to provide construction materials for the TDF embankment.

The current design contemplates that the depth of basin excavation will range from approximately 0 to 35 ft, increasing from south to north and following the trend of increasing depth to bedrock. These depths were established from the boreholes drilled as part of the 2011 geotechnical site investigation, as described in Section 4.0.

After excavating to the design basin surface, the TDF basin will be completed by incorporating one of three liner systems evaluated as part of this PFS level design. The final liner system will be chosen and advanced during detailed design, but Case 2 is currently considered to be the most favorable as it limits seepage from the facility to the greatest extent. The three liner systems evaluated include the following:

- Case 1 (In-situ Soil Liner)
- Case 2 (Full Drainage Blanket)
- Case 3 (TSF Prescriptive Liner)

The fluxes anticipated for each liner system, based on the assumptions outlined in Section 3.3.3, were determined to be:

Liner System Case	Calculated Flux Rate inches/yr
Case 1	0.42
Case 2 (drain open)	0.007
Case 2 (drain closed)	0.55
Case 3	0.55

Based on the assumptions utilized, these fluxes can be viewed as relative fluxes, but may not represent actual total fluxes for the liner systems. As discussed previously, the thickness of the glacial till is estimated to vary from 20 to 120 ft across the proposed location of the TDF, and this will affect unit area fluxes developed.

The following sections discuss details of the liner system alternatives as well as their respective advantages and disadvantages.

5.4.1 Case 1 Liner System (In-Situ Soil Liner)

The Case 1 liner system uses the in-situ material to form the TDF basin liner. This will consist of the underlying glacial till material, which was determined to have a low coefficient of permeability of approximately 2 x 10^{-8} cm/s, to reduce the amount of seepage from the TDF. This liner system is shown in detail on Drawing 154.

The advantage of this liner system is its reduced cost because the in-situ; native ground will be used for hydraulic containment. The estimated thickness of the in-situ, low-permeability material across the TDF site, 20 to 120 ft, is much thicker than any typical engineered soil liner.

One disadvantage of this system is that it doesn't allow for bottom drainage of the tailings. The low hydraulic conductivity of the underlying native material, which is approximately two orders of magnitude lower than that of the tailings, will impose an undrained lower boundary condition on the tailings and thus significantly reduce the rate consolidation of the tailings. Large seepage pore pressures will also develop on this undrained boundary.

Based on the seepage flux modeling presented in Section 3.3.3, it is estimated that the Case 1 liner system will function at roughly the same level of hydraulic containment as the Case 3 liner system.

5.4.2 Case 2 Liner System (Full Drainage Blanket)

The Case 2 liner system consists of 1 ft of in-situ material, below the rough grade (excavated) surface, that will be scarified and re-compacted as a prepared subgrade. The objective is to remove any localized small cracks or silty lenses and produce a dense, uniform and low-permeability layer. For the purposes of the design, a target maximum permeability of 1×10^{-7} cm/s was established since it is a conventional value commonly used for soil liners by regulatory agencies. However, this is higher than the average permeability of the in-situ material, at 2×10^{-8} cm/s, and actual permeability values more in line with this are expected. The 1 ft layer will be underlain by the large depth of 2×10^{-8} cm/s in-situ, glacial till material and thus will have little influence on seepage.

The principal feature of the Case 2 Liner is a 1.5-ft-thick layer of drainage aggregate that will be placed above the prepared subgrade on the TDF basin floor. A network of 4 to 6 inch diameter perforated corrugated polyethylene tubing (CPT) lateral and header pipes will be installed within the drainage blanket to collect and transport seepage from the underside of the tailings mass to the decant sump, where it will join collected decant and embankment seepage waters for reclaiming to the process and/or treatment and release. An 8 ounce per square yard (oz/sy) non-woven geotextile filter fabric will be placed between the prepared subgrade and the drainage aggregate to limit the migration of fines from the clayey subgrade into the drain layer. Two layers of 8 oz/sy non-woven geotextile will be placed above the drain layer to limit the migration of tailings into the drainage aggregate and pipe network. The upper layer of fabric will be used principally to protect the lower layer from UV photo-degradation. This liner system is shown in detail on Drawing 156.

The major advantage of this liner system is the significantly reduced pressure head that will act on the prepared subgrade, which will significantly reduce seepage from the base of the TDF. Based on the seepage flux modeling described in Section 3.3.3, it is estimated that this liner system will reduce the seepage rate from the TDF by approximately two orders of magnitude, compared to the undrained Case 1 and Case 3 options. The drainage blanket will also aid in consolidation of the tailings mass by providing bottom drainage in addition to the top drainage provided at the surface of the tailings. This will reduce the seepage path length and increase the time rate of consolidation thus increasing the overall dry density achieved at the end of operations and thereby decreasing the required embankment heights. Notwithstanding this, after reclamation of the TDF closure of the drain may be necessary to conform to permitting requirements for the facility. This would revert the seepage conditions for the Case 2 liner system to those similar to the undrained Cases 1 and 3. While the Case 2 liner system would not provide two orders of magnitude lower seepage from the facility after closure of the drain, it would still provide increased consolidation of the tailings during operations.

One disadvantage of this system is the potential for the filter fabric to become inundated with fines from the tailings, which would impede the rate of drainage from the base of the tailings and reduce the consolidation rate. However, the drain would still serve as a hydraulic break between the tailings mass and the prepared subbase to reduce seepage. Another disadvantage is the added construction time and cost for placing the filter fabrics, drainage pipes, and drainage aggregate. Thirdly, the outlet pipe from this drain will add a point of penetration from the TDF, which can, unless well designed and constructed, become a weak point in the system.

It is estimated that this liner system will add approximately US$7 Million to the total project cost, using the in-situ soil liner system (Case 1) as the base case.

5.4.3 Case 3 Liner System (TSF Prescriptive Liner)

The Case 3 liner system is the same as the prescriptive liner for a TSF under *Michigan's Nonferrous Metallic Mining Regulations, Part 632, R425.409 Treatment and Containment of Reactive Material*, as follows:

> *(A) A stockpile or storage facility shall have a composite liner system comprised of a flexible synthetic membrane that is not less than 60 mils thick and a layer of at least 3 feet of compacted soil having a maximum hydraulic conductivity of 1.0 x 10^{-7} cm/sec.*
>
> *(B) The department may approve an alternative liner system that uses other materials or designs, including modified soil liners, or technologically advanced systems only if the operator provides data to demonstrate the alternative is capable of providing equivalent or better protection as compared to the requirements under subparagraph (A).*
>
> *(C) A stockpile or storage facility shall have a leachate collection system. The system shall be designed, constructed, and operated to limit the hydraulic head at the lowest point in the system to not more than 1 foot, excluding the collection sump, after construction.*

This liner system comprises of a 3 ft compacted, low-permeability ($k<10^{-7}$ cm/s) soil layer placed on the excavated surface with a 60-mil HDPE geomembrane placed directly over top to form a composite liner. A partial drainage blanket will be placed in the northwestern corner of the TDF, under the deepest portion of the tailings mass. This drainage blanket will be similar to that described for the Case 2 liner system, but would only cover a small area in the northwest corner of the tailings basin. A filter fabric will be placed on top of the geomembrane to serve as protection for the geomembrane in the areas where the partial drainage blanket will be installed. This liner system is shown in detail on Drawings 158 and 159.

The major advantage that could be realized by this liner option is not actually realized at the Copperwood site. In an area of moderate to high ground permeability the composite liner provided by Case 3 would serve as the barrier to seepage, however at Copperwood where there is a large depth of very low-permeability soil under the TDF the composite liner adds very little in terms of seepage reduction.

The partial drainage blanket was designed to cover a 1,000 ft radius of the TDF basin floor, emanating from the northwest corner of the facility. During operations, only this small portion of the tailings mass would benefit from two-sided drainage and a faster rate of consolidation. Identical to the Case 2 liner system, at closure this drain would also likely be required to be shut.

One significant disadvantage of Case 3 is that similar to Case 1 it imparts an undrained base under the tailings (except in the small area of the underdrain). A second is the cost of the 3 ft of soil liner and the geomembrane. Based on the column modeling described in Section 3.3.3, it is estimated that this system will function only nominally better than, but on the same order of magnitude as, the Case 1 liner system in terms of reducing seepage.

It is estimated that this liner system will add approximately US$10 Million to the total project cost, using the in-situ soil liner system (Case 1) as the base case.

5.5 Drainage Collection Systems

Water released from the TDF will primarily be collected from four different points:

- Decant water from the supernatant pond on top of the tailings (discussed in Section 5.6),
- Lateral seepage collected by the internal filter Chimney Drain in the embankment,

- Pore water expelled from the compacted embankment fill collected by the embankment mid-height or blanket foundation drains, and
- Seepage intercepted by the basin drainage blanket (underdrain) system associated with the Case 2 (full drainage blanket) and Case 3 (partial drainage blanket) liner systems.

The TDF embankment Chimney Drain (Zone 2) will be 5 ft wide (measured horizontally) and will primarily collect any small amounts of seepage passing through the upstream face of the embankment for conveyance to the downstream decant sump. A 6-in-diameter perforated CPT (Type SP) collection pipe will be installed at the base of the drain to add hydraulic capacity around its full length and transmit the intercepted seepage to a 16-in-diameter HDPE (SDR 11) outlet pipe to the sump.

The embankment mid-height and foundation drains will primarily accept small amounts of water from dissipating construction pore pressures in the clay fill and underlying foundation, and small amounts of infiltration from precipitation on the downstream face of the embankment.

The embankment mid-height drains will be constructed with trapezoidal cross-sections 1.5 ft in height, with 1.5 ft crest-widths and 6 ft base-widths. The mid-height drains will be comprised only of drainage aggregate without perforated pipes to avoid any problems with potential settlement. The drains will be installed approximately 60 to 70 ft above the embankment foundation surface in sections of the TDF embankment where the ultimate height will exceed 100 ft, such that they will gravity drain to the northwest corner. At this location, a drainage aggregate conduit will connect the mid-height drains to the embankment internal filter drain to evacuate the water.

The embankment foundation drains will be comprised of two partial drainage blankets containing 6-inch-diameter perforated CPT (Type SP) drain pipes running parallel to the embankment for added hydraulic capacity. The drainage blankets will cover approximately the upper and lower thirds of the Downstream Shell footprint, according to the cross-section shown on Drawing 150. The foundation drain pipes will gravity flow to the northwest corner of the embankment where they will discharge into a 16-inch-diameter HDPE (SDR 11) outlet pipe to the decant sump. It has been assumed that the drainage outlet pipes will typically be buried sufficiently deep to prevent freezing during winter; however, this should be checked during future stages of the design. Sections and details for the embankment drains (internal filter, mid-height, and foundation) are presented on Drawings 150 and 152. The outlet pipes plans and profiles are shown on Drawing 162.

The tailings underdrain system will cover the entire TDF basin floor for the Case 2 liner system, and only a small portion in the northwest corner of the basin floor for Case 3. The underdrain system will consist of a network of 4-inch-diameter perforated CPT (Type SP) lateral pipes overlain by a 1.5-ft-thick drainage blanket. Six-inch-diameter perforated CPT (Type SP) header pipes will connect the laterals and convey collected flows to the northwest corner of the TDF where they will discharge into a 22-inch-diameter HDPE (SDR 11) outlet pipe beneath the TDF embankment to the decant sump.

Flow monitoring sensors will be installed on the outlet pipes from the different drain systems to quantify the flows in each. These sensors will be located immediately upstream of the decant sump.

The decant sump will be constructed as a rectangular reinforced concrete structure with interior dimensions 20 ft wide, 30 ft long, and 15 ft deep. The sump will include a 22-inch-diameter HDPE (SDR 26) overflow pipe which will discharge into an adjacent 60 mil smooth HDPE geomembrane-lined pond. The decant sump will accommodate a volume of approximately 8,400 ft^3, or 60,000 gallons, up to the maximum water surface level 1 ft below the crest,. This is equivalent to approximately 20 minutes of maximum inflow. A heated and insulated house will be constructed over the top of the decant sump to protect it and prevent the water from freezing during winter. The pump house structure has not been included in this PFS design, and all pumping from the decant sump is by others. It is anticipated that the following pumps will be installed in the sump to remove the water:

- Reclaim pumps to the process plant,
- Reclaim pumps to the treatment plant, and
- Reclaim pumps to the secondary flocculent addition plant.

The overflow pond will receive water from the decant sump only if the pumps go down and remain down for periods greater than 20 minutes due to power outages. Backup emergency power will be provided to keep these occurrences to a minimum. In the event that longer shut down periods are experienced, the decant tower inlets will be closed in the TDF and, if necessary the embankment and tailings underdrains can also be temporarily closed off at the sump. The decant sump overflow pond has been configured to store approximately 46,000 ft^3, accounting for 2-hr of roughly 110 percent of the maximum design decant flow (1,000 gpm) and the maximum flocculent flow rate (2,100 gpm), in addition to the direct precipitation from the 100-yr/24-hr storm event. An additional 1 ft of freeboard has been provided around the crest of the pond. Consideration will be given to increase the size of this pond in detailed design if the potential for multiple usages during a winter period is considered high. Water will likely freeze in the pond during winter, thus precluding its evacuation, and therefore it may require more storage capacity. The maximum flocculent flow rate is based on the current tailings management strategy presented in Section 5.7.

The decant sump and overflow pond are shown in plan on Drawing 170, while sections and details are presented on Drawings 172, 174, and 176. Anticipated seepage flow rates are discussed in more detail in Section 7.3.

5.6 Decant System

The supernatant pond on the surface of the TDF will receive bleed water from the tailings mass, water separated on the beach from the tailings stream, and direct precipitation and snow melt into the facility. The waters in the pond will be removed by a decant system constructed in the TDF northwest corner. The decant system is shown in plan and profile on Drawing 160.

The decant system will consist of a series of slotted 78-in-diameter CMP pipes mounted vertically on individual concrete foundations and placed in a series of steps up the full height of the TDF embankment northwest corner. Benches will be constructed as part of the fill to support the reinforced concrete footings for each decant tower. The towers will be approximately 20 ft tall (constructed from 20 ft lengths of CMP), and will be positioned at 10 ft elevation intervals to allow for overlap and redundancy. The slotted CMP pipes will be wrapped with a non-woven geotextile, geogrid, or chicken-wire, and then surrounded by coarse drainage aggregate. Each decant tower has been designed to remove 110 percent of the maximum design decant flow (1,000 gpm) plus the maximum flocculent flow rate (2,100 gpm).

The tailings will achieve a steep slope within the coarse aggregate around each tower and this will serve to locally increase the depth of water at the towers. This has the advantages of (1) reducing the inflow velocities and thus reducing the potential for tailings to be carried into the decant pipes, and (2) allowing for the water to be decanted under a thicker ice cover. The surrounding aggregate will also protect the towers from incidental ice damage.

During the winter months, it is anticipated that 3 to 4 ft of ice formation may occur on the TDF supernatant pond. The pond will typically operate with a total depth between 8 and 12 ft as described in Section 6.2; however, a minimum 6-ft-deep water pool will be maintained below the winter ice formation to allow continuous operation of the decant system. Close monitoring of the supernatant pond will be required both approaching and during the winter months, and early closure of a decant tower may be required if it is determined that the water level in the TDF would raise such that access to the decant tower would be cut off by the following spring.

The decanting levels within each tower will be established by placing a series of water tight, friction fit PVC stacking rings over a drainage outlet pipe in the tower base. The inlet flows to the decant towers

have been design based on a 1.5 ft depth of fluid above the inlet. A new ring will be placed on top of the column when a raise to the water level is desired to prevent tailings from being drawn in. The bottom outlet of each tower will be connected to a 12-in-diameter HDPE (SDR 13.5) flow conveyance pipe, which will then connect to the 22-in outlet pipe described earlier leading to the decant sump. The outlet from each tower will also be equipped with a 12-in-diameter butterfly valve to assist in controlling the flow during initial operations and to close off each tower at the end of their use. When permanently closed, the column above the valve within the stacking rings will be filled with concrete for added security against the intrusion of tailings.

A 12-in-diameter perforated CPT (Type SP) drain pipe will be installed adjacent to the 12-in diameter decant header pipe. The drain pipe will be wrapped in non-woven geotextile and will serve to collect and convey long-term seepage flows from within the decant system drainage aggregate following the abandonment of the lower sited decant towers.

Sections and details illustrating the decant system design are presented on Drawings 164 and 166.and the decant outlet pipe, along with the embankment drains outlet pipes, is shown in plan and profile on Drawing 162.

5.7 Tailings Management Strategy

Tailings slurry will be transported from the Plant Site to the TDF and deposited within the impoundment through a piping network designed by others. Under the current design concept, tailings will typically be deposited from several points along the south and east sides of the TDF. For this stage of design, formation of a minus 0.25 percent tailings beach slope has been assumed sloping from the southeast to northwest corners of the facility. Notwithstanding the assumption of a sloped tailings surface, a horizontal, flat, surface was also evaluated to compare the potential difference in associated tailings storage.

During the summer months, the tailings are proposed to be deposited utilizing multiple spigots along the southern and eastern edges of the staged TDF. Banks of multiple spigots allow the tailings to be deposited at lower discharge velocities to promote segregation and aid in the development of a steeper tailings beach. The objective will be to obtain some tailings coverage over the entire basin floor for each stage of development as early as possible. Spigot deposition from frequently rotated banks of spigots will also allow the tailings to be placed in relatively thin lifts which will promote air drying and increase tailings densities. It will be important to deposit tailings such that the basin underdrain, if constructed, becomes blanketed with tailings such that the supernatant pool does not directly contact the underdrain.

During winter months, the deposition scheme will change to several single-point discharges with higher slurry exit velocities to limit the potential for ice formation in the tailings mass. During extremely cold periods the tailings single-point discharges may also need to be extended below water in the supernatant pool to avoid tailings discharge flowing over the ice. Tailings discharge during winter operation should be conducted over areas of accumulated beach with at least 10 ft depth to avoid scour damage to the underdrain, if constructed.

The proposed tailings production schedule has been completed by Marston, and is presented in Table 4.2. This production schedule has been used in conjunction with the material properties and the elevation vs. capacity profile from the proposed TDF to estimate the tailings dry densities throughout the life of the facility. The TDF fillings curves, considering both flat and sloped tailings beach slopes, are presented in Tables 5.1 and 5.2, respectively.

The tailings management plan involves flocculating and thickening the tailings prior to pumping to the TDF. This will bring the tailings to a solids content of approximately 50 percent. In the process of pumping the tailings to the TDF it is expected that the flocs will become sheared, and therefore the slurry may require re-flocculating prior to deposition within the TDF. The current tailings discharge concept is to

add a secondary dose of flocculent to the tailings in the pipeline just prior to discharging into the TDF. This additional dose of flocculent will:

1. Increase the sedimentation and settlement rate of the solids particles, and
2. Reduce the quantity of Total Suspended Solids (TSS) within the decant water that will be reclaimed to the mill.

By reducing the amount of TSS, the reclaim system can work more efficiently with less maintenance over time. Based on information provided from Orvana and its consultants, Hychem Hyperfloc AF-305 is planned for use on the Copperwood Project. It should be noted that this flocculent is often used in conjunction with a coagulant (Hychem Hyperfloc CD-650); however, for this PFS it was assumed that only the flocculent will be added in the secondary dose to the tailings stream prior to deposition.

As part of the SIC testing, described further in Section 5.2, the WPC-4 tailings sample was prepared to the 50 percent solids content and then sheared in a high-speed mixer followed by re-flocculating to mimic the process that would occur during operation of the TDF. Flocculent solution was prepared using the Hychem Hyperfloc AF-305 at a concentration of 0.012 pound per ton of water. Flocculent solution equal to approximately 150 percent of the tailings slurry volume was required for the tested sample to exhibit a fully-flocculated. According to the current mine production schedule, the maximum annual tailings production to the TDF of approximately 2.53 Mt occurs in Year 13 and this corresponds to a maximum flocculent solution rate of approximately 2,100 gpm, and 0.1 pound of flocculent. Further studies to investigate reducing this rate are recommended during detailed design.

5.8 Water Management Strategy

The overall water management concept is to reduce seepage from the TDF to low levels, reuse as much water from the TDF as possible for plant operations and the flocculent system, and limit any releases from the TDF to only the latter years of operations and only after treatment to produce a suitable quality for release.

The majority of the water released from the tailings due to sedimentation and consolidation will report to the supernatant pond in the northwest corner of the TDF on top of the tailings mass. The pond will be maintained in this corner by the gently sloping tailings beach that will be developed from the southeast to northwest corners of the TDF. The supernatant water will be decanted from the surface by a series of decant towers, designed with interior stacking rings and surrounded by coarse drainage aggregate, which will convey the waters by gravity through a pipe under the TDF embankment to a sump downstream of the northwest corner of the facility. Drainage from the embankment filter drain, mid-height drains, and the foundation drains together with drainage from the TDF basin underdrain (for liner Cases 2 and 3) will also be directed to this sump. The flows will be in separate outlet pipes (except the mid-height drains that will be combined with the internal filter Chimney Drain) and will be metered independently. They will then be comingled in the sump for pumping to the process.

If either liner Case 2 or Case 3 is adopted, which include a complete or partial drainage blanket in the bottom of the TDF basin; it will be necessary to throttle back the outflows from the drain during the start-up period. Control of the outflows will be required until tailings cover the drainage blanket and restrict the inflows from the supernatant pond so that the downstream sump will not be overwhelmed.

The water management systems described above have been sized to accommodate flow rates predicted from the TDF process water balance that includes for climatic precipitation and evaporation on the TDF and water from the tailings slurry. The process water balance is summarized in Section 6.0.

5.9 Instrumentation and Monitoring Plan

The TDF embankment will be instrumented to measure its performance against the design assumptions and estimations. This data will be collected during all stages of construction and operations to better predict, and if necessary adjust, the embankment and tailings designs and/or construction procedures for subsequent stages. The instrumentation program will consist of ground water monitoring wells, piezometers, earth pressure and settlement cells, surface movement monuments, and flow meters as described herein.

5.9.1 Groundwater Monitoring Wells

Groundwater monitoring wells are planned for installation around the entire perimeter of the fully developed TDF so they become a part of the permanent monitoring system to meet the requirements of *Michigan's Nonferrous Metallic Mining Regulations, Part 632, R425.406 Protection of Water*. Due to the varying thickness of the till (20 to 120 ft) and depth to the more conductive Copper Harbor bedrock, the groundwater wells will be installed at different elevations to monitor potential impacts. Monitoring wells are planned for installation during the first two stages of TDF construction as follows:

- Stage 1
  - Monitoring well MW1 – to be located north of the northwest corner of the ultimate TDF embankment, and screened at three elevations.
  - Monitoring well MW2 – to be located north of the mid-point of the ultimate TDF northern embankment, and screened at three elevations.
  - Monitoring well MW3 – to be located west of the northwest corner of the ultimate TDF embankment, and screened at three elevations.
  - Monitoring well MW4 – to be located south of the southwest section of the ultimate TDF southern embankment, and screened at two elevations.
  - Monitoring well MW5 – to be located south of the southeast section of the ultimate TDF southern embankment, and screened at two elevations.

- Stage 2
  - Monitoring well MW6 – to be located west of the mid-point of the ultimate TDF western embankment, and screened at two elevations.
  - Monitoring well MW7 – to be located west of the southwest corner of the ultimate TDF embankment, and screened at one elevation.
  - Monitoring well MW8 – to be located north of the northeast corner of the ultimate TDF embankment, and screened at three elevations.
  - Monitoring well MW9 – to be located east of the northeast corner of the ultimate TDF embankment, and screened at two elevations.

Installation of the wells will allow for groundwater samples to be extracted and analyzed for quality to estimate if impacts are occurring. They will also allow for groundwater levels to be monitored for determining directions of flow. Installation of the wells will be in accordance with ASTM standard D 5092-90 entitled *Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers*.

The monitoring well plan is presented on Drawing 186.

5.9.2 Piezometers and Survey Monuments

Vibrating wire piezometers and earth pressure and settlement cells will be installed within the TDF in the western and northern embankment sections, where the embankments will be relatively tall at full build

out. The piezometers will be installed in the drains to confirm they remain at or near atmospheric pressure at all times. They will also be installed in the Seal Zone and Downstream Shell to confirm that construction pore pressures remain suitably low and to confirm that the development of any steady-state phreatic surface in the Downstream Shell remains suitably low over the life of the mine. The earth pressure and settlement cells will be installed in the embankment base to measure vertical load and settlement at selected points. The results will be used to continually evaluate the stability of the embankment and predict future deformations.

Surface movement monuments will be installed on the staged crests of the embankments at similar locations from stage to stage. Their data will be used to predict future deformations and to check for areas of anomalous movement.

5.9.3 Flow Sensors

Flow monitoring will be conducted at the outflow point of each of the water collection systems to the decant sump. These data will be used to evaluate the effectiveness of each of the drain systems by comparing them against the design flow rates. These values will also assist in refining the operation of the water reclaim systems to the process plant, or the water treatment plant during the latter period of the mine life.

5.10 Conceptual Closure Strategy

5.10.1 General

The current TDF closure concept will be initiated during the last few months of tailings deposition into the facility. Near the end of operations, the supernatant pond will be drawn down such that a minimal pond will remain at the end of deposition and after the cessation of deposition the pond will continue to be drawn down until it is removed. The water from the supernatant pond will be passed through water treatment prior to being released to the environment. Once the pond is removed, a soil cover will be placed over the tailings (likely during the winter months when the frozen tailings surface allows for trafficability) to direct surface run-off toward an outlet spillway to be constructed near the southwest corner of the TDF. The spillway will be excavated through the TDF embankment and armored with riprap for erosion protection. The outlet of the spillway will discharge into a stilling basin to absorb excess energy and from there the flow will discharge into the Namebinag Creek.

The soil cap will consist of a multi-layered system of geosynthetics and soils, from bottom to top, as follows:

- A filter fabric (non-woven geotextile) and geogrid placed on top of the tailings surface. These will be used to keep the tailings from entering the cover and to add tensile strength to it.
- A capillary break layer placed above the fabric and geogrid. This will consist of 1 ft of sand or gravel to prevent the upward passage of pore fluids from the tailings mass to the surface of the closure cap. Two options were assessed for placement of this material: (1) mechanically placing during winter months, and (2) slurry placement utilizing the tailings deposition pipeline. It was determined that mechanical placement would be more efficient due to the additional time that would be required for self-weight consolidation of the slurried fill, and the additional length of time that would be required to operate the mill. Furthermore, the slurried fill would produce additional water during the consolidation process which would need to be collected, and potentially treated.
- An initial soil grading layer of till placed over the capillary break layer. This will be used to grade the surface of the cover to the southwest corner of the facility. It is assumed that this layer will be constructed of local borrow materials. The option of placing this material mechanically vs. placing in slurry form was also examined. As was the case for the capillary break material, the current design assumes mechanical placement of this material.

- A low-permeability layer placed over the soil grading layer. This will be used to shed rainfall and reduce the amount of infiltration into the tailings mass. Grading and maintenance of this layer will be important to remove any cracking that may occur due to consolidation of the tailings mass and underlying till.
- An upper topsoil layer that will be vegetated will be placed above the low-permeability layer. The revegitation will aid in mitigating sediment erosion due to surface water flows and also will assist in evapotranspiration of the meteoric waters.

The closure cap structure will require overbuild to accommodate tailings consolidation settlement that would otherwise interfere with positive drainage of the surface. It has been assumed that the tailings will consolidate approximately 15 percent due to self-weight and placement of the soil cover system. This consolidation will produce discharge waters which will need to be collected, treated, and released. If the constructed liner option includes an underdrainage system, the time rate of consolidation will be approximately 4 to 6 years; whereas, if no underdrainage is present, or if the outlet pipes from the underdrain are closed, the time rate of consolidation will be approximately 10 years. Given that the tailings thickness is greatest in the northwest corner of the TDF, even if the cap grading were to be revised to drain to the northwest corner, some overbuilding of the cap would likely still be required. Locating the spillway in the northwest corner would expose the highest portion of the tailings embankment to long term erosion and the associated risk of tailings release in post-closure. The closure spillway was located near the southwest corner of the TDF based on this reasoning.

A maintenance bond will be established for periodic repair of the closure cap and spillway extending beyond at least the primary portion of the tailings consolidation process.

5.10.2 Seepage through Closure Cover

The annual amount of seepage through the TDF closure cap was estimated using the Hydrologic Evaluation of Landfill Performance (HELP) Model (Schroeder et al, 1994). The HELP Model is a quasi-two-dimensional hydrologic model that provides a water balance analysis for solid waste disposal and containment facilities. As such, it was used to estimate the expected amounts of evapotranspiration and runoff from, and seepage through, the TDF conceptual closure cover.

A 50-year time series of daily data was generated by the HELP Model using monthly average values from the 34 years of site and project area meteorological data presented in Knight Piésold's memorandum titled, *Copperwood Project, Climatic Data Analysis, Revision 0*, dated June 15, 2011, and summarized in Section 3.2. This period of generated data was deemed sufficient to assess the potential annual seepage flux rate and runoff volume. Input parameters utilized for the HELP model are presented in the following subsections.

5.10.2.1 Model Inputs

Precipitation
Precipitation data were entered into the HELP Model as monthly averages ranging from a minimum of 1.55 inches in February to 3.45 inches in October.

Air Temperature
Air temperature data were entered into the model as monthly averages ranging from 16.7°F in January to 66.9°F in July.

Solar Radiation
Solar radiation daily values were generated by the HELP model using coefficients corresponding to the project's latitude of 46.68° N.

Wind Speed
The average wind speed at Copperwood utilized in the model was 9.4 miles per hour.

Relative Humidity
Relative humidity data were input into the HELP model as quarterly averages, and were calculated as 78, 72, 80, and 82 percent, respectively.

Evapotranspiration
Evapotranspiration was modeled in HELP using the following variables:

- Evaporative zone depth - Evaporative zone depth defines the depth of evaporation from the soil without the influence of vegetation. An evaporative depth of 6 inches was used to simulate the depth of topsoil cover.
- Leaf area index - Leaf area index (LAI) is a ratio of the total upper leaf vegetation surface area to the land surface area. A leaf area index of 3.5 was used in the model.
- Length of growing season - The growing season used for the Copperwood Project was taken to range from May 26 to September 20 (Julian date 147 to 264).

Material Properties
The following layers of the Copperwood TDF conceptual closure cover were used in the model, from top to bottom:

- A vertical percolation layer of 6 inches, representing the topsoil cover, and
- A barrier soil layer of 13 ft (156 inches), representing the mechanically placed glacial till soil grading layer.

Particle size distributions, dry bulk densities, and particle densities for the glacial till were determined by laboratory testing of samples from the 2011 site investigation as described in Section 3.4. Composite values for these properties were developed, and using these values and the SoilProp computer program (ES&T, 1993) the van Genuchten parameters, field capacity, and wilting point were estimated. The saturated hydraulic conductivity for the till was estimated using several different techniques from the published literature and, based on relatively good agreement with laboratory tested values from the 2011 site investigation, a value of 2×10^{-8} cm/s was used. Default values within the HELP Model were utilized for the topsoil for these same parameters. The SoilProp output data is provided in Appendix C-1, while the material properties used in the HELP Model are presented with the model output data provided in Appendix C-2.

Runoff
Runoff properties were modeled using the Soil Conservation Service (SCS) runoff curve number determined by the HELP Model. The specified SCS curve number of 60.8 was based on:

- Slope – 0.6 percent (the minimum slope allowed as input for the HELP Model; although this is rounded to 1.0 percent in the output data)
- Slope length – 2,200 ft (based on the average dimension across the facility to the closure outlet spillway)
- Soil Texture – 7 (representing the uppermost topsoil layer)
- Vegetation – 4 (representing a “good” stand of grass)

One hundred percent of the area was allowed for runoff. The projected horizontal area was taken to be 1 acre; however, only unit flux rate results from the HELP Model were used for comparison with the columnar model presented in Section 3.3.

5.10.2.2 Model Results

Based on the input data, the average annual seepage flux through the TDF conceptual closure cap was estimated as 0.21 ± 0.01 inches. Comparing this with the flux rate modeling using the columnar approach in Section 3.3, it can be seen that the unit flux rate from the bottom of the TDF will be controlled by the amount of infiltration through the closure cap for the Case 1, Case 2 (drain closed), and Case 3 liner systems.

Liner System Case	Calculated Columnar Flux Rate inches/yr	HELP Model Infiltration inches/yr
Case 1	0.42	0.21
Case 2 (drain open)	0.007	0.21
Case 2 (drain closed)	0.55	0.21
Case 3	0.55	0.21

The average annual runoff from the facility was estimated to be on the order of 14.39 ± 3.70 inches per year. Based on the TDF area of 10.95 Mft^2, interior to the embankment crest, the average annual runoff volume would be approximately 13.13 ± 3.37 Mft^3. The peak daily runoff was estimated to be 5.22 inches (4.77 Mft^3), or approximately 55.2 cubic feet per second over a 24-hr period.

The HELP Model input and output data is provided in Appendix C-2.

Section 6.0 - Process Water Balance

6.1 General Overview and Operating Conditions

A process water balance was completed for the Copperwood Project using the climate information presented in the Knight Piésold memorandum DV-11-0154 titled *Climatic Data Analysis, Revision 0*, dated June 15, 2011, and summarized in Section 3.2 of this report. The process water balance governs the management, storage, and to a minor degree the treatment of water in the tailings slurry and the TDF, mine dewatering water, and water in the process circuit. The objectives of the water balance were:

1. To identify the fluctuations of water volumes in the process circuit on a monthly basis over the operating life of the facility,
2. To provide an estimate of the range of potential water deficits and water surpluses that may occur during operations so that appropriate sources of make-up water as well as provisions for storage or disposition of surplus water can be provided for, and
3. To provide a basis for sizing the TDF, the treatment plant, and other facilities.

Sizing of the five stages of the TDF included for the operational storage required for the supernatant pond as it increases and decreases over the operating seasons and years, as well as for storage of the design storm, which was selected as the 72-hr/half-PMP storm event. The general operating strategy assumed that the supernatant pond will be maintained at a depth of between 8 and 12 ft (with a minimum depth of 6 ft), which should provide enough depth for winter operations and limit the inflow of tailings solids into the decants while avoiding the accumulation of an excessive amount of water in the TDF that will require treatment at closure. The water balance model was developed to reclaim and re-use as much water as possible from the TDF.

Process water at the mill will be primarily sourced from the TDF as reclaimed supernatant or drainage flows, mine dewatering flows and fresh water makeup from Lake Superior. Mine dewatering is expected to contain dissolved metals and anions, and will require treatment prior to use in the process. The TDF supernatant may also contain dissolved metals, anions, suspended solids, and residual process flotation reagents and some treatment is accounted for. The specific amount of the reclaim water from the TDF that may require treatment is beyond the scope of this report; however, any excess reclaim water from the TDF that is not reused in the process is expected to require treatment, and likely polishing, prior to release. Following the end of operations, the intent is to treat and release any water remaining in the TDF supernatant pond in conjunction with constructing a closure cover over the tailings.

The water balance model performs monthly calculations of the amounts of water contained in the system from defined or calculated inflows and outflows due to tailings production, process water requirements, mine dewatering, tailings consolidation, and precipitation and evaporation. The model computes the volume in the TDF supernatant pond together with certain other outputs (reclaim water, discharge, etc.) for each month of the model duration. The period of modeling was taken as approximately 18.3 years, which includes:

- Approximately 14.25 years from the start to end of tailings deposition,
- 2 months of start-up (where the facility would accumulate water prior to initiating deposition, and
- Approximately 4 years after the end of deposition for draining the supernatant pond.

Monthly average, maximum and minimum values were then determined for the output data for each month of each of year.

Figure 6.1 presents a schematic diagram of the water balance flow chart. A brief summary of the results from the water balance analysis is presented in the following sections, while a more detailed description of the water balance model is included in Appendix E.

6.2 Tailings Disposal Facility Supernatant Pond Operation

The TDF supernatant pond is considered to be a primary source of makeup water for operation of the mill. The TDF has been designed to contain, in the supernatant pond, all direct precipitation falling on the footprint of the facility, additional incident precipitation resulting from the 72-hr/half-PMP storm event, and any water liberated from the deposited tailings.

Supernatant water will be removed by decant towers on the upstream face of the TDF embankment and conveyed to a decant sump downstream of the dam. From there water will be pumped to the mill for re-use in the process or pumped to the treatment plant prior to discharge. Some portion of the reclaim water may also require treatment before reuse in the mill. Water from the flocculent addition process will also be decanted to the decant sump for pumping back to the flocculent circuit; however, the flocculent circuit has been considered as a closed loop and therefore these waters have not been included in the process water balance.

During the winter months (December through March) it is estimated that 3 to 4 ft of ice may form on the surface of the supernatant pond. To allow continuous decanting and reclamation of water during these months, a minimum depth of approximately 6 ft will be maintained beneath the ice cover. Some makeup water from Lake Superior will be required during these months to maintain a steady flow of process water to the mill.

The average operational supernatant pond volume is predicted by the water balance model to fluctuate between 13 and 48 Mft^3 from the start to the end of the project. Under maximum conditions, reclaim flows from the TDF were predicted to range from less than 270 gpm to 920 gpm over the life of operations.

At the start of operations, the TDF supernatant pond was predicted by the model to reach a maximum depth of 31 ft and then decrease rapidly over the next 6 months to remain relatively stable; fluctuating between about 8 and 12 ft until the end of operations. Its surface area was predicted to gradually increase to about 7.8 Mft^2 from September of Year 1 through January of Year 8, and then remain relatively constant until the end of deposition. The ultimate tailings surface area will be developed to approximately 10.6 Mft^2 and therefore the supernatant pond is anticipated to eventually cover on the order of 75 percent of the tailings surface.

6.3 Treatment and Makeup Water Requirements

The current operating strategy requires excess water from the TDF to be pumped to the water treatment plant beginning in January of Year 9 to maintain the supernatant pond at a relatively constant depth. From January of Year 9 through February of Year 16 an estimated flow of 330 gpm will be required to be treated and released over several months of each operating year to control the size of the supernatant pond. Beginning in March of Year 16, the model predicts that this flow will need to be increased to 660 gpm and continued until the remaining water in the pond is drawn down for final reclamation and closure.

The total amount of flow to the treatment plant will be the sum of:

- The excess water from the TDF to be released,
- Flows from mine dewatering,
- The amount of TDF reclaim water (bleed water) requiring treatment,
- Sewage flows from the plant, and
- Other sources of wastewater from the facility (truck wash, contact storm water, etc.)

This report only estimates the treatment requirement for excess water from the TDF, above and beyond what is required to be returned to the process, and the flows from mine dewatering.

Three equally possible levels of additional makeup water requirements were estimated by the water balance (average, maximum, and minimum) depending on climatic conditions during operations. Under the current strategy, maximum makeup water requirements were predicted to range from 0 to 266 gpm during Year 2, relatively constant at 374 gpm from Years 3 to Year 6, and from 351 to 374 gpm for several months of each year from years 7 through 14.

The water balance model assumes the TDF will begin filling with direct precipitation in September of Year 1, and will accumulate water until the start of operations in November of Year 1. If desired, the construction of Stage 1 of the TDF could be moved earlier to allow for more water to be accumulated from precipitation for process start-up.

Section 7.0 - Seepage and Stability Analyses

7.1 General

In support of the TDF design, seepage and slope stability analyses were carried out on critical sections through the staged facility configurations. Critical sections through the TDF were selected based on the overall height of the impounding embankment, as well as relative location to nearby topographic features. The results of the seepage and slope stability analyses are discussed in the following sections.

7.2 Seepage Analyses

Seepage analyses were performed using the commercially available software package SEEP/W by GEO-SLOPE International (GEO-SLOPE, 2007) for three sections through the TDF:

- Along the tallest, critical section in the northwest corner,
- On a tall section on the west side of the TDF, and whose foundation dips to the Namebinag Creek, and
- On a section in the southwest corner of the TDF which is less than 100 ft tall and does not have mid-height embankment drains.

SEEP/W is a two-dimensional finite element seepage analysis program which can be used to estimate the phreatic surface within an embankment and estimate seepage quantities through porous materials such as soil and rock. Stage 5 of each of the sections listed above was modeled to estimate the steady-state seepage characteristics of the different embankment configurations

Material properties were established based on results of laboratory and in-situ testing conducted on undisturbed overburden material soil samples taken during the geotechnical site investigation. Packer and in-situ falling head permeability tests were performed to evaluate the characteristics of the underlying bedrock and overburden glacial till, respectively. Flexible wall permeability tests were performed on undisturbed overburden samples, which were assumed to represent the upstream Seal Zone (Zone 1) and Downstream Shell (Zones 3 and 4) material. It should be noted, however, that an anisotropy was applied to the Downstream Shell due to the expected construction process, and a slightly lower permeability was assumed for the upstream Seal Zone, again, due to the construction process, namely placement in thin lifts and compaction. The permeability of the drainage aggregate was assumed from engineering experience, and from testing of similar materials from other projects. The permeability of the tailings was based on results obtained from SIC testing, and in general, is comparable to values obtained from other projects with tailings of similar grain-size and index properties. Information from the Knight Piésold geotechnical site investigation is summarized in Section 3.4, and is presented in its entirety in Appendix B. The unsaturated soil properties for all materials were estimated using the saturated parameters and estimation algorithms which are built into SEEP/W. For these analyses, it was assumed that the Van Genuchten functions sufficiently represent the material properties expected in the field. Table 7.1 lists the materials and material properties used for the seepage, and slope stability, analyses. The geometry, boundary conditions, and results for the three sections described above, associated with the three liner cases described in Section 5.4, are shown on Figures 7.8 through 7.16.

The figures show the estimated total head distribution through the embankment and foundation materials as well as the estimated phreatic surface. As can be seen in the figures, the phreatic surface is drawn-down in the Downstream Shell due to the presence of the embankment partial-blanket foundation drain. Additionally, the effect of the Case 2 and Case 3 liner systems blanket drains within the tailings basin can be seen in the resulting total head distribution in the area of the basin liner. The presence of the blanket drains reduces the applied head, and thereby reduces the seepage potential of pore fluid into the environment.

Flow rates were estimated for the amount of pore fluid entering the seepage collection system (Chimney Drain and embankment foundation drain) as well as the amount of pore fluid underdrainage entering the Case 2 and Case 3 liner systems blanket drains, where applicable. The total estimated flow-rate results are summarized by liner case below considering the seepage waters collected in the internal embankment drains [both the internal filter (chimney) drain and the foundation drains] and the waters collected in the tailings underdrain system, where applicable.

Case 1 (In-situ Soil Liner)
- Seepage collection flow rate: 4.7 gpm

Case 2 (Full Drainage Blanket)
- Seepage collection flow rate: 4.2 gpm
- Underdrain collection flow rate: 406.9 gpm

Case 3 (TSF Prescriptive Liner)
- Seepage collection flow rate: 4.2 gpm
- Underdrain collection flow rate: 88.5 gpm

The seepage rates here were determined by estimating the flow rates through the pipes present in multiple cross sections, including the three shown in Figure 7.1. These were then multiplied by the lengths over which the cross section is considered representative and summed. These values should be considered an order of magnitude estimate for the amount of water being collected in both systems for the purpose of sizing the sumps and pumps associated with each design. It should be noted that these values represent the full build-out scenario and do not consider additional waters produced from the consolidation of the tailings.

7.3 Slope Stability Analyses

Slope stability analyses were conducted on three sections through the TDF embankment using the computer program SLOPE/W, developed by GEO-SLOPE International (GEO-SLOPE, 2007):

- The tallest, “Critical Section” in the northwest corner of the TDF.
- The tall “West Embankment Section” of the TDF, whose foundation dips to the Namebinag Creek.
- The Stage 1 configuration of the “Critical Section” upstream and downstream stability considering rapid loading due to construction.

The analyses used the dam section geometries, estimated material properties, and phreatic conditions estimated in the seepage analyses to evaluate factors of safety for given slope failure surfaces. Static gravitational analyses were performed for critical trial failure surfaces on the upstream and downstream slopes. Pseudo-static analysis was performed on the critical case to examine the effect of a horizontal acceleration due to earthquake ground motion being applied to the sliding failure mass. The earthquake loading was assumed to be 0.06 g, which is twice the ground acceleration prescribed by the United States Geological Survey (USGS) (*http://earthquake.usgs.gov/hazards/*) for a 2,500-year occurrence earthquake in this region. Twice the ground acceleration was used to estimate a factor of safety under conservative conditions since dynamic analyses were not conducted on the materials to establish ground acceleration dissipation or amplification as the ground motion is transferred through the overburden material. Cases analyzed, and the results of the analyses, are presented on Figures 7.2 through 7.7.

The minimum acceptable factors of safety are as follows:

- Long-term, static conditions = 1.4

- Pseudo-static conditions = 1.1
- Short-term, post-construction static conditions = 1.2

Laboratory testing was performed on in-situ soil samples to estimate the strength of the overburden glacial till which is envisaged for use as fill material for the upstream Seal Zone and the Downstream Shell. Triaxial and direct shear testing was performed on undisturbed samples to estimate the drained and undrained shear strength properties of this material. It should be noted that the isotropically consolidated, undrained (ICU) triaxial tests, which produces estimates for the drained strength parameters, may have been run too quickly considering the material properties of the tested specimens; potentially producing results which under-estimated the strength of the material. Therefore, a correlation proposed by Mitchell (Mitchell, 1976), which correlates the friction angle of a normally consolidated clay with the plasticity index of that clay, was used to estimate the effective shear strength of the glacial till. It should be noted that the in-situ clays are slightly over-consolidated, but it is assumed that this correlation provides a friction angle which is acceptable considering the material present at the Copperwood site. The shear strength properties of the drainage aggregate and riprap layer on the upstream face were assumed from engineering judgment and from testing done on similar materials from other projects. Table 7.1 lists the materials and material properties used for the stability analyses. From laboratory data, it was estimated that the underlying glacial till can be divided into three strata, considering the undrained strength of the material as a function of depth intervals. The top 5 ft was estimated to have an undrained shear strength greater than 1.60 t/ft^2, and is assumed to be desiccated to result in a higher shear strength than the underlying material. Below this is a 30 ft layer, to a total depth of 35 ft, which has a lower, estimated undrained shear strength which was estimated to be greater than 1.25 t/ft^2. Below this, the material is estimated to have an undrained shear strength of greater than 1.60 t/ft^2. Although the estimated undrained shear strength of the glacial till is estimated to be greater than the values given above, the lower values were used to add conservatism to the analyses.

Using these material properties and the embankment section geometries, the analyses listed above were performed in SLOPE/W, which performs limit equilibrium analysis considering several different analysis options to determine the critical slope surface. The critical slope surface is that surface which is estimated to have the lowest factor of safety and impact the containment functionality of the dam (i.e., a failure which will cause a loss of containment). For these analyses, Spencer's Method (Spencer, 1967) was used to evaluate slope stability because this method satisfies both moment and force equilibrium, thereby yielding a more rigorous solution than some other commonly used methods. The stability analyses provided factors of safety as follows:

Long-Term, Static Stability:
- Critical Section = 1.4
- West Embankment Section = 1.6

Pseudo-Static Stability:
- Critical Section = 1.2
- West Embankment Section = 1.3

Short-Term, End-of-Construction Stability, with full basin excavation:
- Critical Section, Stage 1, Downstream, undrained = 1.4
- Critical Section, Stage 1, Downstream, drained = 1.6
- Critical Section, Stage 1, Upstream, undrained = 1.2
- Critical Section, Stage 1, Upstream, drained = 1.2

It should be noted that each of these factors of safety is above the minimum factors of safety described above. It is suggested that additional materials testing and modeling be performed during future phases of design to confirm the acceptability of the material properties utilized in these analyses.

Section 8.0 - Estimated Capital Costs

8.1 General

This section presents PFS level cost estimates for the Copperwood Project which specifically account for the structures within Knight Piésold's work scope. This includes both CAPEX and OPEX cost estimates associated with the staged TDF design, the TDF decant structure, decant sump and overflow pond, and the conceptual closure of the TDF. CAPEX cost estimates have been included for each of the three liner systems evaluated within this PFS report as follows:

- Case 1 (In-Situ Soil Liner) – Excavate the basin area to final grade, prepare the excavated surface and place tailings over the surface.
- Case 2 (Full Drainage Blanket) – Construct a blanket underdrain over the excavated and prepared surface of the basin and place tailings over the underdrain.
- Case 3 (TSF Prescriptive Liner) – Install a geomembrane over the excavated and prepared surface of the basin and place tailings over the geomembrane. A layer of drainage aggregate, emanating in a 1,000' radius from the northwest corner of the TDF basin floor, is also included as part of this liner system. This scenario addresses the prescriptive liner for a TSF under *Michigan's Nonferrous Metallic Mining Regulations, Part 632, R425.409 Treatment and Containment of Reactive Material*.

Costs have been estimated for the life of the project and are provided on a time schedule that matches the current mine production plan. The largest CAPEX costs occur during the initial construction of the Stage 1 TDF. This is primarily due to the significant amount of excess cut taken from within the TDF basin and the associated amount of overbuild in the embankment that will avoid stockpiling and double-handling of material. While this increases the upfront CAPEX, it significantly decreases the amount of out-year CAPEX for the life of the project.

In interpreting these cost estimates:

- The cost estimates are presented in 2011 US$ with no escalation or time value of money factors applied for out-year costs.
- The design and costs associated with the tailings delivery and deposition system, flocculent addition to the tailings slurry stream, reclaim water pumping from the decant sump and overflow pond, surface water diversions around the ultimate TDF and the development and/or maintenance of stockpiles and/or borrow areas were not included in Knight Piésold's work scope, and are assumed to be provided by others.
- Geosynthetics for the TDF and decant pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.
- Pipework quantities associated with the TDF account for drains and the decant system and have been increased 5 percent over neat line quantities to account for waste.
- The costs do not include for engineering design or construction supervision and quality assurance/quality control (QA/QC).

8.2 Initial CAPEX

The initial CAPEX cost estimate accounts for the development of the Stage 1 TDF configuration, which has been designed to provide storage through Year 3 of the current mine production schedule. The items accounted for are summarized as follows:

- Clearing and stripping of the Stage 1 footprint area,

- Stage 1 embankment foundation drains,
- Stage 1 basin excavation and embankment construction,
- Stage 1 decant structure and outlet pipe,
- Decant sump and overflow pond,
- Stage 1 basin liner system, where applicable,
- Basin underdrainage outlet pipe, where applicable, and
- Stage 1 perimeter road.

The initial CAPEX has been assumed to occur during Year 0, pre-production.

8.3 Out-Year CAPEX

The out-year CAPEX cost estimates account for the staged development of the remainder of the TDF beyond Stage 1. Each stage has been designed to provide storage for approximately 3 years of the current mine production schedule. The items accounted for are summarized as follows:

- Clearing and stripping of the staged footprint area,
- Staged embankment foundation drains,
- Staged basin excavation (completed during Stage 3) and embankment construction,
- Staged decant structure and outlet pipe,
- Staged basin liner system (completed during Stage 3), where applicable, and
- Staged perimeter road.

Material take-offs and unit rates were used to calculate the CAPEX cost estimates for the five staged configurations and the CAPEX values were assumed to be expended in the year prior to when the additional storage will be required according to the current mine production schedule. However, in agreement with Orvana, annualized CAPEX estimates were also generated for Stages 2 through 5. These were determined by evenly dividing the staged cost estimates by three, the number of years of development that each stage will accommodate.

8.4 Conceptual Closure CAPEX

Conceptual closure CAPEX cost estimates were determined for the Copperwood Project for a mechanically placed closure cap. The items accounted for are summarized as follows:

- Geosynthetics to prevent intrusion of tailings into the closure cap and to improve the strength of the tailings surface for placement of overlying material,
- Capillary break drainage layer,
- Low-permeability closure cap fill,
- Topsoil and seeding for re-establishment of native vegetation, and
- Outlet spillway and diversion channel with energy dissipation structures.

The annualized closure costs are assumed to occur over a 4-year period, starting the year tailings deposition ceases (Year 16) with one-fourth of the closure cap costs occurring in each year. Additionally, the closure cost estimate assumed that one-half of the estimated cover maintenance cost will occur in each of years 17 and 19 and the closure outlet spillway and diversion channel costs will occur in Year 19.

8.5 OPEX

The PFS OPEX costs are assumed to be the same regardless of liner system. OPEX costs have been estimated for the following items:

- Monitoring and reporting of instrumentation and groundwater wells
- Decant system operation and closure
- Decant sump and overflow pond maintenance

Operating costs have been based on the following assumptions:

- Years 1 and 16 of operations will be partial years consisting of approximately 2 and 1 months, respectively

- Monitoring and reporting of instrumentation and groundwater wells
  - $40,000 annual cost - 2 field employees, with an assumed annual salary of $80,000 each, working 25 percent of the time
  - $50,000 annual cost - Installation of replacement or added instrumentation
  - $100,000 annual cost - Water quality analytical testing
  - $30,000 annual cost - Reporting to state regulators
  - Groundwater levels and quality will be monitored for approximately 1 year prior to the start of operations.
  - Monitoring and testing will continue throughout the closure period (although additional monitoring and testing may be required beyond this period)

- Decant system operation and closure
  - $24,000 annual cost - 4 field employees, with an assumed annual salary of $60,000 each, working 10 percent of the time
  - $5,000 annual cost – Installation of PVC stacking rings within decant tower
  - $5,000 annual cost – Concrete infilling for closure of decant towers

- Decant sump and overflow pond maintenance
  - $24,000 annual cost - 4 field employees, with an assumed annual salary of $60,000 each, working 10 percent of the time
  - $30,000 annual cost – Lighting equipment for working around sump and pond

As noted previously, design and costs associated with the tailings delivery pipeline and deposition system, as well as the water reclaim system associated with the return to both the process and flotation circuits were not included in Knight Piésold's work scope, and are assumed to be provided by others.

8.6 Cost Estimates

The cost estimates presented herein are considered to be within a ±25 percent level of accuracy, which is commensurate with a PFS level design. No contingencies have been included at this time; however, a 25 percent contingency is recommended for this level of design. While level of accuracy specifically speaks to the confidence level associated with, and the detail of, the design, contingencies are typically included to account for uncertainties associated with unit rates, as well as potential changes that may be

implemented as the project designs progress. The cost estimates are presented in 2011 US$ with no escalation for out-year costs.

The staged PFS CAPEX cost estimates associated with the three liner systems for the Copperwood TDF and ancillary structures are summarized as follows:

Case 1 (In-Situ Soil Liner)

Stage 1 Years 0 - 2	Stage 2 Years 3 - 5	Stage 3 Years 6 - 8	Stage 4 Years 9 - 11	Stage 5 Years 12 - 14	Closure Years 16 - 19	Total
$22,510,020	$9,433,034	$10,870,884	$10,606,574	$9,921,278	$18,469,603	$81,811,393

Case 2 (Full Drainage Blanket)

Stage 1 Years 0 - 2	Stage 2 Years 3 - 5	Stage 3 Years 6 - 8	Stage 4 Years 9 - 11	Stage 5 Years 12 - 14	Closure Years 16 - 19	Total
$24,279,803	$11,404,712	$10,683,734	$9,814,525	$9,075,316	$18,469,603	$83,727,694

Case 3 (TSF Prescriptive Liner)

Stage 1 Years 0 - 2	Stage 2 Years 3 - 5	Stage 3 Years 6 - 8	Stage 4 Years 9 - 11	Stage 5 Years 12 - 14	Closure Years 16 - 19	Total
$27,401,175	$13,177,356	$11,912,450	$10,606,574	$9,921,278	$18,469,603	$91,488,436

The annual PFS OPEX cost estimate is summarized as follows:

Year 0	Year 1	Years 2 - 15	Year 16	Years 17 - 19	Total
$36,667	$234,667	$308,000	$227,333	$220,000	$5,470,667

Table 8.1 presents an overall summary of the staged development CAPEX costs for the items covered within this PFS work scope. Summarized annual costs, for both CAPEX and OPEX, are presented in Tables 8.2 and 8.3, respectively. More detailed staged development CAPEX costs associated with the three liner systems are presented in Tables 8.3 through 8.6. The breakdown of the information presented in each table is as follows:

- Table 8.1 Staged Summary CAPEX Estimate
- Table 8.2 Annualized Summary CAPEX Estimate
- Table 8.3 Annualized OPEX Estimate
- Table 8.4 Detailed Cost Estimate – Case 1 (In-Situ Soil Liner) CAPEX Estimate
- Table 8.5 Detailed Cost Estimate – Case 2 (Full Drainage Blanket) CAPEX Estimate
- Table 8.6 Detailed Cost Estimate – Case 3 (TSF Prescriptive Liner) CAPEX Estimate

No time value of money calculation has been made, as it is assumed this will be done at the project cost aggregate level.

Section 9.0 - Recommendations for Follow-Up Engineering

The following bullet points present the recommendations of future design refinements for the Copperwood Project that are related to Knight Piésold's work scope.

- Additional Site Investigations and Monitoring
  - Ongoing Monitoring of Site Groundwater Levels
    - Groundwater levels and pressures in the till and bedrock beneath the proposed TDF are not well known but measurements should be made in the standpipe piezometers installed in the 2011 geotechnical investigation to determine them. While the flows are likely to be low in the till as a result of its low hydraulic conductivity, the pressure regimes should be defined in order to avoid problems with quick conditions developing in the base of the excavation for the TDF. It is suspected that the bedrock is acting as an aquifer confined under the till and it is possible that once the excavation is carried out, if its bottom is close enough to the bedrock, upward flows may occur into the excavation. The solution would be to raise the bottom of the excavation.
    - Based on the data from the existing installations and any suspected gaps, additional installations and monitoring programs may be required to establish a reliable groundwater model for use in properly siting the planned TDF and its base excavation.
  - On-Site Borrow for Riprap and/or Filter/Drain Material
    - Riprap and filter/drain material represent significant costs to the project. It is known that these materials are commercially available in close proximity to the Copperwood site but it may be possible to identify on-site borrows areas for sourcing these materials that will reduce the overall construction costs.
- Additional Materials Testing
  - Triaxial Testing for Embankment Stability Parameters
    - It is possible that the triaxial testing may not have been conducted at a slow enough rate of loading to allow for the best selection of effective stress parameters. Additional undisturbed samples should be acquired and tested to confirm or modify the parameters for use in the TDF embankment stability analyses.
    - Testing should be conducted on remolded samples produced from moisture-density testing to better represent the fill materials.
  - Construction Pore Pressures
    - The consolidation tests on the till indicate that its time rate of consolidation is quite slow, which is consistent with its low hydraulic conductivity. Such a material may contain significant excess pore pressures when loaded and compacted, and this indicates that monitoring of pore pressures during construction will be important. The final design of the TDF should investigate limits on the rate of construction and the number and positions of the embankment drains adopted.
  - Geotextile Compatibility Testing
    - A variety of non-woven geotextiles should be evaluated to determine their compatibility with the Copperwood tailings, and more specifically their effectiveness in limiting the passage of the tailings solids through their openings. Non-woven geotextile layers will be placed over the basin underdrain blanket and around the decant towers to limit the ingress of solids into either system.
  - Drainage Material Testing – for conductivity and durability
    - The potential candidate drainage materials should be tested for hydraulic conductivity and durability (if aggregate material) to assess how they will function over the life of the project.

- Tailings Disposal Facility Design Items
  - Tailings Underdrain Retardant Layer
    - It will be necessary to restrict the flows in the blanket underdrain under the TDF during the initial period of operations when the supernatant pond is in contact with the drain in order to prevent the decant sump from being overwhelmed. Once the drain is covered with tailings, the tailings will limit the rate of inflow from the supernatant pond to an appropriate level. The retarding layer may include placing a lower permeability material over the underdrain or placing a series of low-height berms in the basin to more rapidly develop a tailings cover.
  - Drainage Aggregate/Sand Filter Criteria
    - The material planned to for use in the TDF embankment drains should be evaluated to assess how well it meets filter criteria for placement adjacent to the embankment Seal Zone and Downstream Shell materials.
  - Alternative Tailings Disposal
    - The TDF design has been developed assuming the storage of 100 percent of the tailings from the mine at surface. However, the footprint of the TDF could be significantly reduced if some of the tailings can be used as backfill for the underground mine. The reduction of the tailings stored at surface would reduce the required dike construction, surface water diversions, and wetlands impact and thus the total construction and closure costs of the facility. Further engineering studies would be required on potential methods to thicken or filter the tailings in order to produce a suitable material for backfill. The technical feasibility of this alternative would need to be assessed including a tradeoff study of the reduced footprint of the TDF and wetlands implications, construction costs, and operating costs associated with a thickened or filtered tailings plant.
- Decant System and Overflow Pond Design Items
  - Decant Structure Drain Pipe
    - It may be possible to eliminate a 12-in-diameter perforated CPT (Type SP) drain pipe that has been included for enhanced drainage in the decant structure aggregate surround material.
  - Flocculent Analysis
    - As determined through sample preparation for consolidation testing, flocculent addition equal to 150 percent of the incoming tailings slurry flow was required for the sample to exhibit fully flocculated behavior. This is large and should be investigated with a view towards reducing the volume through additional product analysis and testing.
  - Evaluation of Decant Sump Overflow Pond
    - The decant sump overflow pond will need to be re-evaluated based on any changes to the flocculent addition strategy and consideration for multiple usages (i.e., power outages) during each winter.
- Closure Design
  - Tailings Strength to Support Closure Surface
    - For this stage of design, the conceptual closure plan envisages mechanical placement of the cap materials with an estimated thickness between 2 and 27 ft (13 ft average). Testing and modeling of the consolidated tailings strength to support this load should be conducted during future design stages.
  - Closure Surface Slope
    - A 0.25 percent slope was utilized on the closure surface to mimic the slope of the tailings surface; however, this may be unrealistic to construct and maintain with positive drainage. Closure quantities and associated costs should be investigated to consider a range of closure surface slopes from 0.25 to 1 percent.

- Closure Spillway Location
  - The closure spillway is currently planned to be constructed in the TDF southwest corner in order to reduce the drop height to convey flows to the existing ground surface. In order to slope the closure surface to the southwest corner, a substantial amount of fill material is required (13 ft average). A cost trade-off should be conducted to compare the current closure plan, in addition to the costs to provide more slope to the closure surface, with the concept of sloping the surface to the northwest corner of the TDF and construction of the outlet spillway.

Section 10.0 - References

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Section 11.0 - Acronyms and Abbreviations

AECOM	AECOM Technologies
CAPEX	capital expenditures
cm/s	centimeters per second
Coleman	Coleman Engineering Company
CPT	corrugated plastic tubing
^{o}F	degrees Fahrenheit
ft	foot, feet
ft amsl	feet above mean sea level
ft/day	feet per day
ft/ft	feet per feet
ft^3	cubic feet
g	force of gravity
gpm	gallons per minute
hr	hour
ICU	Isotropically consolidated, undrained
inches/yr	inches per year
kPa	kilopascal
Marston	Marston & Marston, Inc.
MDD	Maximum Dry Density
Mft^2	Million square feet
Mft^3	Million cubic feet
Mt	Million tons
Myd^3	Million cubic yards
OCR	over-consolidation ratio
OMC	Optimum Moisture Content
OPEX	operational expenditures
Orvana	Orvana Resources U.S. Corporation
oz/sy	ounces per square yard
pcf	pounds per cubic foot
PFS	Pre-Feasibility Study
PMP	probable maximum precipitation
QA/QC	quality assurance/quality control
SIC	Seepage Induced Consolidation
SICTA	Seepage Induced Consolidation Testing Analysis
SPT	standard penetration test
TDF	Tailings Disposal Facility
t/ft^2	tons per square foot
t/yd^3	tons per cubic yard
TSF	Tailings Storage Facility
US$	2011 United States Dollar
UU	unconsolidated, undrained
yd	yard (s)
yr	year

Tables

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Table 4.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Design Criteria

Item	Design Basis			Source
Site Selection				
Basis of Location	- Favorable topography for TDF development			Orvana and
	- Availability of embankment construction materials			Knight Piésold
	- Sufficient storage capacity for tailing storage			
	- Site amenable for staged development			
	- Site amenable to closure and reclamation			
Required Offsets	- 200 ft from Section 5			Orvana and
	- 150 ft from the apparent crests of two main stream beds (Namebinag			Knight Piésold
	Creek to the west and a tributary of Gipsy Creek to the east)			
	- 250 ft from the Northern Country National Scenic Trail			
	- not to extend more than 30 ft north of the sub-crop boundary			
Tailings Production and Storage				
Mine Schedule	- 16 years (approximate 14.25 year deposition life)			Marston
Operation Schedule	- 24 hr/day, 365 days/yr			Orvana
Production Schedule	- Year	Incremental	Cumulative	Marston
(tailings solids to	1	75.3	75.3	
disposal facility,	2	720.9	796.2	
dry tons x 1,000)	3	1,835.0	2,631.2	
	4	2,025.3	4,656.5	
	5	2,486.4	7,142.9	
	6	2,467.0	9,609.9	
	7	2,487.3	12,097.2	
	8	2,477.7	14,574.9	
	9	2,494.1	17,069.0	
	10	2,492.2	19,561.2	
	11	2,469.9	22,031.1	
	12	2,526.1	24,557.2	
	13	2,531.9	27,089.1	
	14	2,530.0	29,619.1	
	15	2,530.9	32,150.0	
	16	120.4	32,270.4	
	(tailings deposition was assumed to start in November of Year 1 and			
	conclude in January of Year 16, and Years 1 and 16 were considered			
	partial years of operation, such that the overall tailings deposition occurs			
	over approximately 14.25 years)			
Tailings Solids Content	- ~50 percent (pre-flocculant addition)			Orvana
Tailings Dry Density	- 1.07 tons/yd^3 (final)			Knight Piésold
	- 0.95 tons/yd^3 (average during first 5 years)			
Tailings Deposition				
General	- Deposition typically from the southern and eastern edges of the facility			Knight Piésold
	to maintain the supernatant pond in the northwest corner			
Summer	- Banks of multiple spigots to achieve lower discharge velocities			Knight Piésold
Winter	- Single point discharges to achieve higher slurry exit velocities			Knight Piésold
Beach Slope	- minus 0.25 percent (toward northwest corner of facility)			Knight Piésold

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Table 4.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Design Criteria

Item	Design Basis	Source
Water Management During Operations		
Diversion Design Storm Event	- 100-yr/24-hr event	Knight Piésold
Supernatant Pond Depth	- 6 ft (minimum)	Knight Piésold
Freeboard	- 4.5 ft (minimum)	Knight Piésold
Design Storm Event	- 72-hr/half-PMP event (16.40 inches, likely to occur in August)	Knight Piésold
	("high-hazard potential," greater than 40 ft in height, classification	
	according to the Natural Resources and Environmental Protection Act,	
	1994 PA 451, Part 315, Dam Safety)	
Decant Reclaim Flow	- 920 gpm	Knight Piésold
Decant Flocculant Flow	- 2,100 gpm	Knight Piésold
Decant Sump Overflow Pond	- 2-hr storage of incoming flows (reclaim and flocculant)	Knight Piésold
	(seepage not considered due to variance between liner systems)	
Design Storm Event	- 100-yr/24-hr event (4.25 inches)	Knight Piésold
	("low-hazard potential" classification according to the Natural Resources	
	and Environmental Protection Act, 1994 PA 451, Part 315, Dam Safety)	
Embankment and Basin Construction		
Embankment General	- Zoned earthfill embankment constructed using the conventional	Knight Piésold
	downstream method with materials typically sourced from glacial tills	
Seal Zone	- 40 ft width	Knight Piésold
Chimney Drain	- 5 ft width	Knight Piésold
Downstream Shell	- Width varies	Knight Piésold
Embankment Crest Width	- 40 ft (minimum)	Knight Piésold
Upstream Slope	- 2H:1V (horizontal:vertical)	Knight Piésold
Downstream Slope	- 2.5H:1V	Knight Piésold
Seepage Collection System	- Chimney (filter) drain, partial blanket drains, mid-height drains, and	Knight Piésold
	collection and conveyance pipes	
Staged Construction	- 5 stages with each storing approximately 3 years of tailings production	Knight Piésold
Basin Excavation Surface	- 0 ft at the locations of boreholes BH04, BH11, and BH12	Orvana and
	- 12 ft at the location of AECOM monitoring well MW-10-120	Knight Piésold
	- 20 ft in the southeast corner of the ultimate basin and in the locations	
	of boreholes BH01, BH05, and AECOM monitoring well CW-08014	
	- 25 ft in the location of AECOM monitoring well MW-10-134	
	- 30 ft in the location of borehole BH06	
	- 35 ft in the location of borehole BH09	
	(excavation surface "straight-lined" between these points)	

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Table 4.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Design Criteria

Item	Design Basis	Source
Embankment Stability and Hazard Consequence Rating		
Stability Analyses Minimum		
Factors of Safety:		
End of Construction	- 1.3 (upstream and downstream slopes)	Knight Piésold
Rapid Drawdonw	- Not applicable	Knight Piésold
Steady State Seepage	- 1.4 (with maximum supernatant pond)	Knight Piésold
Pseudo-static	- 1.1	Knight Piésold
	(allowable estimated deformations from seismic loading analysis are	
	those judged not be detrimental to on-going performance of the facility)	
Estimated Peak Ground	- Rock PGA = 0.03 g (assuming 2 percent/50-yr event,	Knight Piésold
Acceleration (PGA)	from USGS Seismic Hazard Maps)	
Dam Classification	- High (hazard consequence categories classification according to the	Knight Piésold
	Canadian Dam Association, Dam Safety Guidelines)	
Conceptual Closure		
Surface Slope	- minus 0.25 percent (toward southwest corner of facility to minimize height	Knight Piésold
	of outlet spillway)	
Design Storm Event	- 72-hr/half-PMP event (16.40 inches, likely to occur in August)	Knight Piésold
	("high-hazard potential," greater than 40 ft in height, classification	
	according to the Natural Resources and Environmental Protection Act,	
	1994 PA 451, Part 315, Dam Safety)	
Climatic Input to Water Balance		
100-yr/24-hr Storm Event	- 4.25 inches	Knight Piésold
72-hr/half-PMP Storm Event	- 16.40 inches (likely to occur in August)	Knight Piésold
Annual Precipitation	- 33.02 (average)	Knight Piésold
Maximum Temperature (July)	- 79.2 degrees Fahrenheit (^{o}F, average)	Knight Piésold
Minimum Temperature (July)	- 54.7 ^{o}F (average)	Knight Piésold
Maximum Temperature (Jan.)	- 25.1 ^{o}F (average)	Knight Piésold
Minimum Temperature (Jan.)	- 8.3 ^{o}F (average)	Knight Piésold
Annual Potential Evaporation	- 36.47 inches (average)	Knight Piésold
Annual Tailings Evaporation	- 16.82 inches (average, exposed surface)	Knight Piésold
Annual Pond Evaporation	- 23.71 inches (average)	Knight Piésold

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Table 4.2
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Mine Production Schedule

Year	Dry Tons (x 1,000)				
	Cumulative Mined	Annual Milled[1]	Annual to Concentrate	Annual Tailings Solids to TDF	Cumlative Tailings Solids to TDF
1[2]	80.0	80.0	4.7	75.3	75.3
2	845.0	765.0	44.1	720.9	796.2
3	2,810.0	1,965.0	130.0	1,835.0	2,631.2
4	4,955.0	2,145.0	119.7	2,025.3	4,656.5
5	7,575.0	2,620.0	133.6	2,486.4	7,142.9
6	10,195.0	2,620.0	153.0	2,467.0	9,609.9
7	12,815.0	2,620.0	132.7	2,487.3	12,097.2
8	15,435.0	2,620.0	142.3	2,477.7	14,574.9
9	18,055.0	2,620.0	125.9	2,494.1	17,069.0
10	20,675.0	2,620.0	127.8	2,492.2	19,561.2
11	23,295.0	2,620.0	150.1	2,469.9	22,031.1
12	25,915.0	2,620.0	93.9	2,526.1	24,557.2
13	28,535.0	2,620.0	88.1	2,531.9	27,089.1
14	31,155.0	2,620.0	90.0	2,530.0	29,619.1
15	33,775.0	2,620.0	89.1	2,530.9	32,150.0
16[2]	33,900.0	125.0	4.6	120.4	32,270.4

Notes:

1. The annual milled production is the sum of the annual mineral to concentrate and the annual tailings solids to the TDF.
2. Tailings deposition was assumed to start in November of Year 1, and conclude in January of Year 16. Years 1 and 16 were considered partial years of operation such that the overall life of operations (deposition) is approximately 14.25 years.

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Table 5.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Storage Capacity vs. Elevation and Time
(Horizontal Tailings Surface, Case 2 Liner System[3])

Elevation[1] ft	Area yd^2	Incremental Volume yd^3	Cumulative Volume M yd^3	Cumulative Storage M tons	Time[2] years
808.3	0	0	0.00	0.00	0
810.0	547	104	0.00	0.00	
812.0	2,576	958	0.00	0.00	
814.0	6,102	2,810	0.00	0.00	
816.0	11,125	5,659	0.01	0.01	
818.0	17,469	9,452	0.02	0.01	
820.0	24,832	14,029	0.03	0.02	
822.0	33,182	19,271	0.05	0.04	
824.0	42,518	25,169	0.08	0.05	
825.8			*0.11*	*0.08*	1.0
826.0	52,841	31,724	0.11	0.08	
828.0	64,158	38,938	0.15	0.11	
830.0	76,525	46,834	0.19	0.14	
832.0	89,998	55,447	0.25	0.19	
834.0	104,592	64,802	0.32	0.25	
836.0	120,308	74,906	0.39	0.32	
838.0	137,146	85,757	0.48	0.40	
840.0	155,105	97,356	0.57	0.48	
842.0	174,186	109,702	0.68	0.57	
844.0	194,389	122,797	0.81	0.68	
845.9			*0.94*	*0.80*	2.0
846.0	215,679	136,628	0.94	0.80	
848.0	236,869	150,794	1.09	0.93	
850.0	257,304	164,678	1.26	1.08	
852.0	276,793	177,993	1.44	1.24	
854.0	295,499	190,730	1.63	1.41	
856.0	313,433	202,948	1.83	1.60	
858.0	331,492	214,947	2.04	1.80	
860.0	349,709	227,040	2.27	2.01	
862.0	368,210	239,280	2.51	2.23	
864.0	387,590	251,906	2.76	2.46	
865.4			*2.95*	*2.63*	3.0
866.0	408,240	265,247	3.03	2.71	
868.0	430,160	279,435	3.31	2.97	
870.0	453,351	294,470	3.60	3.25	

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Table 5.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Storage Capacity vs. Elevation and Time
(Horizontal Tailings Surface, Case 2 Liner System[3])

Elevation[1] ft	Area yd^2	Incremental Volume yd^3	Cumulative Volume M yd^3	Cumulative Storage M tons	Time[2] years
872.0	477,812	310,352	3.91	3.55	
874.0	503,544	327,081	4.24	3.86	
876.0	530,546	344,658	4.58	4.20	
878.0	558,819	363,081	4.95	4.55	
878.5			*5.06*	*4.66*	4.0
880.0	588,322	382,338	5.33	4.93	
882.0	618,158	402,119	5.73	5.33	
884.0	647,955	421,999	6.15	5.76	
886.0	677,713	441,852	6.60	6.22	
888.0	707,432	461,679	7.06	6.69	
889.8			*7.49*	*7.14*	5.0
890.0	737,111	481,480	7.54	7.20	
892.0	766,087	501,035	8.04	7.71	
894.0	793,375	519,794	8.56	8.24	
896.0	818,298	537,203	9.10	8.79	
898.0	841,692	553,312	9.65	9.36	
898.8			*9.89*	*9.61*	6.0
900.0	864,518	568,720	10.22	9.96	
902.0	886,813	583,761	10.80	10.57	
904.0	907,805	598,192	11.40	11.21	
906.0	927,500	611,756	12.01	11.86	
906.7			*12.23*	*12.10*	7.0
908.0	946,080	624,516	12.64	12.54	
910.0	963,484	636,512	13.27	13.23	
912.0	979,685	647,716	13.92	13.92	
913.9			*14.54*	*14.57*	8.0
914.0	994,685	658,117	14.58	14.62	
916.0	1,008,481	667,717	15.25	15.34	
918.0	1,021,076	676,515	15.92	16.07	
920.0	1,032,530	684,532	16.61	16.82	
920.7			*16.84*	*17.07*	9.0
922.0	1,042,876	691,799	17.30	17.58	
924.0	1,052,115	698,328	18.00	18.35	
926.0	1,060,246	704,118	18.70	19.13	
927.1			*19.10*	*19.56*	10.0

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Table 5.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Storage Capacity vs. Elevation and Time
(Horizontal Tailings Surface, Case 2 Liner System[3])

Elevation[1] ft	Area yd^2	Incremental Volume yd^3	Cumulative Volume M yd^3	Cumulative Storage M tons	Time[2] years
928.0	1,067,403	709,215	19.41	19.92	
930.0	1,074,351	713,917	20.13	20.72	
932.0	1,081,313	718,553	20.84	21.54	
933.2			*21.28*	*22.03*	11.0
934.0	1,088,291	723,200	21.57	22.36	
936.0	1,095,283	727,857	22.29	23.19	
938.0	1,102,290	732,523	23.03	24.00	
939.4			*23.53*	*24.56*	12.0
940.0	1,109,313	737,200	23.76	24.82	
942.0	1,116,350	741,886	24.51	25.65	
944.0	1,123,403	746,583	25.25	26.49	
945.4			*25.79*	*27.09*	13.0
946.0	1,130,470	751,290	26.00	27.34	
948.0	1,137,553	756,006	26.76	28.19	
950.0	1,144,650	760,733	27.52	29.06	
951.3			*28.02*	*29.62*	14.0
952.0	1,151,762	765,469	28.29	29.93	
954.0	1,158,890	770,216	29.06	30.81	
956.0	1,166,032	774,973	29.83	31.70	
957.0			*30.22*	*32.15*	15.0
957.3			*30.30*	*32.27*	15.04
958.0	1,173,189	779,739	30.61	32.60	

Notes:

1. The values italicised in blue represent interpolated elevations based on the stored tonnage, and the facility filling curve data.
2. Tailings deposition is anticipated to start in November of Year 1, and conclude in January of Year 16. Years 1 and 16 are considered partial years of operation such that the overall life of operations (deposition) is approximately 14.25 years.
3. The elevation vs. storage capacity relationship presented is based on consolidated tailings densities associated with the Case 2 liner system. This liner system includes a full drainage blanket beneath the tailings mass and therefore two-sided drainage of the deposit.

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Table 5.2
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Storage Capacity vs. Elevation and Time
(Minus 0.25 Percent Sloped Tailings Surface, Case 2 Liner System[1, 3, 4])

Average Elevation ft	Area yd^2	Incremental Volume yd^3	Cumulative Volume M yd^3	Cumulative Storage M tons	Time[2] yrs
808.3	0	0	0.00	0.00	0
867.2	428,160	2,983,637	2.98	2.66	3.0
899.3	884,793	6,920,200	9.90	9.62	6.0
920.7	1,044,151	6,998,016	16.90	17.13	9.0
939.5	1,109,427	6,716,071	23.62	24.65	12.0
957.9	1,174,914	7,013,294	30.63	32.63	15.04

Notes:

1. For the purpose of the PFS, it was assumed that a minus 0.25 percent tailings beach slope will be formed from the southeast to northwest corners of the TDF.
2. Tailings deposition is anticipated to start in November of Year 1, and conclude in January of Year 16. Years 1 and 16 are considered partial years of operation such that the overall life of operations (deposition) is approximately 14.25 years.
3. Storages capacities associated with the sloped tailings beach were only developed for the staged facility configurations. Stages 1 through 5 account for tailings storage through years 3, 6, 9, 12, and the end of deposition, respectively.
4. The elevation vs. storage capacity relationship presented is based on consolidated tailings densities associated with the Case 2 liner system. This liner system includes a full drainage blanket beneath the tailings mass and therefore two-sided drainage of the deposit.

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Table 7.1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Summary of Seepage and Slope Stability Analyses Material Properties

Material	Hydraulic Conductivity		Unit Weight		Effective Friction Angle
	cm/s	ft/s	t/m3	pcf	degrees
Tailings	1.0E-05	3.30E-07	1.0	62.4	5
Bedrock	1.0E-06	3.30E-08	-	-	Impenetrable
Sub-Glacial Till	3.0E-08	1.00E-09	2.1	130	30
Drainage Aggregate(1)	3.0E-05	1.00E-06	1.9	120	35
Seal Zone (Zone 1)	3.0E-08	1.00E-09	2.1	130	30
Downstream Shell(2) (Zones 3 and 4)	3.0E-09	1.00E-10	2.1	130	30
Prepared Subgrade(3)	1.0E-07	3.30E-09	1.9	120	25
Geomembrane	1.0E-09	3.30E-11	-	-	-

Notes:

1. The drainage aggregate makes up the embankment mid-height and foundation drains, the embankment chimney drain (Zone 2), and the TDF basin drainage blanket (underdrain), where applicable.
2. It is assumed that the Downstream Shell has a permeability in the x-direction which is 2 times larger than in the y-direction (ie, $k_y = 3 \times 10^{-9}$ cm/s and $k_x = 6 \times 10^{-9}$ cm/s)
3. The prepared subgrade is applicable only to the Case 2 and Case 3 liner systems.

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Table 8.1
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Staged Summary CAPEX Estimates

Item No.	Description	Stage 1 Cost	Stage 2 Cost	Stage 3 Cost	Stage 4 Cost	Stage 5 Cost	Closure Cost	Total
	CASE 1 - IN-SITU CLAY LINER COST SUMMARY							
1	Subtotal - Earthworks - Tailings Disposal Facility Cost	$20,560,183	$8,957,733	$10,455,206	$10,245,684	$9,803,477	$0	$60,022,283
2	Subtotal - Earthworks - Decant Overflow Pond Cost	$72,369	$0	$0	$0	$0	$0	$72,369
3	Subtotal - Geosynthetics - Tailings Disposal Facility Cost	$193,861	$49,241	$73,207	$99,103	$82,445	$0	$497,856
4	Subtotal - Geosynthetics - Decant Overflow Pond Cost	$22,020	$0	$0	$0	$0	$0	$22,020
5	Subtotal - Pipework - Tailings Disposal Facility Cost	$723,088	$253,060	$329,471	$245,788	$29,356	$0	$1,580,762
6	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost	$938,500	$173,000	$13,000	$16,000	$6,000	$0	$1,146,500
7	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost	$0	$0	$0	$0	$0	$18,469,603	$18,469,603
8	**Total Construction Cost**	**$22,510,020**	**$9,433,034**	**$10,870,884**	**$10,606,574**	**$9,921,278**	**$18,469,603**	**$81,811,393**
	CASE 2 - BASIN UNDERDRAIN COST SUMMARY							
1	Subtotal - Earthworks - Tailings Disposal Facility Cost	$20,027,678	$9,146,771	$9,786,283	$9,453,635	$8,957,515	$0	$57,371,882
2	Subtotal - Earthworks - Decant Overflow Pond Cost	$72,369	$0	$0	$0	$0	$0	$72,369
3	Subtotal - Geosynthetics - Tailings Disposal Facility Cost	$1,597,307	$1,300,036	$375,931	$99,103	$82,445	$0	$3,454,822
4	Subtotal - Geosynthetics - Decant Overflow Pond Cost	$22,020	$0	$0	$0	$0	$0	$22,020
5	Subtotal - Pipework - Tailings Disposal Facility Cost	$1,621,929	$784,905	$508,520	$245,788	$29,356	$0	$3,190,498
6	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost	$938,500	$173,000	$13,000	$16,000	$6,000	$0	$1,146,500
7	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost	$0	$0	$0	$0	$0	$18,469,603	$18,469,603
8	**Total Construction Cost**	**$24,279,803**	**$11,404,712**	**$10,683,734**	**$9,814,525**	**$9,075,316**	**$18,469,603**	**$83,727,694**
	CASE 3 - TSF PRESCRIPTIVE LINE COST SUMMARY							
1	Subtotal - Earthworks - Tailings Disposal Facility Cost	$20,777,949	$9,007,410	$10,474,324	$10,245,684	$9,803,477	$0	$60,308,845
2	Subtotal - Earthworks - Decant Overflow Pond Cost	$72,369	$0	$0	$0	$0	$0	$72,369
3	Subtotal - Geosynthetics - Tailings Disposal Facility Cost	$4,596,832	$3,703,383	$1,032,217	$99,103	$82,445	$0	$9,513,980
4	Subtotal - Geosynthetics - Decant Overflow Pond Cost	$22,020	$0	$0	$0	$0	$0	$22,020
5	Subtotal - Pipework - Tailings Disposal Facility Cost	$993,505	$293,563	$392,909	$245,788	$29,356	$0	$1,955,120
6	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost	$938,500	$173,000	$13,000	$16,000	$6,000	$0	$1,146,500
7	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost	$0	$0	$0	$0	$0	$18,469,603	$18,469,603
8	**Total Construction Cost**	**$27,401,175**	**$13,177,356**	**$11,912,450**	**$10,606,574**	**$9,921,278**	**$18,469,603**	**$91,488,436**

Notes:

1. No contingency has been applied to these costs; however, a minimum of 25 percent contingency is recommended.
2. No time value of money has been applied to these costs. All costs presented in 2011 United States dollars ($US).
3. Geosynthetics for the tailings disposal facility and decant sump overflow pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.
4. Pipeworks quantities have been increased 5 percent over neat line quantities to account for waste. Pipes are for drains and decants only. No pipes are included herein for the tailings delivery or deposition systems or the water reclaim system, which have been accounted for by others.
5. Costs do not include for engineering design or construction supervision and/or QA/QC.

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Table 8.2
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Annualized Summary CAPEX Estimates

Item No.	Description	Stage	1				2			3			4			5			Closure				Total Cost
		Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
			Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	
	CASE 1 - IN-SITU CLAY LINER COST SUMMARY																						
1	Subtotal - Earthworks - Tailings Disposal Facility Cost		$20,560,183	$0	$0	$2,985,911	$2,985,911	$2,985,911	$3,485,069	$3,485,069	$3,485,069	$3,415,228	$3,415,228	$3,415,228	$3,267,826	$3,267,826	$3,267,826	$0	$0	$0	$0	$0	$60,022,283
2	Subtotal - Earthworks - Decant Overflow Pond Cost		$72,369	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$72,369
3	Subtotal - Geosynthetics - Tailings Disposal Facility Cost		$193,861	$0	$0	$16,414	$16,414	$16,414	$24,402	$24,402	$24,402	$33,034	$33,034	$33,034	$27,482	$27,482	$27,482	$0	$0	$0	$0	$0	$497,856
4	Subtotal - Geosynthetics - Decant Overflow Pond Cost		$22,020	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$22,020
5	Subtotal - Pipework - Tailings Disposal Facility Cost		$723,088	$0	$0	$84,353	$84,353	$84,353	$109,824	$109,824	$109,824	$81,929	$81,929	$81,929	$9,785	$9,785	$9,785	$0	$0	$0	$0	$0	$1,580,762
6	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost		$938,500	$0	$0	$57,667	$57,667	$57,667	$4,333	$4,333	$4,333	$5,333	$5,333	$5,333	$2,000	$2,000	$2,000	$0	$0	$0	$0	$0	$1,146,500
7	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,538,667	$4,556,464	$4,538,667	$4,835,804	$18,469,603
8	**Total Construction Cost**		**$22,510,020**	**$0**	**$0**	**$3,144,345**	**$3,144,345**	**$3,144,345**	**$3,623,628**	**$3,623,628**	**$3,623,628**	**$3,535,525**	**$3,535,525**	**$3,535,525**	**$3,307,093**	**$3,307,093**	**$3,307,093**	**$0**	**$4,538,667**	**$4,556,464**	**$4,538,667**	**$4,835,804**	**$81,811,393**
	CASE 2 - BASIN UNDERDRAIN COST SUMMARY																						
1	Subtotal - Earthworks - Tailings Disposal Facility Cost		$20,027,678	$0	$0	$3,048,924	$3,048,924	$3,048,924	$3,262,094	$3,262,094	$3,262,094	$3,151,212	$3,151,212	$3,151,212	$2,985,838	$2,985,838	$2,985,838	$0	$0	$0	$0	$0	$57,371,882
2	Subtotal - Earthworks - Decant Overflow Pond Cost		$72,369	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$72,369
3	Subtotal - Geosynthetics - Tailings Disposal Facility Cost		$1,597,307	$0	$0	$433,345	$433,345	$433,345	$125,310	$125,310	$125,310	$33,034	$33,034	$33,034	$27,482	$27,482	$27,482	$0	$0	$0	$0	$0	$3,454,822
4	Subtotal - Geosynthetics - Decant Overflow Pond Cost		$22,020	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$22,020
5	Subtotal - Pipework - Tailings Disposal Facility Cost		$1,621,929	$0	$0	$261,635	$261,635	$261,635	$169,507	$169,507	$169,507	$81,929	$81,929	$81,929	$9,785	$9,785	$9,785	$0	$0	$0	$0	$0	$3,190,498
6	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost		$938,500	$0	$0	$57,667	$57,667	$57,667	$4,333	$4,333	$4,333	$5,333	$5,333	$5,333	$2,000	$2,000	$2,000	$0	$0	$0	$0	$0	$1,146,500
7	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,538,667	$4,556,464	$4,538,667	$4,835,804	$18,469,603
8	**Total Construction Cost**		**$24,279,803**	**$0**	**$0**	**$3,801,571**	**$3,801,571**	**$3,801,571**	**$3,561,245**	**$3,561,245**	**$3,561,245**	**$3,271,508**	**$3,271,508**	**$3,271,508**	**$3,025,105**	**$3,025,105**	**$3,025,105**	**$0**	**$4,538,667**	**$4,556,464**	**$4,538,667**	**$4,835,804**	**$83,727,694**
	CASE 3 - TSF PRESCRIPTIVE LINE COST SUMMARY																						
1	Subtotal - Earthworks - Tailings Disposal Facility Cost		$20,777,949	$0	$0	$3,002,470	$3,002,470	$3,002,470	$3,491,441	$3,491,441	$3,491,441	$3,415,228	$3,415,228	$3,415,228	$3,267,826	$3,267,826	$3,267,826	$0	$0	$0	$0	$0	$60,308,845
2	Subtotal - Earthworks - Decant Overflow Pond Cost		$72,369	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$72,369
3	Subtotal - Geosynthetics - Tailings Disposal Facility Cost		$4,596,832	$0	$0	$1,234,461	$1,234,461	$1,234,461	$344,072	$344,072	$344,072	$33,034	$33,034	$33,034	$27,482	$27,482	$27,482	$0	$0	$0	$0	$0	$9,513,980
4	Subtotal - Geosynthetics - Decant Overflow Pond Cost		$22,020	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$22,020
5	Subtotal - Pipework - Tailings Disposal Facility Cost		$993,505	$0	$0	$97,854	$97,854	$97,854	$130,970	$130,970	$130,970	$81,929	$81,929	$81,929	$9,785	$9,785	$9,785	$0	$0	$0	$0	$0	$1,955,120
6	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost		$938,500	$0	$0	$57,667	$57,667	$57,667	$4,333	$4,333	$4,333	$5,333	$5,333	$5,333	$2,000	$2,000	$2,000	$0	$0	$0	$0	$0	$1,146,500
7	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,538,667	$4,556,464	$4,538,667	$4,835,804	$18,469,603
8	**Total Construction Cost**		**$27,401,175**	**$0**	**$0**	**$4,392,452**	**$4,392,452**	**$4,392,452**	**$3,970,817**	**$3,970,817**	**$3,970,817**	**$3,535,525**	**$3,535,525**	**$3,535,525**	**$3,307,093**	**$3,307,093**	**$3,307,093**	**$0**	**$4,538,667**	**$4,556,464**	**$4,538,667**	**$4,835,804**	**$91,488,436**

Notes:

1. No contingency has been applied to these costs; however, a minimum of 25 percent contingency is recommended.
2. No time value of money has been applied to these costs. All costs presented in 2011 United States dollars ($US).
3. Geosynthetics for the tailings disposal facility and decant sump overflow pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.
4. Pipeworks quantities have been increased 5 percent over neat line quantities to account for waste. Pipes are for drains and decants only. No pipes are included herein for the tailings delivery or deposition systems or the water reclaim system, which have been accounted for by others.
5. Costs do not include for engineering design or construction supervision and/or QA/QC.
6. The Stage 1 facility provides storage through Year 3 of the current mine production schedule, but is shown to be constructed in its entirety during Year 0 pre-production. The Stage 1 layout could be revised to store only the first 2 years of production (0.8 M tons vs. 2.6 M tons) to reduce pre-production CAPEX; however, this is recommended to be investigated during future design.
7. Stages 2 through 5 typically each provide storage for 3 years of the current mine production schedule. The annualized costs have been estimated as one-third of the construction cost for each stage. The annualized costs occur 1 year prior to when tailings storage is required.

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Table 8.3
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Annualized OPEX Estimate

Item No.	Description	Stage	1				2			3			4			5			Closure				Total Cost
		Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
		Annual Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	Cost	
	Monitoring and Reporting of Instrumentation and Groundwater Wells																						
1	Field Labor (2 persons 25 percent of time at $80,000 salary)	$40,000	$6,667	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$766,667
2	Installation of Replacement or Added Instrumentation	$50,000	$8,333	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$958,333
3	Water Quality Analytical Testing	$100,000	$16,667	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$1,916,667
4	Reporting to State Regulators	$30,000	$5,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$575,000
	Sub-Total Operating Cost		**$36,667**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$220,000**	**$4,216,667**
	Decant System Operation and Closure																						
5	Field Labor (4 persons 10 percent of time at $60,000 salary)	$24,000	$0	$4,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$2,000	$0	$0	$0	$342,000
6	Installation of PVC Stacking Rings within Decant Tower	$5,000	$0	$833	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$417	$0	$0	$0	$71,250
7	Decant Tower Closure (concrete infilling)	$5,000	$0	$833	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$417	$0	$0	$0	$71,250
	Sub-Total Operating Cost		**$0**	**$5,667**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$34,000**	**$2,833**	**$0**	**$0**	**$0**	**$484,500**
	Decant Sump and Overflow Pond Maintenance																						
8	Field Labor (4 persons 10 percent of time at $60,000 salary)	$24,000	$0	$4,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$24,000	$2,000	$0	$0	$0	$342,000
9	Lighting Equipment	$30,000	$0	$5,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000	$2,500	$0	$0	$0	$427,500
	Sub-Total Operating Cost		**$0**	**$9,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$54,000**	**$4,500**	**$0**	**$0**	**$0**	**$769,500**
	Total Operating Cost		**$36,667**	**$234,667**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$308,000**	**$227,333**	**$220,000**	**$220,000**	**$220,000**	**$5,470,667**

Notes:
1. No contingency has been applied to these costs; however, a minimum of 25 percent contingency is recommended.
2. No time value of money has been applied to these costs. All costs presented in 2011 United States dollars ($US).
3. It has been assumed that groundwater levels and quality will be monitored for approximately 1 year prior to the start of operations. Accordingly, the Year 0 costs account for 2 months of this work. Additionally, monitoring and testing has been assumed to continue throughout the closure period, and may be required for a period beyond closure.
4. The Year 1 costs for "Decant System Operation and Closure" and "Decant Sump and Overflow Pond" assume a partial year of operation, and account for 2 months of this work. The Year 16 costs for these items accounts for a 1 month duration.

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Table 8.4
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Detailed Cost Estimate - Case 1 (In-Situ Soil Liner) CAPEX

Item No.	Description	Unit	Unit Rate	Incremental Quantities and Costs (US$) without Contingency												Total
				Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Closure		
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	
	EARTHWORKS - TAILINGS DISPOSAL FACILITY															
1	Clear and grub vegetation (assumed 80% of TDF footprint area including perimeter road)	SY	$0.50	648,863	$324,431	474,947	$237,474	152,150	$76,075	94,868	$47,434	2,758	$1,379	0	$0	$686,793
2	Excavate and haul topsoil to stockpile (assumed 1' average topsoil depth)	CY	$3.50	270,359	$946,258	197,895	$692,631	63,396	$221,885	39,528	$138,349	1,149	$4,023	0	$0	$2,003,146
3	Excavate and haul unsuitable material to stockpile (assumed 2' average unsuitable material depth within stream drainages only)	CY	$3.50	143,148	$501,019	36,464	$127,622	23,434	$82,019	7,957	$27,848	0	$0	0	$0	$738,509
4	Foundation preparation for embankment random fill placement (foundation proof rolling)	SY	$0.10	294,196	$29,420	212,878	$21,288	105,508	$10,551	118,132	$11,813	3,538	$354	0	$0	$73,425
5	Excavate to produce rough grade surface (TDF basin, cost accounted for in TDF fill line items)	CY	$0.00	3,590,001	$0	1,857,103	$0	410,375	$0	0	$0	0	$0	0	$0	$0
6	Cut to fill from basin to produce TDF embankment seal zone (Zone 1, 12-in lifts with grader levelling and smooth drum roller compaction)	CY	$3.00	728,525	$2,185,574	171,310	$513,931	131,426	$394,277	0	$0	0	$0	0	$0	$3,093,782
7	Cut to fill from borrow to produce TDF embankment seal zone (Zone 1, 12-in lifts with grader levelling and smooth drum roller compaction)	CY	$3.50	0	$0	0	$0	0	$0	464,801	$1,626,802	333,722	$1,168,027	0	$0	$2,794,829
8	Cut to fill from basin to produce TDF embankment downstream shell (Zone 3) and basin grading (2-ft lifts with grader leveling and loaded truck compaction)	CY	$2.85	1,885,170	$5,372,736	997,976	$2,844,231	278,949	$795,004	0	$0	0	$0	0	$0	$9,011,971
9	Cut to fill from borrow to produce TDF embankment downstream shell (Zone 3) and basin grading (2-ft lifts with grader leveling and loaded truck compaction)	CY	$3.25	0	$0	0	$0	953,808	$3,099,875	914,697	$2,972,764	1,058,317	$3,439,529	0	$0	$9,512,168
10	Cut to fill from basin to produce TDF embankment downstream shell (Zone 4, 4-ft lifts with grader leveling and loaded truck compaction)	CY	$2.85	976,306	$2,782,473	687,816	$1,960,277	0	$0	0	$0	0	$0	0	$0	$4,742,750
11	Cut to fill from borrow to produce TDF embankment downstream shell (Zone 4, 4-ft lifts with grader leveling and loaded truck compaction)	CY	$3.25	908,864	$2,953,808	310,160	$1,008,018	1,232,756	$4,006,458	914,697	$2,972,764	1,058,317	$3,439,529	0	$0	$14,380,578
12	Supply, place, and compact drainage aggregate for TDF embankment chimney drain (12-in-thick lifts with dozer levelling and smooth drum roller compaction)	CY	$5.00	90,465	$452,325	20,740	$103,698	18,953	$94,766	54,614	$273,072	51,485	$257,424	0	$0	$1,181,284
13	Supply, place, and compact drainage aggregate for TDF embankment foundation drains	CY	$5.00	105,019	$525,093	77,465	$387,323	40,315	$201,574	46,467	$232,333	1,510	$7,552	0	$0	$1,353,875
14	Supply, place, and compact drainage aggregate for TDF embankment mid-height drains	CY	$5.00	495	$2,475	0	$0	1,298	$6,490	185	$927	259	$1,293	0	$0	$11,186
15	Excavate and backfill geotextile anchor trenches (for TDF Embankment upstream face riprap protection)	LF	$1.00	12,118	$12,118	8,273	$8,273	15,889	$15,889	16,188	$16,188	13,395	$13,395	0	$0	$65,863
16	Supply, place and compact road wearing course (perimeter road and embankment crest)	CY	$15.00	8,978	$134,665	8,060	$120,902	11,991	$179,861	12,524	$187,858	7,217	$108,258	0	$0	$731,544
17	Supply, place and compact safety berm material (perimeter road and embankment crest)	CY	$15.00	3,425	$51,381	1,847	$27,709	7,110	$106,657	7,243	$108,649	5,983	$89,750	0	$0	$384,146
18	Supply and place decant towers drainage aggregate	CY	$15.00	11,788	$176,820	0	$0	250	$3,750	1,543	$23,145	0	$0	0	$0	$203,715
19	Supply and install decant towers (includes concrete supports and tower pipes)	EA	$75,000	13	$975,000	0	$0	0	$0	2	$150,000	0	$0	0	$0	$1,125,000
20	Supply and place TDF embankment upstream face 18" thick layer riprap (d50 = 9")	CY	$30.00	71,851	$2,155,530	15,927	$477,798	22,074	$662,208	32,262	$967,846	26,871	$806,133	0	$0	$5,069,514
21	Mobilization\Demobilization (percentage of direct cost)	%	5%	$19,581,126	$979,056	$8,531,174	$426,558.72	$9,957,339	$497,867	$9,757,794	$487,890	$9,336,645	$466,832	$0	$0	$2,858,204
	Subtotal - Earthworks - Tailings Disposal Facility Cost				**$20,560,183**		**$8,957,733**		**$10,455,206**		**$10,245,684**		**$9,803,477**		**$0**	**$60,022,283**
	EARTHWORKS - DECANT SUMP AND OVERFLOW POND															
22	Clear and grub vegetation (assumed 80% of footprint area)	SY	$0.50	9,243	$4,621	0	$0	0	$0	0	$0	0	$0	0	$0	$4,621
23	Excavate and haul topsoil to stockpile (assumed 1' average topsoil depth)	CY	$3.50	3,851	$13,479	0	$0	0	$0	0	$0	0	$0	0	$0	$13,479
24	Excavate and haul unsuitable material to stockpile (assumed 2' average unsuitable material depth over 50% of pond daylight area)	CY	$3.50	3,851	$13,479	0	$0	0	$0	0	$0	0	$0	0	$0	$13,479
25	Excavate to produce rough grade surface (cost accounted for in TDF fill line items)	CY	$0.00	49,044	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
26	Fill from cut to TDF embankment fill (cost accounted for in TDF fill line items)	CY	$0.00	49,044	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
27	Supply and install concrete decant sump (includes inlet pipe connections and valves, overflow outlet pipe, and concrete sealant)	LS	$30,000	1	$30,000	0	$0	0	$0	0	$0	0	$0	0	$0	$30,000
28	Supply, place, and compact structural backfill around concrete sump	CY	$8.00	388	$3,103	0	$0	0	$0	0	$0	0	$0	0	$0	$3,103
29	Smooth grade and smooth drum roll liner prepared subgrade surface	SY	$0.10	1,509	$151	0	$0	0	$0	0	$0	0	$0	0	$0	$151
30	Excavate and backfill geomembrane anchor trenches	LF	$1.00	516	$516	0	$0	0	$0	0	$0	0	$0	0	$0	$516
31	Supply, place and compact road wearing course (pond perimeter road)	CY	$15.00	218	$3,267	0	$0	0	$0	0	$0	0	$0	0	$0	$3,267
32	Supply, place and compact safety berm material (pond perimeter)	CY	$2.85	108	$307	0	$0	0	$0	0	$0	0	$0	0	$0	$307
33	Mobilization\Demobilization (percentage of direct cost)	%	5%	$68,923	$3,446	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,446
	Subtotal - Earthworks - Decant Overflow Pond Cost				**$72,369**		**$0**		**$0**		**$0**		**$0**		**$0**	**$72,369**
	GEOSYNTHETICS - TAILINGS DISPOSAL FACILITY															
34	Supply and install 8 oz/yd² non-woven geotextile for embankment upstream face (increased 10% for waste and scrap)	SY	$1.00	190,060	$190,060	48,275	$48,275	71,772	$71,772	97,159	$97,159	80,828	$80,828	0	$0	$488,094
35	Mobilization\Demobilization (percentage of direct cost)	%	2%	$190,060	$3,801	$48,275	$966	$71,772	$1,435	$97,159	$1,943	$80,828	$1,617	$0	$0	$9,762
	Subtotal - Geosynthetics - Tailings Disposal Facility Cost				**$193,861**		**$49,241**		**$73,207**		**$99,103**		**$82,445**		**$0**	**$497,856**
	GEOSYNTHETICS - DECANT OVERFLOW POND															
36	Supply and install 60 mil smooth HDPE pond geomembrane (increased 10% for waste and scrap)	SY	$8.50	2,540	$21,588	0	$0	0	$0	0	$0	0	$0	0	$0	$21,588
37	Mobilization\Demobilization (percentage of direct cost)	%	2%	$21,588	$432	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$432
	Subtotal - Geosynthetics - Decant Overflow Pond Cost				**$22,020**		**$0**		**$0**		**$0**		**$0**		**$0**	**$22,020**
	PIPEWORK - TAILINGS DISPOSAL FACILITY															
38	Supply and install 12" dia CPT (Type SP) decant structure drain (increased 5% for waste and scrap)	LF	$22.00	408	$8,986	0	$0	9	$208	65	$1,432	38	$832	0	$0	$11,458
39	Supply and install 12" dia HDPE (SDR 13.5) decant header pipe (increased 5% for waste and scrap)	LF	$38.00	422	$16,040	0	$0	0	$0	69	$2,633	0	$0	0	$0	$18,673
40	Supply and install 22" dia HDPE (SDR 11) decant outlet pipe (increased 5% for waste and scrap)	LF	$135.00	1,483	$200,151	0	$0	0	$0	0	$0	0	$0	0	$0	$200,151
41	Supply and install 6" dia perforated CPT (Type SP) TDF embankment chimney drain pipe (increased 5% for waste and scrap)	LF	$13.00	7,539	$98,009	3,160	$41,080	5,409	$70,314	0	$0	0	$0	0	$0	$209,403
42	Supply and install 12" dia HDPE (SDR 11) TDF embankment chimney drain outlet pipe (increased 5% for waste and scrap)	LF	$45.00	1,323	$59,546	0	$0	0	$0	0	$0	0	$0	0	$0	$59,546
43	Supply and install 6" dia perforated CPT (Type SP) TDF embankment foundation drain pipe (increased 5% for waste and scrap)	LF	$13.00	16,427	$213,553	15,369	$199,792	12,156	$158,033	16,749	$217,732	782	$10,165	0	$0	$799,275
44	Supply and install 6" dia perforated CPT (Type SP) TDF embankment mid-height drain pipe (increased 5% for waste and scrap)	LF	$13.00	2,495	$32,432	0	$0	6,542	$85,048	935	$12,152	1,303	$16,945	0	$0	$146,577
45	Supply and install 12" dia HDPE (SDR 11) TDF embankment drains outlet pipe (increased 5% for waste and scrap)	LF	$45.00	1,323	$59,546	0	$0	0	$0	0	$0	0	$0	0	$0	$59,546
46	Pipework fittings (est. 3% of pipework costs)	%	3%	$688,261	$20,648	$240,872	$7,226	$313,603	$9,408	$233,950	$7,018	$27,942	$838	$0	$0	$45,139
47	Mobilization\Demobilization (percentage of direct cost)	%	2%	$708,909	$14,178	$248,098	$4,962	$323,011	$6,460	$240,968	$4,819	$28,780	$576	$0	$0	$30,995
	Subtotal - Pipework - Tailings Disposal Facility Cost				**$723,088**		**$253,060**		**$329,471**		**$245,788**		**$29,356**		**$0**	**$76,134**

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Table 8.4
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Detailed Cost Estimate - Case 1 (In-Situ Soil Liner) CAPEX

Item No.	Description	Unit	Unit Rate	Incremental Quantities and Costs (US$) without Contingency												Total
				Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Closure		
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	
	INSTRUMENTATION - TAILINGS DISPOSAL FACILITY AND DECANT OVERFLOW POND															
48	Supply and install ground water monitoring well	EA	$50,000	18	$900,000	3	$150,000	0	$0	0	$0	0	$0	0	$0	$1,050,000
49	Supply and install settlement monument	EA	$1,000	3	$3,000	3	$3,000	3	$3,000	6	$6,000	6	$6,000	0	$0	$21,000
50	Supply and install vibrating wire piezometer (includes data logger and cables)	EA	$2,000	10	$20,000	10	$20,000	5	$10,000	5	$10,000	0	$0	0	$0	$60,000
51	Supply and install flowmeter and totalizer (decant outlet pipe, embankment chimney drain, and foundation drains)	EA	$5,000	3	$15,000	0	$0	0	$0	0	$0	0	$0	0	$0	$15,000
52	Supply and install pond water level sensors (high and low level switches with high level alarm)	EA	$500	1	$500	0	$0	0	$0	0	$0	0	$0	0	$0	$500
	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost				**$938,500**		**$173,000**		**$13,000**		**$16,000**		**$6,000**		**$0**	**$1,146,500**
	CLOSURE - TAILINGS DISPOSAL FACILITY AND DECANT OVERFLOW POND															
53	Supply and install 8 oz/yd² non-woven geotextile (tailings surface to prevent ingress into closure cap, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,292,406	$1,292,406	$1,292,406
54	Supply and install geogrid (tailings surface to increase strength for closure cap, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,292,406	$1,292,406	$1,292,406
55	Fill from borrow to produce rough grade closure surface	CY	$3.00	0	$0	0	$0	0	$0	0	$0	0	$0	2,543,297	$7,629,892	$7,629,892
56	Supply, place, and compact capillary break layer drainage aggregate/sand for closure cap (12-in-thick lift)	CY	$5.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,174,914	$5,874,571	$5,874,571
57	Topsoil from stockpile to produce vegetation growth layer (6-in-thick layer, includes seed)	CY	$4.50	0	$0	0	$0	0	$0	0	$0	0	$0	197,745	$889,851	$889,851
58	Supply and place seeding for vegetation growth (tractor spread)	SY	$0.25	0	$0	0	$0	0	$0	0	$0	0	$0	1,184,157	$296,039	$296,039
59	Excavate to produce rough grade surface (closure spillway and surface water diversion channel)	CY	$4.50	0	$0	0	$0	0	$0	0	$0	0	$0	2,869	$12,913	$12,913
60	Supply and install 8 oz/yd² non-woven geotextile (closure spillway and surface water diversion channel, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	4,088	$4,088	$4,088
61	Supply and install closure spillway articulated block lining (Contech 50T block)	SY	$90.00	0	$0	0	$0	0	$0	0	$0	0	$0	848	$76,288	$76,288
62	Supply and place surface water diversion channel 18" thick layer riprap (d50 = 9")	CY	$30.00	0	$0	0	$0	0	$0	0	$0	0	$0	2,868	$86,052	$86,052
63	Supply and install energy dissipation structures	LS	$50,000	0	$0	0	$0	0	$0	0	$0	0	$0	2	$100,000	$100,000
64	Maintenance regrading and sloping of post-closure construction surface	SY	$0.18	0	$0	0	$0	0	$0	0	$0	0	$0	197,745	$35,594	$35,594
65	Mobilization\Demobilization (percentage of direct cost)	%	5%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,590,098	$879,505	$879,505
	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost				**$0**		**$0**		**$0**		**$0**		**$0**		**$18,469,603**	**$18,469,603**
	ENGINEERING DESIGN QA/QC															
66	Construction QA/QC	EST			$0		$0		$0		$0		$0		$0	$0
67	Survey	EST			$0		$0		$0		$0		$0		$0	$0
68	As-built report	EST			$0		$0		$0		$0		$0		$0	$0
	Subtotal - Engineering Design QA/QC Cost				**$0**		**$0**		**$0**		**$0**		**$0**		**$0**	**$0**
	COST SUMMARY															
69	Subtotal - Earthworks - Tailings Disposal Facility Cost				$20,560,183		$8,957,733		$10,455,206		$10,245,684		$9,803,477		$0	$60,022,283
70	Subtotal - Earthworks - Decant Overflow Pond Cost				$72,369		$0		$0		$0		$0		$0	$72,369
71	Subtotal - Geosynthetics - Tailings Disposal Facility Cost				$193,861		$49,241		$73,207		$99,103		$82,445		$0	$497,856
72	Subtotal - Geosynthetics - Decant Overflow Pond Cost				$22,020		$0		$0		$0		$0		$0	$22,020
73	Subtotal - Pipework - Tailings Disposal Facility Cost				$723,088		$253,060		$329,471		$245,788		$29,356		$0	$1,580,762
74	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost				$938,500		$173,000		$13,000		$16,000		$6,000		$0	$1,146,500
75	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost				$0		$0		$0		$0		$0		$18,469,603	$18,469,603
76	**Total Construction Cost**				**$22,510,020**		**$9,433,034**		**$10,870,884**		**$10,606,574**		**$9,921,278**		**$18,469,603**	**$81,811,393**

Notes:
1. No contingency has been applied to these costs; however, a minimum of 25 percent contingency is recommended.
2. No time value of money has been applied to these costs. All costs presented in 2011 United States dollars ($US).
3. Geosynthetics for the tailings disposal facility and decant sump overflow pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.
4. Pipeworks quantities have been increased 5 percent over neat line quantities to account for waste. Pipes are for drains and decants only. No pipes are included herein for the tailings delivery or deposition systems or the water reclaim system, which have been accounted for by others.
5. Costs do not include for engineering design or construction supervision and/or QA/QC.

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Table 8.5
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Detailed Cost Estimate - Case 2 (Full Drainage Blanket) CAPEX

Item No.	Description	Unit	Unit Rate	Incremental Quantities and Costs (US$) without Contingency												Total
				Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Closure		
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	
	EARTHWORKS - TAILINGS DISPOSAL FACILITY															
1	Clear and grub vegetation (assumed 80% of TDF footprint area including perimeter road)	SY	$0.50	648,863	$324,431	474,947	$237,474	152,150	$76,075	94,868	$47,434	2,758	$1,379	0	$0	$686,793
2	Excavate and haul topsoil to stockpile (assumed 1' average topsoil depth)	CY	$3.50	270,359	$946,258	197,895	$692,631	63,396	$221,885	39,528	$138,349	1,149	$4,023	0	$0	$2,003,146
3	Excavate and haul unsuitable material to stockpile (assumed 2' average unsuitable material depth within stream drainages only)	CY	$3.50	143,148	$501,019	36,464	$127,622	23,434	$82,019	7,957	$27,848	0	$0	0	$0	$738,509
4	Foundation preparation for embankment random fill placement (foundation proof rolling)	SY	$0.10	294,196	$29,420	212,878	$21,288	105,508	$10,551	118,132	$11,813	3,538	$354	0	$0	$73,425
5	Excavate to produce rough grade surface (TDF basin, cost accounted for in TDF fill line items)	CY	$0.00	3,765,720	$0	1,948,002	$0	430,461	$0	0	$0	0	$0	0	$0	$0
6	Cut to fill from basin to produce TDF embankment seal zone (Zone 1, 12-in lifts with grader levelling and smooth drum roller compaction)	CY	$3.00	728,525	$2,185,574	171,310	$513,931	131,426	$394,277	0	$0	0	$0	0	$0	$3,093,782
7	Cut to fill from borrow to produce TDF embankment seal zone (Zone 1, 12-in lifts with grader levelling and smooth drum roller compaction)	CY	$3.50	0	$0	0	$0	0	$0	464,801	$1,626,802	333,722	$1,168,027	0	$0	$2,794,829
8	Cut to fill from basin to produce TDF embankment downstream shell (Zone 3) and basin grading (2-ft lifts with grader leveling and loaded truck compaction)	CY	$2.85	1,657,597	$4,724,150	888,346	$2,531,785	299,035	$852,250	0	$0	0	$0	0	$0	$8,108,186
9	Cut to fill from borrow to produce TDF embankment downstream shell (Zone 3) and basin grading (2-ft lifts with grader leveling and loaded truck compaction)	CY	$3.25	0	$0	0	$0	802,356	$2,607,657	798,645	$2,595,598	934,366	$3,036,690	0	$0	$8,239,945
10	Cut to fill from basin to produce TDF embankment downstream shell (Zone 4, 4-ft lifts with grader leveling and loaded truck compaction)	CY	$2.85	1,379,599	$3,931,856	888,346	$2,531,785	0	$0	0	$0	0	$0	0	$0	$6,463,641
11	Cut to fill from borrow to produce TDF embankment downstream shell (Zone 4, 4-ft lifts with grader leveling and loaded truck compaction)	CY	$3.25	277,998	$903,493	0	$0	1,101,391	$3,579,521	798,645	$2,595,598	934,366	$3,036,690	0	$0	$10,115,302
12	Supply, place, and compact drainage aggregate for TDF embankment chimney drain (12-in-thick lifts with dozer levelling and smooth drum roller compaction)	CY	$5.00	90,465	$452,325	20,740	$103,698	18,953	$94,766	54,614	$273,072	51,485	$257,424	0	$0	$1,181,284
13	Supply, place, and compact drainage aggregate for TDF embankment foundation drains	CY	$5.00	105,019	$525,093	77,465	$387,323	40,315	$201,574	46,467	$232,333	1,510	$7,552	0	$0	$1,353,875
14	Supply, place, and compact drainage aggregate for TDF embankment mid-height drains	CY	$5.00	495	$2,475	0	$0	1,298	$6,490	185	$927	259	$1,293	0	$0	$11,186
15	Excavate and backfill geotextile anchor trenches (for TDF Embankment upstream face riprap protection)	LF	$1.00	12,118	$12,118	8,273	$8,273	15,889	$15,889	16,188	$16,188	13,395	$13,395	0	$0	$65,863
16	Supply and place underdrainage system blanket drain aggregate material (1-ft-thick full blanket, Case 2 Liner System)	CY	$5.00	208,474	$1,042,369	185,798	$928,992	44,968	$224,840	0	$0	0	$0	0	$0	$2,196,202
17	Supply, place and compact road wearing course (perimeter road and embankment crest)	CY	$15.00	8,978	$134,665	8,060	$120,902	11,991	$179,861	12,524	$187,858	7,217	$108,258	0	$0	$731,544
18	Supply, place and compact safety berm material (perimeter road and embankment crest)	CY	$15.00	3,425	$51,381	1,847	$27,709	7,110	$106,657	7,243	$108,649	5,983	$89,750	0	$0	$384,146
19	Supply and place decant towers drainage aggregate	CY	$15.00	11,788	$176,820	0	$0	250	$3,750	1,543	$23,145	0	$0	0	$0	$203,715
20	Supply and install decant towers (includes concrete supports and tower pipes)	EA	$75,000	13	$975,000	0	$0	0	$0	2	$150,000	0	$0	0	$0	$1,125,000
21	Supply and place TDF embankment upstream face 18" thick layer riprap (d50 = 9")	CY	$30.00	71,851	$2,155,530	15,927	$477,798	22,074	$662,208	32,262	$967,846	26,871	$806,133	0	$0	$5,069,514
22	Mobilization\Demobilization (percentage of direct cost)	%	5%	$19,073,979	$953,699	$8,711,210	$435,561	$9,320,269	$466,013	$9,003,462	$450,173	$8,530,967	$426,548	$0	$0	$2,731,994
	Subtotal - Earthworks - Tailings Disposal Facility Cost				**$20,027,678**		**$9,146,771**		**$9,786,283**		**$9,453,635**		**$8,957,515**		**$0**	**$57,371,882**
	EARTHWORKS - DECANT SUMP AND OVERFLOW POND															
23	Clear and grub vegetation (assumed 80% of footprint area)	SY	$0.50	9,243	$4,621	0	$0	0	$0	0	$0	0	$0	0	$0	$4,621
24	Excavate and haul topsoil to stockpile (assumed 1' average topsoil depth)	CY	$3.50	3,851	$13,479	0	$0	0	$0	0	$0	0	$0	0	$0	$13,479
25	Excavate and haul unsuitable material to stockpile (assumed 2' average unsuitable material depth over 50% of pond daylight area)	CY	$3.50	3,851	$13,479	0	$0	0	$0	0	$0	0	$0	0	$0	$13,479
26	Excavate to produce rough grade surface (cost accounted for in TDF fill line items)	CY	$0.00	49,044	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
27	Fill from cut to TDF embankment fill (cost accounted for in TDF fill line items)	CY	$0.00	49,044	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
28	Supply and install concrete decant sump (includes inlet pipe connections and valves, overflow outlet pipe, and concrete sealant)	LS	$30,000	1	$30,000	0	$0	0	$0	0	$0	0	$0	0	$0	$30,000
29	Supply, place, and compact structural backfill around concrete sump	CY	$8.00	388	$3,103	0	$0	0	$0	0	$0	0	$0	0	$0	$3,103
30	Smooth grade and smooth drum roll liner prepared subgrade surface	SY	$0.10	1,509	$151	0	$0	0	$0	0	$0	0	$0	0	$0	$151
31	Excavate and backfill geomembrane anchor trenches	LF	$1.00	516	$516	0	$0	0	$0	0	$0	0	$0	0	$0	$516
32	Supply, place and compact road wearing course (pond perimeter road)	CY	$15.00	218	$3,267	0	$0	0	$0	0	$0	0	$0	0	$0	$3,267
33	Supply, place and compact safety berm material (pond perimeter)	CY	$2.85	108	$307	0	$0	0	$0	0	$0	0	$0	0	$0	$307
34	Mobilization\Demobilization (percentage of direct cost)	%	5%	$68,923	$3,446	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,446
	Subtotal - Earthworks - Decant Overflow Pond Cost				**$72,369**		**$0**		**$0**		**$0**		**$0**		**$0**	**$72,369**
	GEOSYNTHETICS - TAILINGS DISPOSAL FACILITY															
35	Supply and install 8 oz/yd² non-woven geotextile for full blanket drain (increased 10% for waste and scrap) (Case 2 Liner System)	SY	$1.00	1,375,928	$1,375,928	1,226,270	$1,226,270	296,788	$296,788	0	$0	0	$0	0	$0	$2,898,986
36	Supply and install 8 oz/yd² non-woven geotextile for embankment upstream face (increased 10% for waste and scrap)	SY	$1.00	190,060	$190,060	48,275	$48,275	71,772	$71,772	97,159	$97,159	80,828	$80,828	0	$0	$488,094
37	Mobilization\Demobilization (percentage of direct cost)	%	2%	$1,565,987	$31,320	$1,274,545	$25,491	$368,560	$7,371	$97,159	$1,943	$80,828	$1,617	$0	$0	$67,742
	Subtotal - Geosynthetics - Tailings Disposal Facility Cost				**$1,597,307**		**$1,300,036**		**$375,931**		**$99,103**		**$82,445**		**$0**	**$3,454,822**
	GEOSYNTHETICS - DECANT OVERFLOW POND															
38	Supply and install 60 mil smooth HDPE pond geomembrane (increased 10% for waste and scrap)	SY	$8.50	2,540	$21,588	0	$0	0	$0	0	$0	0	$0	0	$0	$21,588
39	Mobilization\Demobilization (percentage of direct cost)	%	2%	$21,588	$432	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$432
	Subtotal - Geosynthetics - Decant Overflow Pond Cost				**$22,020**		**$0**		**$0**		**$0**		**$0**		**$0**	**$22,020**

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Table 8.5
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Detailed Cost Estimate - Case 2 (Full Drainage Blanket) CAPEX

Item No.	Description	Unit	Unit Rate	Incremental Quantities and Costs (US$) without Contingency												Total
				Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Closure		
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	
	PIPEWORK - TAILINGS DISPOSAL FACILITY															
40	Supply and install 4" dia perforated CPT (Type SP) underdrainage lateral (increased 5% for waste and scrap) (Case 2 Liner System)	LF	$5.00	78,803	$394,016	70,232	$351,159	16,998	$84,989	0	$0	0	$0	0	$0	$830,164
41	Supply and install 6" dia perforated CPT (Type SP) underdrainage header (increased 5% for waste and scrap) (Case 2 Liner System)	LF	$13.00	27,291	$354,788	11,929	$155,071	6,572	$85,436	0	$0	0	$0	0	$0	$595,295
42	Supply and install 16" dia HDPE (SDR 11) underdrainage outlet pipe (increased 5% for waste and scrap) (Case 2 Liner System)	LF	$72.00	1,483	$106,747	0	$0	0	$0	0	$0	0	$0	0	$0	$106,747
43	Supply and install 12" dia CPT (Type SP) decant structure drain (increased 5% for waste and scrap)	LF	$22.00	408	$8,986	0	$0	9	$208	65	$1,432	38	$832	0	$0	$11,458
44	Supply and install 12" dia HDPE (SDR 13.5) decant header pipe (increased 5% for waste and scrap)	LF	$38.00	422	$16,040	0	$0	0	$0	69	$2,633	0	$0	0	$0	$18,673
45	Supply and install 22" dia HDPE (SDR 11) decant outlet pipe (increased 5% for waste and scrap)	LF	$135.00	1,483	$200,151	0	$0	0	$0	0	$0	0	$0	0	$0	$200,151
46	Supply and install 6" dia perforated CPT (Type SP) TDF embankment chimney drain pipe (increased 5% for waste and scrap)	LF	$13.00	7,539	$98,009	3,160	$41,080	5,409	$70,314	0	$0	0	$0	0	$0	$209,403
47	Supply and install 12" dia HDPE (SDR 11) TDF embankment chimney drain outlet pipe (increased 5% for waste and scrap)	LF	$45.00	1,323	$59,546	0	$0	0	$0	0	$0	0	$0	0	$0	$59,546
48	Supply and install 6" dia perforated CPT (Type SP) TDF embankment foundation drain pipe (increased 5% for waste and scrap)	LF	$13.00	16,427	$213,553	15,369	$199,792	12,156	$158,033	16,749	$217,732	782	$10,165	0	$0	$799,275
49	Supply and install 6" dia perforated CPT (Type SP) TDF embankment mid-height drain pipe (increased 5% for waste and scrap)	LF	$13.00	2,495	$32,432	0	$0	6,542	$85,048	935	$12,152	1,303	$16,945	0	$0	$146,577
50	Supply and install 12" dia HDPE (SDR 11) TDF embankment drains outlet pipe (increased 5% for waste and scrap)	LF	$45.00	1,323	$59,546	0	$0	0	$0	0	$0	0	$0	0	$0	$59,546
51	Pipework fittings (est. 3% of pipework costs)	%	3%	$1,543,812	$46,314	$747,102	$22,413	$484,028	$14,521	$233,950	$7,018	$27,942	$838	$0	$0	$91,105
52	Mobilization\Demobilization (percentage of direct cost)	%	2%	$1,590,126	$31,803	$769,515	$15,390	$498,549	$9,971	$240,968	$4,819	$28,780	$576	$0	$0	$62,559
	Subtotal - Pipework - Tailings Disposal Facility Cost				**$1,621,929**		**$784,905**		**$508,520**		**$245,788**		**$29,356**		**$0**	**$3,190,498**
	INSTRUMENTATION - TAILINGS DISPOSAL FACILITY AND DECANT OVERFLOW POND															
53	Supply and install ground water monitoring well	EA	$50,000	18	$900,000	3	$150,000	0	$0	0	$0	0	$0	0	$0	$1,050,000
54	Supply and install settlement monument	EA	$1,000	3	$3,000	3	$3,000	3	$3,000	6	$6,000	6	$6,000	0	$0	$21,000
55	Supply and install vibrating wire piezometer (includes data logger and cables)	EA	$2,000	10	$20,000	10	$20,000	5	$10,000	5	$10,000	0	$0	0	$0	$60,000
56	Supply and install flowmeter and totalizer (decant outlet pipe, embankment chimney drain, and foundation drains)	EA	$5,000	3	$15,000	0	$0	0	$0	0	$0	0	$0	0	$0	$15,000
57	Supply and install pond water level sensors (high and low level switches with high level alarm)	EA	$500	1	$500	0	$0	0	$0	0	$0	0	$0	0	$0	$500
	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost				**$938,500**		**$173,000**		**$13,000**		**$16,000**		**$6,000**		**$0**	**$1,146,500**
	CLOSURE - TAILINGS DISPOSAL FACILITY AND DECANT OVERFLOW POND															
58	Supply and install 8 oz/yd² non-woven geotextile (tailings surface to prevent ingress into closure cap, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,292,406	$1,292,406	$1,292,406
59	Supply and install geogrid (tailings surface to increase strength for closure cap, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,292,406	$1,292,406	$1,292,406
60	Fill from borrow to produce rough grade closure surface	CY	$3.00	0	$0	0	$0	0	$0	0	$0	0	$0	2,543,297	$7,629,892	$7,629,892
61	Supply, place, and compact capillary break layer drainage aggregate/sand for closure cap (12-in-thick lift)	CY	$5.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,174,914	$5,874,571	$5,874,571
62	Topsoil from stockpile to produce vegetation growth layer (6-in-thick layer, includes seed)	CY	$4.50	0	$0	0	$0	0	$0	0	$0	0	$0	197,745	$889,851	$889,851
63	Supply and place seeding for vegetation growth (tractor spread)	SY	$0.25	0	$0	0	$0	0	$0	0	$0	0	$0	1,184,157	$296,039	$296,039
64	Excavate to produce rough grade surface (closure spillway and surface water diversion channel)	CY	$4.50	0	$0	0	$0	0	$0	0	$0	0	$0	2,869	$12,913	$12,913
65	Supply and install 8 oz/yd² non-woven geotextile (closure spillway and surface water diversion channel, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	4,088	$4,088	$4,088
66	Supply and install closure spillway articulated block lining (Contech 50T block)	SY	$90.00	0	$0	0	$0	0	$0	0	$0	0	$0	848	$76,288	$76,288
67	Supply and place surface water diversion channel 18" thick layer riprap (d50 = 9")	CY	$30.00	0	$0	0	$0	0	$0	0	$0	0	$0	2,868	$86,052	$86,052
68	Supply and install energy dissipation structures	LS	$50,000	0	$0	0	$0	0	$0	0	$0	0	$0	2	$100,000	$100,000
69	Maintenance regrading and sloping of post-closure construction surface	SY	$0.18	0	$0	0	$0	0	$0	0	$0	0	$0	197,745	$35,594	$35,594
70	Mobilization\Demobilization (percentage of direct cost)	%	5%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,590,098	$879,505	$879,505
	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost				**$0**		**$0**		**$0**		**$0**		**$0**		**$18,469,603**	**$18,469,603**
	ENGINEERING DESIGN QA/QC															
71	Construction QA/QC	EST			$0		$0		$0		$0		$0		$0	$0
72	Survey	EST			$0		$0		$0		$0		$0		$0	$0
73	As-built report	EST			$0		$0		$0		$0		$0		$0	$0
	Subtotal - Engineering Design QA/QC Cost				**$0**		**$0**		**$0**		**$0**		**$0**		**$0**	**$0**
	COST SUMMARY															
74	Subtotal - Earthworks - Tailings Disposal Facility Cost				$20,027,678		$9,146,771		$9,786,283		$9,453,635		$8,957,515		$0	$57,371,882
75	Subtotal - Earthworks - Decant Overflow Pond Cost				$72,369		$0		$0		$0		$0		$0	$72,369
76	Subtotal - Geosynthetics - Tailings Disposal Facility Cost				$1,597,307		$1,300,036		$375,931		$99,103		$82,445		$0	$3,454,822
77	Subtotal - Geosynthetics - Decant Overflow Pond Cost				$22,020		$0		$0		$0		$0		$0	$22,020
78	Subtotal - Pipework - Tailings Disposal Facility Cost				$1,621,929		$784,905		$508,520		$245,788		$29,356		$0	$3,190,498
79	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost				$938,500		$173,000		$13,000		$16,000		$6,000		$0	$1,146,500
80	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost				$0		$0		$0		$0		$0		$18,469,603	$18,469,603
81	**Total Construction Cost**				**$24,279,803**		**$11,404,712**		**$10,683,734**		**$9,814,525**		**$9,075,316**		**$18,469,603**	**$83,727,694**

Notes:
1. No contingency has been applied to these costs; however, a minimum of 25 percent contingency is recommended.
2. No time value of money has been applied to these costs. All costs presented in 2011 United States dollars ($US).
3. Geosynthetics for the tailings disposal facility and decant sump overflow pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.
4. Pipeworks quantities have been increased 5 percent over neat line quantities to account for waste. Pipes are for drains and decants only. No pipes are included herein for the tailings delivery or deposition systems or the water reclaim system, which have been accounted for by others.
5. Costs do not include for engineering design or construction supervision and/or QA/QC.

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Table 8.6
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Detailed Cost Estimate - Case 3 (TSF Prescriptive Liner) CAPEX

Item No.	Description	Unit	Unit Rate	Incremental Quantities and Costs (US$) without Contingency												Total
				Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Closure		
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	
	EARTHWORKS - TAILINGS DISPOSAL FACILITY															
1	Clear and grub vegetation (assumed 80% of TDF footprint area including perimeter road)	SY	$0.50	648,863	$324,431	474,947	$237,474	152,150	$76,075	94,868	$47,434	2,758	$1,379	0	$0	$686,793
2	Excavate and haul topsoil to stockpile (assumed 1' average topsoil depth)	CY	$3.50	270,359	$946,258	197,895	$692,631	63,396	$221,885	39,528	$138,349	1,149	$4,023	0	$0	$2,003,146
3	Excavate and haul unsuitable material to stockpile (assumed 2' average unsuitable material depth within stream drainages only)	CY	$3.50	143,148	$501,019	36,464	$127,622	23,434	$82,019	7,957	$27,848	0	$0	0	$0	$738,509
4	Foundation preparation for embankment random fill placement (foundation proof rolling)	SY	$0.10	294,196	$29,420	212,878	$21,288	105,508	$10,551	118,132	$11,813	3,538	$354	0	$0	$73,425
5	Excavate to produce rough grade surface (TDF basin, cost accounted for in TDF fill line items)	CY	$0.00	3,590,001	$0	1,857,103	$0	410,375	$0	0	$0	0	$0	0	$0	$0
6	Cut to fill from basin to produce TDF embankment seal zone (Zone 1, 12-in lifts with grader levelling and smooth drum roller compaction)	CY	$3.00	728,525	$2,185,574	171,310	$513,931	131,426	$394,277	0	$0	0	$0	0	$0	$3,093,782
7	Cut to fill from borrow to produce TDF embankment seal zone (Zone 1, 12-in lifts with grader levelling and smooth drum roller compaction)	CY	$3.50	0	$0	0	$0	0	$0	464,801	$1,626,802	333,722	$1,168,027	0	$0	$2,794,829
8	Cut to fill from basin to produce TDF embankment downstream shell (Zone 3) and basin grading (2-ft lifts with grader leveling and loaded truck compaction)	CY	$2.85	1,885,170	$5,372,736	997,976	$2,844,231	278,949	$795,004	0	$0	0	$0	0	$0	$9,011,971
9	Cut to fill from borrow to produce TDF embankment downstream shell (Zone 3) and basin grading (2-ft lifts with grader leveling and loaded truck compaction)	CY	$3.25	0	$0	0	$0	953,808	$3,099,875	914,697	$2,972,764	1,058,317	$3,439,529	0	$0	$9,512,168
10	Cut to fill from basin to produce TDF embankment downstream shell (Zone 4, 4-ft lifts with grader leveling and loaded truck compaction)	CY	$2.85	976,306	$2,782,473	687,816	$1,960,277	0	$0	0	$0	0	$0	0	$0	$4,742,750
11	Cut to fill from borrow to produce TDF embankment downstream shell (Zone 4, 4-ft lifts with grader leveling and loaded truck compaction)	CY	$3.25	908,864	$2,953,808	310,160	$1,008,018	1,232,756	$4,006,458	914,697	$2,972,764	1,058,317	$3,439,529	0	$0	$14,380,578
12	Supply, place, and compact drainage aggregate for TDF embankment chimney drain (12-in-thick lifts with dozer levelling and smooth drum roller compaction)	CY	$5.00	90,465	$452,325	20,740	$103,698	18,953	$94,766	54,614	$273,072	51,485	$257,424	0	$0	$1,181,284
13	Supply, place, and compact drainage aggregate for TDF embankment foundation drains	CY	$5.00	105,019	$525,093	77,465	$387,323	40,315	$201,574	46,467	$232,333	1,510	$7,552	0	$0	$1,353,875
14	Supply, place, and compact drainage aggregate for TDF embankment mid-height drains	CY	$5.00	495	$2,475	0	$0	1,298	$6,490	185	$927	259	$1,293	0	$0	$11,186
15	Smooth grade and smooth drum roll liner prepared subgrade surface (Case 3 Liner System)	SY	$0.10	425,473	$42,547	375,794	$37,579	95,507	$9,551	0	$0	0	$0	0	$0	$89,677
16	Excavate and backfill geomembrane anchor trenches (Case 3 Liner System)	LF	$1.00	11,331	$11,331	7,084	$7,084	4,510	$4,510	0	$0	0	$0	0	$0	$22,925
17	Excavate and backfill geotextile anchor trenches (for TDF Embankment upstream face riprap protection)	LF	$1.00	12,118	$12,118	8,273	$8,273	15,889	$15,889	16,188	$16,188	13,395	$13,395	0	$0	$65,863
18	Supply and place underdrainage system blanket drain aggregate material (1-ft-thick partial blanket 1000 ft radius, Case 3 Liner System)	CY	$5.00	30,704	$153,519	530	$2,648	829	$4,147	0	$0	0	$0	0	$0	$160,314
19	Supply, place and compact road wearing course (perimeter road and embankment crest)	CY	$15.00	8,978	$134,665	8,060	$120,902	11,991	$179,861	12,524	$187,858	7,217	$108,258	0	$0	$731,544
20	Supply, place and compact safety berm material (perimeter road and embankment crest)	CY	$15.00	3,425	$51,381	1,847	$27,709	7,110	$106,657	7,243	$108,649	5,983	$89,750	0	$0	$384,146
21	Supply and place decant towers drainage aggregate	CY	$15.00	11,788	$176,820	0	$0	250	$3,750	1,543	$23,145	0	$0	0	$0	$203,715
22	Supply and install decant towers (includes concrete supports and tower pipes)	EA	$75,000	13	$975,000	0	$0	0	$0	2	$150,000	0	$0	0	$0	$1,125,000
23	Supply and place TDF embankment upstream face 18" thick layer riprap (d50 = 9")	CY	$30.00	71,851	$2,155,530	15,927	$477,798	22,074	$662,208	32,262	$967,846	26,871	$806,133	0	$0	$5,069,514
24	Mobilization\Demobilization (percentage of direct cost)	%	5%	$19,788,523	$989,426	$8,578,485	$428,924	$9,975,547	$498,777	$9,757,794	$487,890	$9,336,645	$466,832	$0	$0	$2,871,850
	Subtotal - Earthworks - Tailings Disposal Facility Cost				**$20,777,949**		**$9,007,410**		**$10,474,324**		**$10,245,684**		**$9,803,477**		**$0**	**$60,308,845**
	EARTHWORKS - DECANT SUMP AND OVERFLOW POND															
25	Clear and grub vegetation (assumed 80% of footprint area)	SY	$0.50	9,243	$4,621	0	$0	0	$0	0	$0	0	$0	0	$0	$4,621
26	Excavate and haul topsoil to stockpile (assumed 1' average topsoil depth)	CY	$3.50	3,851	$13,479	0	$0	0	$0	0	$0	0	$0	0	$0	$13,479
27	Excavate and haul unsuitable material to stockpile (assumed 2' average unsuitable material depth over 50% of pond daylight area)	CY	$3.50	3,851	$13,479	0	$0	0	$0	0	$0	0	$0	0	$0	$13,479
28	Excavate to produce rough grade surface (cost accounted for in TDF fill line items)	CY	$0.00	49,044	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
29	Fill from cut to TDF embankment fill (cost accounted for in TDF fill line items)	CY	$0.00	49,044	$0	0	$0	0	$0	0	$0	0	$0	0	$0	$0
30	Supply and install concrete decant sump (includes inlet pipe connections and valves, overflow outlet pipe, and concrete sealant)	LS	$30,000	1	$30,000	0	$0	0	$0	0	$0	0	$0	0	$0	$30,000
31	Supply, place, and compact structural backfill around concrete sump	CY	$8.00	388	$3,103	0	$0	0	$0	0	$0	0	$0	0	$0	$3,103
32	Smooth grade and smooth drum roll liner prepared subgrade surface	SY	$0.10	1,509	$151	0	$0	0	$0	0	$0	0	$0	0	$0	$151
33	Excavate and backfill geomembrane anchor trenches	LF	$1.00	516	$516	0	$0	0	$0	0	$0	0	$0	0	$0	$516
34	Supply, place and compact road wearing course (pond perimeter road)	CY	$15.00	218	$3,267	0	$0	0	$0	0	$0	0	$0	0	$0	$3,267
35	Supply, place and compact safety berm material (pond perimeter)	CY	$2.85	108	$307	0	$0	0	$0	0	$0	0	$0	0	$0	$307
36	Mobilization\Demobilization (percentage of direct cost)	%	5%	$68,923	$3,446	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,446
	Subtotal - Earthworks - Decant Overflow Pond Cost				**$72,369**		**$0**		**$0**		**$0**		**$0**		**$0**	**$72,369**
	GEOSYNTHETICS - TAILINGS DISPOSAL FACILITY															
37	Supply and install 60 mil smooth HDPE geomembrane (floor only, increased 10% for waste and scrap) (Case 3 Liner System)	SY	$8.50	479,495	$4,075,706	420,678	$3,575,761	109,372	$929,663	0	$0	0	$0	0	$0	$8,581,129
38	Supply and install 8 oz/yd² non-woven geotextile for partial blanket drain (increased 10% for waste and scrap) (Case 3 Liner System)	SY	$1.00	142,584	$142,584	6,731	$6,731	10,543	$10,543	0	$0	0	$0	0	$0	$159,858
39	Supply and install 16 oz/yd² non-woven geotextile for partial blanket drain (increased 10% for waste and scrap) (Case 3 Liner System)	SY	$1.50	65,566	$98,349	0	$0	0	$0	0	$0	0	$0	0	$0	$98,349
40	Supply and install 8 oz/yd² non-woven geotextile for embankment upstream face (increased 10% for waste and scrap)	SY	$1.00	190,060	$190,060	48,275	$48,275	71,772	$71,772	97,159	$97,159	80,828	$80,828	0	$0	$488,094
41	Mobilization\Demobilization (percentage of direct cost)	%	2%	$4,506,698	$90,134	$3,630,768	$72,615	$1,011,977	$20,240	$97,159	$1,943	$80,828	$1,617	$0	$0	$186,549
	Subtotal - Geosynthetics - Tailings Disposal Facility Cost				**$4,596,832**		**$3,703,383**		**$1,032,217**		**$99,103**		**$82,445**		**$0**	**$9,513,980**
	GEOSYNTHETICS - DECANT OVERFLOW POND															
42	Supply and install 60 mil smooth HDPE pond geomembrane (increased 10% for waste and scrap)	SY	$8.50	2,540	$21,588	0	$0	0	$0	0	$0	0	$0	0	$0	$21,588
43	Mobilization\Demobilization (percentage of direct cost)	%	2%	$21,588	$432	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$432
	Subtotal - Geosynthetics - Decant Overflow Pond Cost				**$22,020**		**$0**		**$0**		**$0**		**$0**		**$0**	**$22,020**

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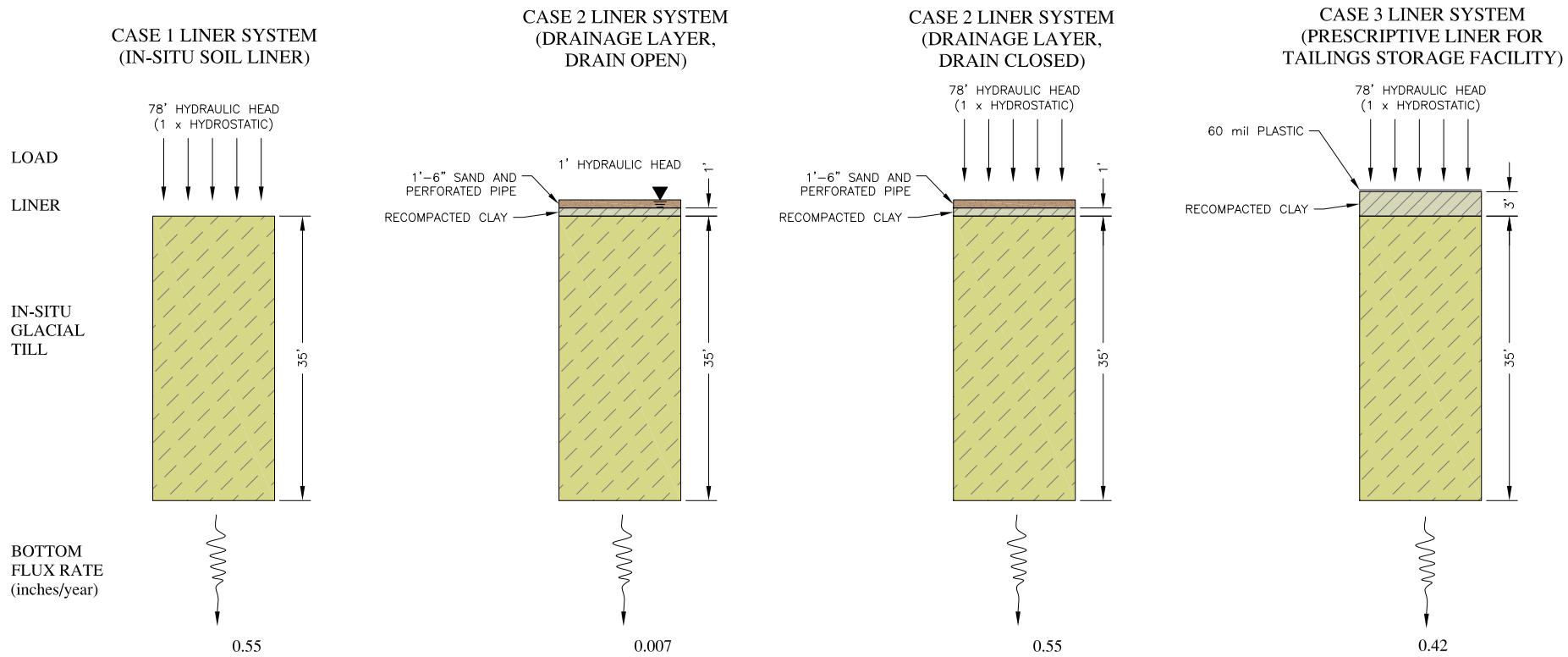
Table 8.6
Orvana Resources, U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study

Detailed Cost Estimate - Case 3 (TSF Prescriptive Liner) CAPEX

Item No.	Description	Unit	Unit Rate	Incremental Quantities and Costs (US$) without Contingency												Total
				Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Closure		
				Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	
	PIPEWORK - TAILINGS DISPOSAL FACILITY															
44	Supply and install 4" dia perforated CPT (Type SP) underdrainage lateral (increased 5% for waste and scrap) (Case 3 Liner System)	LF	$5.00	11,265	$56,327	0	$0	0	$0	0	$0	0	$0	0	$0	$56,327
45	Supply and install 6" dia perforated CPT (Type SP) underdrainage header (increased 5% for waste and scrap) (Case 3 Liner System)	LF	$13.00	3,150	$40,950	0	$0	0	$0	0	$0	0	$0	0	$0	$40,950
46	Supply and install 6" dia perforated CPT (Type SP) toe drain pipe (increased 5% for waste and scrap) (Case 3 Liner System)	LF	$13.00	7,185	$93,399	2,966	$38,552	4,645	$60,382	0	$0	0	$0	0	$0	$192,333
47	Supply and install 12" dia HDPE (SDR 11) underdrainage outlet pipe (increased 5% for waste and scrap) (Case 3 Liner System)	LF	$45.00	1,483	$66,717	0	$0	0	$0	0	$0	0	$0	0	$0	$66,717
48	Supply and install 12" dia CPT (Type SP) decant structure drain (increased 5% for waste and scrap)	LF	$22.00	408	$8,986	0	$0	9	$208	65	$1,432	38	$832	0	$0	$11,458
49	Supply and install 12" dia HDPE (SDR 13.5) decant header pipe (increased 5% for waste and scrap)	LF	$38.00	422	$16,040	0	$0	0	$0	69	$2,633	0	$0	0	$0	$18,673
50	Supply and install 22" dia HDPE (SDR 11) decant outlet pipe (increased 5% for waste and scrap)	LF	$135.00	1,483	$200,151	0	$0	0	$0	0	$0	0	$0	0	$0	$200,151
51	Supply and install 6" dia perforated CPT (Type SP) TDF embankment chimney drain pipe (increased 5% for waste and scrap)	LF	$13.00	7,539	$98,009	3,160	$41,080	5,409	$70,314	0	$0	0	$0	0	$0	$209,403
52	Supply and install 12" dia HDPE (SDR 11) TDF embankment chimney drain outlet pipe (increased 5% for waste and scrap)	LF	$45.00	1,323	$59,546	0	$0	0	$0	0	$0	0	$0	0	$0	$59,546
53	Supply and install 6" dia perforated CPT (Type SP) TDF embankment foundation drain pipe (increased 5% for waste and scrap)	LF	$13.00	16,427	$213,553	15,369	$199,792	12,156	$158,033	16,749	$217,732	782	$10,165	0	$0	$799,275
54	Supply and install 6" dia perforated CPT (Type SP) TDF embankment mid-height drain pipe (increased 5% for waste and scrap)	LF	$13.00	2,495	$32,432	0	$0	6,542	$85,048	935	$12,152	1,303	$16,945	0	$0	$146,577
55	Supply and install 12" dia HDPE (SDR 11) TDF embankment drains outlet pipe (increased 5% for waste and scrap)	LF	$45.00	1,323	$59,546	0	$0	0	$0	0	$0	0	$0	0	$0	$59,546
56	Pipework fittings (est. 3% of pipework costs)	%	3%	$945,654	$28,370	$279,424	$8,383	$373,985	$11,220	$233,950	$7,018	$27,942	$838	$0	$0	$55,829
57	Mobilization\Demobilization (percentage of direct cost)	%	2%	$974,024	$19,480	$287,807	$5,756	$385,204	$7,704	$240,968	$4,819	$28,780	$576	$0	$0	$38,336
	Subtotal - Pipework - Tailings Disposal Facility Cost				**$993,505**		**$293,563**		**$392,909**		**$245,788**		**$29,356**		**$0**	**$1,955,120**
	INSTRUMENTATION - TAILINGS DISPOSAL FACILITY AND DECANT OVERFLOW POND															
58	Supply and install ground water monitoring well	EA	$50,000	18	$900,000	3	$150,000	0	$0	0	$0	0	$0	0	$0	$1,050,000
59	Supply and install settlement monument	EA	$1,000	3	$3,000	3	$3,000	3	$3,000	6	$6,000	6	$6,000	0	$0	$21,000
60	Supply and install vibrating wire piezometer (includes data logger and cables)	EA	$2,000	10	$20,000	10	$20,000	5	$10,000	5	$10,000	0	$0	0	$0	$60,000
61	Supply and install flowmeter and totalizer (decant outlet pipe, embankment chimney drain, and foundation drains)	EA	$5,000	3	$15,000	0	$0	0	$0	0	$0	0	$0	0	$0	$15,000
62	Supply and install pond water level sensors (high and low level switches with high level alarm)	EA	$500	1	$500	0	$0	0	$0	0	$0	0	$0	0	$0	$500
	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost				**$938,500**		**$173,000**		**$13,000**		**$16,000**		**$6,000**		**$0**	**$1,146,500**
	CLOSURE - TAILINGS DISPOSAL FACILITY AND DECANT OVERFLOW POND															
63	Supply and install 8 oz/yd² non-woven geotextile (tailings surface to prevent ingress into closure cap, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,292,406	$1,292,406	$1,292,406
64	Supply and install geogrid (tailings surface to increase strength for closure cap, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,292,406	$1,292,406	$1,292,406
65	Fill from borrow to produce rough grade closure surface	CY	$3.00	0	$0	0	$0	0	$0	0	$0	0	$0	2,543,297	$7,629,892	$7,629,892
66	Supply, place, and compact capillary break layer drainage aggregate/sand for closure cap (12-in-thick lift)	CY	$5.00	0	$0	0	$0	0	$0	0	$0	0	$0	1,174,914	$5,874,571	$5,874,571
67	Topsoil from stockpile to produce vegetation growth layer (6-in-thick layer, includes seed)	CY	$4.50	0	$0	0	$0	0	$0	0	$0	0	$0	197,745	$889,851	$889,851
68	Supply and place seeding for vegetation growth (tractor spread)	SY	$0.25	0	$0	0	$0	0	$0	0	$0	0	$0	1,184,157	$296,039	$296,039
69	Excavate to produce rough grade surface (closure spillway and surface water diversion channel)	CY	$4.50	0	$0	0	$0	0	$0	0	$0	0	$0	2,869	$12,913	$12,913
70	Supply and install 8 oz/yd² non-woven geotextile (closure spillway and surface water diversion channel, increased 10% for waste and scrap)	SY	$1.00	0	$0	0	$0	0	$0	0	$0	0	$0	4,088	$4,088	$4,088
71	Supply and install closure spillway articulated block lining (Contech 50T block)	SY	$90.00	0	$0	0	$0	0	$0	0	$0	0	$0	848	$76,288	$76,288
72	Supply and place surface water diversion channel 18" thick layer riprap (d50 = 9")	CY	$30.00	0	$0	0	$0	0	$0	0	$0	0	$0	2,868	$86,052	$86,052
73	Supply and install energy dissipation structures	LS	$50,000	0	$0	0	$0	0	$0	0	$0	0	$0	2	$100,000	$100,000
74	Maintenance regrading and sloping of post-closure construction surface	SY	$0.18	0	$0	0	$0	0	$0	0	$0	0	$0	197,745	$35,594	$35,594
75	Mobilization\Demobilization (percentage of direct cost)	%	5%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$17,590,098	$879,505	$879,505
	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost				**$0**		**$0**		**$0**		**$0**		**$0**		**$18,469,603**	**$18,469,603**
	ENGINEERING DESIGN QA/QC															
76	Construction QA/QC	EST			$0		$0		$0		$0		$0		$0	$0
77	Survey	EST			$0		$0		$0		$0		$0		$0	$0
78	As-built report	EST			$0		$0		$0		$0		$0		$0	$0
	Subtotal - Engineering Design QA/QC Cost				**$0**		**$0**		**$0**		**$0**		**$0**		**$0**	**$0**
	COST SUMMARY															
79	Subtotal - Earthworks - Tailings Disposal Facility Cost				$20,777,949		$9,007,410		$10,474,324		$10,245,684		$9,803,477		$0	$60,308,845
80	Subtotal - Earthworks - Decant Overflow Pond Cost				$72,369		$0		$0		$0		$0		$0	$72,369
81	Subtotal - Geosynthetics - Tailings Disposal Facility Cost				$4,596,832		$3,703,383		$1,032,217		$99,103		$82,445		$0	$9,513,980
82	Subtotal - Geosynthetics - Decant Overflow Pond Cost				$22,020		$0		$0		$0		$0		$0	$22,020
83	Subtotal - Pipework - Tailings Disposal Facility Cost				$993,505		$293,563		$392,909		$245,788		$29,356		$0	$1,955,120
84	Subtotal - Instrumentation - Tailings Disposal Facility and Decant Overflow Pond Cost				$938,500		$173,000		$13,000		$16,000		$6,000		$0	$1,146,500
85	Subtotal - Closure - Tailings Disposal Facility and Decant Overflow Pond Cost				$0		$0		$0		$0		$0		$18,469,603	$18,469,603
86	**Total Construction Cost**				**$27,401,175**		**$13,177,356**		**$11,912,450**		**$10,606,574**		**$9,921,278**		**$18,469,603**	**$91,488,436**

Notes:
1. No contingency has been applied to these costs; however, a minimum of 25 percent contingency is recommended.
2. No time value of money has been applied to these costs. All costs presented in 2011 United States dollars ($US).
3. Geosynthetics for the tailings disposal facility and decant sump overflow pond have been increased 10 percent over neat line quantities to account for waste, trench anchorage, and overlap.
4. Pipeworks quantities have been increased 5 percent over neat line quantities to account for waste. Pipes are for drains and decants only. No pipes are included herein for the tailings delivery or deposition systems or the water reclaim system, which have been accounted for by others.
5. Costs do not include for engineering design or construction supervision and/or QA/QC.

Figures



NOTES:

1. THE THICKNESS OF THE UNDERLYING GLACIAL TILL RANGES FROM 20 TO 120 FEET ACROSS THE TAILINGS FACILITY BASIN, AND GENERALLY INCREASES IN THICKNESS FROM SOUTH TO NORTH. IT WAS ASSUMED THAT 35 FEET COULD BE USED AS A REPRESENTATIVE THICKNESS FOR MODELING PURPOSES.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SCHEMATIC LINER DESIGNS WITH RELATIVE FLUX RATES AT BASE OF IN–SITU GLACIAL TILL
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	CC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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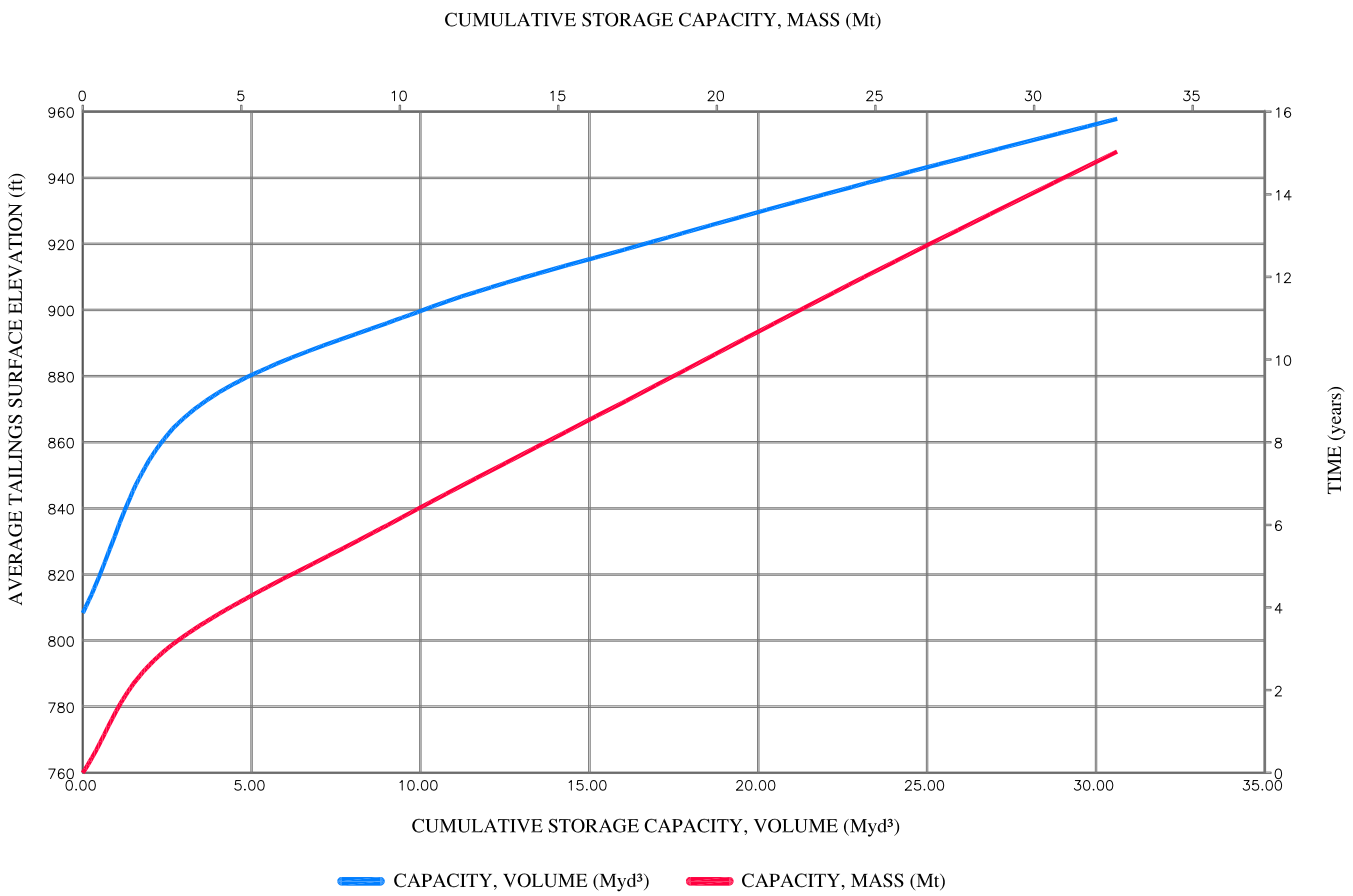

NOTES:

1. THE TAILINGS DISPOSAL FACILITY STORAGE CAPACITY, VOLUME, IS PLOTTED VERSUS THE AVERAGE TAILINGS SURFACE ELEVATION, WHILE THE STORAGE CAPACITY, MASS, IS PLOTTED VERSUS TIME.
2. THE TAILINGS STORAGE CAPACITY CURVES WERE DEVELOPED CONSIDERING CONCURRENT DEPOSITION AND CONSOLIDATION, AND ACCOUNTING FOR THE INCLUSION OF AN UNDERDRAINAGE SYSTEM AND THEREFORE TWO SIDED DRAINAGE OF THE TAILINGS MASS.

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: STORAGE CAPACITY VS. ELEVATION AND TIME
0.25 PERCENT SLOPED TAILINGS SURFACE

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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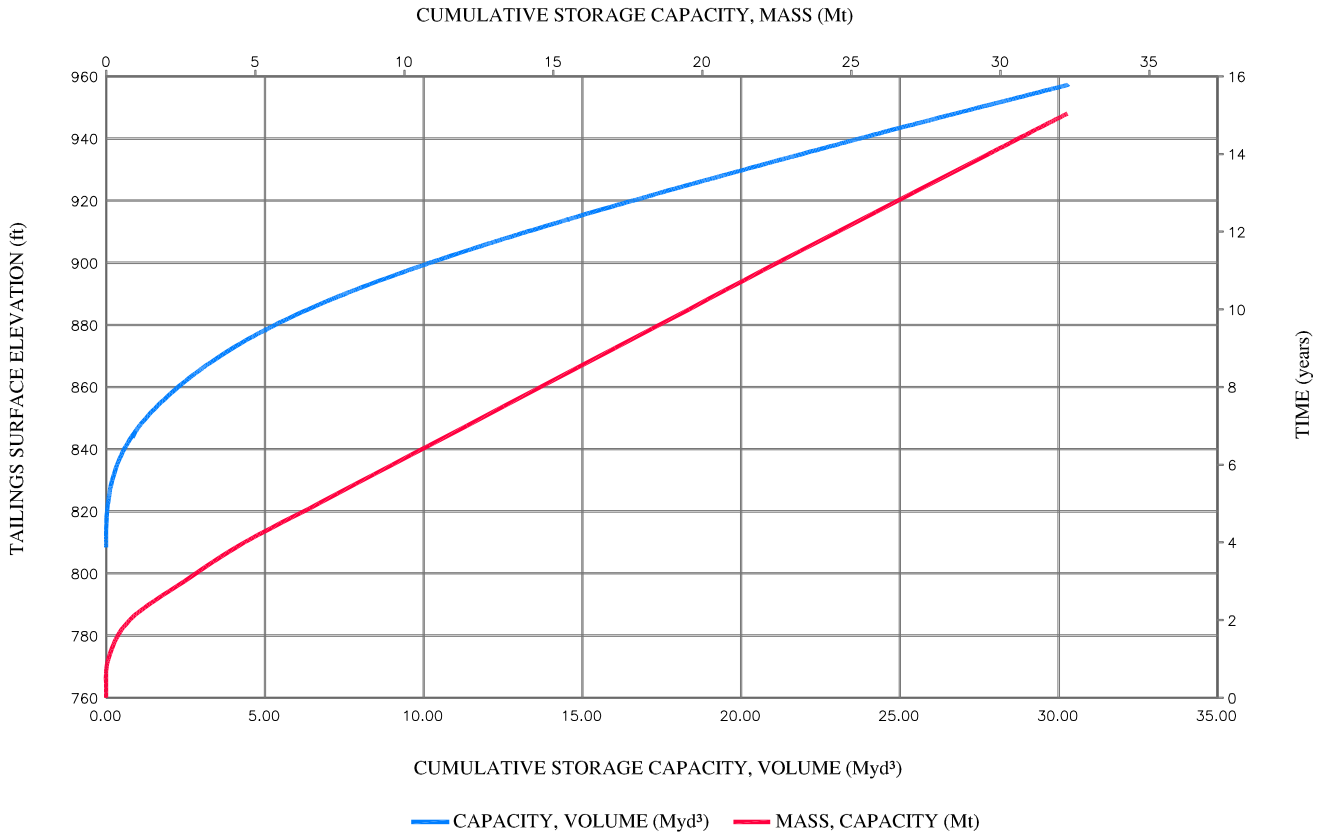

NOTES:

1. THE TAILINGS DISPOSAL FACILITY STORAGE CAPACITY, VOLUME, IS PLOTTED VERSUS THE TAILINGS SURFACE ELEVATION, WHILE THE STORAGE CAPACITY, MASS, IS PLOTTED VERSUS TIME.
2. THE TAILINGS STORAGE CAPACITY CURVES WERE DEVELOPED CONSIDERING CONCURRENT DEPOSITION AND CONSOLIDATION, AND ACCOUNTING FOR THE INCLUSION OF AN UNDERDRAINAGE SYSTEM AND THEREFORE TWO SIDED DRAINAGE OF THE TAILINGS MASS.

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: STORAGE CAPACITY VS. ELEVATION AND TIME
HORIZONTAL TAILINGS SURFACE

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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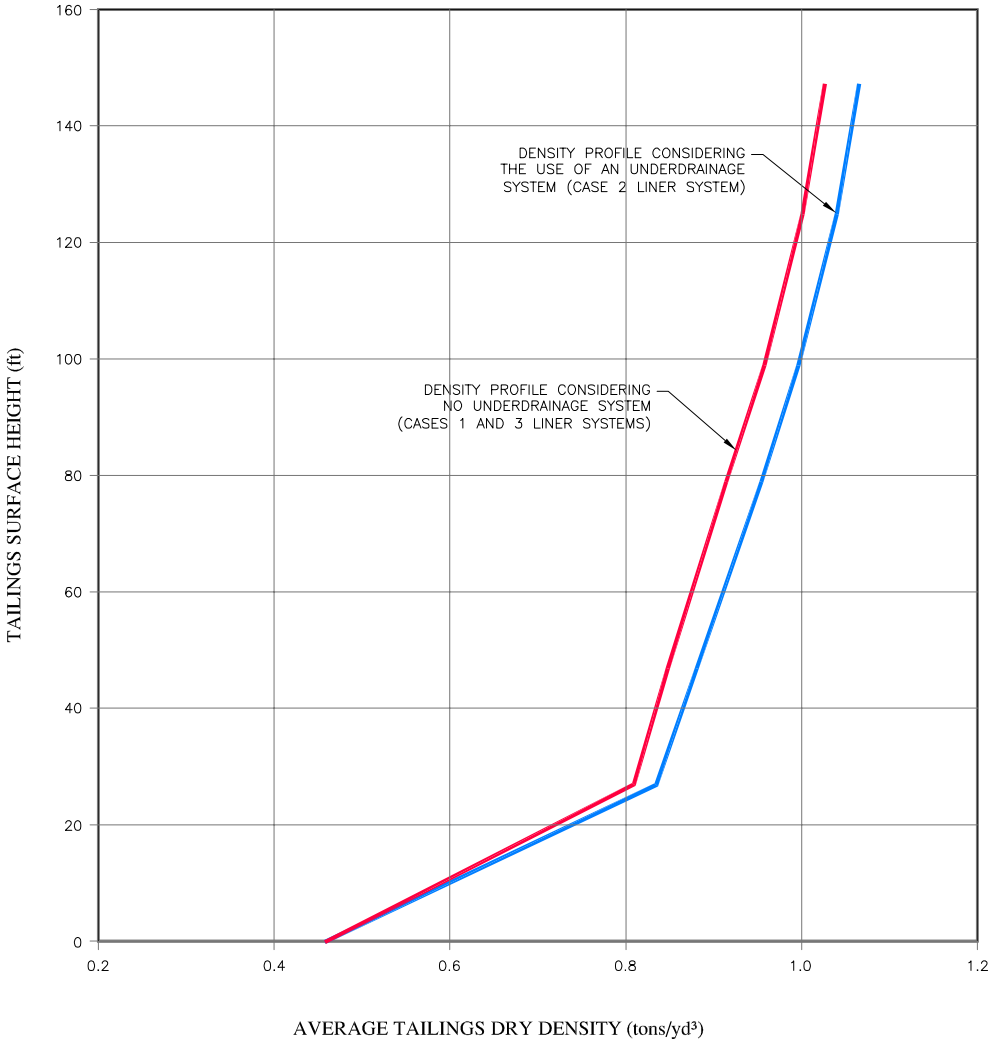

NOTES:

1. TAILINGS DENSITY PROFILES WERE DEVELOPED CONSIDERING CONCURRENT DEPOSITION AND CONSOLIDATION.
2. BOTH CASES, WITH AND WITHOUT AN UNDERDRAINAGE SYSTEM, ASSUME THE SAME DEPTH–CAPACITY CURVE FOR THE TAILINGS DISPOSAL FACILITY.
3. THE UNDRAINED BOTTOM, FOR CASE THE CASES 1 AND 3 LINER SYSTEMS, ACCOMMODATES ONLY 13.9 YEARS OF TAILINGS STORAGE UNDER THE CURRENT MINE PRODUCTION SCHEDULE.
4. NO CONSIDERATION FOR ADDITIONAL CONSOLIDATION AND TAILINGS STORAGE ASSOCIATED WITH THE PARTIAL UNDERDRAINAGE BLANKET WAS ACCOUNTED FOR IN THE CASE 3 LINER SYSTEM.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	AVERAGE TAILINGS DRY DENSITY VS. TAILINGS SURFACE HEIGHT				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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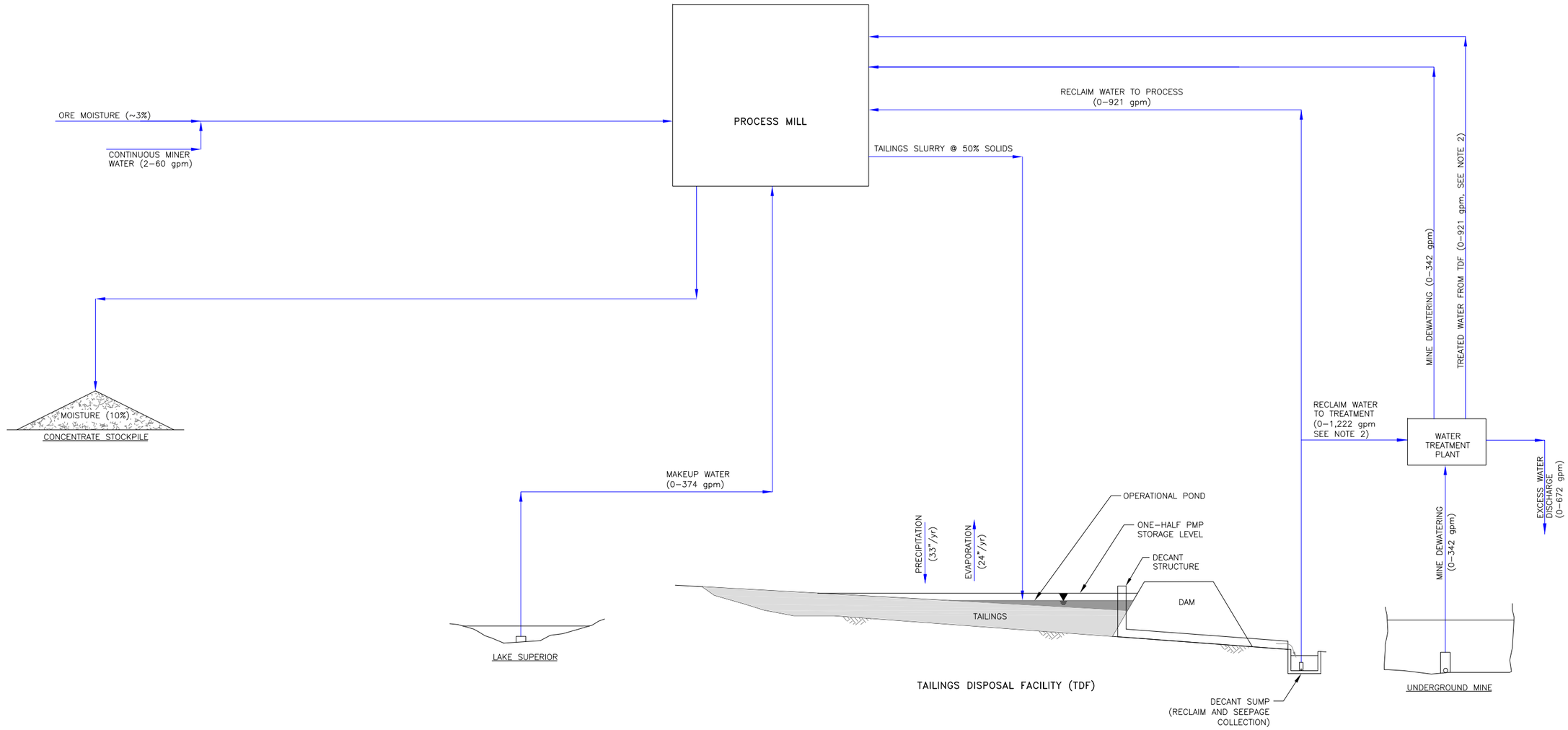

NOTES:

1. SEE APPENDIX D FOR MONTHLY WATER BALANCE FLOW RATES.
2. THE "RECLAIM WATER TO TREATMENT" AND "TREATED WATER FROM TDF" (RETURNED TO THE PROCESS) ARE POTENTIAL VALUES ONLY, AND WERE NOT SPECIFICALLY ACCOUNTED FOR IN THE PROCESS WATER BALANCE. WITHIN THE WATER BALANCE, ONLY THE TREATMENT OF EXCESS RECLAIM WATER FOR DISCHARGE IS ADDRESSED, AND NOT RECLAIM WATER TREATMENT DUE TO PROCESS REQUIREMENTS. WATER TREATMENT DUE TO PROCESS REQUIREMENTS WAS CONDUCTED BY GOLDER AND ASSOCIATES.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	PROCESS WATER BALANCE SCHEMATIC
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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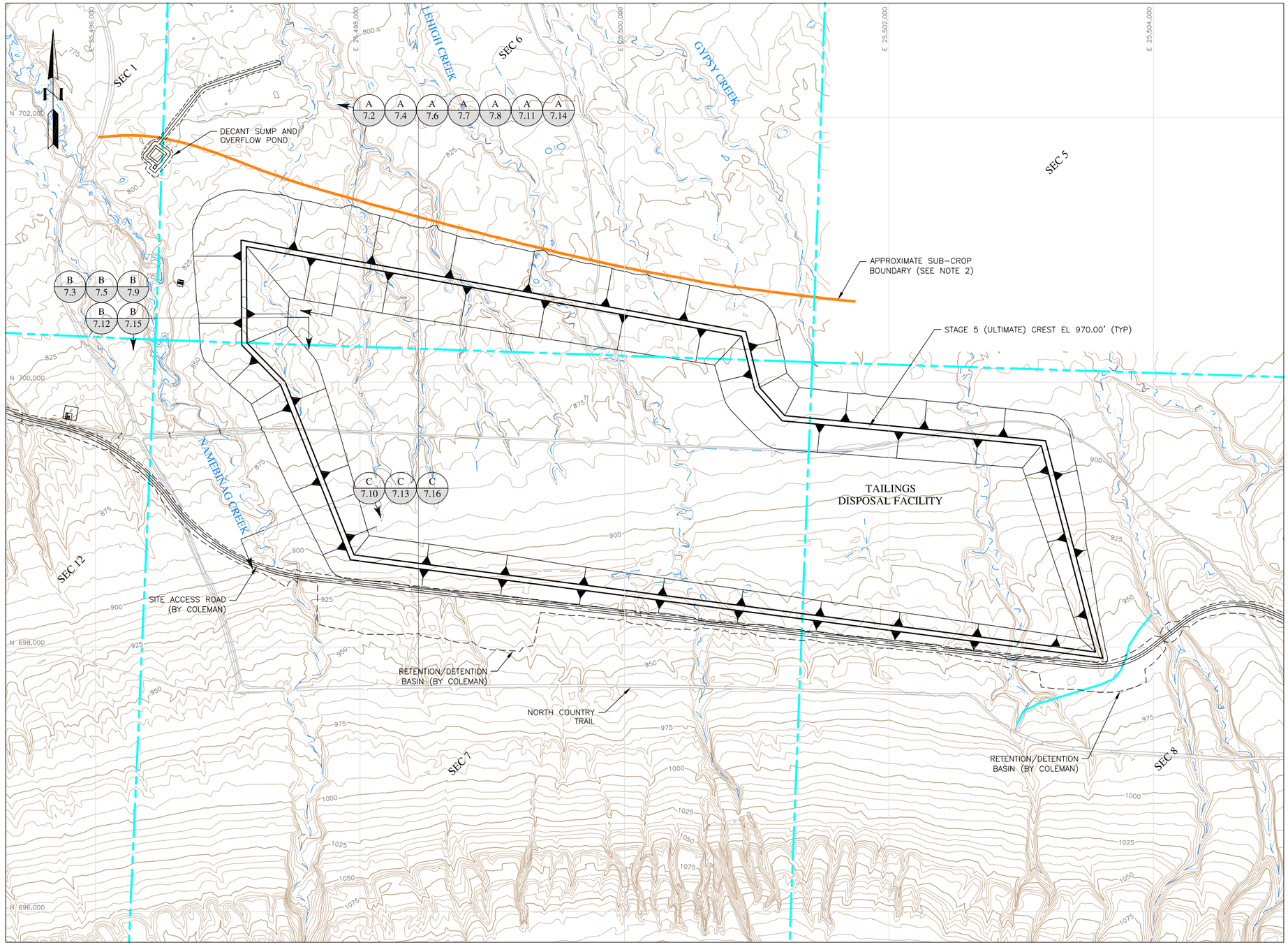

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SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

LEGEND:

- 880 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE SUB–CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: SEEPAGE AND SLOPE STABILITY SECTIONS LOCATION PLAN

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

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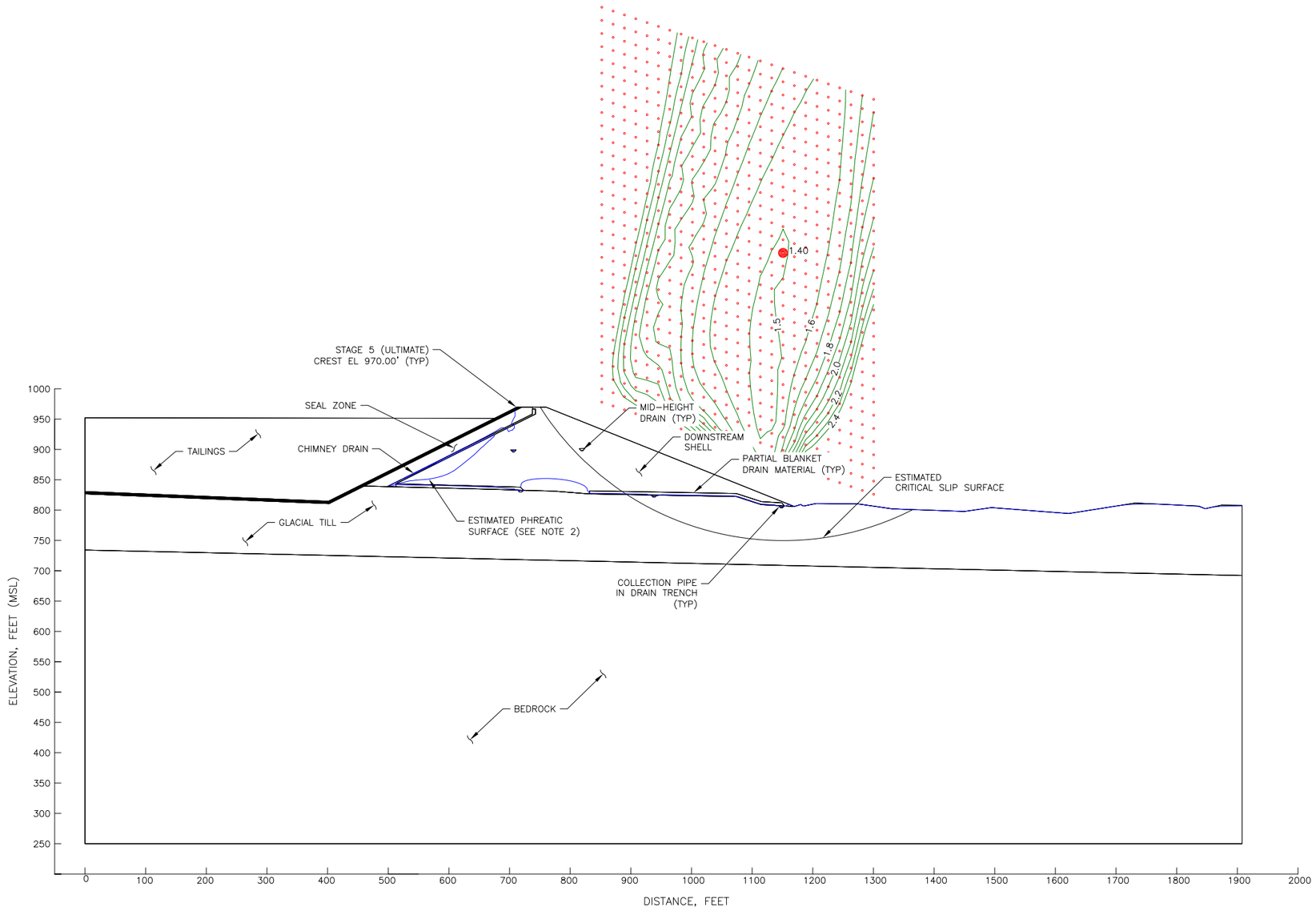

A
7.1

STATIC SLOPE STABILITY ANALYSIS
NORTH / NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 1 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. PHREATIC SURFACE ESTIMATED FROM FINITE ELEMENT ANALYSIS PERFORMED IN SEEP/W.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	STATIC SLOPE STABILITY ANALYSIS SECTION A				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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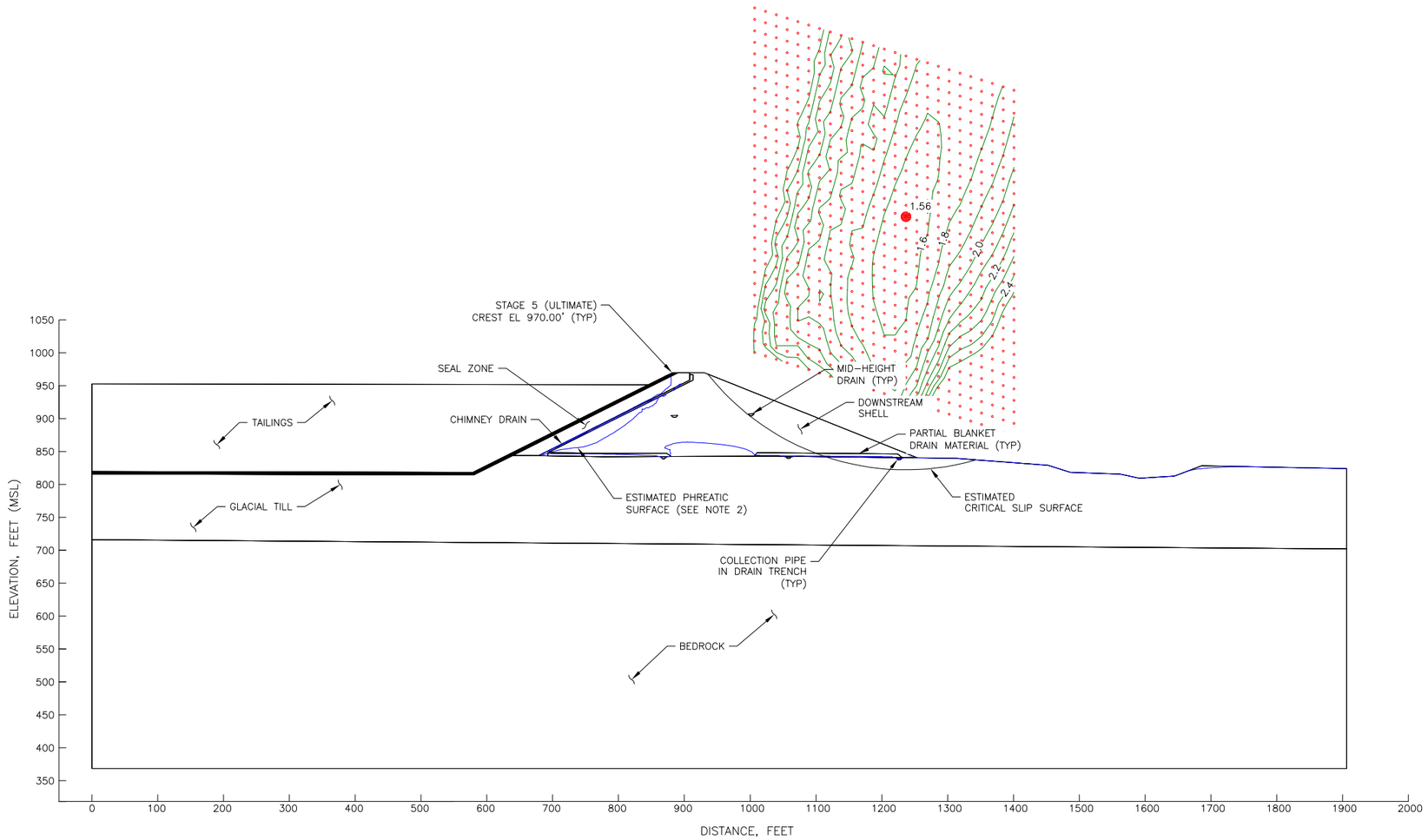

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. PHREATIC SURFACE ESTIMATED FROM FINITE ELEMENT ANALYSIS PERFORMED IN SEEP/W.

B
7.1

STATIC SLOPE STABILITY ANALYSIS
WEST / NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	STATIC SLOPE STABILITY ANALYISIS SECTION B
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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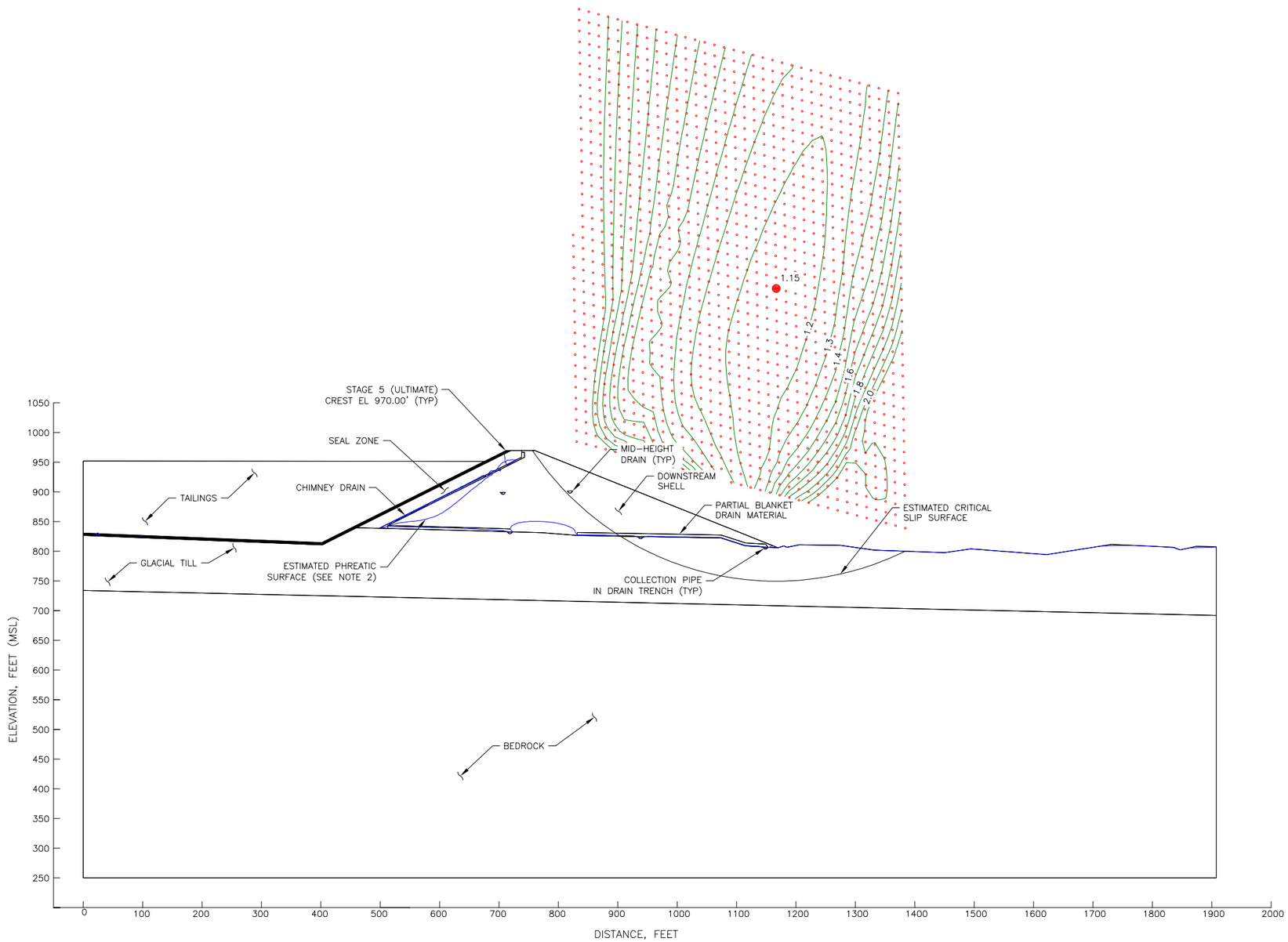

A
7.1

PSEUDO STATIC SLOPE STABILITY ANALYSIS
NORTH / NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 1 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. PHREATIC SURFACE ESTIMATED FROM FINITE ELEMENT ANALYSIS PERFORMED IN SEEP/W.
3. HORIZONTAL ACCELERATION EQUAL TO 0.06g.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	PSEUDO STATIC SLOPE STABILITY ANALYSIS SECTION A				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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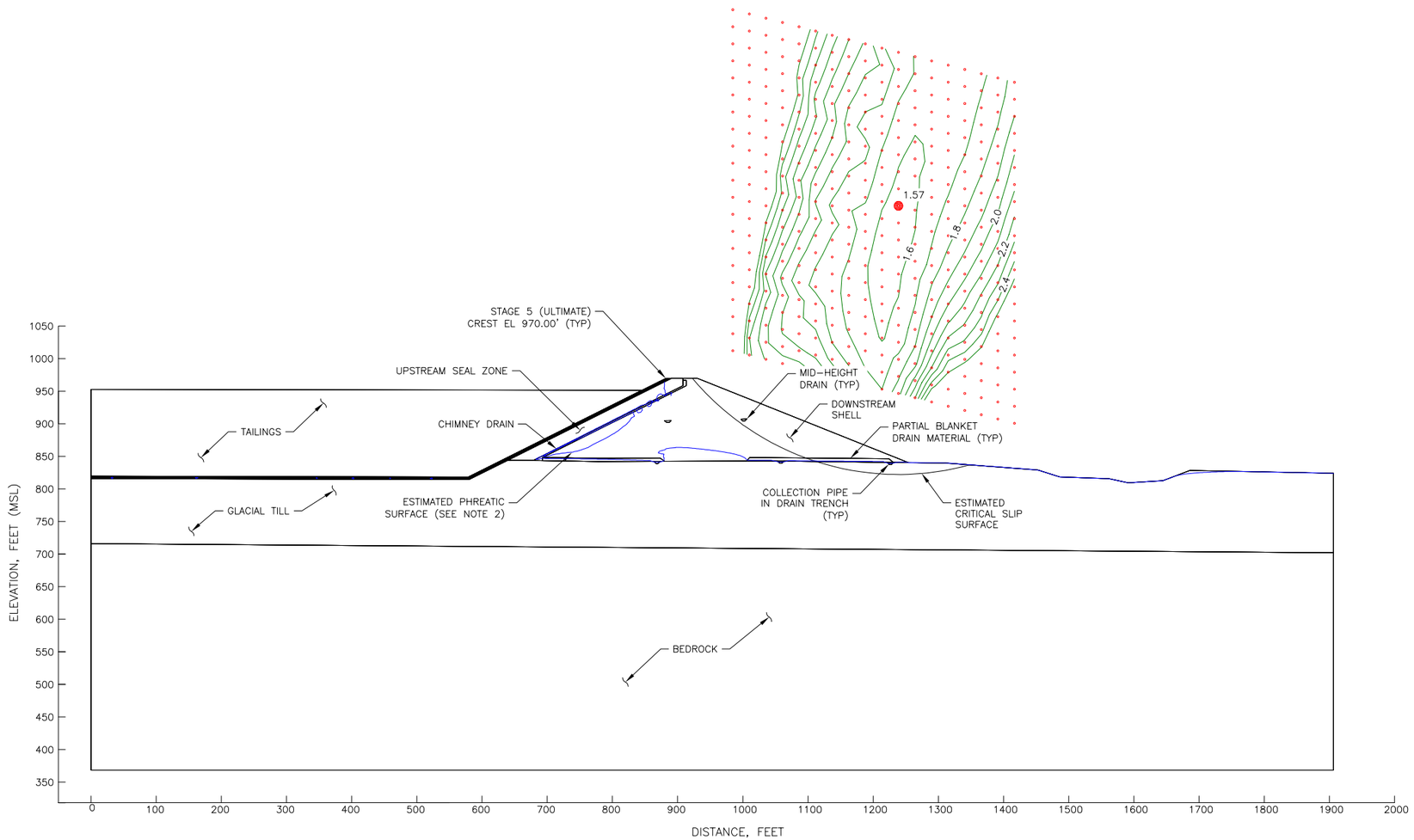

B
7.1

PSEUDO STATIC SLOPE STABILITY ANALYSIS
WEST / NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. PHREATIC SURFACE ESTIMATED FROM FINITE ELEMENT ANALYSIS PERFORMED IN SEEP/W.
3. HORIZONTAL ACCELERATION EQUAL TO 0.06g.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	PSEUDO STATIC SLOPE STABILITY ANALYSIS SECTION B				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
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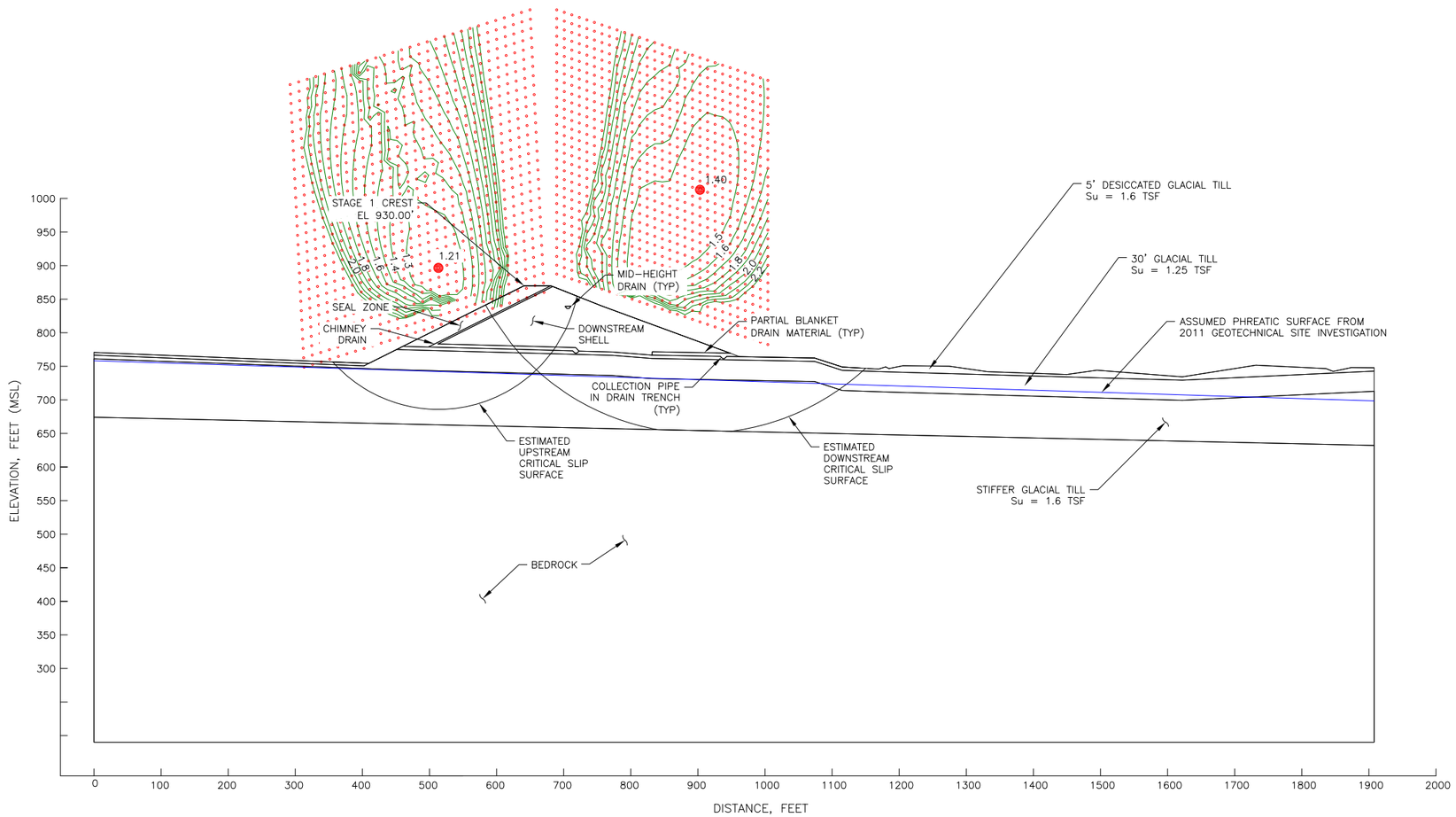

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ANALYSIS CONDUCTED ASSUMING UNDRAINED CONDITIONS.

A / 7.1 STAGE 1 POST-CONSTRUCTION TOTAL STRESS SLOPE STABILITY ANALYSIS
NORTH / NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	STAGE 1 POST-CONSTRUCTION TOTAL STRESS SLOPE STABILITY ANALYSIS SECTION A
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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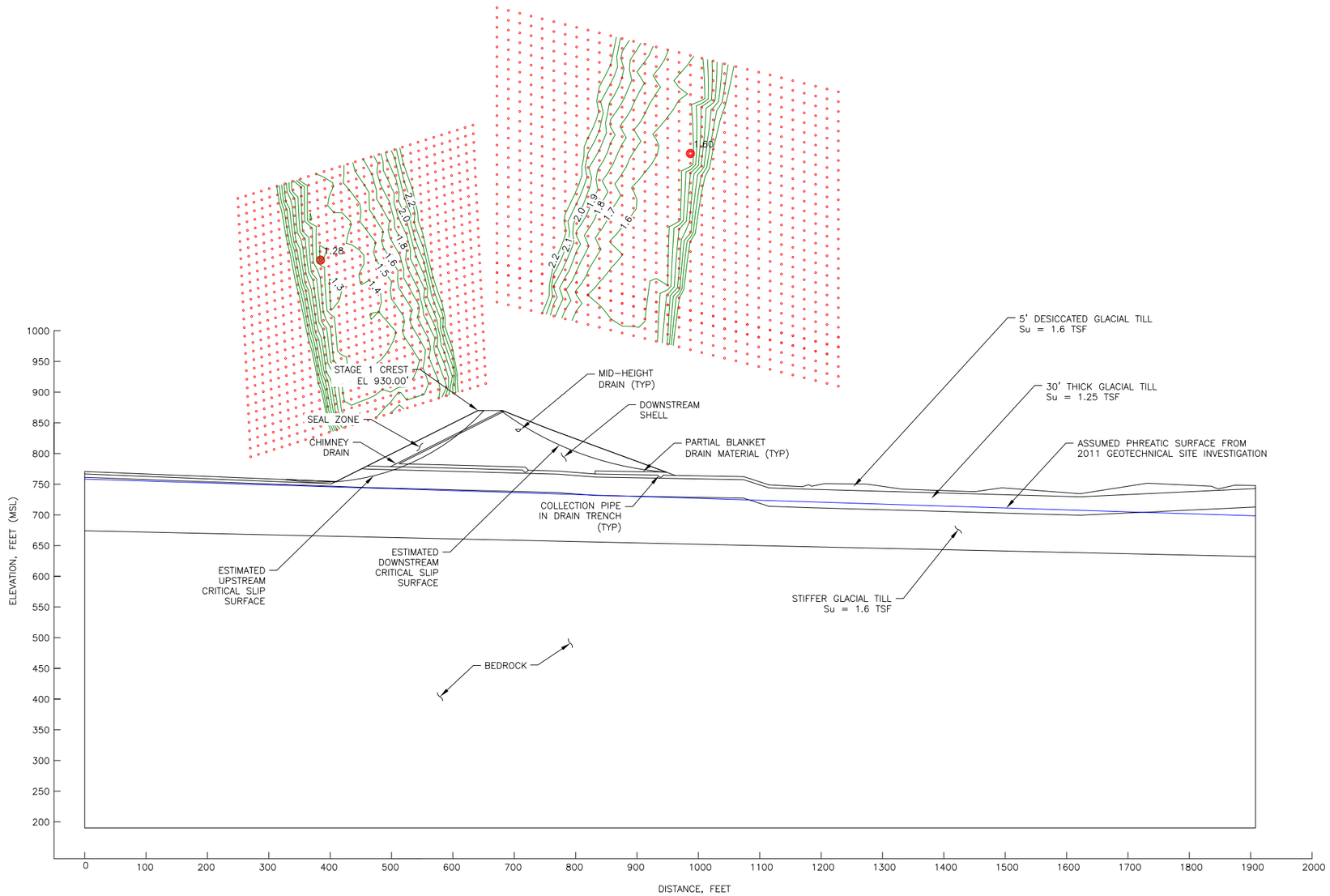

A
7.1

STAGE 1 POST-CONSTRUCTION EFFECTIVE STRESS SLOPE STABILITY ANALYSIS
NORTH / NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ANALYSIS CONDUCTED ASSUMING UNDRAINED CONDITIONS.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	STAGE 1 POST-CONSTRUCTION EFFECTIVE STRESS SLOPE STABILITY ANALYSIS SECTION A
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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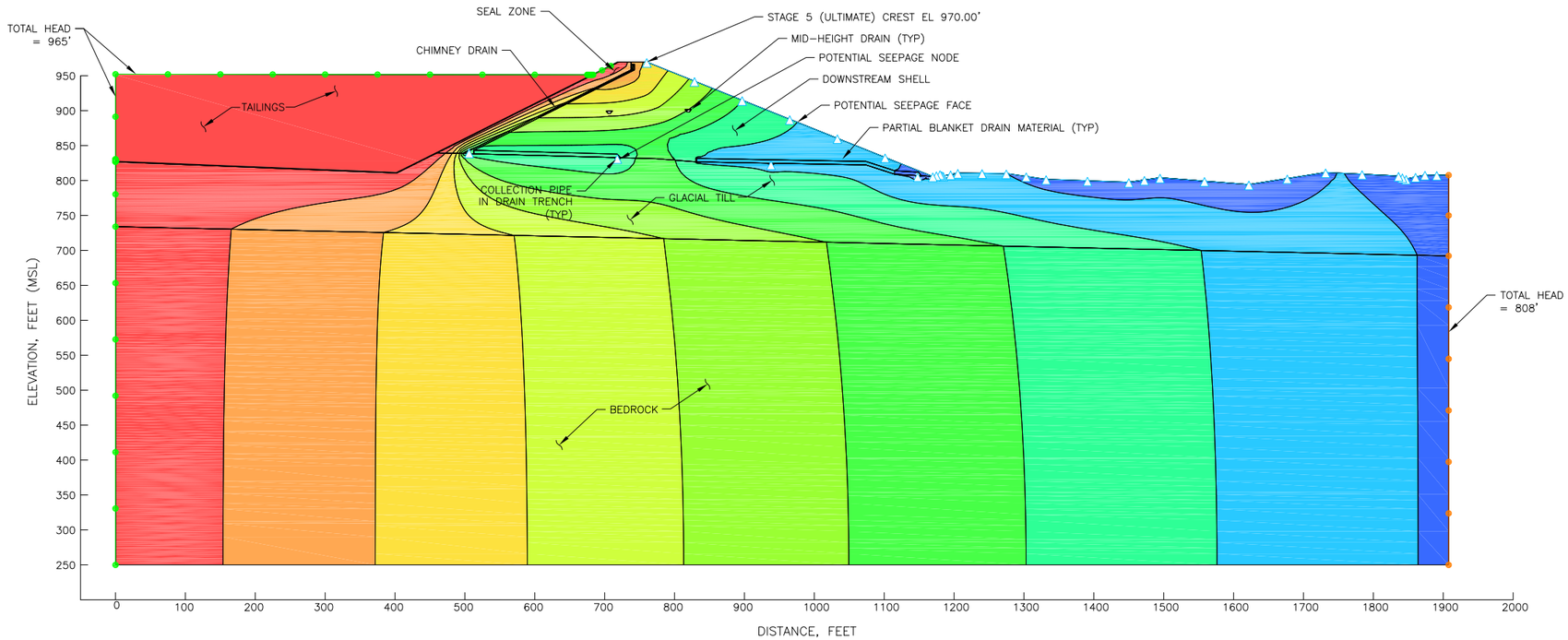

A
7.1

SEEPAGE ANALYSIS CASE 1 LINER SYSTEM
NORTH/NORTHWEST SECTION

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:

- 951
- 931
- 911
- 891
- 871
- 851
- 831
- 811

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	SEEPAGE ANALYSIS CASE 1 LINER SYSTEM SECTION A				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
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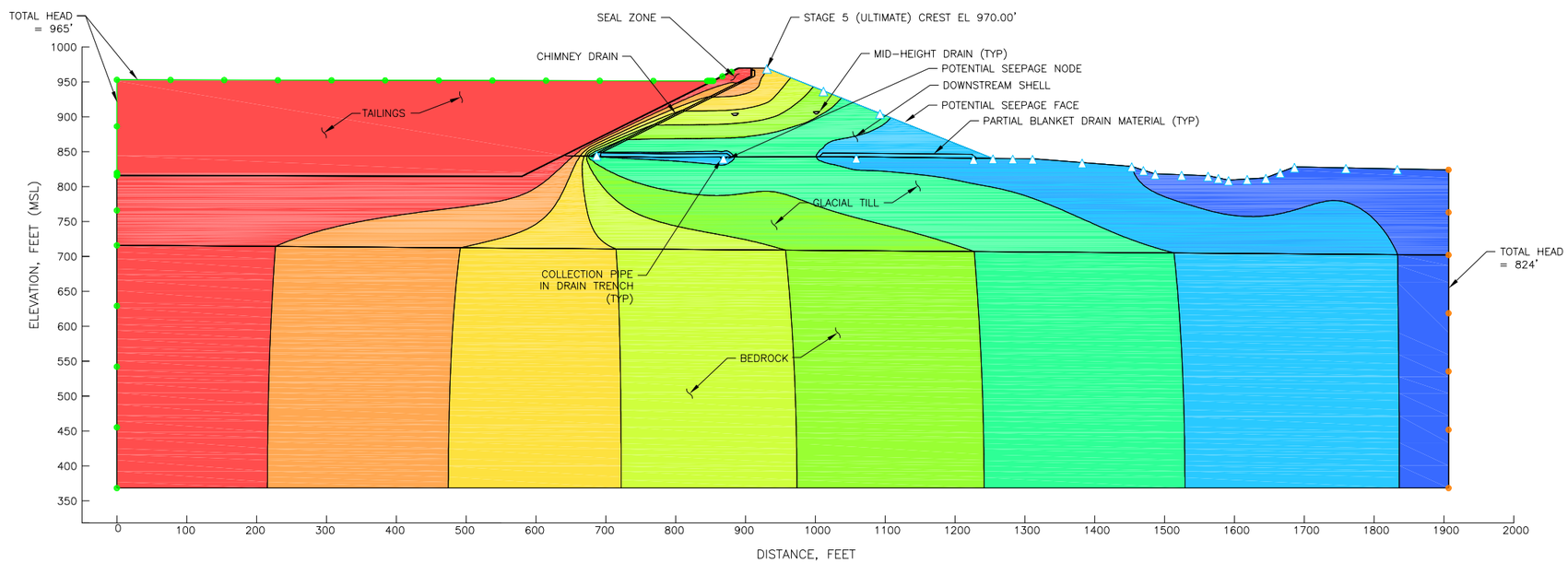

B
7.1

SEEPAGE ANALYSIS CASE 1 LINER SYSTEM
WEST/NORTHWEST SECTION

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:

949
929
909
889
869
849
829

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SEEPAGE ANALYSIS CASE 1 LINER SYSTEM SECTION B
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	7.9	0
ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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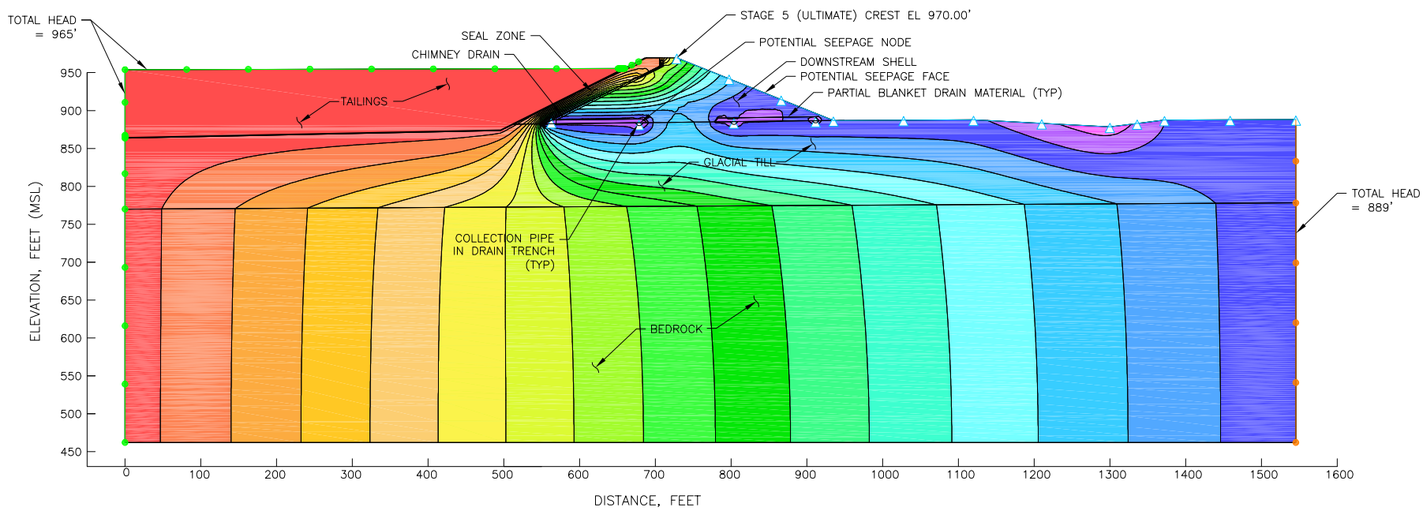
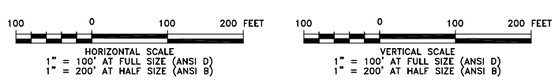


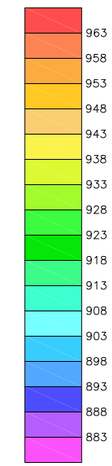
C
7.1

SEEPAGE ANALYSIS CASE 1 LINER SYSTEM
WEST/SOUTHWEST SECTION



LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:



NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	SEEPAGE ANALYSIS CASE 1 LINER SYSTEM SECTION C				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	7.10	0
ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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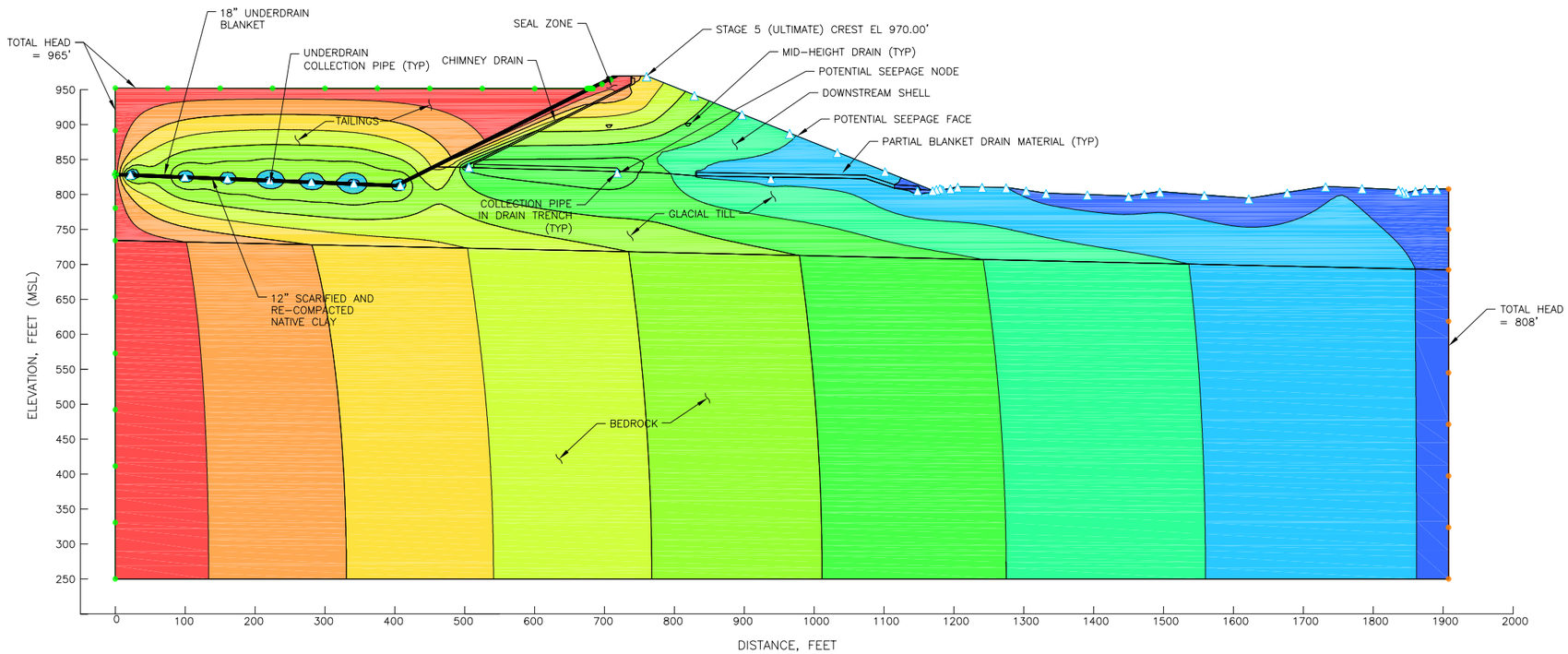

A
7.1

SEEPAGE ANALYSIS CASE 2 LINER SYSTEM
NORTH/NORTHWEST SECTION

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:

951
931
911
891
871
851
831
811

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

100 0 100 200 FEET

HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET

VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SEEPAGE ANALYSIS CASE 2 LINER SYSTEM SECTION A
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	7.11	0
ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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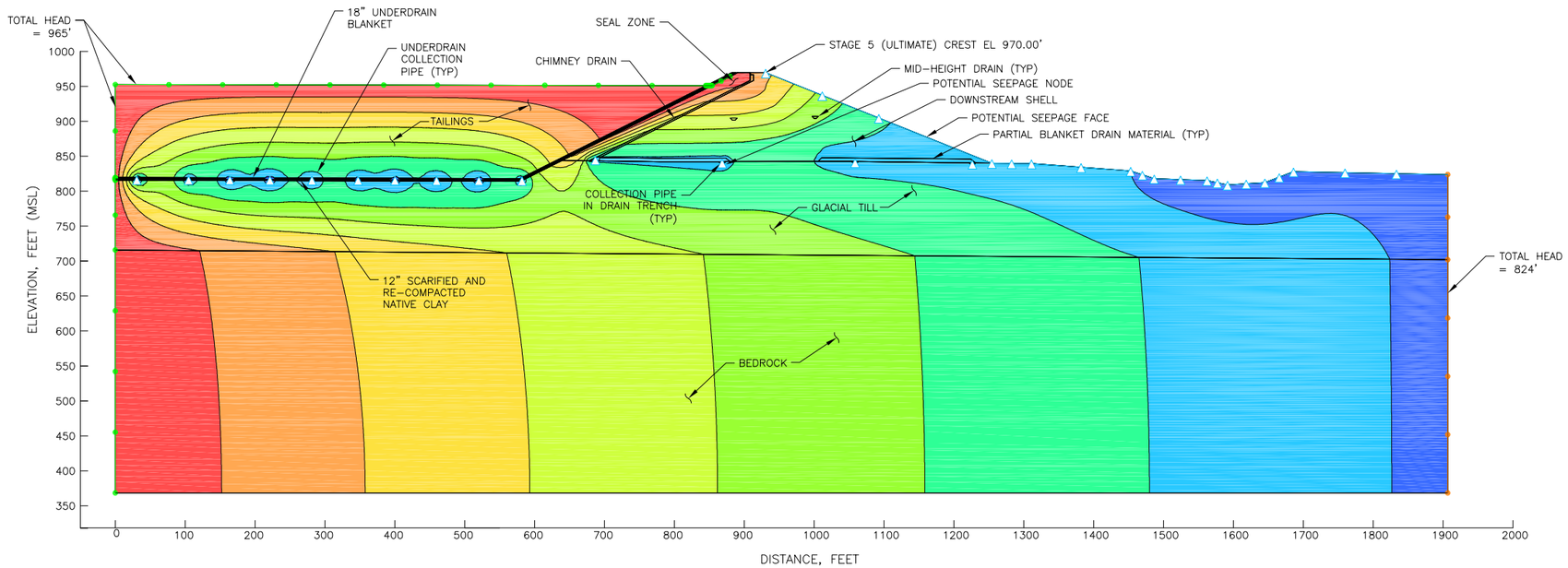
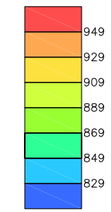


B
7.1

SEEPAGE ANALYSIS CASE 2 LINER SYSTEM
WEST/NORTHWEST SECTION

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:



HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	SEEPAGE ANALYSIS CASE 2 LINER SYSTEM SECTION B				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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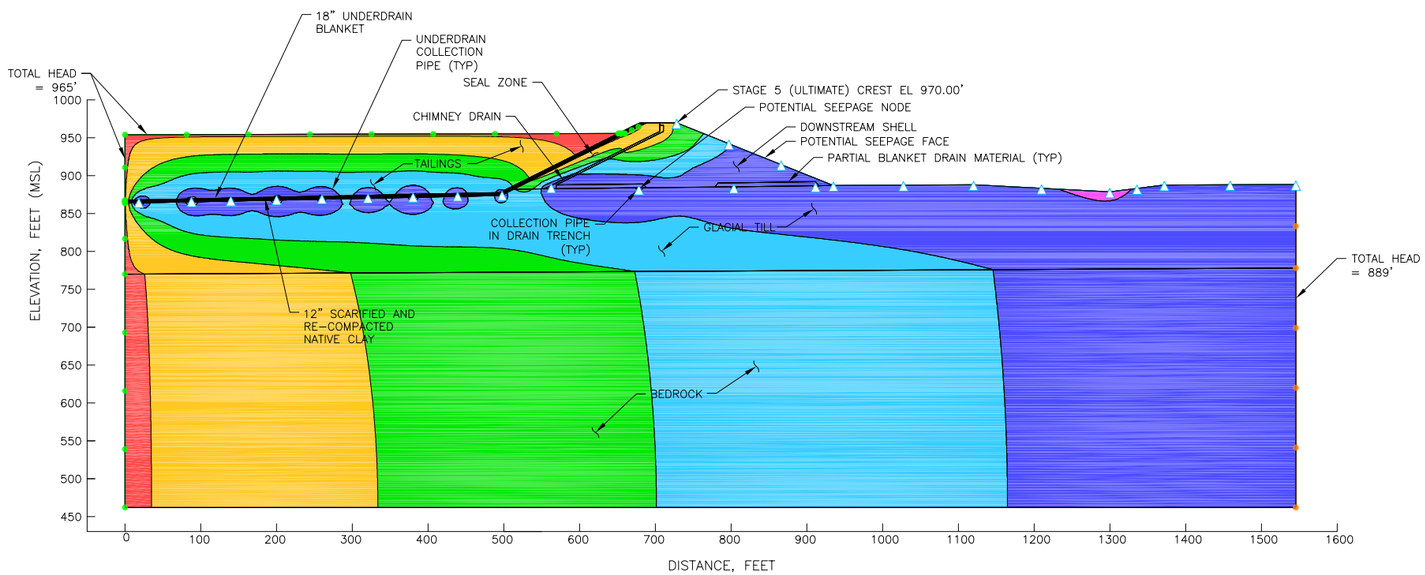


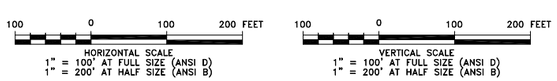
C
7.1

SEEPAGE ANALYSIS CASE 2 LINER SYSTEM
WEST/SOUTHWEST SECTION

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:

- 963
- 943
- 923
- 903
- 883



NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SEEPAGE ANALYSIS CASE 2 LINER SYSTEM SECTION C
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	7.13	0
ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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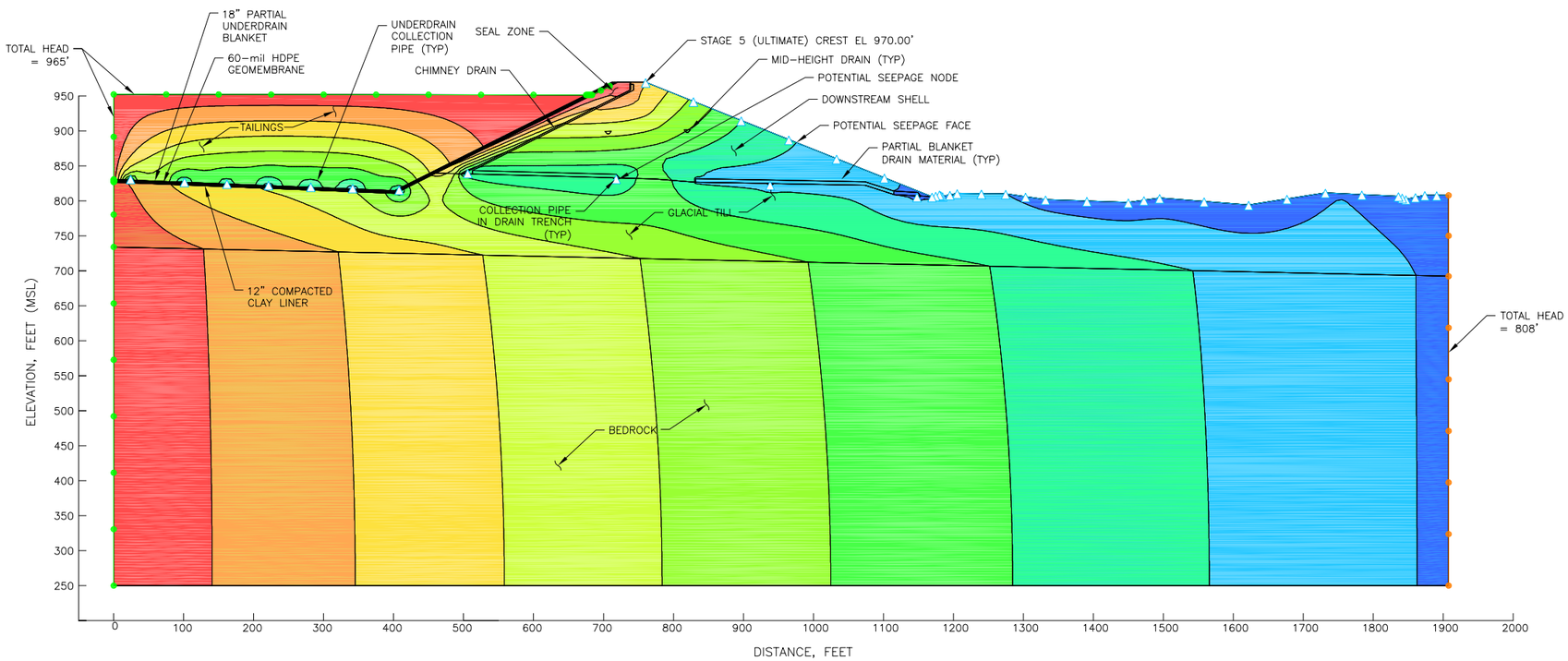

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:

951
931
911
891
871
851
831
811

A / 7.1 SEEPAGE ANALYSIS CASE 3 LINER SYSTEM
NORTH/NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY				
TITLE	SEEPAGE ANALYSIS CASE 3 LINER SYSTEM SECTION A				
CLIENT	ORVANA RESOURCES U.S. CORPORATION				
	Knight Piésold CONSULTING				
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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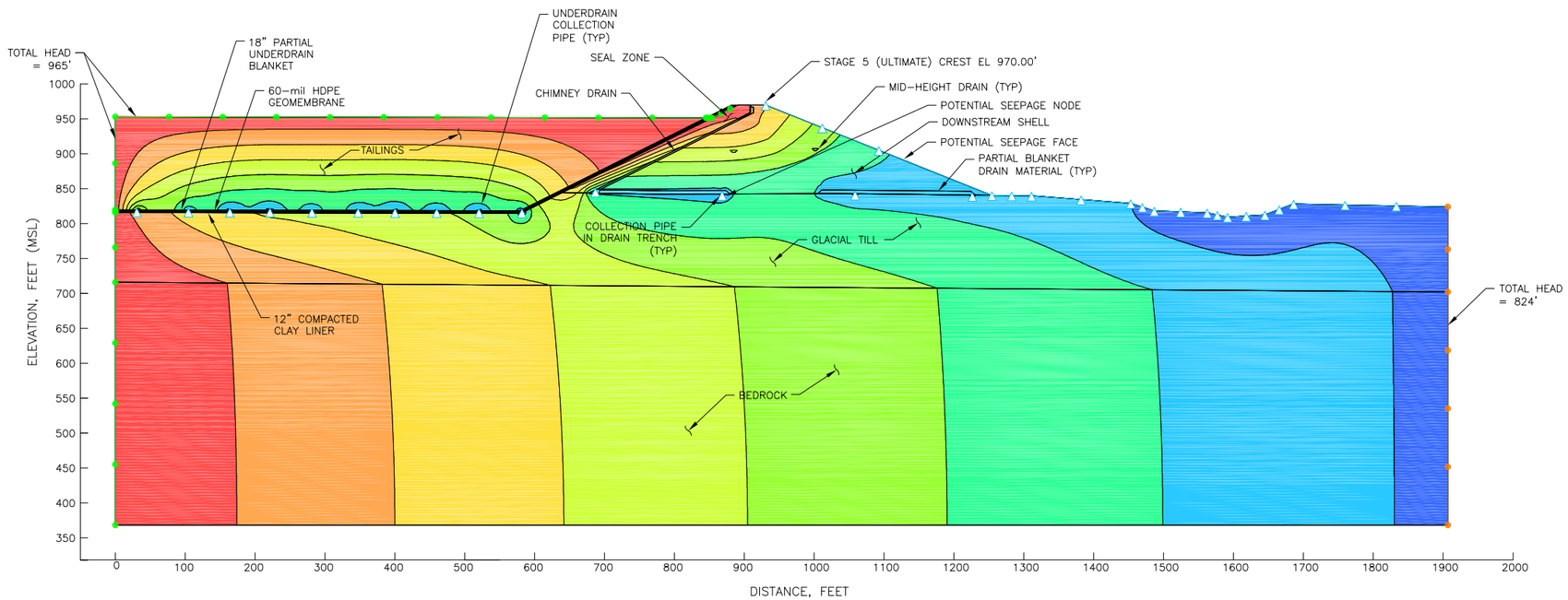

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:

949
929
909
889
869
849
829

B / 7.1 SEEPAGE ANALYSIS CASE 3 LINER SYSTEM
WEST/NORTHWEST SECTION

100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

100 0 100 200 FEET
VERTICAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SEEPAGE ANALYSIS CASE 3 LINER SYSTEM SECTION B
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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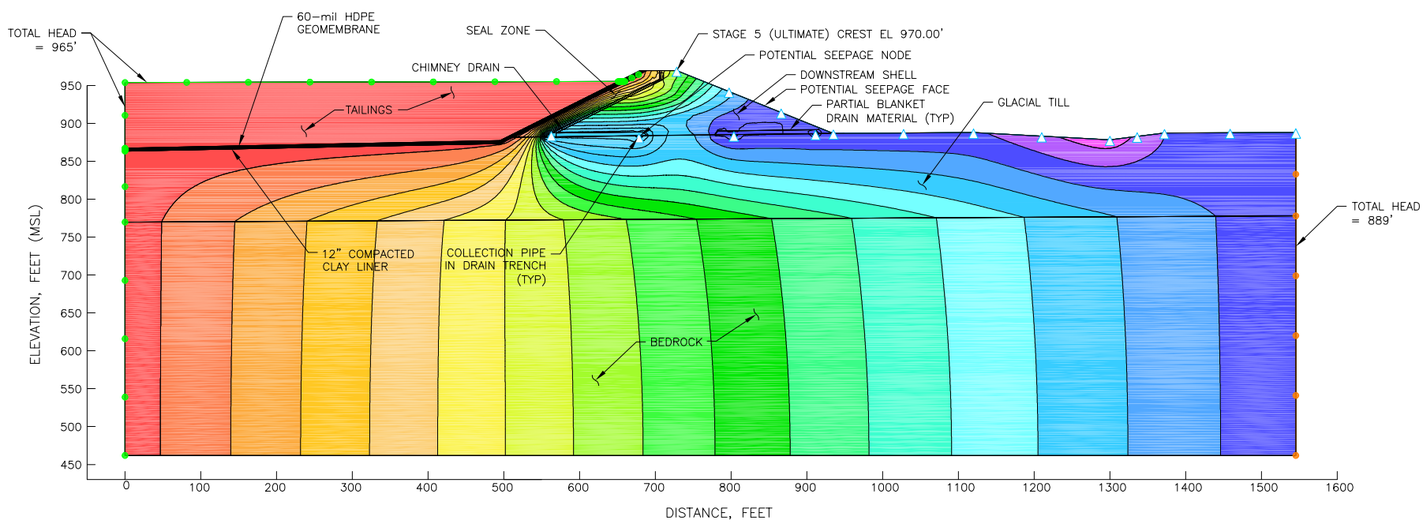
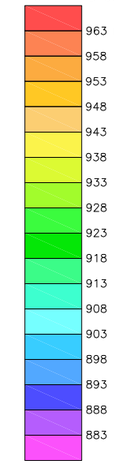


C
7.1

SEEPAGE ANALYSIS CASE 3 LINER SYSTEM
WEST/SOUTHWEST SECTION

LEGEND:

TOTAL HEAD CONTOUR INTERVALS, FEET:



NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. ASSUMES GROUNDWATER FLOW REGIME IS HYDROSTATIC.
3. SECTION C IS OUTSIDE THE LIMITS OF THE PARTIAL UNDERDRAIN BLANKET.

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SEEPAGE ANALYSIS CASE 3 LINER SYSTEM SECTION C
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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ACTIVITY CODE	N/A	XREF NUMBER	N/A		

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Drawings

ORVANA RESOURCES U.S. CORPORATION
COPPERWOOD PROJECT
IRONWOOD AND WAKEFIELD TOWNSHIPS, GOGEBIC COUNTY, MICHIGAN

TAILINGS DISPOSAL FACILITY

DRAWING INDEX

SHEET	TITLE	REVISION	REVISION DATE
1	COVER	B	07/29/11
110	GENERAL SITE LOCATION MAP	B	07/29/11
120	OVERALL SITE PLAN	B	07/29/11
130	GEOTECHNICAL SITE INVESTIGATION PLAN	B	07/29/11
132	GENERAL CROSS-SECTIONS – SHEET 1 OF 2	B	07/29/11
134	GENERAL CROSS-SECTIONS – SHEET 2 OF 2	B	07/29/11
140	STAGE 1 (YEAR 3) GRADING PLAN	B	07/29/11
142	STAGE 2 (YEAR 6) GRADING PLAN	B	07/29/11
144	STAGE 3 (YEAR 9) GRADING PLAN	B	07/29/11
146	STAGE 4 (YEAR 12) GRADING PLAN	B	07/29/11
148	STAGE 5 (YEAR 15) GRADING PLAN	B	07/29/11
150	EMBANKMENT SECTIONS AND DETAILS – SHEET 1 OF 2	B	07/29/11
152	EMBANKMENT SECTIONS AND DETAILS – SHEET 2 OF 2	B	07/29/11
154	BASIN SECTIONS AND DETAILS – SHEET 1 OF 4	B	07/29/11
156	BASIN SECTIONS AND DETAILS – SHEET 2 OF 4	B	07/29/11
158	BASIN SECTIONS AND DETAILS – SHEET 3 OF 4	B	07/29/11
159	BASIN SECTIONS AND DETAILS – SHEET 4 OF 4	B	07/29/11
160	DECANT SYSTEM – PLAN AND PROFILE	B	07/29/11
162	OUTLET PIPE PLAN AND PROFILE	B	07/29/11
164	DECANT SYSTEM SECTIONS AND DETAILS – SHEET 1 OF 2	B	07/29/11
166	DECANT SYSTEM SECTIONS AND DETAILS – SHEET 2 OF 2	B	07/29/11
170	DECANT SUMP AND OVERFLOW POND PLAN	B	07/29/11
172	DECANT SUMP AND OVERFLOW POND – SECTIONS AND DETAILS – SHEET 1 OF 3	B	07/29/11
174	DECANT SUMP AND OVERFLOW POND – SECTIONS AND DETAILS – SHEET 2 OF 3	B	07/29/11
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180	TAILINGS DISTRIBUTION SYSTEM SCHEMATIC – SHEET 1 OF 2	B	07/29/11
182	TAILINGS DISTRIBUTION SYSTEM SCHEMATIC – SHEET 2 OF 2	B	07/29/11
186	MONITORING WELL PLAN	B	07/29/11
190	CONCEPTUAL CLOSURE SCHEMATIC – SHEET 1 OF 2	B	07/29/11
192	CONCEPTUAL CLOSURE SCHEMATIC – SHEET 2 OF 2	B	07/29/11

ISSUED FOR PRE-FEASIBILITY STUDY
ISSUED DATE: JULY 29, 2011

Prepared for:

ORVANA RESOURCES U.S. CORPORATION

10199 LAKE ROAD
IRONWOOD, MICHIGAN 49938

Prepared by:

Knight Piésold CONSULTING

1580 Lincoln Street, Suite 1000
Denver, Colorado 80203-1512

3275 W. Ina Road, Suite 109
Tucson, Arizona 85741

406 West Silver Street, Suite 106
Elko, Nevada 89801

3333 Warrenville Road, Suite 200
Chicago, Illinois 60532

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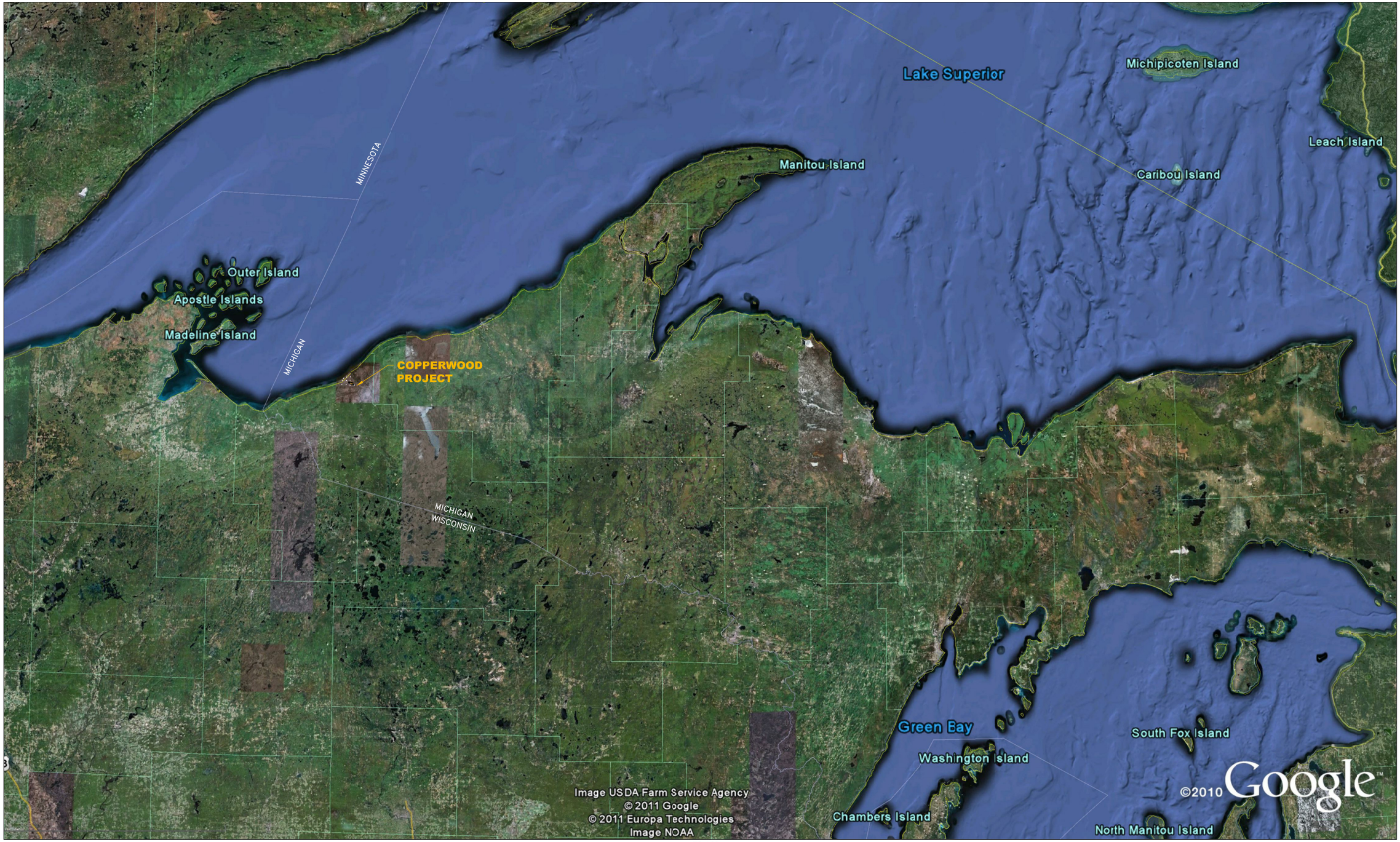

PLAN

60,000 0 60,000 120,000 FEET

1" = 60,000' AT FULL SIZE (ANSI D)
1" = 120,000' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

DISCLAIMER

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ACTIVITY CODE N/A

XREF N/A

CLIENT

ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT

COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE

GENERAL SITE LOCATION MAP

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	110	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs revs\101-429-02-110-b.dwg
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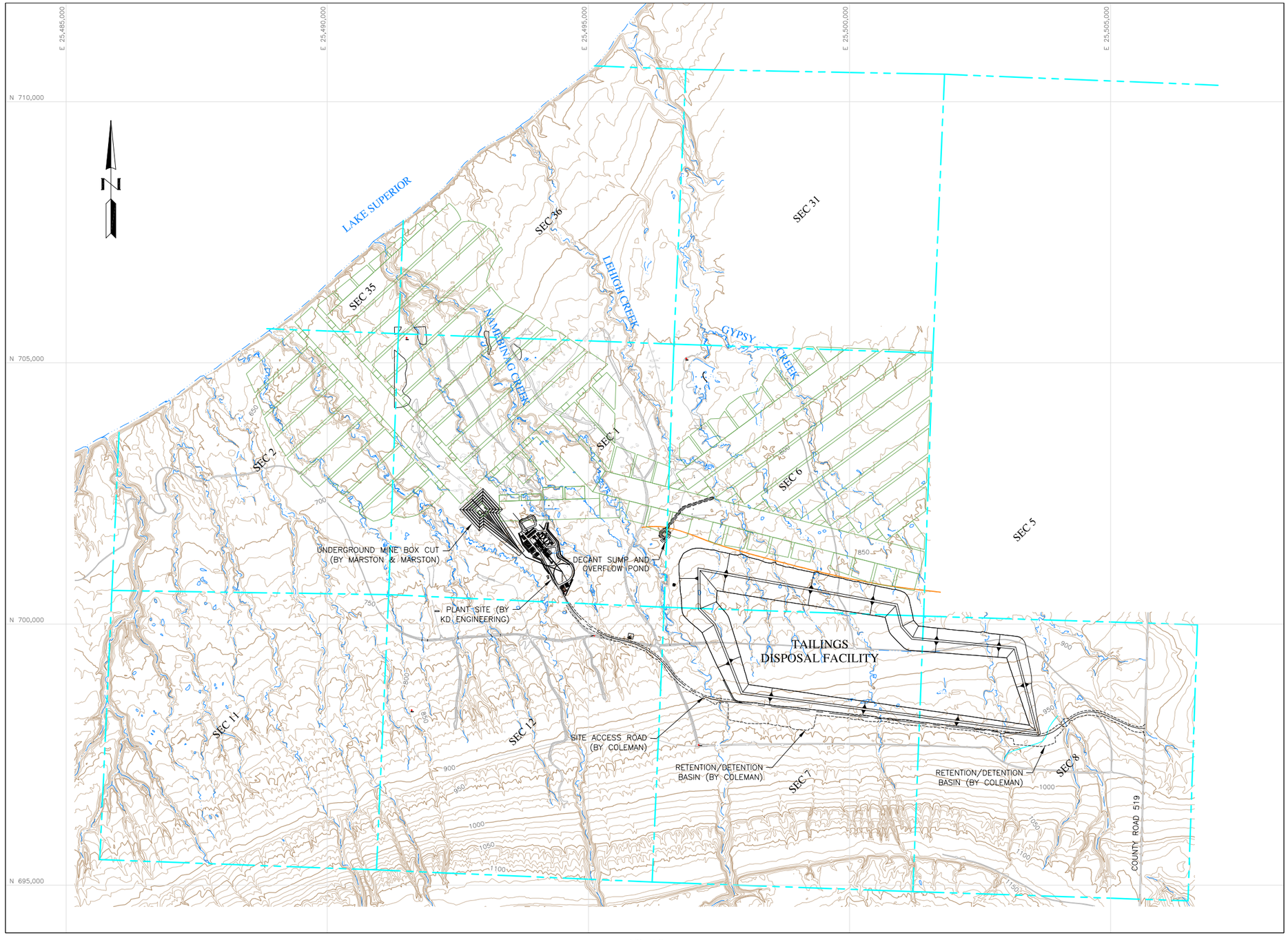

LEGEND:

- 880 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE
- UNDERGROUND MINE WORKINGS (BY MARSTON AND MARSTON)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).

PLAN

1000 0 1000 2000 FEET

1" = 1000' AT FULL SIZE (ANSI D)
1" = 2000' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D	CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR	RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR	RMG

DISCLAIMER
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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
OVERALL SITE PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	120	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pts rev0\101–429–02–120–b.dwg
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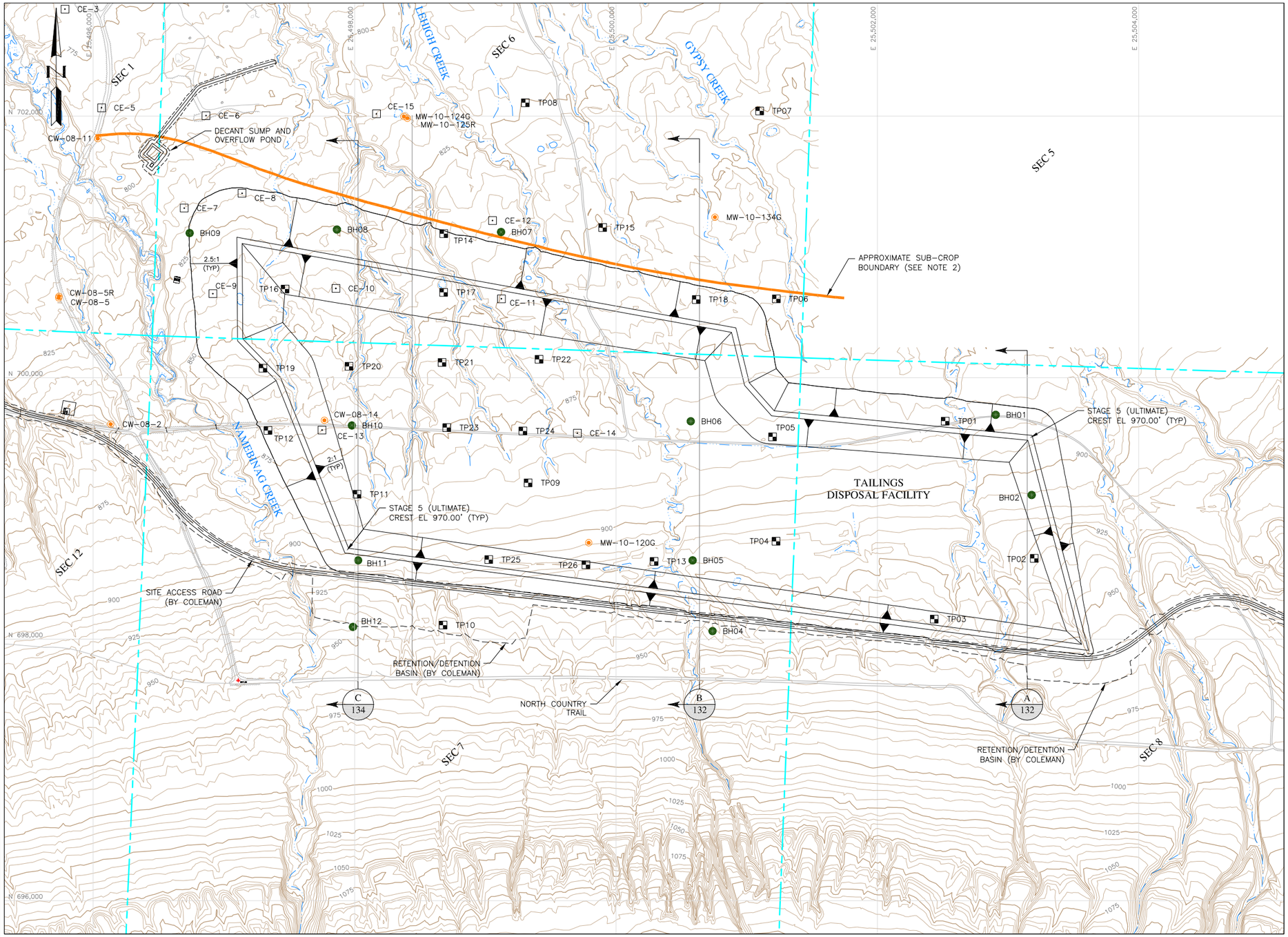

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE
- CW-08-5 — AECOM MONITORING WELL (2008)
- MW-10-1206 — AECOM MONITORING WELL (2010)
- BH01 — KNIGHT PIESOLD BOREHOLE (2011)
- TP01 — KNIGHT PIESOLD TEST PIT (2011)
- CE-1 — COLEMAN TEST PIP (2010)

TABLE 1
BOREHOLE AND TEST PIT INFORMATION

BOREHOLE ID	DEPTH TO BEDROCK (ft)	DEPTH TO EXCAVATION SURFACE (ft)	NORTHING (ft)	EASTING (ft)	GROUND SURFACE ELEVATION (ft)
BH01	99	20	699715.60	25502906.14	886.79
BH02	86	14.8	699102.45	25503181.03	905.02
BH04	52	0	698061.96	25500738.91	935.62
BH05	62	20	698602.39	25500586.56	917.73
BH06	83	30	699666.23	25500572.74	881.88
BH07	134	30.6	701114.60	25499121.10	843.27
BH08	124	25.5	701132.90	25497865.22	824.71
BH09	93	35	701105.92	25496737.61	821.38
BH10	109	20.8	699634.37	25497979.04	870.44
BH11	12	0	698602.87	25498027.23	901.95
BH12	13	0	698094.04	25497987.82	944.02
CW-08-014	97	20	699673.78	25497768.94	862.45
MW-10-120	48	12	698737.80	25499791.48	902.76
MW-10-134	119	25	701227.73	25500757.45	852.37
TP01	–	–	699667.75	25502520.03	887.92
TP02	–	–	698617.80	25503201.21	927.26
TP03	–	–	698153.42	25502435.70	938.56
TP04	–	–	698748.40	25501225.08	914.13
TP05	–	–	699547.58	25501198.44	886.19
TP06	–	–	700602.94	25501227.08	868.66
TP07	–	–	702040.01	25501100.09	849.43
TP08	–	–	702103.03	25499307.07	824.45
TP09	–	–	699196.06	25499328.13	885.91
TP10	–	–	698107.32	25498676.83	936.10
TP11	–	–	699108.17	25498018.65	883.56
TP12	–	–	699596.37	25497336.95	868.76
TP13	–	–	698594.34	25500291.98	912.67
TP14	–	–	701101.41	25498683.09	836.12
TP15	–	–	701147.77	25499898.98	848.88
TP16	–	–	700678.32	25497467.52	839.28
TP17	–	–	700652.71	25498681.23	845.18
TP18	–	–	700598.04	25500613.87	864.72
TP19	–	–	700072.58	25497299.27	855.34
TP20	–	–	700087.03	25497957.67	857.37
TP21	–	–	700116.83	25498669.83	859.14
TP22	–	–	700140.25	25499411.84	862.89
TP23	–	–	699618.19	25498705.50	874.56
TP24	–	–	699591.98	25499288.12	877.48
TP25	–	–	698608.38	25499026.67	904.27
TP26	–	–	698569.02	25499770.23	914.87

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE SUB-CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. THE TAILINGS DISPOSAL FACILITY EXCAVATION SURFACE WAS CREATED BASED ON THE BOREHOLE POINTS LISTED IN TABLE 1, EXCLUDING BOREHOLES BH02, BH07, BH08, AND BH10. THE SURFACE WAS "STRAIGHT-LINED" BETWEEN THE REMAINING POIINTS TO CREATE THE FLOOR OF THE FACILITY.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO-METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg
ORVANA DRILL HOLE INFORMATION RECEIVED FROM ORVANA RESOURCES VIA COLEMAN ENGINEERING ON DECEMBER 12, 2010
SEE G:\101\00429.02\External\2010 1214 – TSF Draft Map with Drill Holes

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE: N/A
XREF: N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: GEOTECHNICAL SITE INVESTIGATION PLAN

DESIGNED BY	JC/JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	130	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs revb\101-429-02-130-b.dwg
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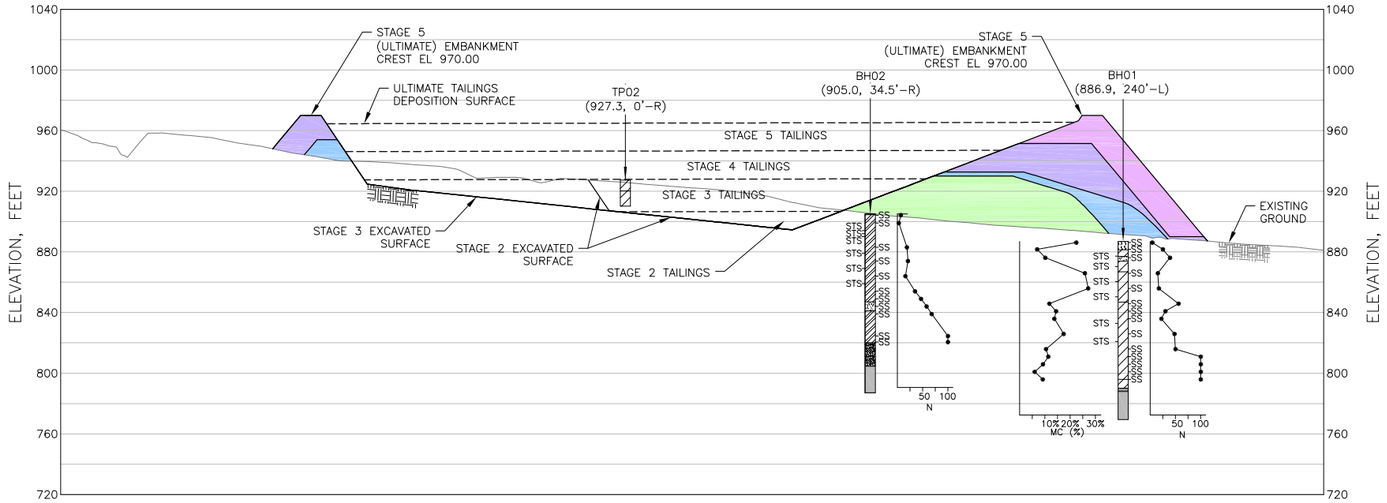


A
130

SOUTH TO NORTH SECTION THROUGH EASTERN
PORTION OF TAILINGS DISPOSAL FACILITY

150 0 150 300 FEET
HORIZONTAL SCALE
1" = 150' AT FULL SIZE (ANSI D)
1" = 300' AT HALF SIZE (ANSI B)

50 0 50 100 FEET
VERTICAL SCALE
1" = 50' AT FULL SIZE (ANSI D)
1" = 100' AT HALF SIZE (ANSI B)

LEGEND:

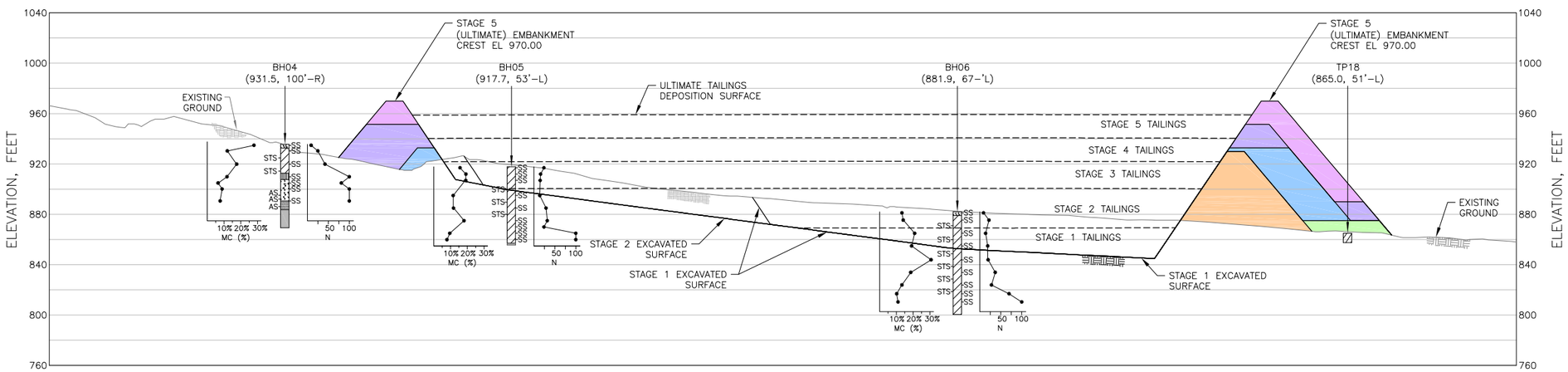
- SAND (SM) – RED-BROWN, FINE TO COARSE, WITH SILT, SOME FINE GRAVEL, WET, DENSE
- SILTY SAND (SM) – BROWN, FINE TO MEDIUM, MOIST, LOOSE
- SANDY SILT (ML) – BROWN, FINE TO COARSE SAND, SOME FINE GRAVEL, SLIGHTLY PLASTIC, HARD
- CLAY (CL) – RED-BROWN, SOME FINE SAND, PLASTIC, MOIST, STIFF TO VERY STIFF
- FAT CLAY (CH) – RED-BROWN, SOME FINE TO COARSE SAND, PLASTIC, MOIST, STIFF
- LEAN CLAY (CH) – RED-BROWN, SANDY, TRACE FINE GRAVEL, SLIGHTLY PLASTIC, WET, HARD
- BEDROCK – SANDSTONE, RED-BROWN, FINE TO MEDIUM (COPPER HARBOR CONGLOMERATE)
- WEATHERED BEDROCK

SS – SPLIT SPOON TEST
STS – SHELBY TUBE SAMPLE
AS – AUGER SAMPLE

- STAGE 1 EMBANKMENT
- STAGE 2 EMBANKMENT
- STAGE 3 EMBANKMENT
- STAGE 4 EMBANKMENT
- STAGE 5 EMBANKMENT

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).



B
130

SOUTH TO NORTH SECTION THROUGH MIDDLE
PORTION OF TAILINGS DISPOSAL FACILITY

150 0 150 300 FEET
HORIZONTAL SCALE
1" = 150' AT FULL SIZE (ANSI D)
1" = 300' AT HALF SIZE (ANSI B)

50 0 50 100 FEET
VERTICAL SCALE
1" = 50' AT FULL SIZE (ANSI D)
1" = 100' AT HALF SIZE (ANSI B)

REFERENCE:
BOREHOLE DATA PROVIDED BY COLEMAN ENGINEERING COMPANY
DURING 2011 SITE INVESTIGATION

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

DISCLAIMER
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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
GENERAL CROSS-SECTIONS
SHEET 1 OF 2

DESIGNED BY	JC/JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	132	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev0\101-429-02-132-134-B.dwg
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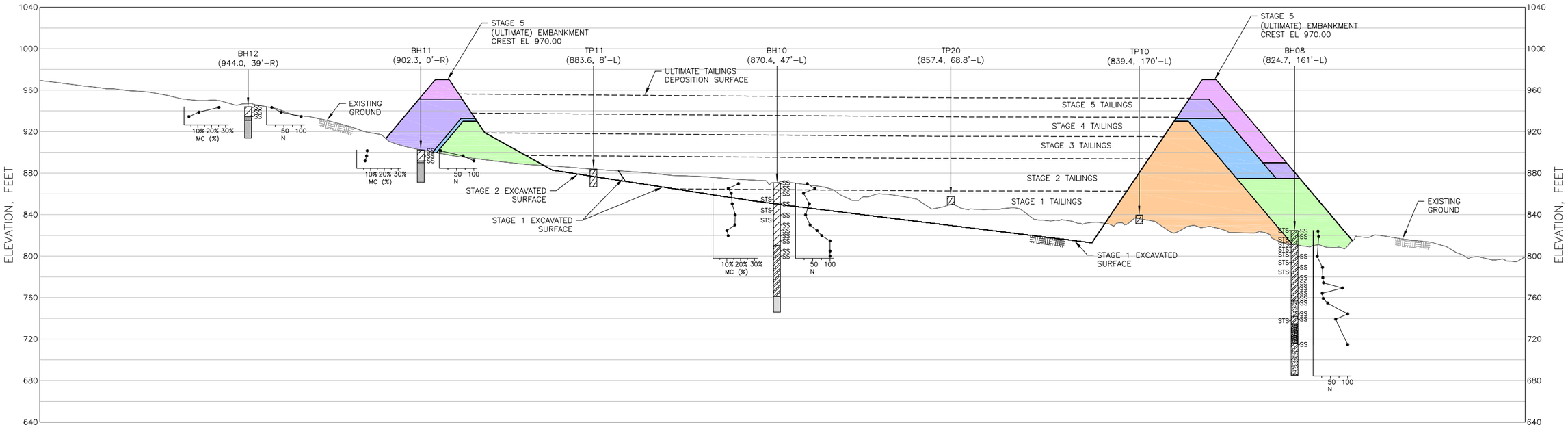

C
130

SOUTH TO NORTH SECTION THROUGH WESTERN
PORTION OF TAILINGS DISPOSAL FACILITY

150 0 150 300 FEET
HORIZONTAL SCALE
1" = 150' AT FULL SIZE (ANSI D)
1" = 300' AT HALF SIZE (ANSI B)

50 0 50 100 FEET
VERTICAL SCALE
1" = 50' AT FULL SIZE (ANSI D)
1" = 100' AT HALF SIZE (ANSI B)

LEGEND:

- SAND (SM) – RED–BROWN, FINE TO COARSE, WITH SILT, SOME FINE GRAVEL, WET, DENSE
- SILTY SAND (SM) – BROWN, FINE TO MEDIUM, MOIST, LOOSE
- SANDY SILT (ML) – BROWN, FINE TO COARSE SAND, SOME FINE GRAVEL, SLIGHTLY PLASTIC, HARD
- CLAY (CL) – RED–BROWN, SOME FINE SAND, PLASTIC, MOIST, STIFF TO VERY STIFF
- FAT CLAY (CH) – RED–BROWN, SOME FINE TO COARSE SAND, PLASTIC, MOIST, STIFF
- LEAN CLAY (CH) – RED–BROWN, SANDY, TRACE FINE GRAVEL, SLIGHTLY PLASTIC, WET, HARD
- BEDROCK – SANDSTONE, RED–BROWN, FINE TO MEDIUM (COPPER HARBOR CONGLOMERATE)
- WEATHERED BEDROCK

SS – SPLIT SPOON TEST
STS – SHELBY TUBE SAMPLE
AS – AUGER SAMPLE

- STAGE 1 EMBANKMENT
- STAGE 2 EMBANKMENT
- STAGE 3 EMBANKMENT
- STAGE 4 EMBANKMENT
- STAGE 5 EMBANKMENT

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).

REFERENCE:
BOREHOLE DATA PROVIDED BY COLEMAN ENGINEERING COMPANY DURING 2011 SITE INVESTIGATION

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
GENERAL CROSS–SECTIONS
SHEET 2 OF 2

DESIGNED BY	JC/JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	134	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs revb\101–429–02–132–134–B.dwg
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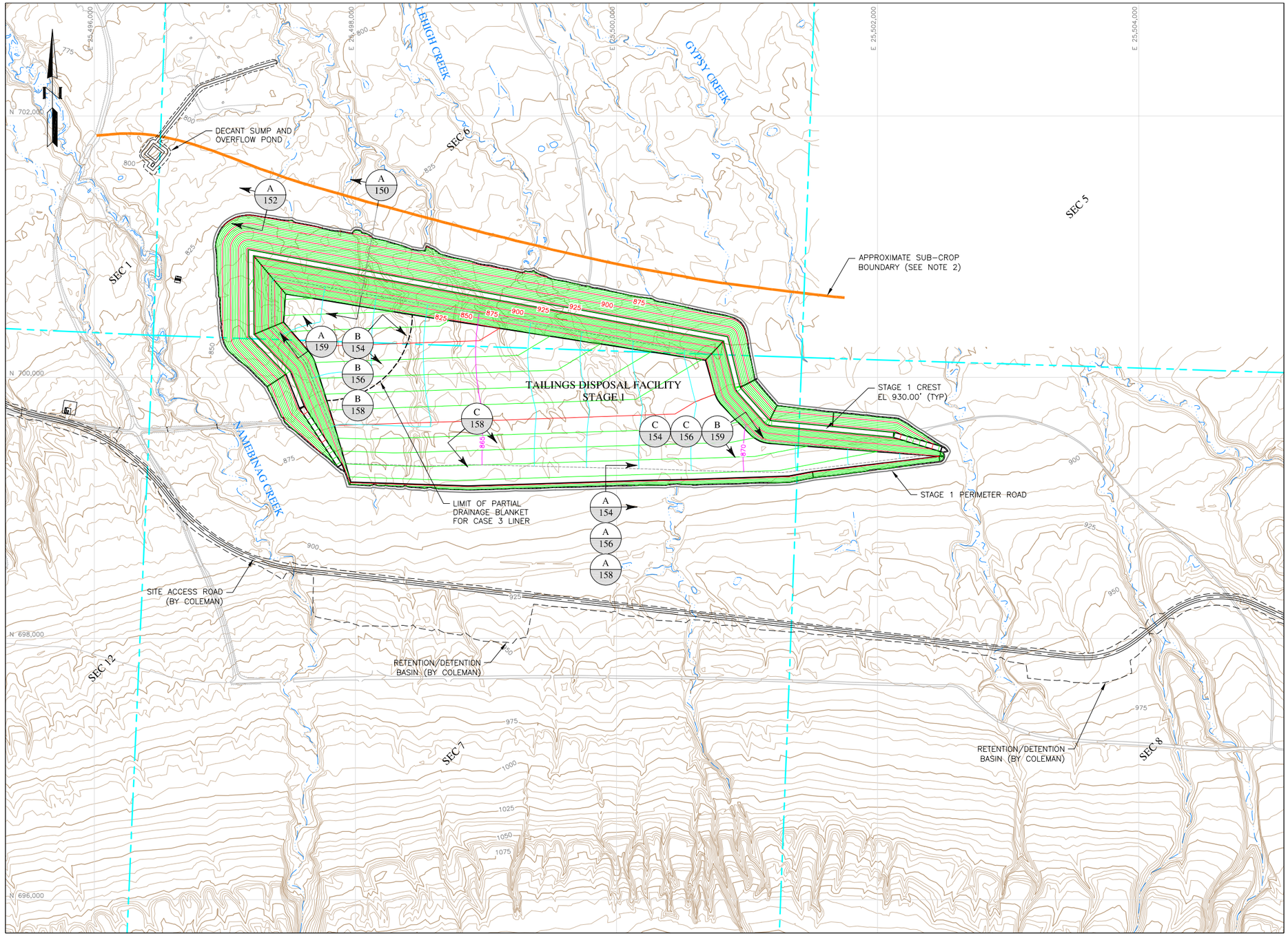

LEGEND:

- 900 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- 870 — TAILINGS STORAGE SURFACE CONTOUR AND EL, FEET
- 875 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE SUB–CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. THE TAILINGS DISPOSAL FACILITY CONFIGURATION ASSUMES EXTERIOR EMBANKMENT SLOPES OF 2.5H:1V AND INTERIOR SLOPES OF 2H:1V.
4. THE TAILINGS SURFACE HAS BEEN CONFIGURED WITH AN ASSUMED SLOPE OF 0.25 PERCENT.
5. THE STAGE 1 CONFIGURATION CONTAINS APPROXIMATELY 4.5 ft OF FREEBOARD IN THE SOUTHEAST CORNER OF THE FACILITY, AND 69 ft IN THE NORTHWEST CORNER, FROM THE DESIGN TAILINGS SURFACE TO THE LOW–POINT EMBANKMENT CREST.
6. THE STAGE 1 CONFIGURATION PROVIDES TAILINGS STORAGE THROUGH YEAR 3 OF THE CURRENT MINE SCHEDULE.
7. REFER TO DRAWINGS 130, 132, AND 134 FOR GENERAL CROSS–SECTIONS THROUGH THE STAGED DEVELOPMENT OF THE TAILINGS DISPOSAL FACILITY.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D	CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR	RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR	RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
STAGE 1 (YEAR 3) GRADING PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	140	B

LAST SAVED BY: RGRAHAM
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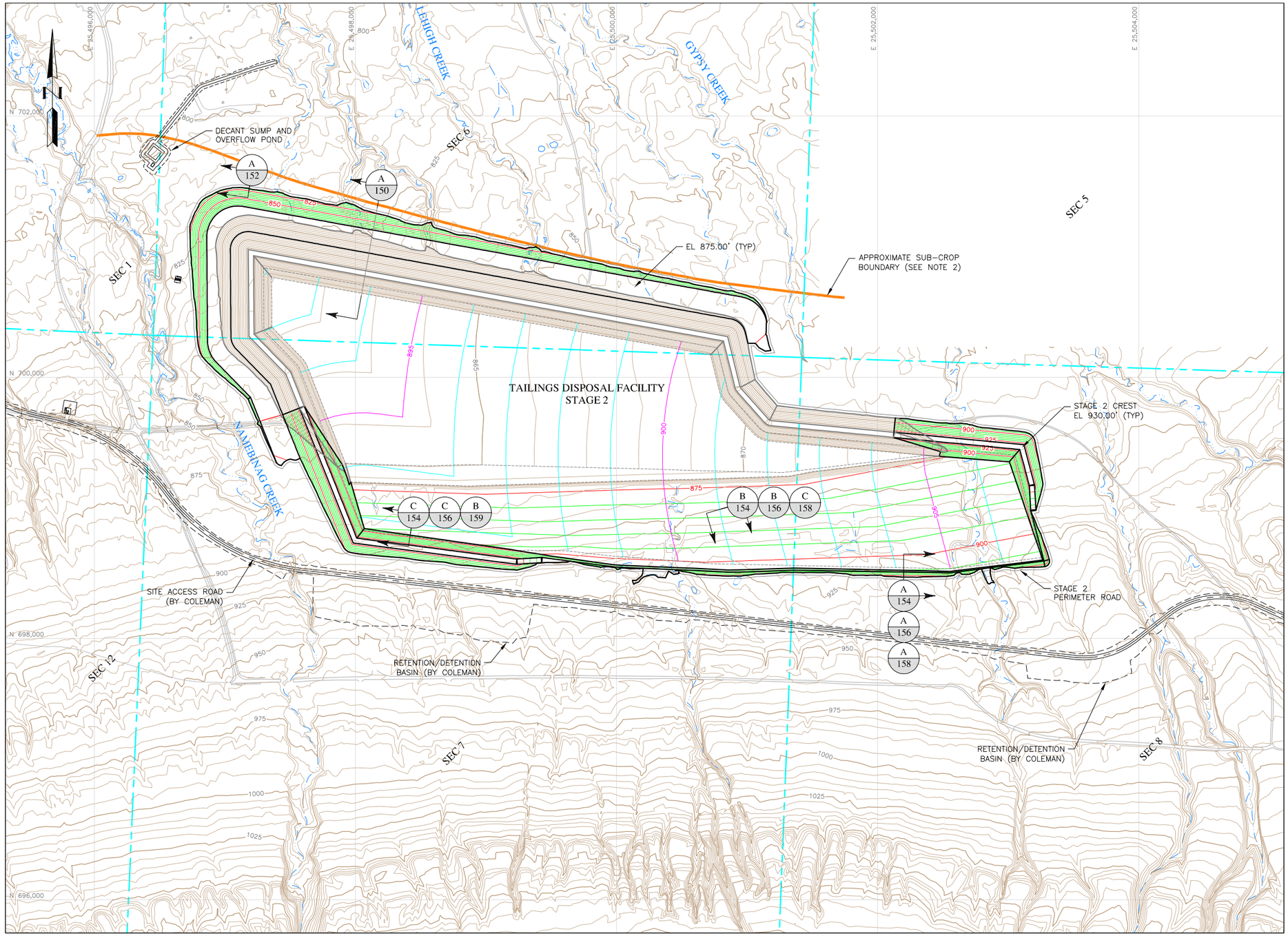

LEGEND:

- 850 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- 900 — TAILINGS STORAGE SURFACE CONTOUR AND EL, FEET
- 900 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE SUB–CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. THE TAILINGS DISPOSAL FACILITY CONFIGURATION ASSUMES EXTERIOR EMBANKMENT SLOPES OF 2.5H:1V AND INTERIOR SLOPES OF 2H:1V.
4. THE TAILINGS SURFACE HAS BEEN CONFIGURED WITH AN ASSUMED SLOPE OF 0.25 PERCENT.
5. THE STAGE 2 CONFIGURATION CONTAINS APPROXIMATELY 4.5 ft OF FREEBOARD IN THE SOUTHEAST CORNER OF THE FACILITY, AND 19.3 ft IN THE NORTHWEST CORNER, FROM THE DESIGN TAILINGS SURFACE TO THE LOW–POINT EMBANKMENT CREST.
6. THE STAGE 2 CONFIGURATION PROVIDES TAILINGS STORAGE THROUGH YEAR 6 OF THE CURRENT MINE SCHEDULE.
7. REFER TO DRAWINGS 130, 132, AND 134 FOR GENERAL CROSS–SECTIONS THROUGH THE STAGED DEVELOPMENT OF THE TAILINGS DISPOSAL FACILITY.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

DISCLAIMER
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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
STAGE 2 (YEAR 6) GRADING PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	142	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev6\101–429–02–142–b.dwg
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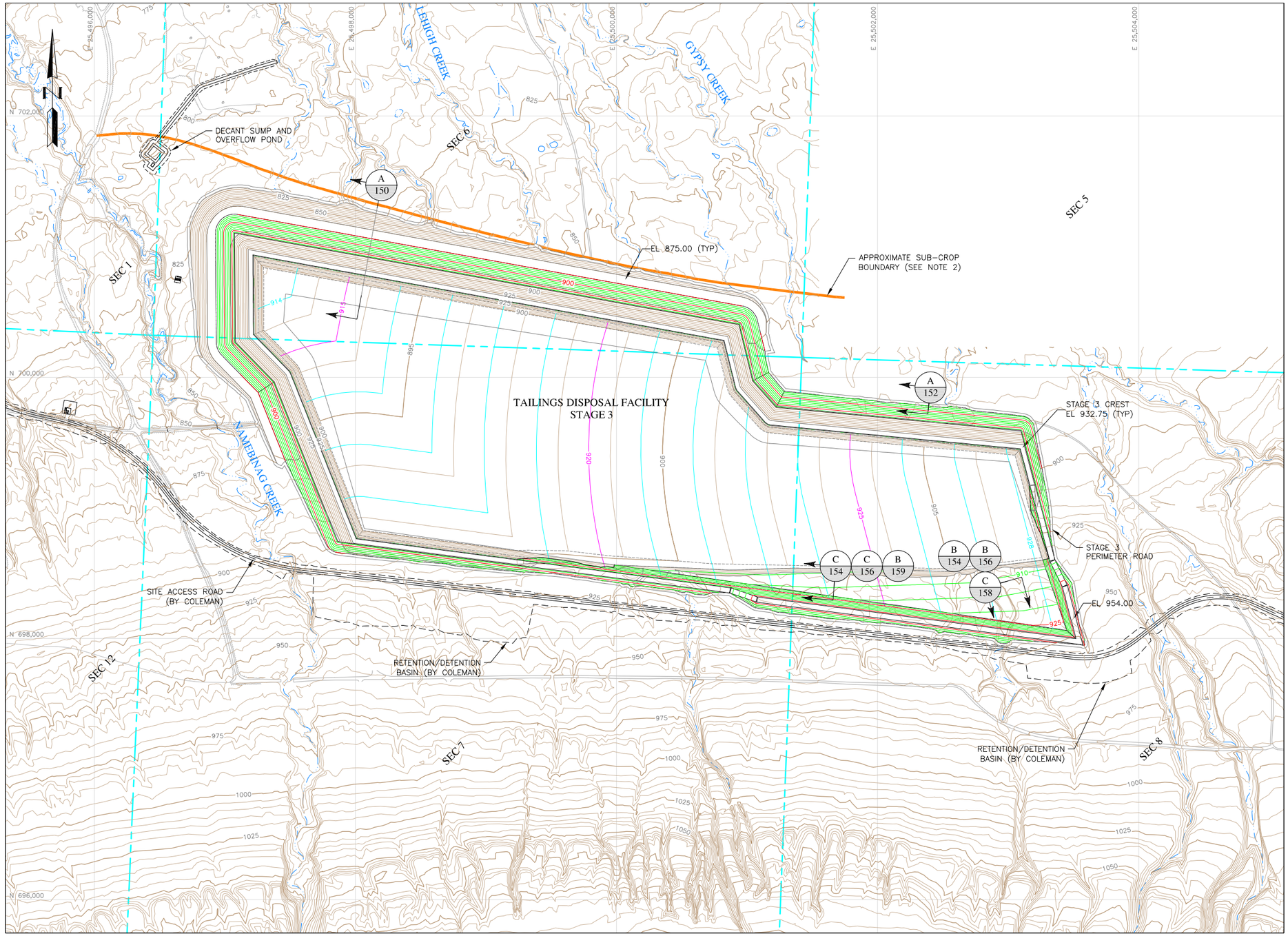

LEGEND:

- 850 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- 925 — TAILINGS STORAGE SURFACE CONTOUR AND EL, FEET
- 900 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE SUB–CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. THE TAILINGS DISPOSAL FACILITY CONFIGURATION ASSUMES EXTERIOR EMBANKMENT SLOPES OF 2.5H:1V AND INTERIOR SLOPES OF 2H:1V.
4. THE TAILINGS SURFACE HAS BEEN CONFIGURED WITH AN ASSUMED SLOPE OF 0.25 PERCENT.
5. THE STAGE 3 CONFIGURATION CONTAINS APPROXIMATELY 4.5 ft OF FREEBOARD IN THE SOUTHEAST CORNER OF THE FACILITY, AND 19.5 ft IN THE NORTHWEST CORNER, FROM THE DESIGN TAILINGS SURFACE TO THE LOW–POINT EMBANKMENT CREST.
6. THE STAGE 3 CONFIGURATION PROVIDES TAILINGS STORAGE THROUGH YEAR 9 OF THE CURRENT MINE SCHEDULE.
7. REFER TO DRAWINGS 130, 132, AND 134 FOR GENERAL CROSS–SECTIONS THROUGH THE STAGED DEVELOPMENT OF THE TAILINGS DISPOSAL FACILITY.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

DISCLAIMER
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ACTIVITY CODE N/A
XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: STAGE 3 (YEAR 9) GRADING PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	144	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev b\101–429–02–144–b.dwg
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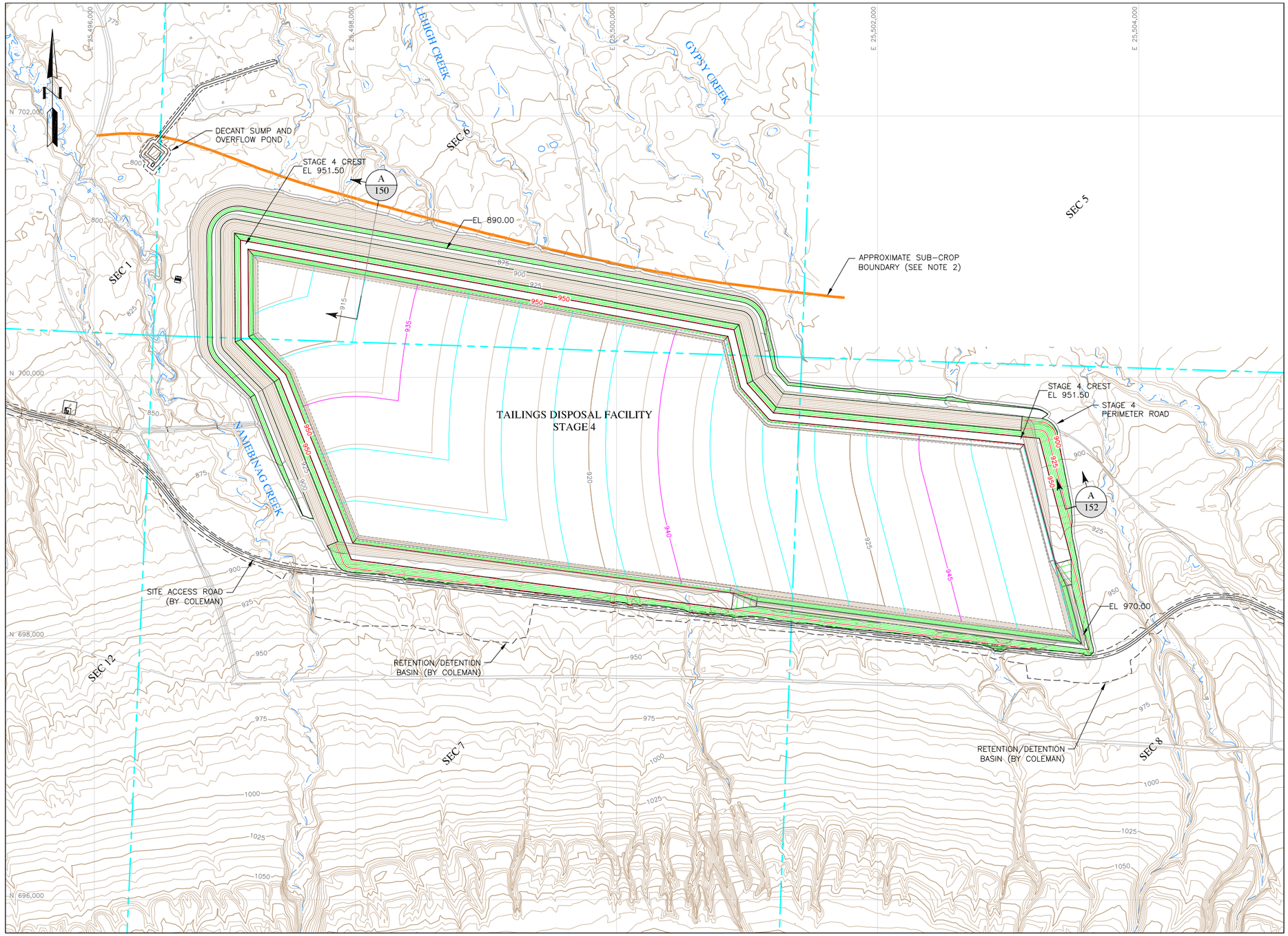

LEGEND:

- 900 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- 945 — TAILINGS STORAGE SURFACE CONTOUR AND EL, FEET
- 950 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE SUB–CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. THE TAILINGS DISPOSAL FACILITY CONFIGURATION ASSUMES EXTERIOR EMBANKMENT SLOPES OF 2.5H:1V AND INTERIOR SLOPES OF 2H:1V.
4. THE TAILINGS SURFACE HAS BEEN CONFIGURED WITH AN ASSUMED SLOPE OF 0.25 PERCENT.
5. THE STAGE 4 CONFIGURATION CONTAINS APPROXIMATELY 4.5 ft OF FREEBOARD IN THE SOUTHEAST CORNER OF THE FACILITY, AND 19.5 ft IN THE NORTHWEST CORNER, FROM THE DESIGN TAILINGS SURFACE TO THE LOW–POINT EMBANKMENT CREST.
6. THE STAGE 4 CONFIGURATION PROVIDES TAILINGS STORAGE THROUGH YEAR 12 OF THE CURRENT MINE SCHEDULE.
7. REFER TO DRAWINGS 130, 132, AND 134 FOR GENERAL CROSS–SECTIONS THROUGH THE STAGED DEVELOPMENT OF THE TAILINGS DISPOSAL FACILITY.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE: N/A
XREF: N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

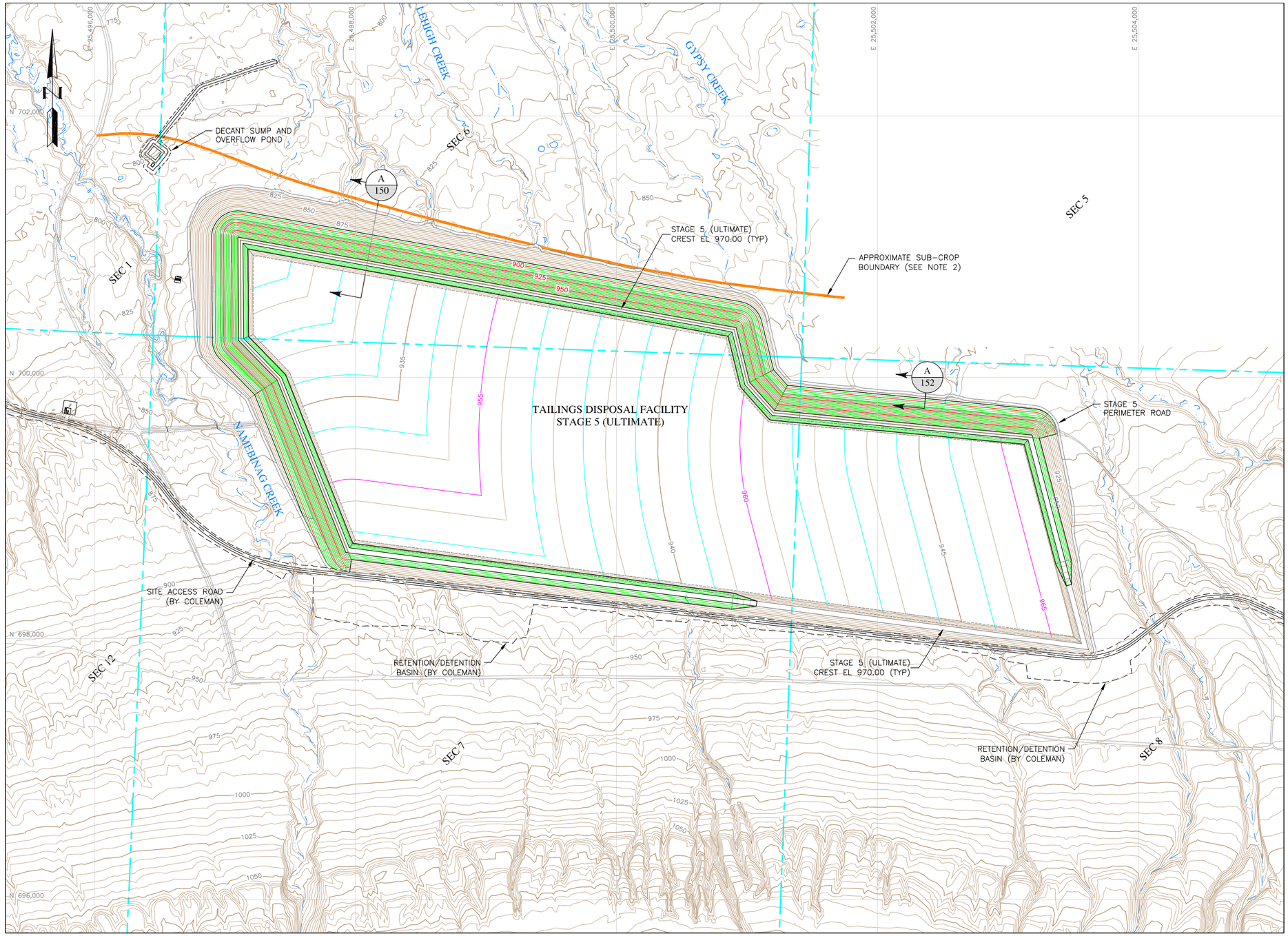
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: STAGE 4 (YEAR 12) GRADING PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	146	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev2\101–429–02–146–b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:53 AM



LEGEND:

- 900 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- 870 — TAILINGS STORAGE SURFACE CONTOUR AND EL, FEET
- 875 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE SUB–CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. THE TAILINGS DISPOSAL FACILITY CONFIGURATION ASSUMES EXTERIOR EMBANKMENT SLOPES OF 2.5H:1V AND INTERIOR SLOPES OF 2H:1V.
4. THE TAILINGS SURFACE HAS BEEN CONFIGURED WITH AN ASSUMED SLOPE OF 0.25 PERCENT.
5. THE STAGE 5 CONFIGURATION CONTAINS APPROXIMATELY 4.5 ft OF FREEBOARD IN THE SOUTHEAST CORNER OF THE FACILITY, AND 19.7 ft IN THE NORTHWEST CORNER, FROM THE DESIGN TAILINGS SURFACE TO THE LOW–POINT EMBANKMENT CREST.
6. THE STAGE 5 CONFIGURATION PROVIDES TAILINGS STORAGE THROUGH YEAR 15.1 OF THE CURRENT MINE SCHEDULE (END OF MINE LIFE).
7. REFER TO DRAWINGS 130, 132, AND 134 FOR GENERAL CROSS–SECTIONS THROUGH THE STAGED DEVELOPMENT OF THE TAILINGS DISPOSAL FACILITY.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

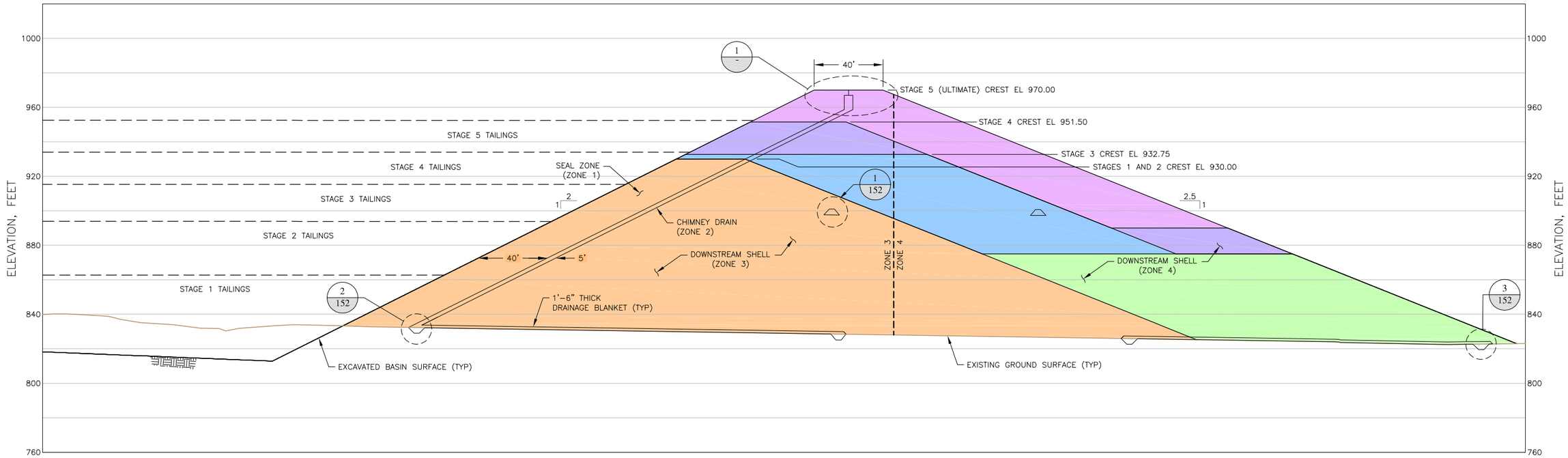
Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
STAGE 5 (YEAR 15) GRADING PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	148	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev6\101–429–02–148–b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:54 AM



A 140 | A 142 | A 144 | A 146 | A 148

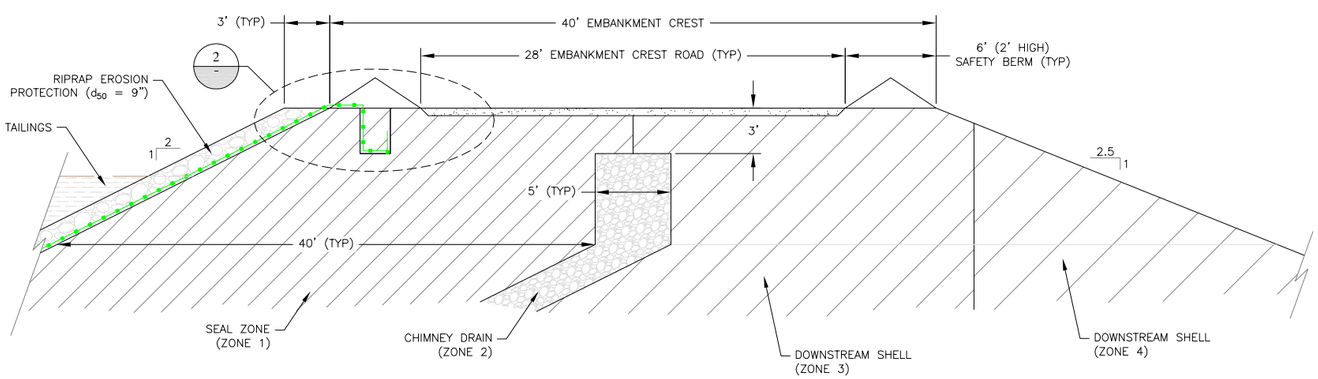
TYPICAL SECTION THROUGH MAIN EMBANKMENT

30 0 30 60 FEET
HORIZONTAL SCALE
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)

30 0 30 60 FEET
VERTICAL SCALE
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)

LEGEND:

- STAGE 1 EMBANKMENT
- STAGE 2 EMBANKMENT
- STAGE 3 EMBANKMENT
- STAGE 4 EMBANKMENT
- STAGE 5 EMBANKMENT

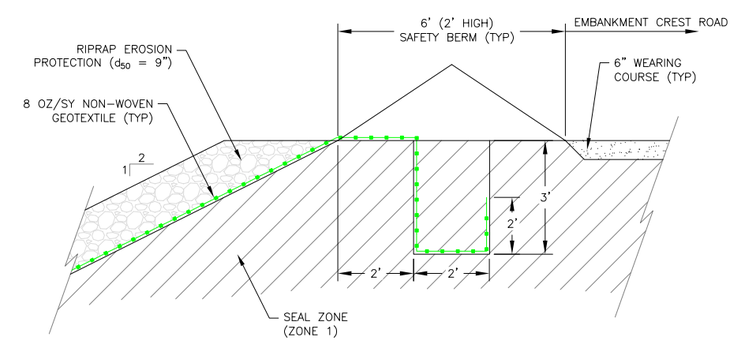


1 - STAGE 5 (ULTIMATE) EMBANKMENT CREST

5 0 5 10 FEET
1" = 5' AT FULL SIZE (ANSI D)
1" = 10' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE EMBANKMENT CREST ELEVATIONS PRESENTED ARE FOR THE CASE 2 (FULL DRAINAGE BLANKET) LINER SYSTEM.



2 - TYPICAL EMBANKMENT INTERIOR SLOPE PROTECTION AND GEOTEXTILE TERMINATION

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

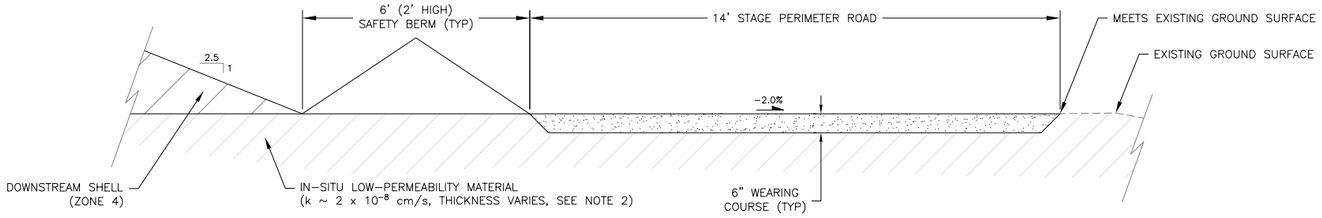
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: EMBANKMENT SECTIONS AND DETAILS
SHEET 1 OF 2

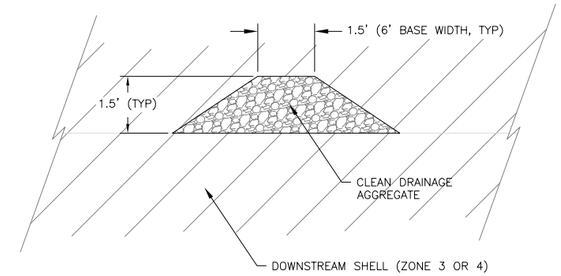
DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	150	B

LAST SAVED BY: CBENLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev b\101-429-02-150-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:54 AM



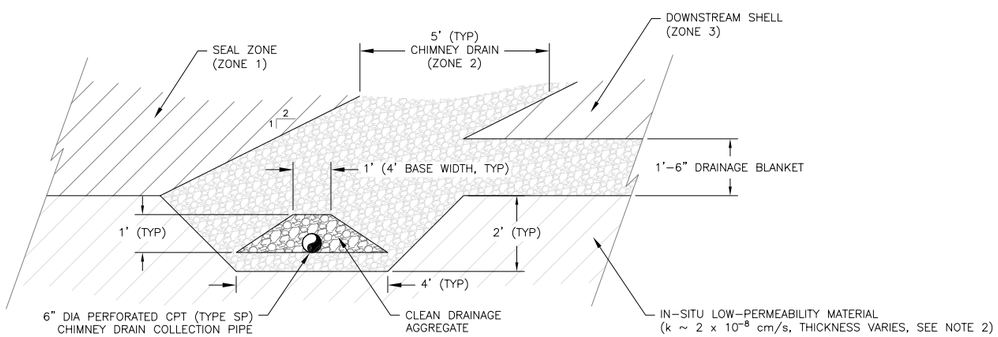
A 140 A 142 A 144 A 146 A 148 TYPICAL STAGE PERIMETER ROAD AT EMBANKMENT DOWNSTREAM TOE

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



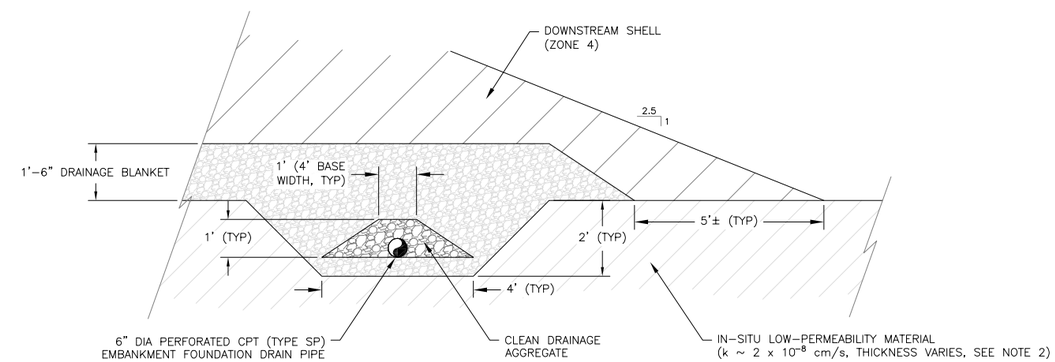
1 150 TYPICAL EMBANKMENT MID-HEIGHT DRAIN (EMBANKMENT HEIGHTS > 100')

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



2 150 TYPICAL BASE OF EMBANKMENT CHIMNEY DRAIN

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



3 150 TYPICAL EMBANKMENT FOUNDATION DRAIN (NEAR EMBANKMENT DOWNSTREAM TOE)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE UNDERLYING SUB-GLACIAL TILL HAS BEEN TESTED TO PROVIDE HYDRAULIC CONDUCTIVITIES ON THE ORDER OF 2 x 10^{-8} cm/s. THE THICKNESS OF THE SUB-GLACIAL TILL, ABOVE THE BEDROCK INTERFACE VARIES BENEATH THE TAILINGS DISPOSAL FACILITY FOOTPRINT.
3. THE EMBANKMENT MID-HEIGHT DRAINS ARE ENVISIONED TO BE CONNECTED, VIA A FRENCH DRAIN ROCK CONDUIT AT THEIR LOW-POINTS NEAR THE TAILINGS DISPOSAL FACILITY EMBANKMENT NORTHWEST CORNER, TO THE EMBANKMENT CHIMNEY DRAIN FOR OUTLET OF COLLECTED WATER.
4. THE EMBANKMENT FOUNDATION AND CHIMNEY DRAIN OUTLET PIPES WILL EMANATE FROM THEIR LOW-POINTS NEAR THE TAILINGS DISPOSAL FACILITY EMBANKMENT NORTHWEST CORNER. REFER TO DRAWING 162 FOR MORE INFORMATION.
5. THE EMBANKMENT FOUNDATION SURFACE SHALL BE GRADED SUCH THAT THE FOUNDATION DRAINS, CHIMNEY DRAIN COLLECTION PIPE, AND DRAINAGE BLANKET MAINTAIN GRAVITY DRAINAGE WITHOUT LOW-POINTS.
6. THE STAGE PERIMETER ROAD SAFETY BERM SHALL BE BREACHED EVERY 20' TO ALLOW RUNOFF FROM THE EMBANKMENT DOWNSTREAM FACE TO BE CONVEYED ACROSS THE ROAD.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

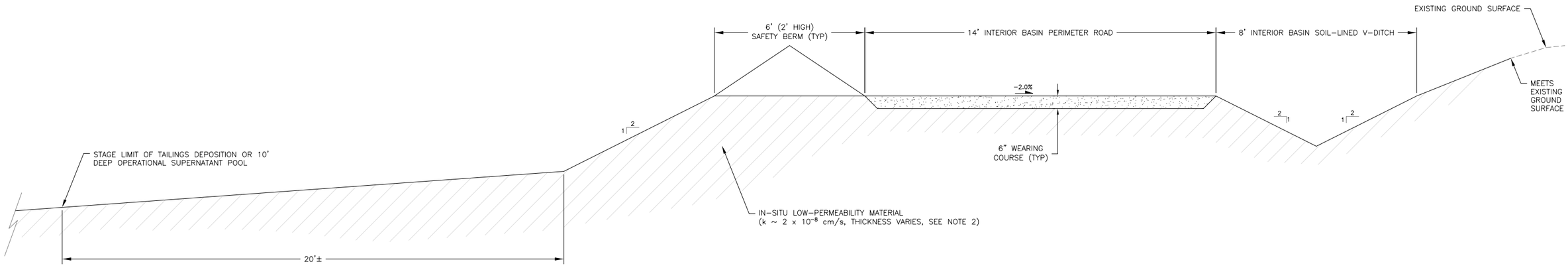
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: EMBANKMENT SECTIONS AND DETAILS
SHEET 2 OF 2

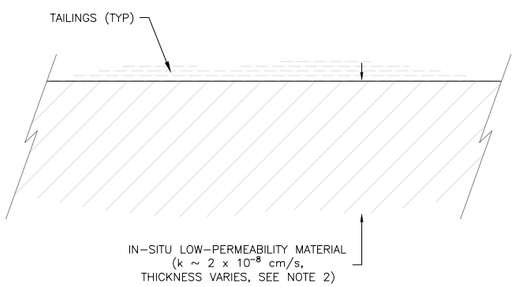
DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	152	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev8\101-429-02-152-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:54 AM



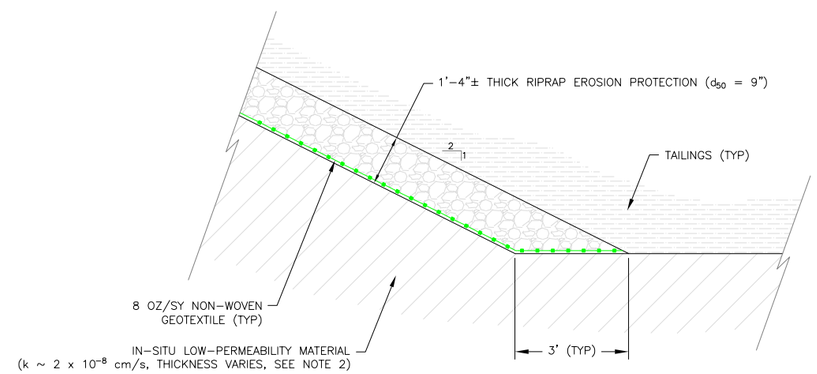
A 140 A 142 TYPICAL INTERIOR BASIN INTERMEDIATE STAGE TERMINATION
CASE 1 LINER SYSTEM (IN-SITU SOIL LINER)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



B 140 B 142 B 144 TYPICAL BASIN CASE 1 LINER SYSTEM
(IN-SITU SOIL LINER)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



C 140 C 142 C 144 TYPICAL BASIN PERIMETER CASE 1 LINER SYSTEM
(IN-SITU SOIL LINER)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE UNDERLYING SUB-GLACIAL TILL HAS BEEN TESTED TO PROVIDE HYDRAULIC CONDUCTIVITIES ON THE ORDER OF 2 x 10^{-8} cm/s. THE THICKNESS OF THE SUB-GLACIAL TILL, ABOVE THE BEDROCK INTERFACE VARIES BENEATH THE TAILINGS DISPOSAL FACILITY FOOTPRINT.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

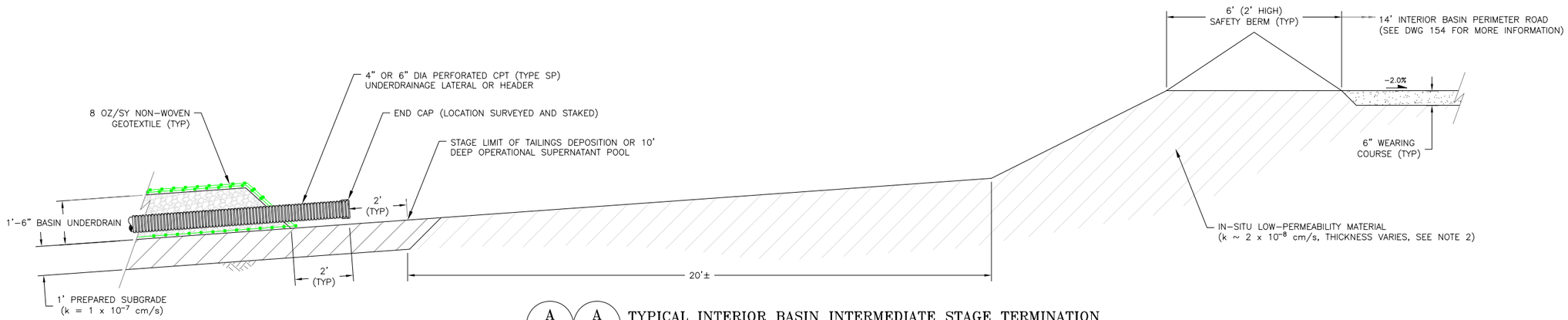
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: BASIN SECTIONS AND DETAILS
SHEET 1 OF 4

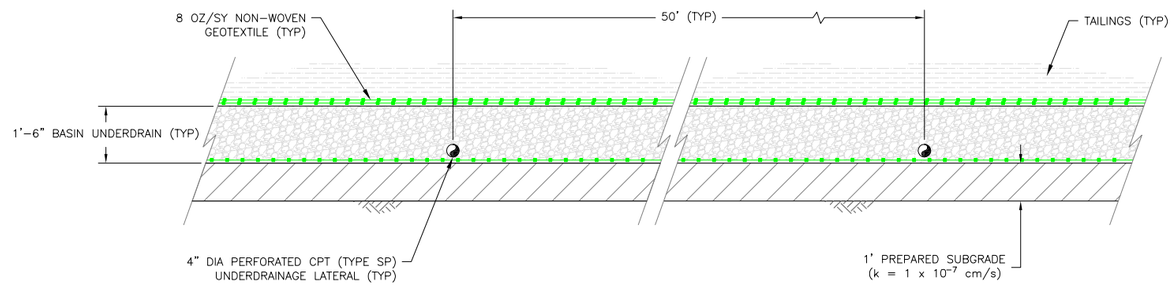
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	154	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev6\101-429-02-154-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:54 AM



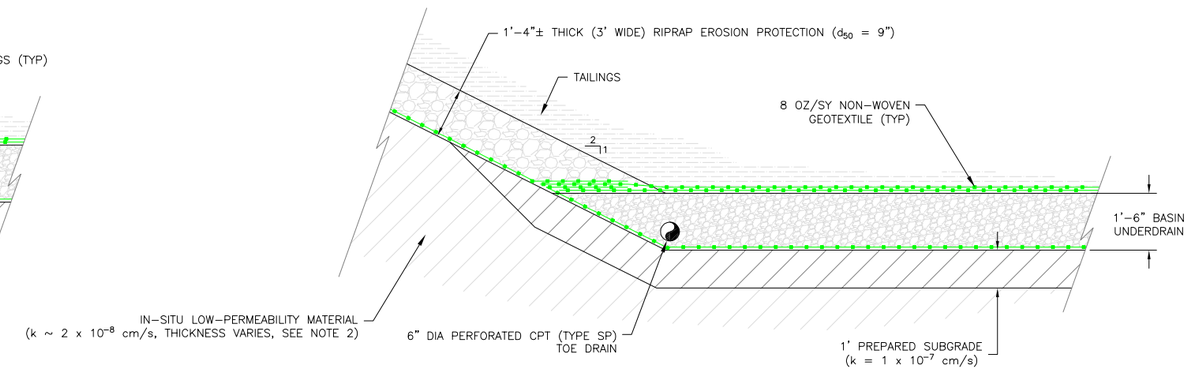
A 140 A 142 TYPICAL INTERIOR BASIN INTERMEDIATE STAGE TERMINATION
CASE 2 LINER SYSTEM (FULL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



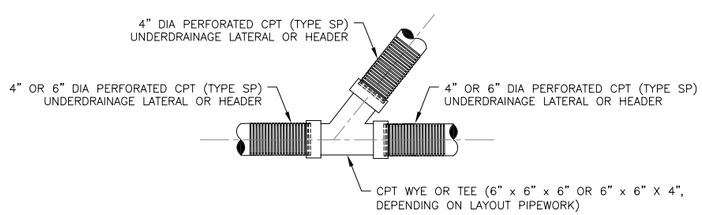
B 140 B 142 B 144 TYPICAL BASIN CASE 2 LINER SYSTEM
(FULL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



C 140 C 142 C 144 TYPICAL BASIN PERIMETER CASE 2 LINER SYSTEM
(FULL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



1 – TYPICAL 4" OR 6" DIA PERFORATED CPT
CONNECTION TO 6" DIA PERFORATED CPT

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE UNDERLYING SUB-GLACIAL TILL HAS BEEN TESTED TO PROVIDE HYDRAULIC CONDUCTIVITIES ON THE ORDER OF 2 x 10^{-8} cm/s. THE THICKNESS OF THE SUB-GLACIAL TILL, ABOVE THE BEDROCK INTERFACE VARIES BENEATH THE TAILINGS DISPOSAL FACILITY FOOTPRINT.
3. THE GEOSYNTHETICS TERMINATION TRENCH BACKFILL SHALL BE A COMPACTED FINE GRAINED MATERIAL FREE OF EXCESSIVE GRAVEL.
4. ALL PIPE CONNECTIONS SHALL BE FORMED USING MANUFACTURER SUPPLIED FABRICATED TEES OR WYES. ALL CPT CONNECTIONS WHICH CHANGE DIAMETER, SLOPE OR ALIGNMENT MUST BE WIRE-TIED AROUND BOTH ENDS OF THE CONNECTION.
5. ALL TERMINATIONS OF THE CPT UNDERDRAINAGE PIPES SHALL BE FITTED WITH MANUFACTURER SUPPLIED END CAPS AND SURVEYED FOR TIE-IN DURING FUTURE EXPANSIONS.
6. THE UPPER LAYER OF GEOTEXTILE ABOVE THE BASIN UNDERDRAIN IS A SACRIFICIAL LAYER TO ACCOUNT FOR U.V. DEGRADATION.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

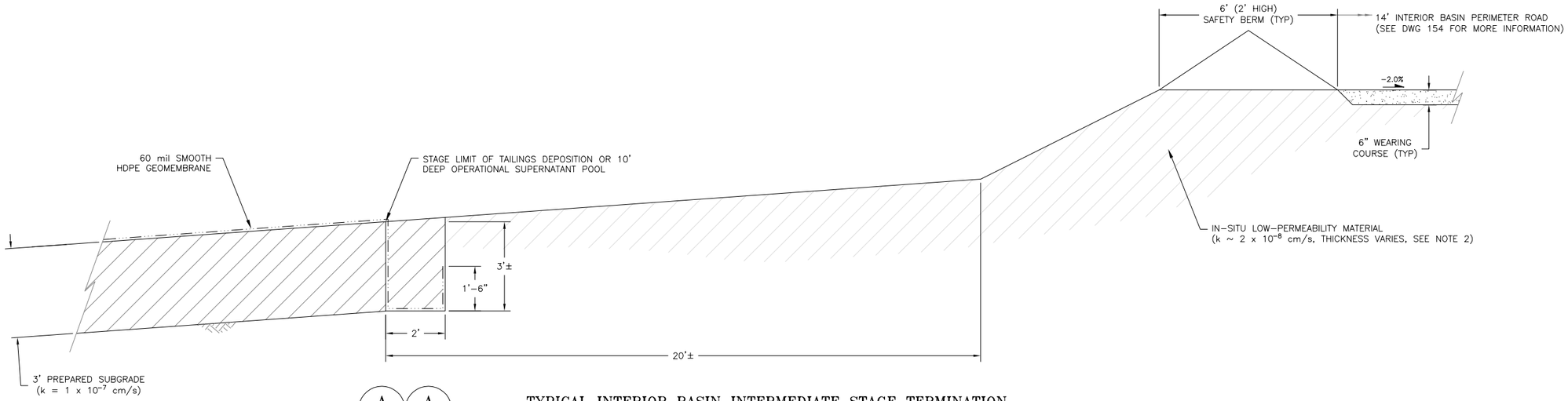
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: BASIN SECTIONS AND DETAILS
SHEET 2 OF 4

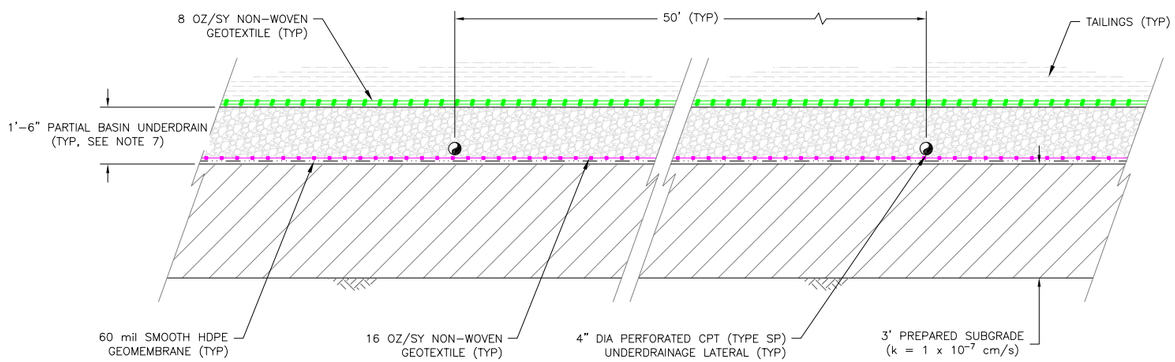
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	156	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev0\101-429-02-156-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:54 AM



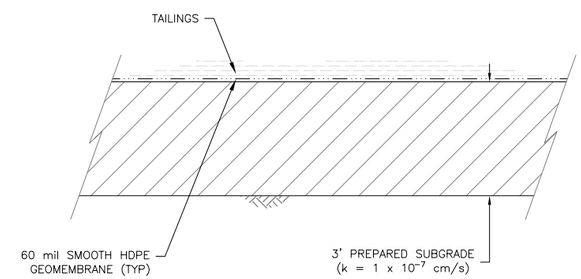
A 140 / A 142 TYPICAL INTERIOR BASIN INTERMEDIATE STAGE TERMINATION
CASE 3 LINER SYSTEM (GEOMEMBRANE, OUTSIDE PARTIAL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



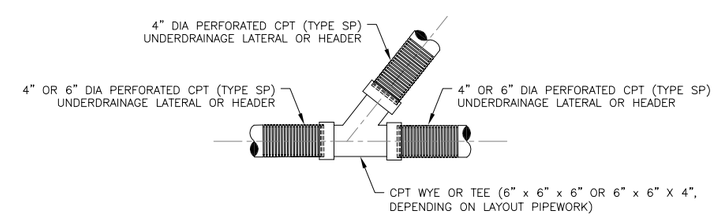
B 140 TYPICAL BASIN CASE 3 LINER SYSTEM
(GEOMEMBRANE, WITH PARTIAL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



C 140 / C 142 / C 144 TYPICAL BASIN CASE 3 LINER SYSTEM
(GEOMEMBRANE, OUTSIDE PARTIAL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



1 / – TYPICAL 4" OR 6" DIA PERFORATED CPT
CONNECTION TO 6" DIA PERFORATED CPT

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE UNDERLYING SUB-GLACIAL TILL HAS BEEN TESTED TO PROVIDE HYDRAULIC CONDUCTIVITIES ON THE ORDER OF 2×10^{-8} cm/s. THE THICKNESS OF THE SUB-GLACIAL TILL, ABOVE THE BEDROCK INTERFACE VARIES BENEATH THE TAILINGS DISPOSAL FACILITY FOOTPRINT.
3. THE GEOSYNTHETICS TERMINATION TRENCH BACKFILL SHALL BE A COMPACTED FINE GRAINED MATERIAL FREE OF EXCESSIVE GRAVEL.
4. ALL PIPE CONNECTIONS SHALL BE FORMED USING MANUFACTURER SUPPLIED FABRICATED TEES OR WYES. ALL CPT CONNECTIONS WHICH CHANGE DIAMETER, SLOPE OR ALIGNMENT MUST BE WIRE-TIED AROUND BOTH ENDS OF THE CONNECTION.
5. ALL TERMINATIONS OF THE CPT UNDERDRAINAGE PIPES SHALL BE FITTED WITH MANUFACTURER SUPPLIED END CAPS AND SURVEYED FOR TIE-IN DURING FUTURE EXPANSIONS.
6. THE UPPER LAYER OF GEOTEXTILE ABOVE THE BASIN UNDERDRAIN IS A SACRIFICIAL LAYER TO ACCOUNT FOR U.V. DEGRADATION.
7. THE CASE 3 LINER SYSTEM INCLUDES A PARTIAL BASIN UNDERDRAIN THAT WOULD COVER A 1,000' RADIUS FROM THE NORTHWEST CORNER OF THE TAILINGS DISPOSAL FACILITY BASIN FLOOR.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

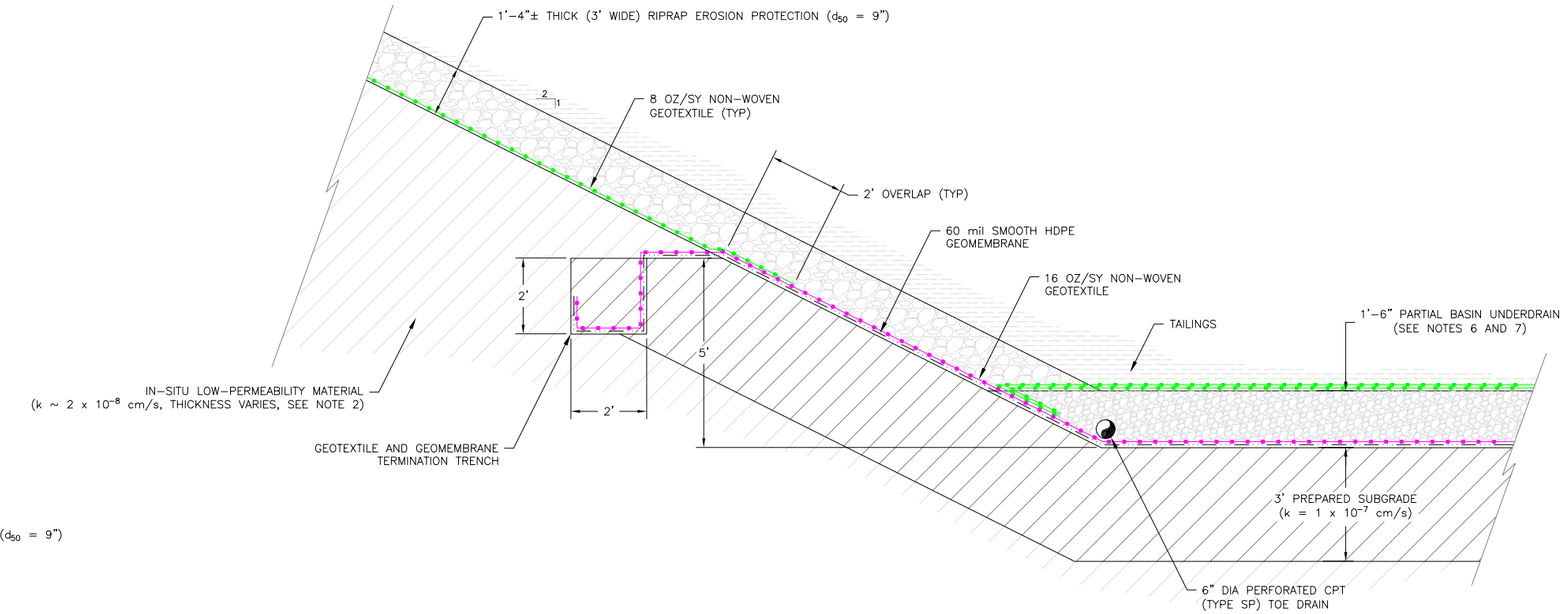
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: BASIN SECTIONS AND DETAILS
SHEET 3 OF 4

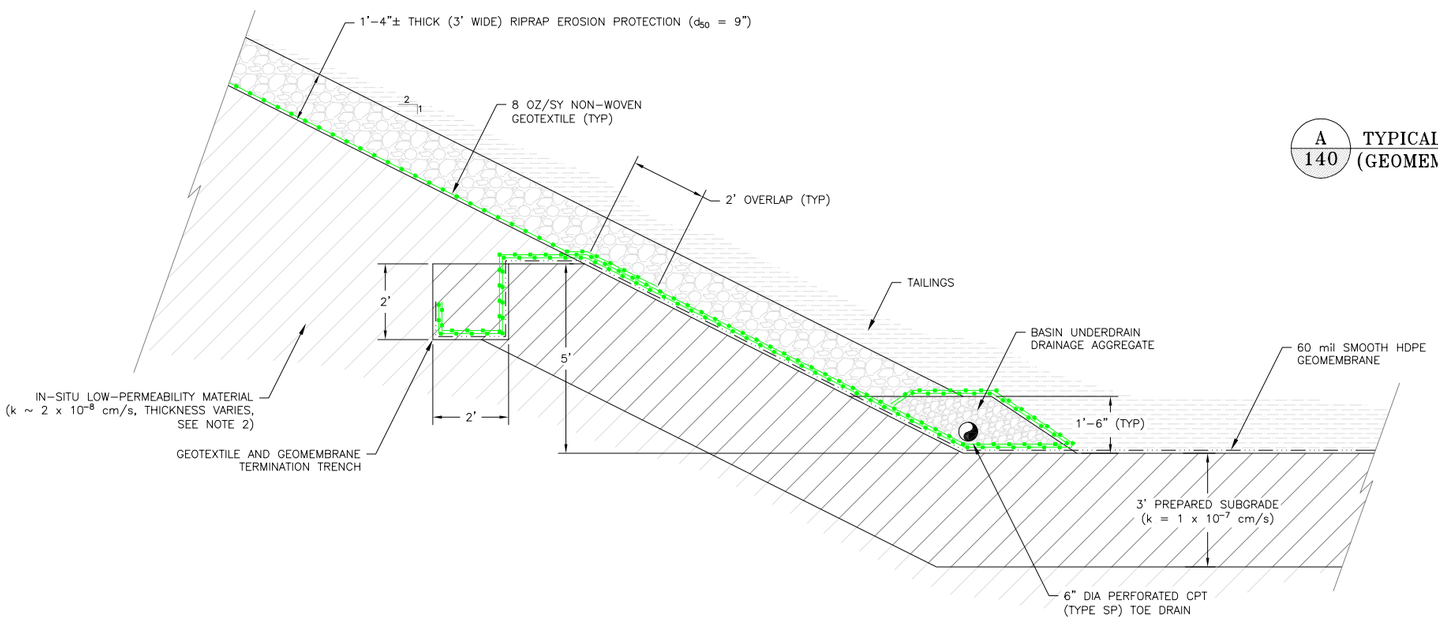
DESIGNED BY	JC	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	158	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev2\101-429-02-158-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:55 AM



A / 140 TYPICAL BASIN PERIMETER CASE 3 LINER SYSTEM (GEOMEMBRANE, WITH PARTIAL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)



B / 140 B / 142 B / 144 TYPICAL BASIN PERIMETER CASE 3 LINER SYSTEM (GEOMEMBRANE, OUTSIDE PARTIAL DRAINAGE BLANKET)

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE UNDERLYING SUB-GLACIAL TILL HAS BEEN TESTED TO PROVIDE HYDRAULIC CONDUCTIVITIES ON THE ORDER OF 2×10^{-8} cm/s. THE THICKNESS OF THE SUB-GLACIAL TILL, ABOVE THE BEDROCK INTERFACE VARIES BENEATH THE TAILINGS DISPOSAL FACILITY FOOTPRINT.
3. THE GEOSYNTHETICS TERMINATION TRENCH BACKFILL SHALL BE A COMPACTED FINE GRAINED MATERIAL FREE OF EXCESSIVE GRAVEL.
4. ALL PIPE CONNECTIONS SHALL BE FORMED USING MANUFACTURER SUPPLIED FABRICATED TEES OR WYES. ALL CPT CONNECTIONS WHICH CHANGE DIAMETER, SLOPE OR ALIGNMENT MUST BE WIRE-TIED AROUND BOTH ENDS OF THE CONNECTION.
5. ALL TERMINATIONS OF THE CPT UNDERDRAINAGE PIPES SHALL BE FITTED WITH MANUFACTURER SUPPLIED END CAPS AND SURVEYED FOR TIE-IN DURING FUTURE EXPANSIONS.
6. THE UPPER LAYER OF GEOTEXTILE ABOVE THE BASIN UNDERDRAIN IS A SACRIFICIAL LAYER TO ACCOUNT FOR U.V. DEGRADATION.
7. THE CASE 3 LINER SYSTEM INCLUDES A PARTIAL BASIN UNDERDRAIN THAT WOULD COVER A 1,000' RADIUS FROM THE NORTHWEST CORNER OF THE TAILINGS DISPOSAL FACILITY BASIN FLOOR.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

DISCLAIMER
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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

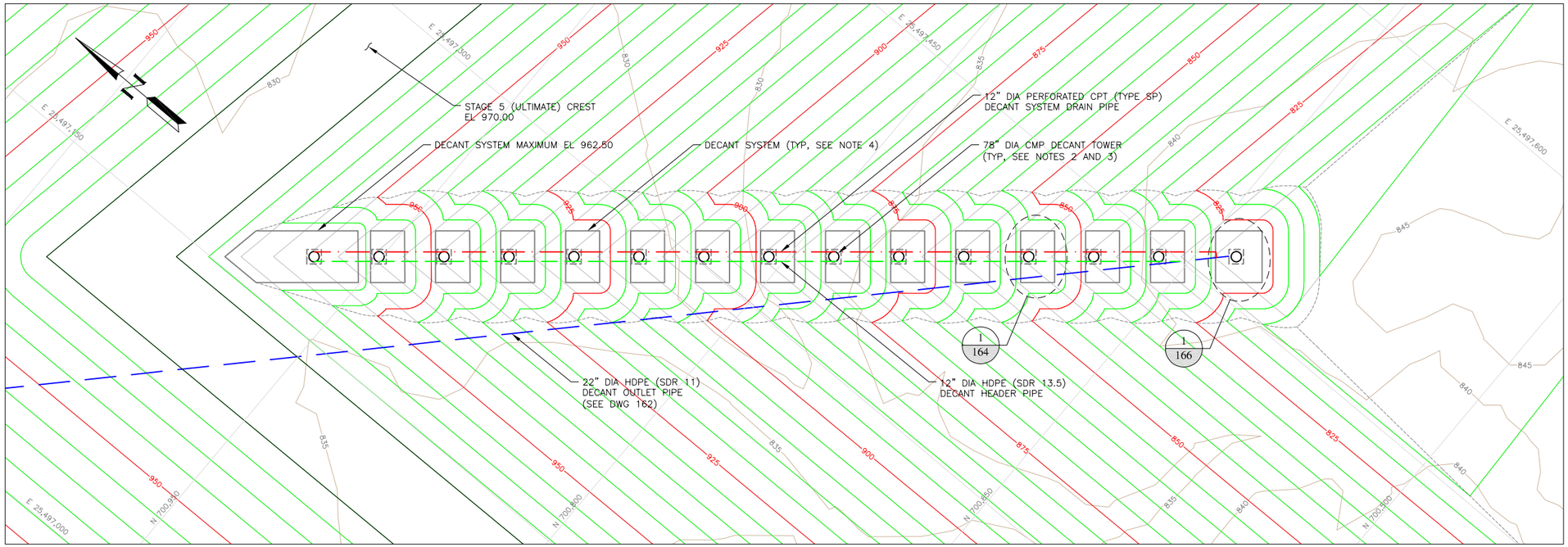
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY

TITLE: BASIN SECTIONS AND DETAILS SHEET 4 OF 4

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	159	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs revb\101-429-02-159-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:55 AM



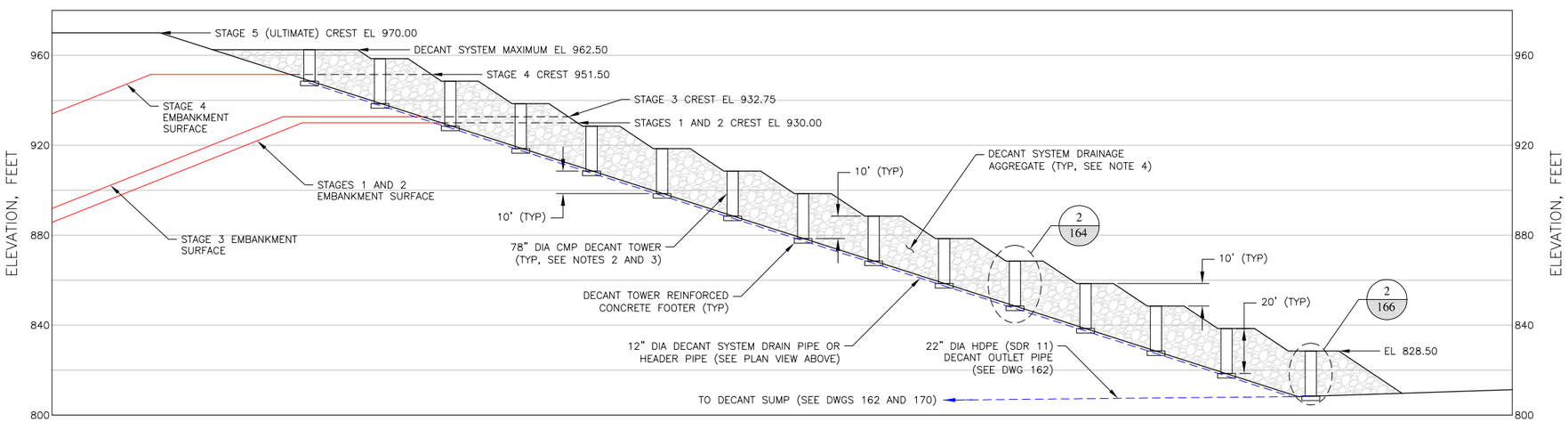
REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO-METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

PLAN

30 0 30 60 FEET
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)

LEGEND:

845 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET
PROPOSED UNDERLYING EMBANKMENT SURFACE CONTOUR
825 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET



PROFILE

30 0 30 60 FEET
HORIZONTAL SCALE
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)

30 0 30 60 FEET
VERTICAL SCALE
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. OPENINGS WILL BE TORCH-CUT IN THE CMP DECANT TOWERS PRIOR TO INSTALLATION. ONCE INSTALLED, THE TOWERS WILL BE WRAPPED WITH CHICKEN WIRE MESH OR NON-WOVEN GEOTEXTILE TO MITIGATE INTRUSION OF THE DECANT SYSTEM DRAINAGE AGGREGATE.
3. WHEN THE TAILINGS LEVEL WITHIN THE DISPOSAL FACILITY COMES WITHIN 1' OF A DECANT TOWER, THE INDIVIDUAL DECANT TOWER SHALL BE PLUGGED AND FILLED WITH CONCRETE FOR ABANDONMENT.
4. THE DECANT SYSTEM DRAINAGE AGGREGATE SHALL BE PLACED SUCH THAT THE TOP ELEVATION MATCHES THE CURRENT LIFT OF EMBANKMENT FILL BEING PLACED UNTIL THE MAXIMUM DECANT SYSTEM ELEVATION, 962.50', IS REACHED.

REV	DATE	DESCRIPTION	APP'D
			CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

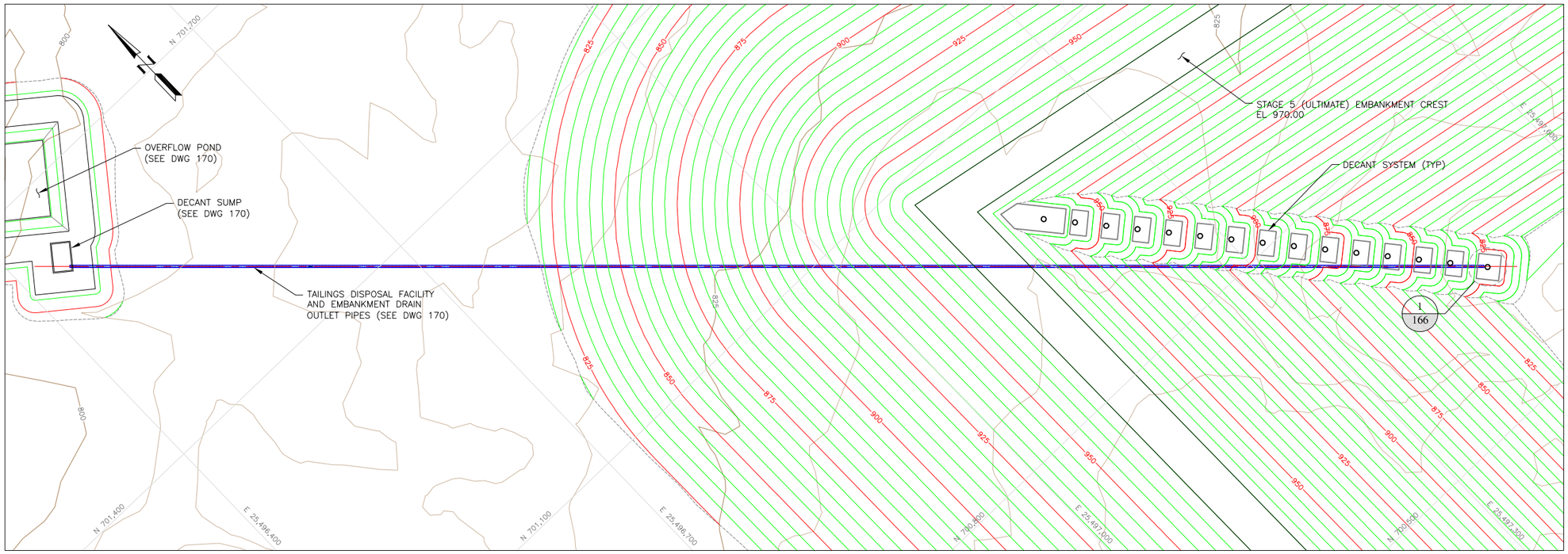
Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
DECANT SYSTEM
PLAN AND PROFILE

DESIGNED BY	JTR/ML	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	160	B

LAST SAVED BY: CBENJANO
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev0\101-429-02-160-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:55 AM



LEGEND:

825 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET

825 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET

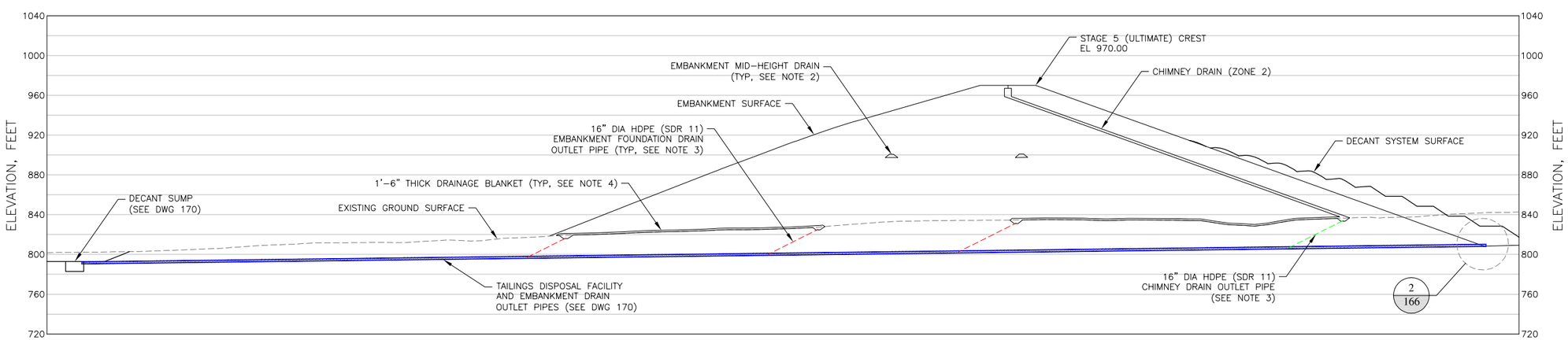
NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE EMBANKMENT MID–HEIGHT DRAINS ARE ENVISIONED TO BE CONNECTED, VIA A FRENCH DRAIN ROCK CONDUIT AT THEIR LOW–POINTS NEAR THE TAILINGS DISPOSAL FACILITY EMBANKMENT NORTHWEST CORNER, TO THE EMBANKMENT CHIMNEY DRAIN FOR OUTLET OF COLLECTED WATER.
3. THE EMBANKMENT FOUNDATION AND CHIMNEY DRAIN OUTLET PIPES WILL EMANATE FROM THEIR LOW–POINTS NEAR THE TAILINGS DISPOSAL FACILITY EMBANKMENT NORTHWEST CORNER.
4. THE EMBANKMENT FOUNDATION SURFACE SHALL BE GRADED SUCH THAT THE FOUNDATION DRAINS, CHIMNEY DRAIN COLLECTION PIPE, AND DRAINAGE BLANKET MAINTAIN GRAVITY DRAINAGE WITHOUT LOW–POINTS.
5. EMBANKMENT FOUNDATION DRAINS, CHIMNEY DRAIN COLLECTION PIPE, AND MID–HEIGHT DRAINS NOT SHOWN IN PLAN VIEW FOR CLARITY.

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

PLAN

60 0 60 120 FEET
1" = 60' AT FULL SIZE (ANSI D)
1" = 120' AT HALF SIZE (ANSI B)



PROFILE

60 0 60 120 FEET
HORIZONTAL SCALE
1" = 60' AT FULL SIZE (ANSI D)
1" = 120' AT HALF SIZE (ANSI B)

30 0 30 60 FEET
VERTICAL SCALE
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: OUTLET PIPE PLAN AND PROFILE

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	162	B

LAST SAVED BY: CBRANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev0\101–429–02–162–b.dwg
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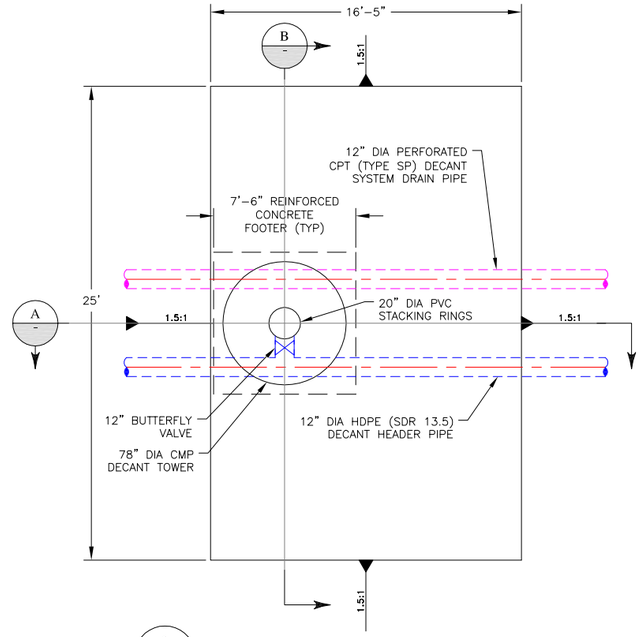
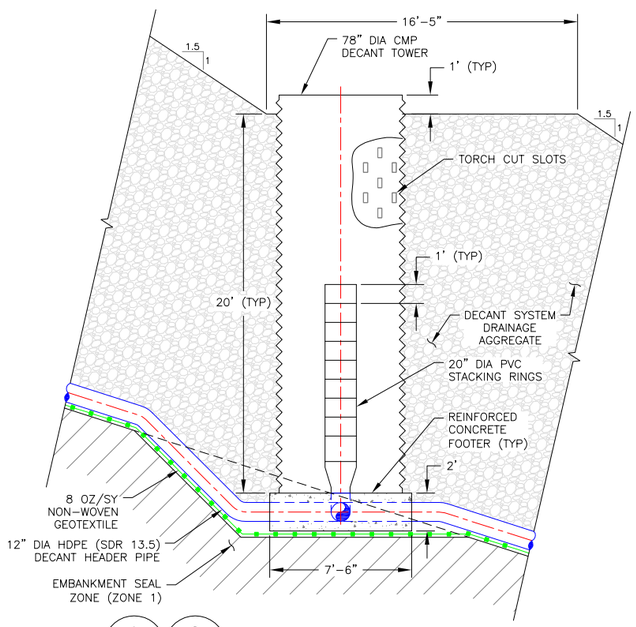


1 / 160 TYPICAL DECANT TOWER PLAN

4 0 4 8 FEET
1" = 4' AT FULL SIZE (ANSI D)
1" = 8' AT HALF SIZE (ANSI B)

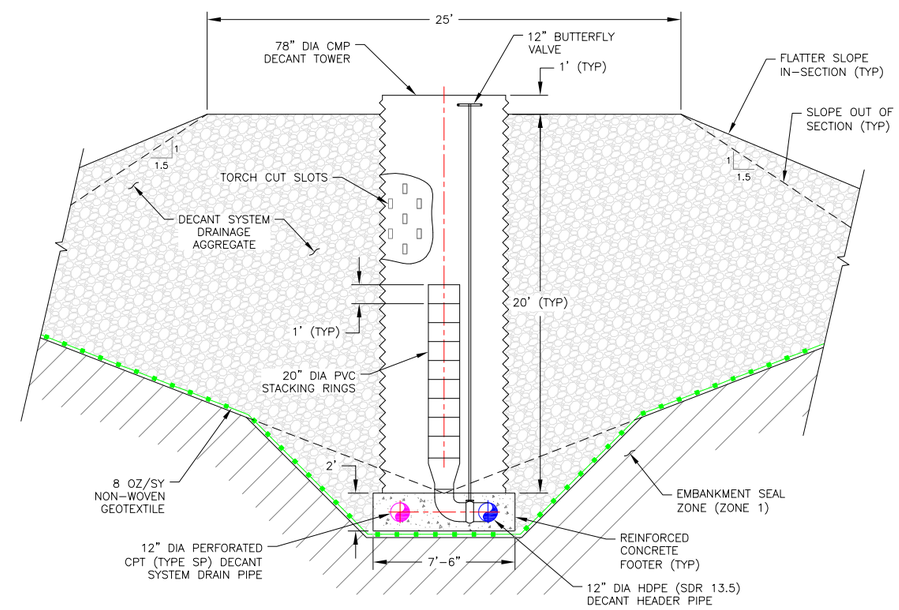
NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. OPENINGS WILL BE TORCH-CUT IN THE CMP DECANT TOWERS PRIOR TO INSTALLATION. ONCE INSTALLED, THE TOWERS WILL BE WRAPPED WITH CHICKEN WIRE MESH OR NON-WOVEN GEOTEXTILE TO MITIGATE INTRUSION OF THE DECANT SYSTEM DRAINAGE AGGREGATE.
3. WHEN THE TAILINGS LEVEL WITHIN THE DISPOSAL FACILITY COMES WITHIN 1' OF A DECANT TOWER, THE INDIVIDUAL DECANT TOWER SHALL BE PLUGGED AND FILLED WITH CONCRETE FOR ABANDONMENT.
4. THE DECANT SYSTEM DRAINAGE AGGREGATE SHALL BE PLACED SUCH THAT THE TOP ELEVATION MATCHES THE CURRENT LIFT OF EMBANKMENT FILL BEING PLACED UNTIL THE MAXIMUM DECANT SYSTEM ELEVATION, 962.50', IS REACHED.



A / - 2 / 160 TYPICAL SECTION THROUGH DECANT TOWER

4 0 4 8 FEET
1" = 4' AT FULL SIZE (ANSI D)
1" = 8' AT HALF SIZE (ANSI B)



B / - TYPICAL SECTION THROUGH DECANT TOWER

4 0 4 8 FEET
1" = 4' AT FULL SIZE (ANSI D)
1" = 8' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

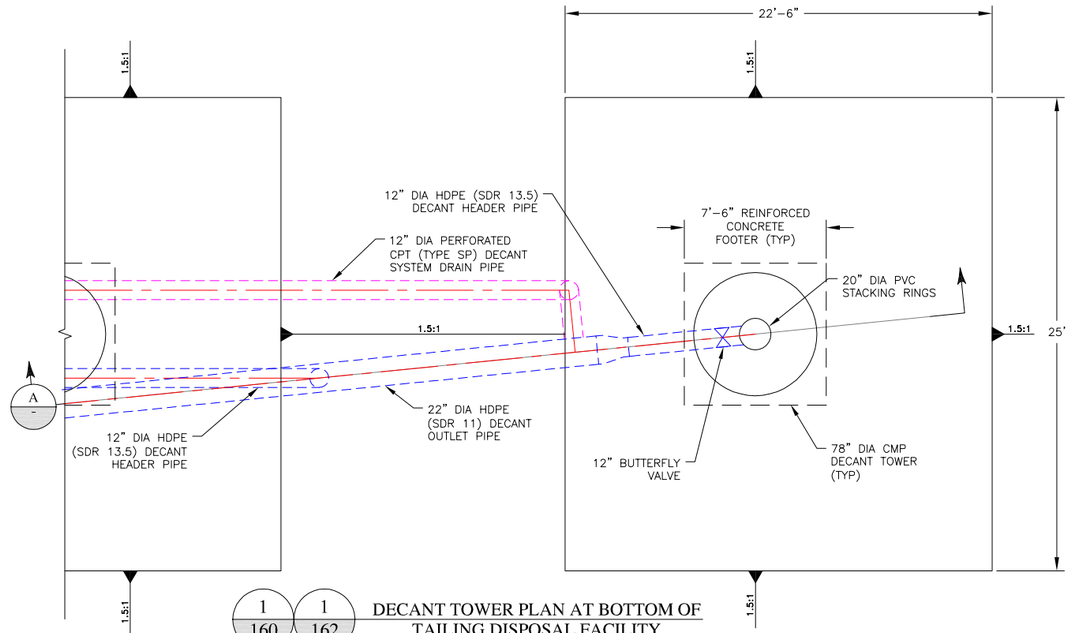
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: DECANT SYSTEM SECTIONS AND DETAILS
SHEET 1 OF 2

DESIGNED BY	ML/JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	164	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev6\101-429-02-164-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:55 AM



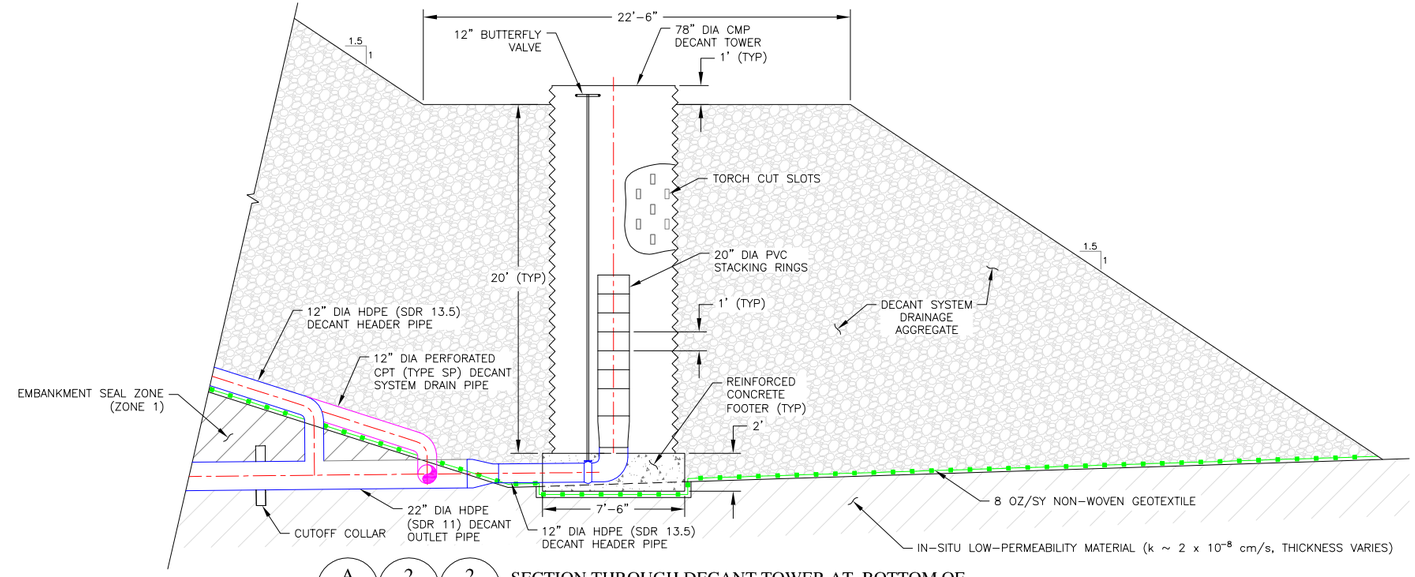
1 160 / 1 162 DECANT TOWER PLAN AT BOTTOM OF TAILING DISPOSAL FACILITY

4 0 4 8 FEET
1" = 4' AT FULL SIZE (ANSI D)
1" = 8' AT HALF SIZE (ANSI B)

REFERENCE:
Replace this text with proper reference of the source(s) of info
found on this drawing

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. OPENINGS WILL BE TORCH-CUT IN THE CMP DECANT TOWERS PRIOR TO INSTALLATION. ONCE INSTALLED, THE TOWERS WILL BE WRAPPED WITH CHICKEN WIRE MESH OR NON-WOVEN GEOTEXTILE TO MITIGATE INTRUSION OF THE DECANT SYSTEM DRAINAGE AGGREGATE.
3. WHEN THE TAILINGS LEVEL WITHIN THE DISPOSAL FACILITY COMES WITHIN 1' OF A DECANT TOWER, THE INDIVIDUAL DECANT TOWER SHALL BE PLUGGED AND FILLED WITH CONCRETE FOR ABANDONMENT.
4. THE DECANT SYSTEM DRAINAGE AGGREGATE SHALL BE PLACED SUCH THAT THE TOP ELEVATION MATCHES THE CURRENT LIFT OF EMBANKMENT FILL BEING PLACED UNTIL THE MAXIMUM DECANT SYSTEM ELEVATION, 962.50', IS REACHED.



A - / 2 160 / 2 162 SECTION THROUGH DECANT TOWER AT BOTTOM OF TAILING DISPOSAL FACILITY

4 0 4 8 FEET
1" = 4' AT FULL SIZE (ANSI D)
1" = 8' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

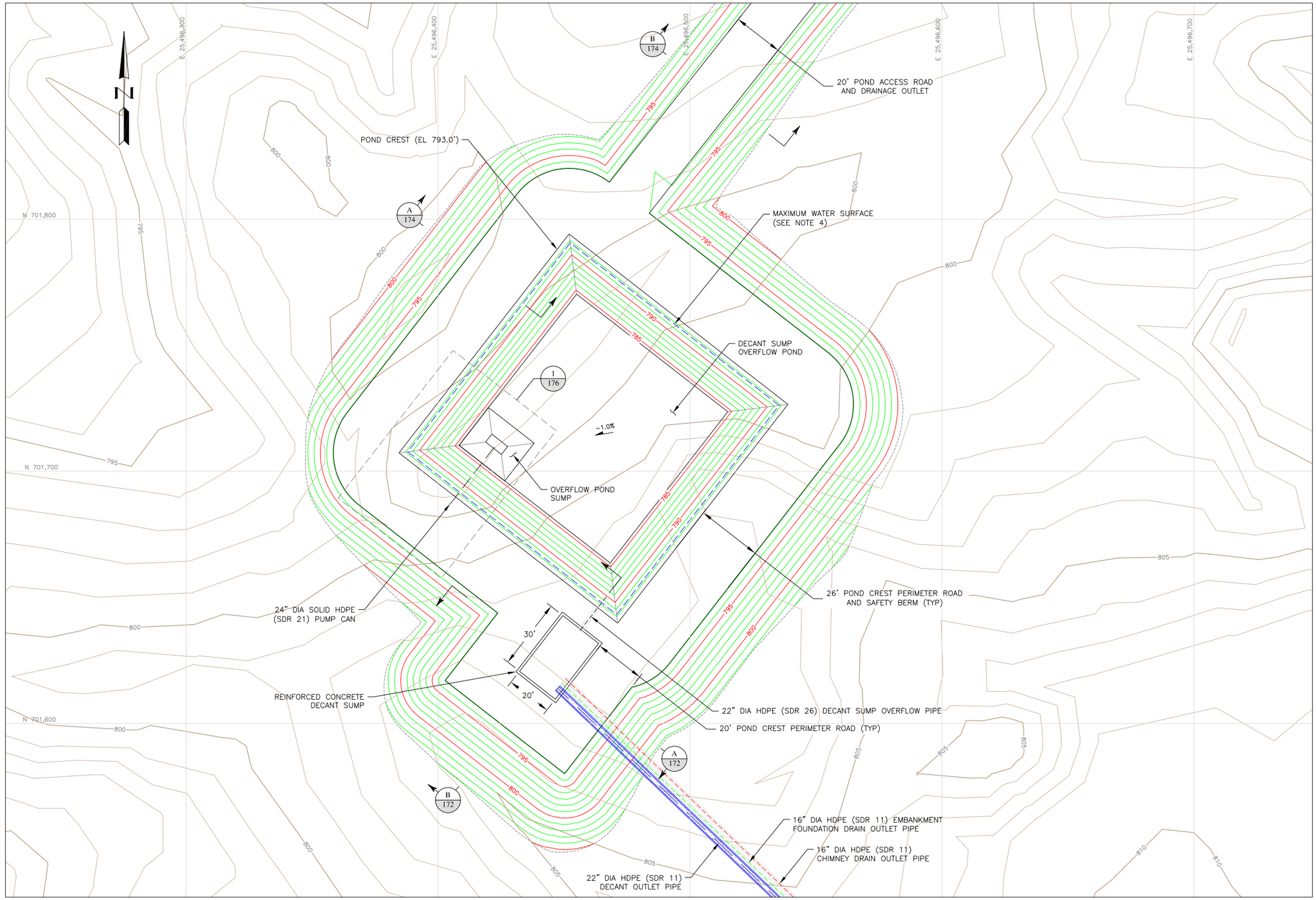
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: DECANT SYSTEM SECTIONS AND DETAILS
SHEET 2 OF 2

DESIGNED BY	ML/JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	166	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs rev b\101-429-02-166-b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:56 AM



LEGEND:

800 — EXISTING GROUND SURFACE CONTOUR AND EL, FEET

800 — PROPOSED REGRADE SURFACE CONTOUR AND EL, FEET

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE EMBANKMENT FOUNDATION AND CHIMNEY DRAIN OUTLET PIPES WILL EMANATE FROM THEIR LOW–POINTS NEAR THE TAILINGS DISPOSAL FACILITY EMBANKMENT NORTHWEST CORNER.
3. THE POND SIZING ACCOMMODATES THE DIRECT PRECIPITATION TO THE POND ASSOCIATED WITH THE ½ PROBABLE MAXIMUM PRECIPITATION (PMP) STORM EVENT IN ADDITION TO 2 HOURS OF DECANT FLOW FROM THE TAILINGS DISPOSAL FACILITY AT MAXIMUM PRODUCTION.
4. THE MAXIMUM WATER SURFACE FOR THE POND IS LOCATED 1' BELOW THE POND CREST. THE 1' IS THE POND FREEBOARD.
5. THE POND CREST PERIMETER ROAD SHALL TYPICALLY BE GRADED AWAY FROM THE POND SAFETY BERM.
6. A BREAK SHALL BE PROVIDED IN THE POND SAFETY BERM AS REQUIRED WHERE THE SUMP PUMP MEETS THE POND CREST.

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

PLAN

20 0 20 40 FEET

1" = 20' AT FULL SIZE (ANSI D)
1" = 40' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	APD / CAD
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE: N/A
XREF: N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

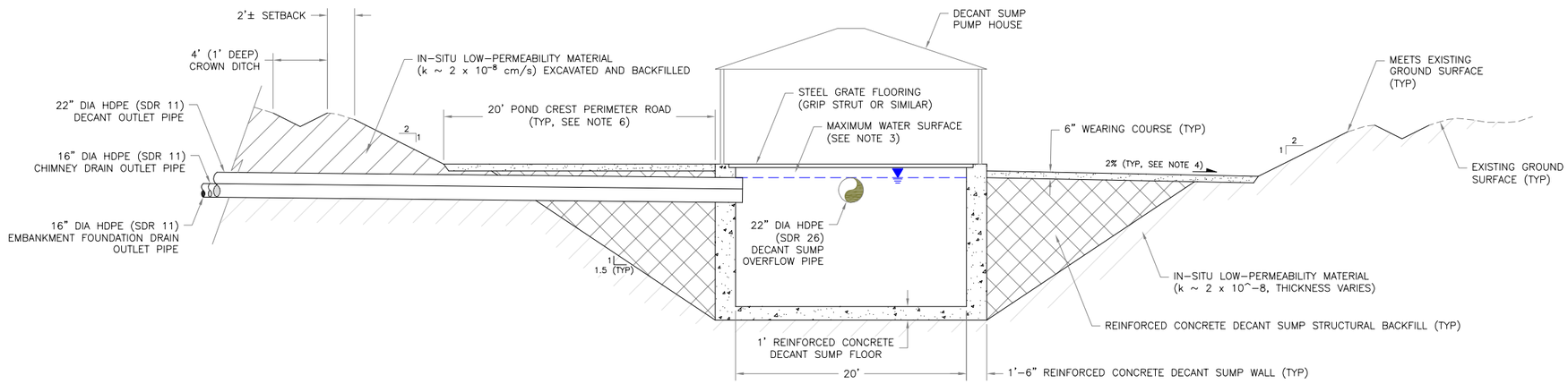
Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: DECANT SUMP AND OVERFLOW POND
PLAN

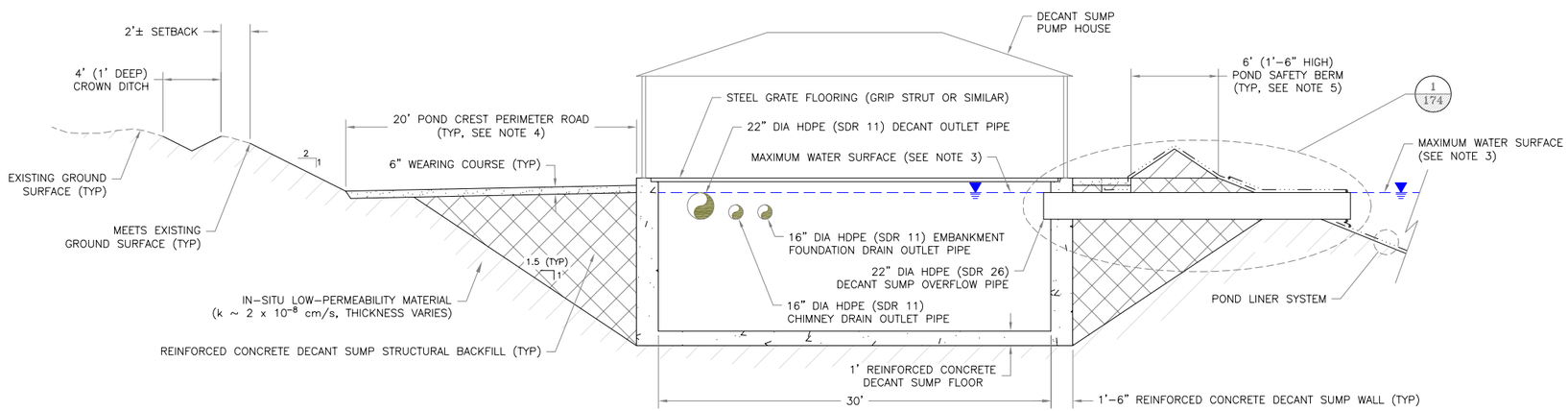
DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	170	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev0\101–429–02–170–b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:56 AM



A / 170 TAILINGS DISPOSAL FACILITY OUTLET PIPES TO DECANT SUMP

5 0 5 10 FEET



B / 170 OVERFLOW PIPE FROM DECANT SUMP TO OVERFLOW POND

5 0 5 10 FEET

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE POND SIZING ACCOMMODATES THE DIRECT PRECIPITATION TO THE POND ASSOCIATED WITH THE ½ PROBABLE MAXIMUM PRECIPITATION (PMP) STORM EVENT IN ADDITION TO 2 HOURS OF DECANT FLOW FROM THE TAILINGS DISPOSAL FACILITY AT MAXIMUM PRODUCTION.
3. THE MAXIMUM WATER SURFACE FOR THE POND IS LOCATED 1' BELOW THE POND CREST. THE 1' IS THE POND FREEBOARD.
4. THE POND CREST PERIMETER ROAD SHALL TYPICALLY BE GRADED AWAY FROM THE POND SAFETY BERM.
5. A BREAK SHALL BE PROVIDED IN THE POND SAFETY BERM AS REQUIRED WHERE THE SUMP PUMP MEETS THE POND CREST.
6. THE POND CREST PERIMETER ROAD SHALL BE LOCALLY RAISED WHERE THE TAILINGS DISPOSAL FACILITY OUTLET PIPES APPROACH THE DECANT SUMP.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY

TITLE: DECANT SUMP AND OVERFLOW POND SECTIONS AND DETAILS – SHEET 1 OF 3

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	172	B

LAST SAVED BY: CBEANLAND
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 - pfs revb\101-429-02-172-b.dwg
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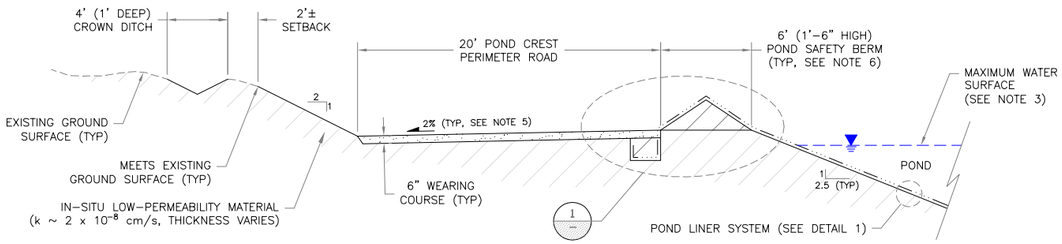
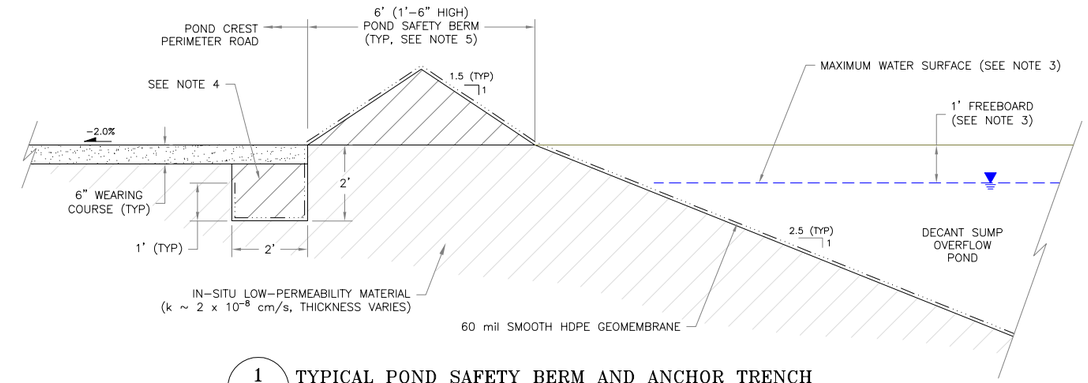
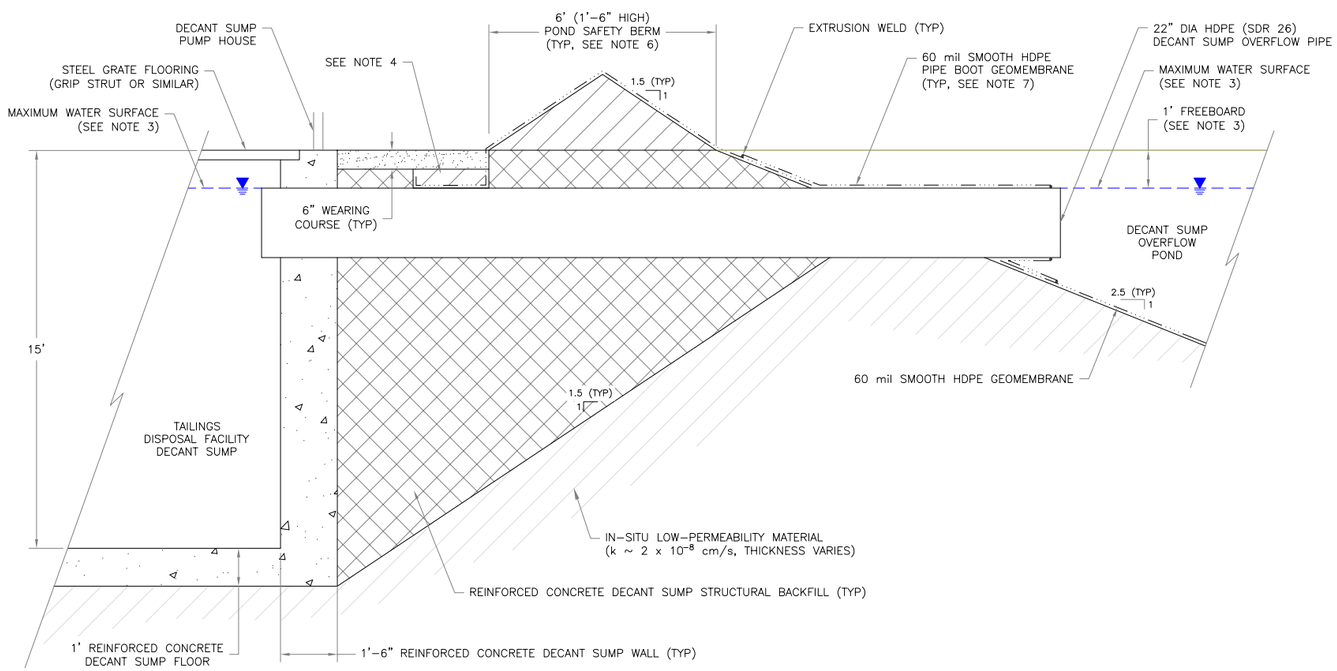


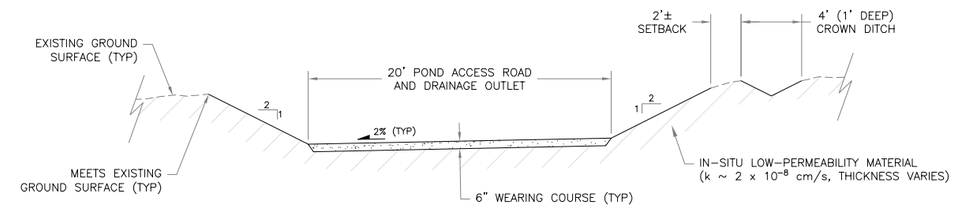
A
170
TYPICAL POND PERIMETER ROAD
5 0 5 10 FEET



1
–
TYPICAL POND SAFETY BERM AND ANCHOR TRENCH
2 0 2 4 FEET



1
172
OVERFLOW PIPE FROM DECANT SUMP
TO OVERFLOW POND
2 0 2 4 FEET



B
170
TYPICAL POND ACCESS ROAD
AND DRAINAGE OUTLET
5 0 5 10 FEET

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE POND SIZING ACCOMMODATES THE DIRECT PRECIPITATION TO THE POND ASSOCIATED WITH THE ½ PROBABLE MAXIMUM PRECIPITATION (PMP) STORM EVENT IN ADDITION TO 2 HOURS OF DECANT FLOW FROM THE TAILINGS DISPOSAL FACILITY AT MAXIMUM PRODUCTION.
3. THE MAXIMUM WATER SURFACE FOR THE POND IS LOCATED 1' BELOW THE POND CREST. THE 1' IS THE POND FREEBOARD.
4. THE GEOSYNTHETICS TERMINATION TRENCH BACKFILL SHALL BE A COMPACTED FINE GRAINED MATERIAL FREE OF EXCESSIVE GRAVEL.
5. THE POND CREST PERIMETER ROAD SHALL TYPICALLY BE GRADED AWAY FROM THE POND SAFETY BERM.
6. A BREAK SHALL BE PROVIDED IN THE POND SAFETY BERM AS REQUIRED WHERE THE SUMP PUMP MEETS THE POND CREST.
7. HDPE PIPE BOOTS SHALL BE OF THE SAME GEOMEMBRANE THICKNESS AS THE PENETRATED LINER. PIPE BOOTS SHALL BE EXTRUSION WELDED TO THE PENETRATED LINER.

REV	DATE	DESCRIPTION	APP'D	CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR	RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR	RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
DECANT SUMP AND OVERFLOW POND
SECTIONS AND DETAILS – SHEET 2 OF 3

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	174	B

LAST SAVED BY: CBEANLAND
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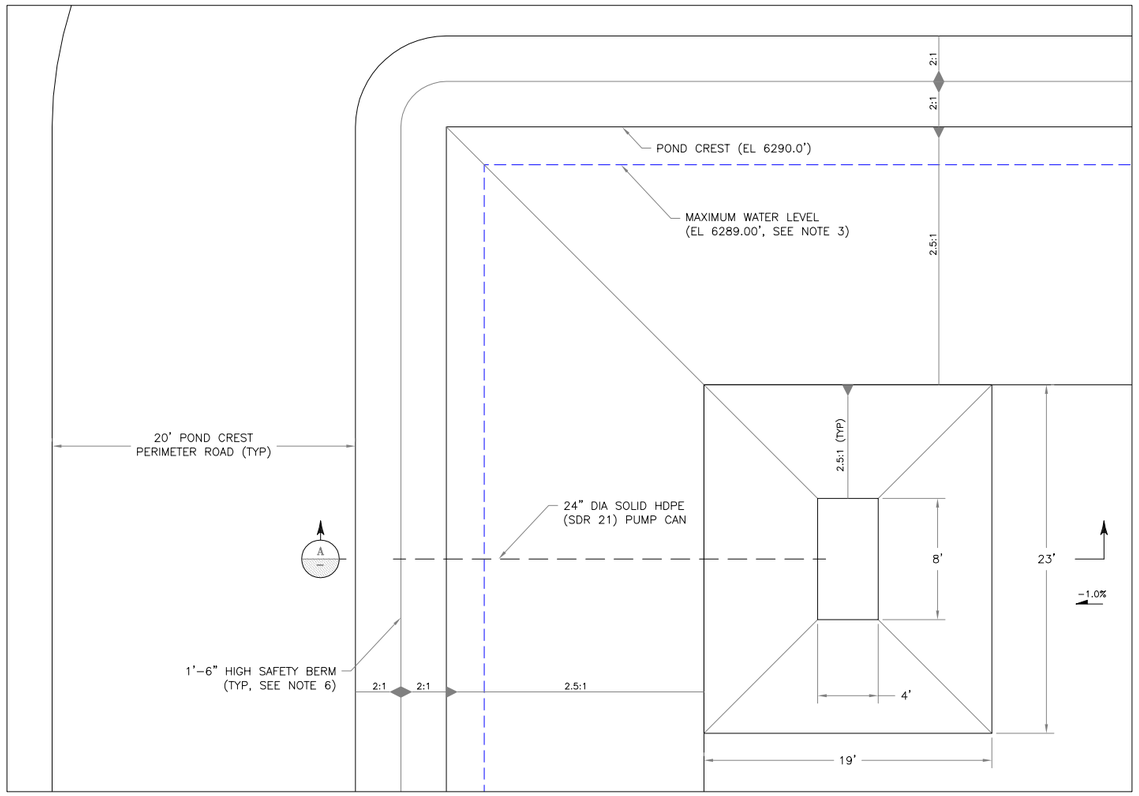
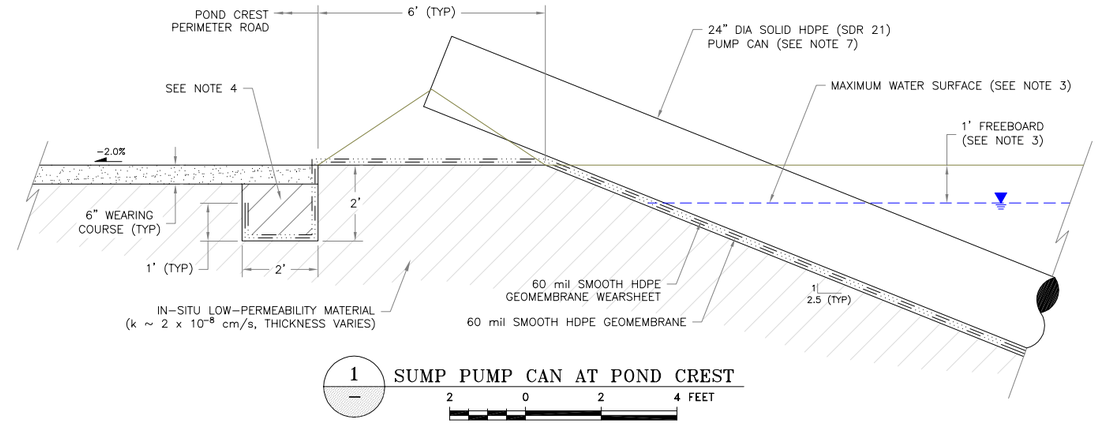
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:56 AM



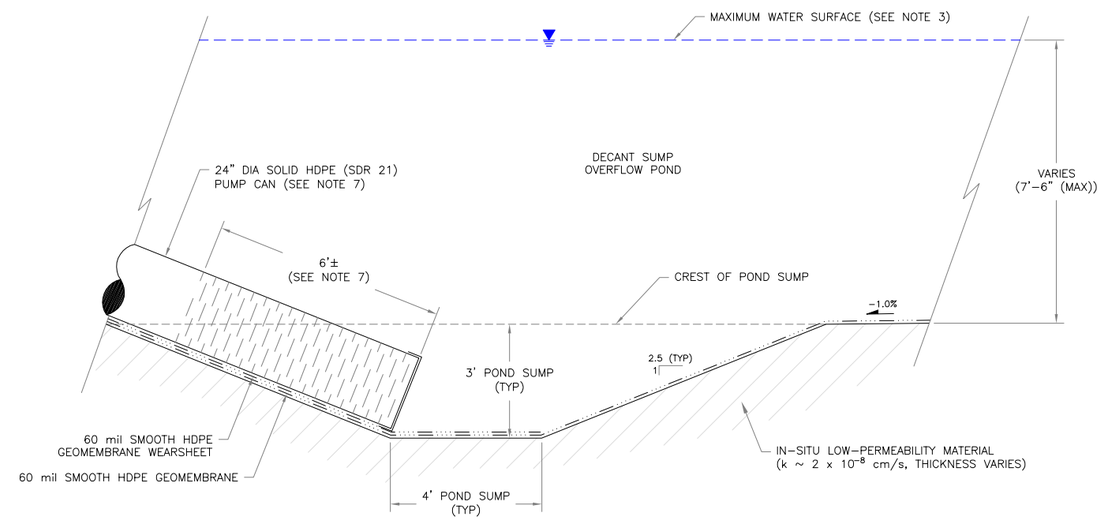
1 / 170 POND SUMP

5 0 5 10 FEET



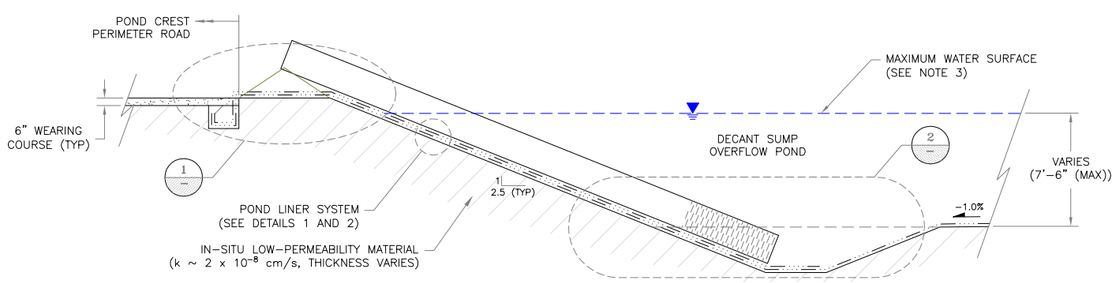
1 / — SUMP PUMP CAN AT POND CREST

2 0 2 4 FEET



2 / — TYPICAL POND SUMP WITH PUMP CAN

2 0 2 4 FEET



A / — TYPICAL POND SUMP WITH PUMP CAN

5 0 5 10 FEET

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE POND SIZING ACCOMMODATES THE DIRECT PRECIPITATION TO THE POND ASSOCIATED WITH THE ½ PROBABLE MAXIMUM PRECIPITATION (PMP) STORM EVENT IN ADDITION TO 2 HOURS OF DECANT FLOW FROM THE TAILINGS DISPOSAL FACILITY AT MAXIMUM PRODUCTION.
3. THE MAXIMUM WATER SURFACE FOR THE POND IS LOCATED 1' BELOW THE POND CREST. THE 1' IS THE POND FREEBOARD.
4. THE GEOSYNTHETICS TERMINATION TRENCH BACKFILL SHALL BE A COMPACTED FINE GRAINED MATERIAL FREE OF EXCESSIVE GRAVEL.
5. THE POND CREST PERIMETER ROAD SHALL TYPICALLY BE GRADED AWAY FROM THE POND SAFETY BERM.
6. A BREAK SHALL BE PROVIDED IN THE POND SAFETY BERM AS REQUIRED WHERE THE SUMP PUMP MEETS THE POND CREST.
7. THREE ROWS OF SLOTS SHALL BE EQUALLY SPACED AROUND THE BOTTOM 6' OF THE POND SUMP PUMP CAN. SLOTS SHALL BE 1/8" x 2" ON 2 1/8" CENTERS.

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: DECANT SUMP AND OVERFLOW POND SECTIONS AND DETAILS – SHEET 3 OF 3

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	176	B

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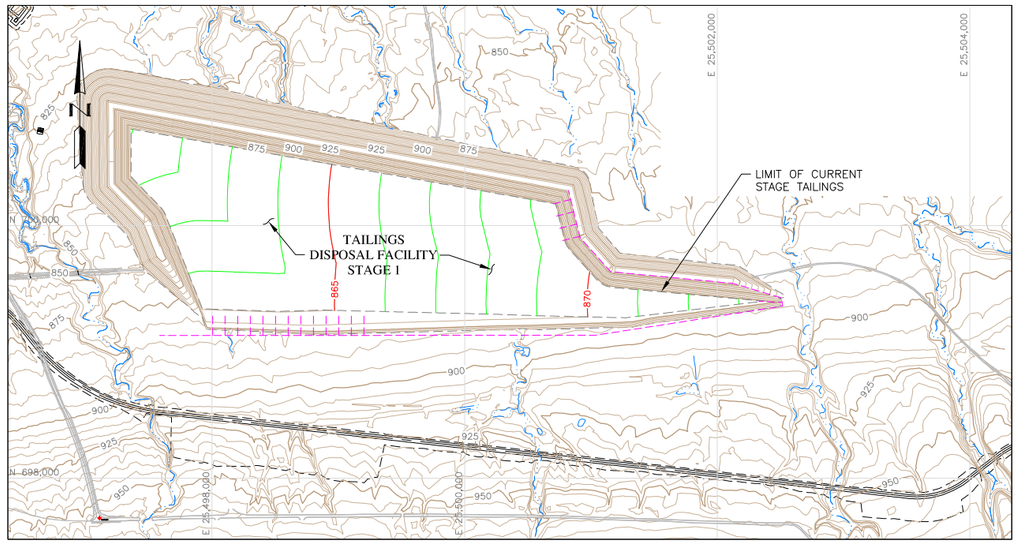
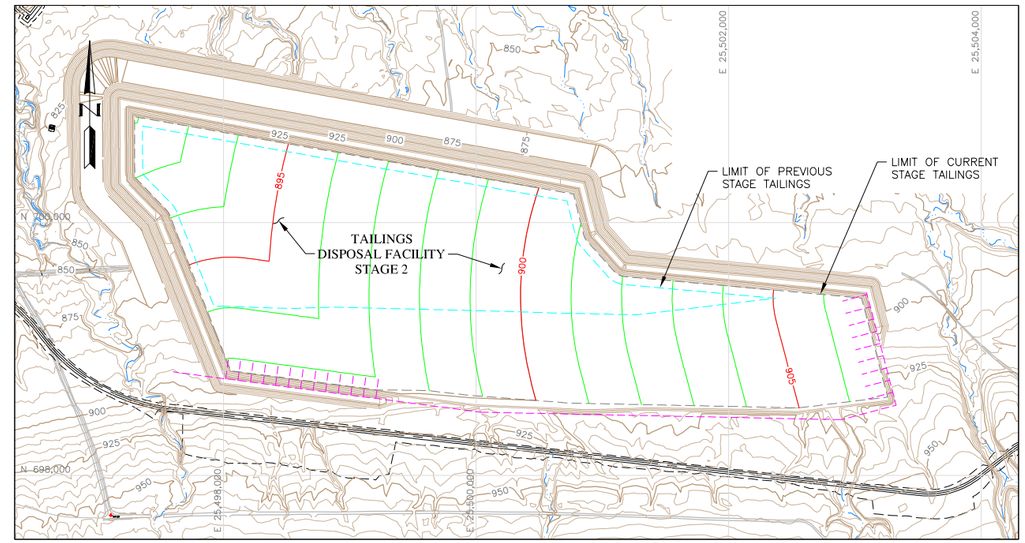
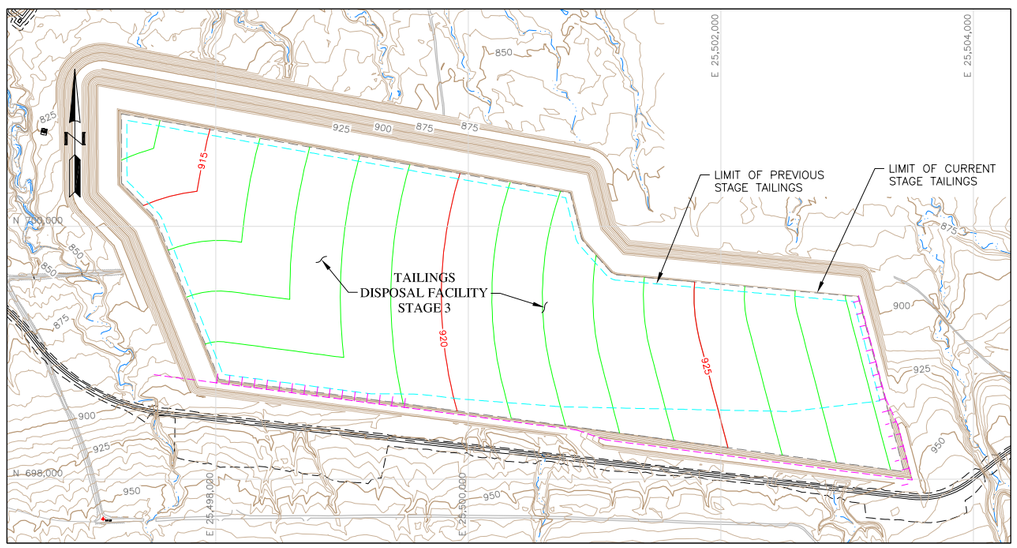
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:56 AM



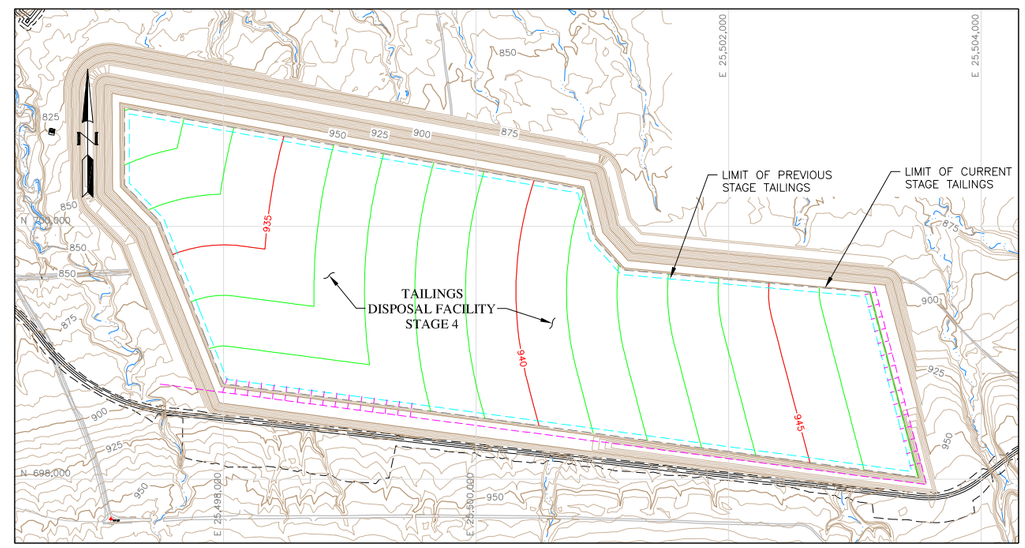
STAGE 1



STAGE 2



STAGE 3



STAGE 4

PLAN

600 0 600 1200 FEET

1" = 600' AT FULL SIZE (ANSI D)
1" = 1200' AT HALF SIZE (ANSI B)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. SUFFICIENT DROP BARS SHALL BE EXTENDED ACROSS THE BASIN ALONG TOPOGRAPHIC LOW POINTS TO FACILITATE INITIAL FILLING OF THE LATERAL EXPANSION FACILITY FROM THE BOTTOM UP. AS THE TAILINGS LEVEL RISES AND REACHES THE SHORTER DROP BARS, THE SHORTER DROP BARS SHALL BE PUT INTO OPERATION UNTIL SUCH TIME AS SUFFICIENT DROP BARS ARE AVAILABLE TO BEGIN A ROTATIONAL DEPOSITION PATTERN. ACTUAL LENGTH OF SHORTER DROP BARS TO BE DETERMINED AT TIME OF CONSTRUCTION. DROP BARS TO BE EXTENDED A MINIMUM OF 5' ONTO RELATIVELY FLAT SECTIONS OF THE BASIN.
3. TO LIMIT EROSION OF EMBANKMENT AND BASIN SURFACES, NO MORE THAN A 6' LENGTH (MEASURED ALONG THE SLOPE) OF EACH DROP BAR SHOULD BE NOTCHED OR DRILLED WITH HOLES AT ANY GIVEN TIME. WHERE DROP BARS TRAVERSE RELATIVELY FLAT SECTIONS OF THE BASIN, AND RAPID RISES IN TAILINGS CAN BE EXPECTED, MORE HOLES MAY BE PROVIDED.
4. LOCATION AND SPACING OF VALVES AND DROP BARS MAY BE VARIED AT THE OWNER'S DISCRETION TO MAINTAIN TAILINGS DISTRIBUTION CONSISTENT WITH THIN–LAYER MANAGED DEPOSITION.
5. CONCEPTUALLY THE DISTRIBUTION SYSTEM WILL BE DIVIDED INTO ZONES TYPICALLY CONSISTING OF 8 DROP BARS. IT IS ENVISIONED THAT THESE ZONES WILL BE UTILIZED TO ACHIEVE A ROTATIONAL DEPOSITION PATTERN IN FILLING THE FACILITY WITH TAILINGS.

LEGEND:

- 950 — GROUND SURFACE CONTOUR AND EL, FEET
- 945 — PROPOSED TAILINGS SURFACE CONTOUR AND EL, FEET
- NEW TAILINGS DISTRIBUTION LINE WITH DROP BAR
- EXISTING DRAINAGE

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D	CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR	RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR	RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

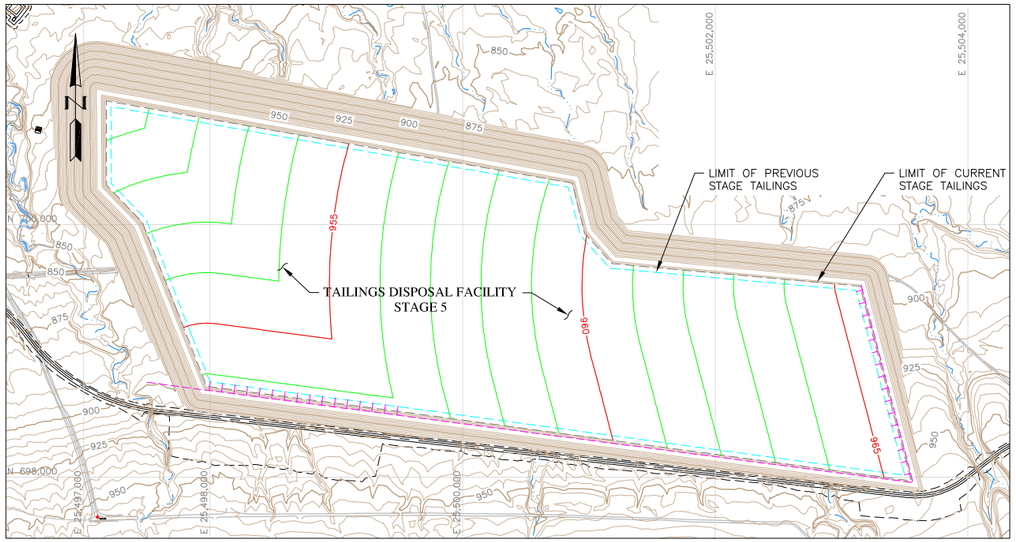
Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
TAILINGS DISTRIBUTION SYSTEM SCHEMATIC
SHEET 1 OF 2

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	180	B

LAST SAVED BY: RGRAHAM
DRAWING PATH: g:\101\00429.02\CAD\CAD Dept\Drawings\2011 0722 – pfs rev0\101–429–02–180–b.dwg
PRINTED BY: ROBERT GRAHAM, PRINT TIME: 7/27/2011 9:57 AM



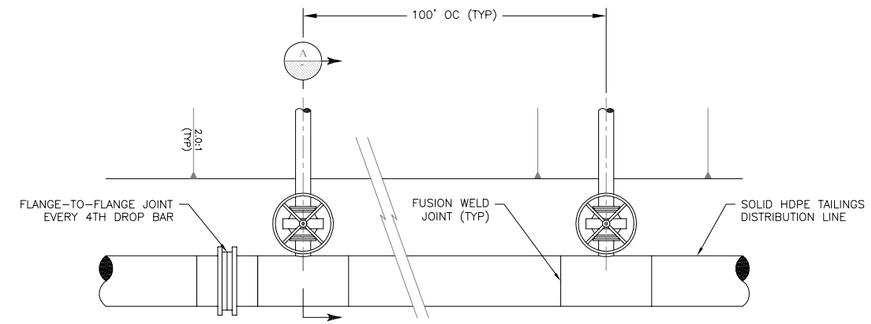
STAGE 5

600 0 600 1200 FEET

1" = 600' AT FULL SIZE (ANSI D)
1" = 1200' AT HALF SIZE (ANSI B)

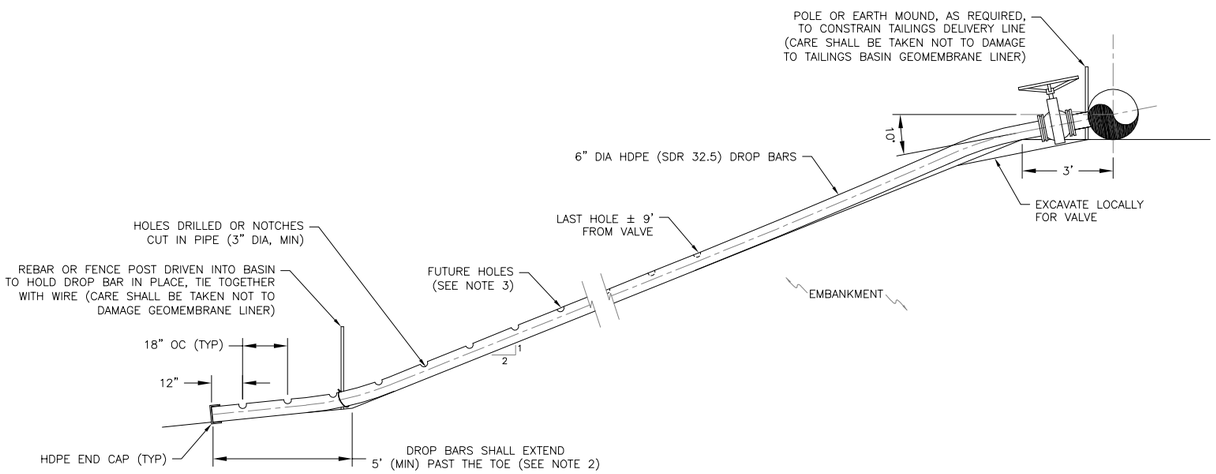
LEGEND:

- 950 — GROUND SURFACE CONTOUR AND EL, FEET
- 965 — PROPOSED TAILINGS SURFACE COUNTOUR AND EL, FEET
- NEW TAILINGS DISTRIBUTION LINE WITH DROP BAR
- EXISTING DRAINAGE



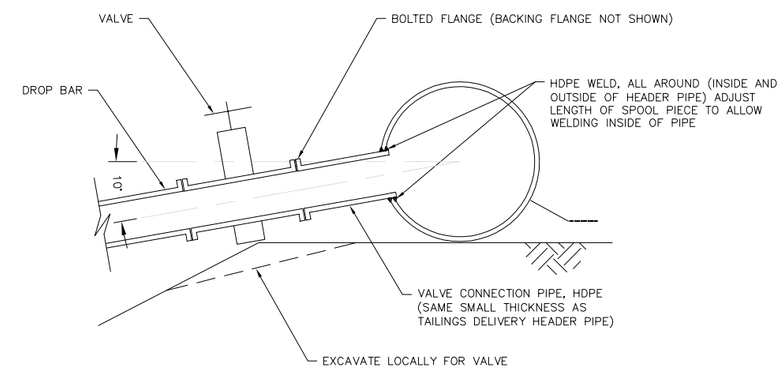
1 — TYPICAL LAYOUT OF DROP BARS

NTS



A — DROP BAR OFF MAIN DISTRIBUTION LINE

NTS



2 — DETAIL OF DROP BAR CONNECTION TO TAILING DELIVERY HEADER PIPE

NTS

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. SUFFICIENT DROP BARS SHALL BE EXTENDED ACROSS THE BASIN ALONG TOPOGRAPHIC LOW POINTS TO FACILITATE INITIAL FILLING OF THE LATERAL EXPANSION FACILITY FROM THE BOTTOM UP. AS THE TAILINGS LEVEL RISES AND REACHES THE SHORTER DROP BARS, THE SHORTER DROP BARS SHALL BE PUT INTO OPERATION UNTIL SUCH TIME AS SUFFICIENT DROP BARS ARE AVAILABLE TO BEGIN A ROTATIONAL DEPOSITION PATTERN. ACTUAL LENGTH OF SHORTER DROP BARS TO BE DETERMINED AT TIME OF CONSTRUCTION. DROP BARS TO BE EXTENDED A MINIMUM OF 5' ONTO RELATIVELY FLAT SECTIONS OF THE BASIN.
3. TO LIMIT EROSION OF EMBANKMENT AND BASIN SURFACES, NO MORE THAN A 6' LENGTH (MEASURED ALONG THE SLOPE) OF EACH DROP BAR SHOULD BE NOTCHED OR DRILLED WITH HOLES AT ANY GIVEN TIME. WHERE DROP BARS TRAVERSE RELATIVELY FLAT SECTIONS OF THE BASIN, AND RAPID RISES IN TAILINGS CAN BE EXPECTED, MORE HOLES MAY BE PROVIDED.
4. LOCATION AND SPACING OF VALVES AND DROP BARS MAY BE VARIED AT THE OWNER'S DISCRETION TO MAINTAIN TAILINGS DISTRIBUTION CONSISTENT WITH THIN-LAYER MANAGED DEPOSITION.
5. CONCEPTUALLY THE DISTRIBUTION SYSTEM WILL BE DIVIDED INTO ZONES TYPICALLY CONSISTING OF 8 DROP BARS. IT IS ENVISIONED THAT THESE ZONES WILL BE UTILIZED TO ACHIEVE A ROTATIONAL DEPOSITION PATTERN IN FILLING THE FACILITY WITH TAILINGS.

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO-METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 - Aerial Data - Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D / CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR / RMG
B	07/29/11	ISSUED FOR PRE-FEASIBILITY STUDY	JTR / RMG

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ACTIVITY CODE N/A | XREF N/A

CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: TAILINGS DISTRIBUTION SYSTEM SCHEMATIC
SHEET 2 OF 2

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	182	B

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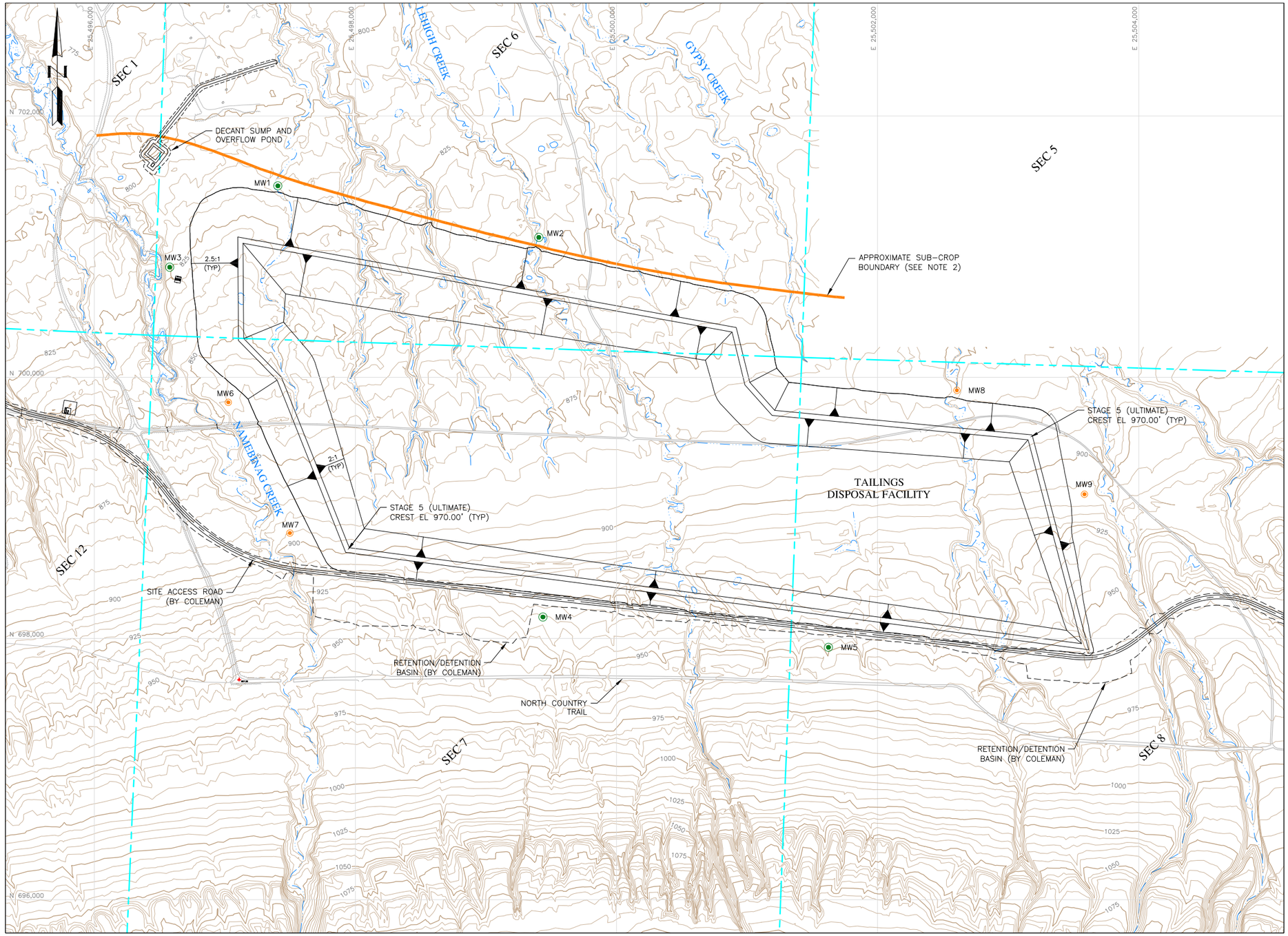

LEGEND:

- EXISTING GROUND SURFACE CONTOUR AND EL, FEET
- EXISTING DRAINAGE
- SECTION LINE
- PROPOSED STAGE 1 MONITORING WELL SET
- PROPOSED STAGE 2 MONITORING WELL SET

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE SUB-CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.
3. IT IS ENVISIONED THAT MONITORING WELL SETS MW1, MW2, MW3, AND MW8 WILL BE SCREENED AT THREE ELEVATIONS WITHIN EACH HOLE. MONITORING WELL SETS MW4, MW5, MW6, AND MW9 WILL BE SCREENED AT TWO ELEVATIONS WITHIN EACH HOLE, AND MW7 WILL BE SCREENED AT ONE ELEVATION.

PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

REV	DATE	DESCRIPTION	APP'D	CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR	RMG
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XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
MONITORING WELL PLAN

DESIGNED BY	JTR	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	186	B

LAST SAVED BY: RGRAHAM
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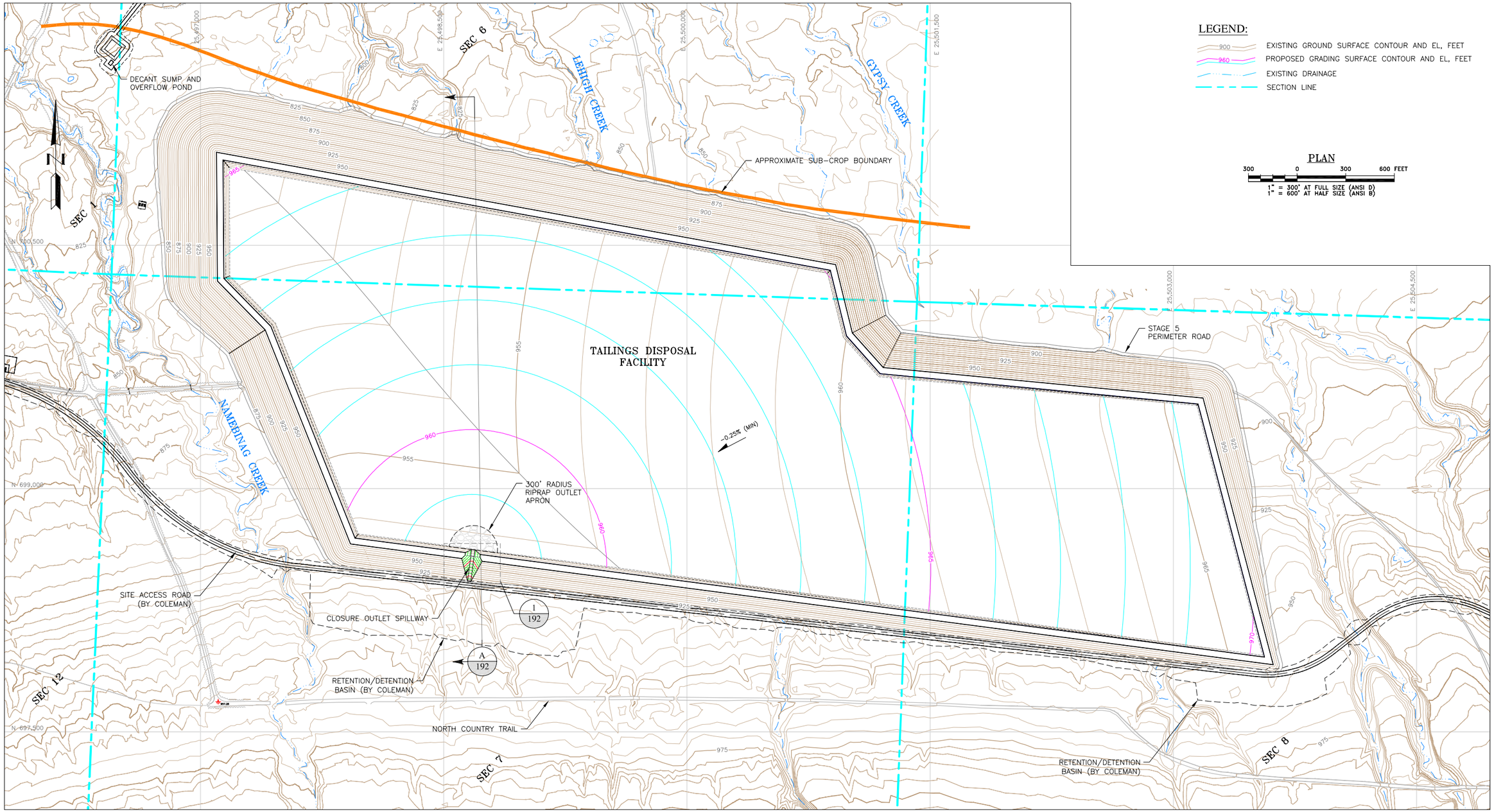

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI–D) AND 1.5" ON A HALF SIZE PLOT (ANSI–B).
2. THE DEPOSITED TAILINGS SURFACE HAS BEEN CONFIGURED WITH AN ASSUMED SLOPE OF –0.25 PERCENT TOWARD THE NORTHWEST CORNER OF THE FACILITY. AS THE TAILINGS CONSOLIDATE AFTER THE END OF DEPOSITION, THE SLOPE ON THE TAILINGS SURFACE WILL BE INCREASED DUE TO THE RELATIVE THICKNESS OF TAILINGS. THE CLOSURE CAP WILL BE CONSTRUCTED TO REVERSE THE SLOPE OF THE CLOSURE SURFACE TOWARD THE SOUTHWEST CORNER OF THE FACILITY AND WILL NOT BE CONSTRUCTED UNTIL CONSOLIDATION HAS SLOWED AND THE SUPERNATANT POOL HAS BEEN EVACUATED FROM THE TAILINGS SURFACE.
3. BASED ON CONSOLIDATION TESTING FOR THE CASE 2 LINER SYSTEM (FULL DRAINAGE BLANKET), THE THICKNESS OF THE DEPOSITED TAILINGS IS EXPECTED TO REDUCE BY APPROXIMATELY 10 PERCENT DUE TO SELF–WEIGHT OF THE TAILINGS AFTER DEPOSITION WITHIN THE FACILITY CEASES. THE MAJORITY OF TAILINGS CONSOLIDATION IS EXPECTED TO OCCUR OVER APPROXIMATELY 4 YEARS AFTER DEPOSITION CEASES.
4. EMBANKMENT FILL MAY BE UTILIZED FOR A SOURCE OF CLOSURE CAP MATERIAL. IT IS ENVISIONED THAT THE CLOSURE CAP RANDOM FILL WILL PREDOMINANTLY BE A LOW–PERMEABILITY MATERIAL. THE CLOSURE CAP IS CURRENTLY ESTIMATED TO REQUIRE 2.5 MILLION CUBIC YARDS OF RANDOM FILL.
5. A 300' RADIUS RIPRAP APRON WILL BE INSTALLED UPSTREAM OF THE CLOSURE SPILLWAY AS PART OF THE CLOSURE CAP TO REDUCE THE AMOUNT OF SEDIMENT TRANSPORTED OUT OF THE FACILITY DUE TO EROSION.
6. THE CLOSURE SPILLWAY WILL BE CUT THROUGH THE EMBANKMENT FILL TO REDUCE THE SPILLWAY SLOPE TO THE EXTENT POSSIBLE.
7. THE CLOSURE SPILLWAY WILL BE LINED WITH ARTICULATED BLOCK LINING (SUCH AS CONTECH 50T BLOCK) AND WILL RELEASE RUNOFF TO THE RETENTION/DETENTION BASIN BEING PROPOSED BY COLEMAN ENGINEERING. THE ADEQUACY OF THE RETENTION/DETENTION BASIN TO ACCEPT THE POTENTIAL RUNOFF FROM THE CLOSURE SURFACE SHOULD BE EVALUATED DURING FUTURE DESIGN.

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO–METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
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SEE G:\101\00429.02\External\2010 1119 – Aerial Data – Disc from Client\CEC Orvana Minerals.dwg

REV	DATE	DESCRIPTION	APP'D	CADD
A	6/3/2011	ISSUED FOR CLIENT REVIEW	JTR	RMG
B	07/29/11	ISSUED FOR PRE–FEASIBILITY STUDY	JTR	RMG

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ACTIVITY CODE N/A
XREF N/A

CLIENT
ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT
COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE
CONCEPTUAL CLOSURE SCHEMATIC
SHEET 1 OF 2

DESIGNED BY	CV	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429–02	190	B

LAST SAVED BY: RGRAHAM
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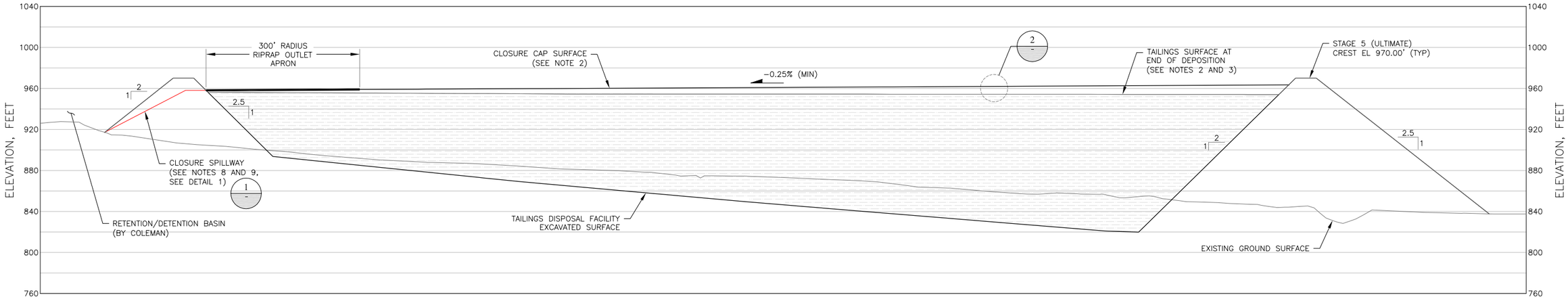
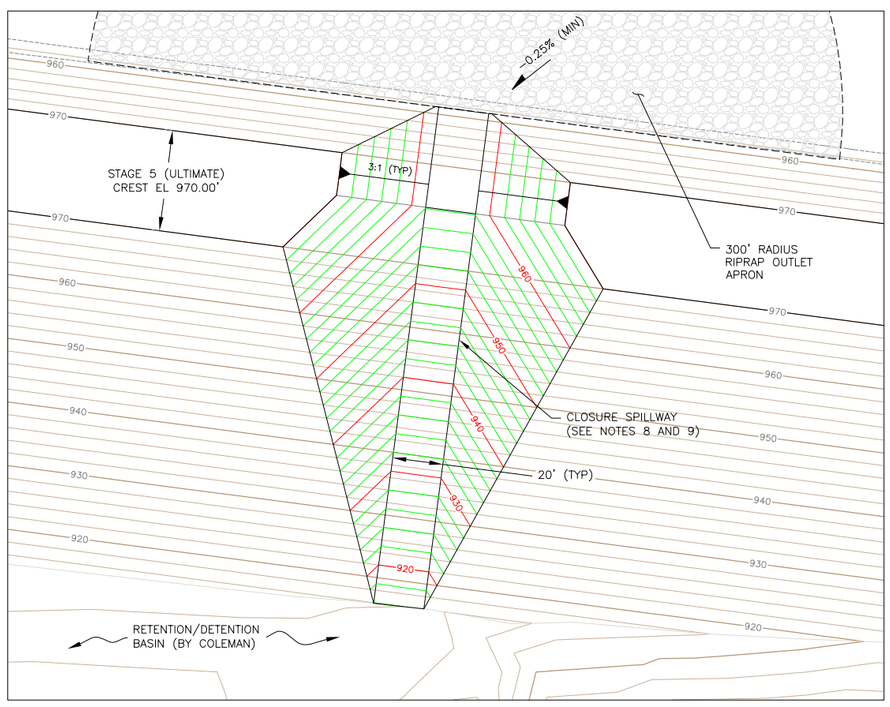


A / 190 TYPICAL SECTION THROUGH TAILINGS DISPOSAL FACILITY AT CLOSURE

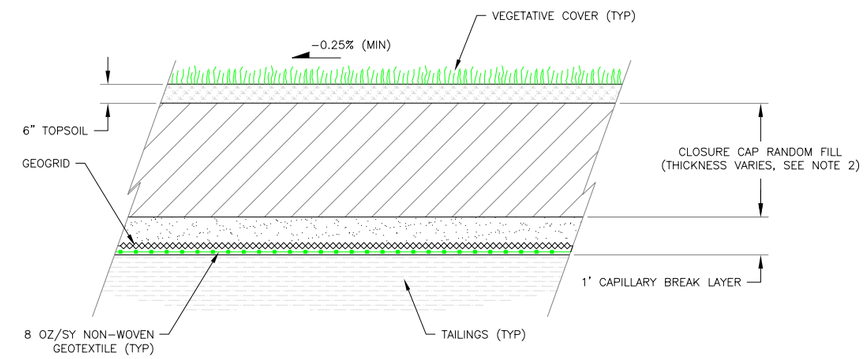
100 0 100 200 FEET
HORIZONTAL SCALE
1" = 100' AT FULL SIZE (ANSI D)
1" = 200' AT HALF SIZE (ANSI B)

50 0 50 100 FEET
VERTICAL SCALE
1" = 50' AT FULL SIZE (ANSI D)
1" = 100' AT HALF SIZE (ANSI B)



1 / - 1 / 190 CLOSURE SPILLWAY

30 0 30 60 FEET
1" = 30' AT FULL SIZE (ANSI D)
1" = 60' AT HALF SIZE (ANSI B)



2 / - TYPICAL CLOSURE CAP

2 0 2 4 FEET
1" = 2' AT FULL SIZE (ANSI D)
1" = 4' AT HALF SIZE (ANSI B)

NOTES:

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4. THE LAYER OF NON-WOVEN GEOTEXTILE IS INTENDED TO MITIGATE THE INGRESS OF TAILINGS INTO THE CLOSURE CAP CAPILLARY BREAK LAYER. ADDITIONALLY, THE GEOTEXTILE ALONG WITH THE GEOGRID ARE INTENDED TO PROVIDE ADDITIONAL STRENGTH TO THE TAILINGS SURFACE FOR CLOSURE CAP CONSTRUCTION.
5. THE CAPILLARY BREAK LAYER IS INTENDED TO PREVENT SMALL AMOUNTS OF PORE WATER RELEASED FROM THE TAILINGS FROM CONTAMINATING THE OVERLYING CLOSURE CAP AND VEGETATIVE GROWTH LAYER.
6. EMBANKMENT FILL MAY BE UTILIZED FOR A SOURCE OF CLOSURE CAP MATERIAL. IT IS ENVISIONED THAT THE CLOSURE CAP RANDOM FILL WILL PREDOMINANTLY BE A LOW-PERMEABILITY MATERIAL. THE CLOSURE CAP IS CURRENTLY ESTIMATED TO REQUIRE 2.5 MILLION CUBIC YARDS OF RANDOM FILL.
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ACTIVITY CODE N/A
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CLIENT: ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

PROJECT: COPPERWOOD PROJECT
TAILINGS DISPOSAL FACILITY

TITLE: CONCEPTUAL CLOSURE SCHEMATIC
SHEET 2 OF 2

DESIGNED BY	CV	LOCATION	PROJECT NUMBER	DRAWING NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	192	B

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Appendices

Knight Piésold
CONSULTING

Appendix A

Copperwood Project, Climatic Data Analysis, Revision 0, memorandum prepared by Knight Piésold and Co., June 15, 2011

Knight Piésold
CONSULTING

Knight Piésold and Co.

1580 Lincoln Street, Suite 1000
Denver, Colorado 80203-1512 USA
Telephone: (303) 629-8788
Facsimile: (303) 629-8789
E-mail: *denver@knightpiesold.com*

Memorandum

Date: June 15, 2011

To: Orvana Resources U.S. Corporation
10199 Lake Rd.
Ironwood, MI 49938

Attn: Mr. Bill Williams

Subject: Copperwood Project
Climatic Data Analysis, Revision 0

KP Project No.: DV101.00429.02
KP Doc. No.: DV-11-365

From: Mr. John Dwyer

Introduction

The Copperwood Project, which is being developed by Orvana Resources U.S. Corporation, will consist of an underground copper mine and associated facilities. The project site is located in Gogebic County at the western end of Michigan's Upper Peninsula, approximately 16 miles northeast of Ironwood, Michigan.

As a water retaining structure, the Tailings Disposal Facility (TDF) embankment classifies as a "high-hazard potential" dam, greater than 40 ft in height, according to the Dam Safety Laws and Regulations of the State of Michigan (Natural Resources and Environmental Protection Act, 1994 PA 451, Part 315, Dam Safety). As such, the TDF will be required to pass (or contain) the one-half Probable Maximum Flood (half-PMF), which is defined as the runoff associated with the one-half Probable Maximum Precipitation (half-PMP).

This memo summarizes the results of the climatic data analysis, including:

- Identification of available climatic data from stations at, or near, the site.
- Calculation of average monthly precipitation, minimum monthly temperature and maximum monthly temperature for a long-term period of record (October 1977 to December 2010) based on data from the Ontonogan, Michigan weather station.
- Calculation of the theoretical average monthly potential evaporation, pond evaporation, and evaporation from the exposed tailings surface based on the long-term period of record (1977-2010).
- Calculation of the annual and monthly 24-hour (hr) precipitation values for return periods of 2, 5, 10, 25, 50, and 100 years, and the all-season and monthly 72-hr PMP and 72-hr/half-PMP.
- Calculation of the maximum daily snow depth and the maximum daily mean temperature, by month for selected return periods, to determine potential snowmelt.
- Calculation of monthly rain-on-snow water equivalent depths for the 100-year (yr)/24-hr, the 72-hr PMP, and the 72-hr/half-PMP storm events.

Identification of Available Climatic Data

The project site can be classified as a humid continental climate (*Dfb* in the Köppen climate classification system), which is strongly influenced by its proximity to Lake Superior. Winters tend to be long, cold, and snowy, and because of its northern latitude, the daylight hours are short - around 8 hours between sunrise and sunset in the winter. The project is located in the Midwestern Snow Belt, with an average annual snowfall of 180 inches at Ironwood, Michigan. Summers are warm and humid, with a mean maximum temperature of 79.2 degrees Fahrenheit (^{o}F) in July.

A search of the Michigan State Climatologist's database, the Midwestern Climate Center database, and the National Climatic Data Center, found that nearby weather stations with long-term daily records include Ontonogan, Ironwood, and the Bergland Hydro Plant (see Figure 1 and Table 1). As part of this climatic analysis, these long-term daily records were obtained and evaluated, together with daily precipitation and

temperature data from the mine site weather station (from June to October, 2009, and from April to September, 2010). This information was used to generate the monthly precipitation data for years 2009 and 2010, for the mine site and the nearby stations, which are summarized in Table 2.

Average Monthly Precipitation and Mean Minimum/Maximum Monthly Temperatures

To construct a statistically reliable water balance for a project, it is preferable to have at least 30 years of monthly precipitation and temperature data for the site. Due to the very short period of record for the mine site weather station (5 months of precipitation data for 2009, and 6 months of data for 2010), it was not possible to make a valid statistical comparison of the precipitation at the mine site with that at the other nearby stations. However, based on a review of the location, elevation, and data from the three nearby stations, the Ontonogan station appears to provide a good representation of climatic conditions at the mine site. Data from the Ontonogan station, from October 1977 to December 2010, was used to represent precipitation, mean monthly minimum, and mean monthly maximum air temperatures at the Copperwood site. These data are shown in Tables 3, 4 and 5.

The average annual precipitation at the site (based on the Ontonogan data) was determined to be 33.02 inches. The precipitation was determined to be fairly evenly distributed throughout the year, with average monthly precipitation ranging from 1.55 inches in February to 3.45 inches in October.

Mean maximum temperatures were found to range from 25.1 to 79.2 ^{o}F, from January to June, respectively. Mean minimum temperatures were found to range from 8.1 to 54.7 ^{o}F, from February to July, respectively.

Average Monthly Evaporation

The theoretical average monthly potential evaporation at the site was calculated using the EPIC computer model (USDA, 1990), which uses the Hargreaves and Samani (1985) method to predict potential evaporation; the method uses mean, maximum, and minimum monthly temperatures and extraterrestrial solar radiation. The monthly potential evaporations, determined for years 1977 through 2010, are shown in Table 6. The average annual potential evaporation was calculated to be 36.5 inches, ranging from 0.4 inches in January to 6.7 inches in July.

The monthly pond evaporation values for the site (for years 1977 through 2010) were calculated by multiplying the potential evaporation by a coefficient of 0.65,and are shown in Table 7. Using this conversion factor, the average annual pond evaporation was calculated to be 23.7 inches, which agrees closely with the value of 24 inches given in the *Climatic Atlas of the United States* (U.S. Department of Commerce, 1968).

The monthly evaporation from exposed (unsaturated) tailings surfaces was estimated using a method developed by Ritchie (1972) which uses the potential evaporation, tailings properties (gradation, transmissivity, and moisture content), and climatological conditions (temperature, precipitation, solar radiation, number of wet and dry days), and is shown in Table 8. The average annual evaporation from exposed tailings surfaces was determined to be 16.8 inches, ranging from 0.4 inches in January to 2.2 inches in April.

Annual and Monthly 24-Hr Precipitation and 72-Hr PMP Values

Daily precipitation values for the long-term period of record were ranked using the partial duration series method. The values were then multiplied by 1.13 to adjust for a fixed observational period, and then utilized as input data for analyzing the 24-hr precipitation values for various return periods. The monthly and annual ranked and adjusted values of the partial duration series are shown in Table 9.

Daily precipitation statistics for each month were analyzed for use in the water balance model and are shown in Table 10. The average daily precipitation, for those days when precipitation occurs, was determined to range from 0.1 inches in February to 0.3 inches in July and August.

The ranked daily precipitation data were used to develop annual and monthly 24-hr precipitation values for storm events with return periods of 2, 5, 10, 25, 50, and 100 years using an Extreme Value, Type I (Gumbel) probability distribution (see Table 11).

The all-season 72-hr PMP was estimated using the publication *Hydrometeorological Report No. 51* (U.S. Department of Commerce, 1978). The half-PMP values were assumed to be one-half of the corresponding PMP values. Monthly PMP values were estimated by assuming that the ratio of the monthly to all-season PMPs is the same as the ratio of the monthly to annual 100-yr/24-hr precipitations. The results of this analysis are shown in Table 11.

Maximum Daily Snow Depth and Maximum Daily Mean Temperature for Potential Snowmelt

Rain-on-snow events may result in higher total runoff values than runoff due to rainfall on bare ground. To address this possibility, snowmelt due to rainfall was estimated using an equation developed by the U.S. Army Corps of Engineers (USACE, 1998). The equation for snowmelt due to rain-on-snow in the USACE report does not limit the snowmelt to the actual amount of snow available. Thus, to establish a limit, the daily snow depths recorded at the Ontonogan station were analyzed to calculate the frequency of a given snow depth for each month when snow data were recorded at the Copperwood site. Also, because the snowmelt equation requires the saturated air temperature (assumed to be the same as air temperature), daily mean air temperature values were also analyzed to obtain monthly frequency results for an Extreme Type I (Gumbel) distribution.

Tables 12 and 13, respectively, show the maximum daily snow depths and maximum mean daily air temperatures at the Ontonogan station, from January through May and October through December. Average maximum daily snow depths for these months ranged from 0.6 inches in May to 24.9 inches in February. June, July, August, and September had snow depths of zero for all years in the long-term period of record. Precipitation during the winter months can occur as rain or snow, depending on the air temperature.

Average maximum daily mean air temperatures for these months ranged from 33.9 ^{o}F in January to 71 ^{o}F in May.

The resulting Extreme Value Type I (Gumbel) probability distribution results for both snow depth and air temperature for the 2-, 5-, 10-, 25-, 50-, 100-, 500-, and 1,000-yr return periods are summarized in Table 14. For purposes of the snowmelt analyses for this project, it has been assumed that because the joint probability of a 10-yr snow depth coupled with a 10-yr air temperature occurring in any given year is 0.01 (100 years), these return periods can be used to calculate snowmelt, and that the available snowmelt is limited to snow on the ground.

Rain-on-Snow Depth by Month for the 100-yr/24-hr, 72-hr PMP, and 72-hr/half-PMP Storm Events

Table 15 summarizes the rain-on-snow depths for the 100-yr/24-hr , 72-hr PMP, and 72-hr/half PMP storm events at the Ontonogan station. The potential rain-on-snow depth for each month is calculated by adding the associated monthly rainfall to the snowmelt that would occur during the same storm event. As noted above, snowmelt was determined utilizing the snow depth and maximum daily mean air temperature with return periods of 10 years. The resulting snowmelt value with the, 72-hr/half-PMP rainfall should provide a reasonable and conservative value for the rain-on-snow event; 100-yr/ 24-hr and 72-hr PMP rain-on-snow values have additionally been presented for comparative purposes.

To determine the governing storm event for the Copperwood Project, the rain-on-snow event for each individual month was assessed and compared with the individual month values occurring as precipitation alone. As shown in Table 15,the maximum precipitation associated with the 72-hr/half-PMP storm event has been modeled to occur during the month of August (16.4 inches). This monthly 72-hr/half-PMP precipitation, occurring as rainfall alone, exceeds the modeled monthly maximum rain-on-snow event (13.0 inches occurring in March) which combines the 72-hr/half-PMP precipitation with the associated amount of snowmelt that would occur during that storm event. Therefore, the 72-hr/half-PMP storm event, neglecting rain-on-snow conditions, governs the design.

Knight Piésold
CONSULTING

Mr. Bill Williams
Orvana Resources U.S. Corporation

June 15, 2011

Closure
The analyses utilized, and resulting values, were used in the Copperwood process water balance and for the sizing of the proposed TDF and ancillary structures. We would be happy to answer any questions you might have.

Sincerely,
Knight Piésold and Co.

Thomas F. Kerr, P.E.
President

John Dwyer, P.E.
Senior Project Engineer

cc: Jim Jacques (Orvana)
Dave Anderson (Orvana)

Enclosures: Figure 1 and Tables 1 through 15

References:

Gumbel, E.J., 1954, *A Statistical Theory of Extreme Values and Some Practical Applications*, National Bureau of Standards Applied Mathematics Series 33, U.S. Government Printing Office, Washington D.C. February 12, 51 pp.

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Figures

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PRINTED BY: JASON REIVA, PRINT TIME: 7/1/2011 4:22 PM

PLAN

15,000 0 15,000 30,000 FEET

1" = 30,000'

LEGEND

WEATHER STATION

PROJECT	COPPERWOOD PROJECT
TITLE	WEATHER STATION LOCATION MAP
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
DRAWN BY	RG	DV101	00429–02	1	0
ACTIVITY CODE	N/A	XREF NUMBER	N/A		

Tables

Knight Piésold CONSULTING

Table 1
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Weather Stations Near Copperwood Project

Name	Elevation (ft)	Distance from Project (miles)	Latitude	Longitude
Mine Site	760	0	46° 40'	90° 0'
Ironwood	1430	16.1	46° 28'	90° 11'
Ontonagon	790	40	46° 50'	89° 12'
Bergland	1300	22.5	46° 35'	89° 33'

Knight Piésold CONSULTING

Table 2
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Comparision of Monthly Precipitation (inches)

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Mine Site (2009)	ND	ND	ND	ND	ND	1.49	2.21	3.17	1.51	4.96	ND	ND	ND
Mine Site (2010)	ND	ND	ND	0.92	1.67	3.70	1.85	4.89	4.77	ND	ND	ND	ND
Ontonagon (2009)	3.77	1.66	0.81	3.83	0.88	2.87	1.92	6.61	2.09	5.55	1.27	4.23	35.49
Ontonagon (2010)	1.95	1.50	0.13	1.19	2.30	3.50	1.31	2.22	5.61	0.94	2.30	2.37	25.32
Ironwood (2009)	1.71	1.27	0.83	3.22	0.87	2.05	2.56	4.02	2.27	6.04	1.17	2.79	28.80
Ironwood (2010)	2.32	1.26	0.3	0.61	2.92	6.91	4.64	4.99	7.23	1.81	1.62	2.05	36.66
Bergland (2009)	3.66	2.75	N/D	3.77	1.28	3.17	2.28	5.33	2.18	5.70	2.15	5.86	38.13
Bergland (2010)	4.06	2.55	0.95	0.88	4.12	6.6	2.35	3.29	7.06	1.89	2.57	4.41	40.73
Ontonagon (30-yr avg)	3.02	1.47	2.04	2.08	3.00	3.08	3.46	3.34	3.09	3.13	2.79	3.06	33.56
Ironwood (30-yr avg)	2.07	1.22	2.08	2.11	2.97	4.16	4.00	3.72	3.80	3.38	3.09	2.05	34.65
Bergland (30-yr avg)	2.84	1.62	2.52	2.31	3.40	3.92	3.92	4.01	3.73	3.55	3.57	2.99	38.38

ND = No data recorded

Onto Diff. (2009)	ND	ND	ND	ND	ND	1.38	-0.29	3.44	0.58	0.59	ND	ND
Ironwd Diff (2009)	ND	ND	ND	ND	ND	0.56	0.35	0.85	0.76	1.08	ND	ND
Onto Diff (2010)	ND	ND	ND	0.27	0.63	-0.20	-0.54	-2.67	0.84	ND	ND	ND
Ironwd Diff (2010)	ND	ND	ND	-0.31	1.25	3.21	2.79	0.10	2.46	ND	ND	ND

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Table 3
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Copperwood Estimated Monthly Precipitation (inches)

Station	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Ontonogan	1977										2.31	2.43	3.56	
Ontonogan	1978	2.58	0.97	1.06	1.88	4.24	1.79	4.74	5.93	2.09	1.49	3.89	3.37	34.03
Ontonogan	1979	3.34	1.37	4.4	0.72	2.58	5.75	2.74	2.08	3.39	4.98	2.89	1.16	35.40
Ontonogan	1980	3.58	0.93	0.85	2.22	2.21	1.96	4.54	5.47	6.71	3.61	1.87	2.81	36.76
Ontonogan	1981	2.79	3.99	1.56	3.3	4.45	5.59	2.49	3.36	2.58	5.11	0.98	3.9	40.10
Ontonogan	1982	4.51	0.9	0.88	4.26	3.93	0.76	5.51	2.94	2.24	5.37	3.33	3.58	38.21
Ontonogan	1983	2.47	0.98	2.63	2.07	4.04	3.06	2.11	2.85	5.59	4.2	3.35	3.88	37.23
Ontonogan	1984	1.74	2.37	2.32	2.11	3.67	4.07	1.25	4	4.77	2.04	0.97	3.9	33.21
Ontonogan	1985	3.68	1.69	1.93	3.7	3.34	1.57	2.93	4.07	6.19	3.52	5.42	4.75	42.79
Ontonogan	1986	2.95	1.34	2.19	2.13	0.77	3.67	5.22	4.26	2.57	4.11	2.3	1.86	33.37
Ontonogan	1987	1.58	0.47	0.78	1.08	3.59	1.38	8.09	2.77	2.46	3.6	2.75	2.78	31.33
Ontonogan	1988	4.28	1.95	2.79	0.73	1.79	1.46	2.05	6.86	2.35	4.54	4.55	4.22	37.57
Ontonogan	1989	2.41	2.07	1.15	1.95	2.54	6.65	1.11	2.42	0.79	1.97	3.03	3.9	29.99
Ontonogan	1990	1.52	0.96	1.86	2.4	1.75	6.83	2.45	0.7	3.11	5.07	1.24	1.86	29.75
Ontonogan	1991	2.4	1.04	2.45	1.85	4.67	1.84	7.9	1.23	3.31	3.52	6.53	1.52	38.26
Ontonogan	1992	2.43	1.7	0.83	0.97	1.54	1.07	5.51	2.39	3.18	3.49	2.94	3.08	29.13
Ontonogan	1993	2.24	0.71	0.81	2.81	3.94	3.74	1.65	3.2	2.82	2.4	2.2	3.06	29.58
Ontonogan	1994	3.13	0.48	1.34	2.86	1.86	3.14	2.77	3.01	2.88	1.43	0.46	3.06	26.42
Ontonogan	1995	2.82	1.8	1.97	2.05	4.17	1.33	3.24	3.55	3.92	6.59	2.56	2.82	36.82
Ontonogan	1996	3.63	2.48	2.97	4.6	1.35	4.88	4.35	2.03	2.51	3.72	2.95	4.05	39.52
Ontonogan	1997	4.6	0.51	1.82	0.48	3.61	2.93	3.41	3.96	3.08	1.66	1.91	2.36	30.33
Ontonogan	1998	2.5	0.27	3.76	0.77	2.59	3.88	1.44	2.13	2.78	2.19	2.77	3.92	29.00
Ontonogan	1999	2.78	1.98	0.23	1.88	5.01	2.59	5.12	3.76	2.97	2.23	1.97	2.68	33.20
Ontonogan	2000	2.49	0.95	2.75	1.51	1.33	3.82	1.65	1.46	1.23	0.98	2.98	3.56	24.71
Ontonogan	2001	2.41	2.76	1.1	5.03	3.3	2.47	1.58	3.5	2.44	3.12	2.93	2.99	33.63
Ontonogan	2002	1.58	2.52	2.73	3.29	2.76	3.1	4.31	2.09	3.24	4.61	1.62	1.52	33.37
Ontonogan	2003	2.54	1.75	1.75	2.53	4.85	1.84	5.48	1.73	2.63	1.94	2.91	2.07	32.02
Ontonogan	2004	4.27	1.43	1.78	2.83	4.06	1.76	2.56	3.01	1.7	3.72	1.71	3.58	32.41
Ontonogan	2005	2.53	1.43	1.93	1.18	2.79	3.11	0.95	0.67	3.39	5.52	3.57	2.9	29.97
Ontonogan	2006	1.69	1.8	2.01	0.62	3.86	2.94	2.82	1.77	1.38	3.08	1.16	3.18	26.31
Ontonogan	2007	1.55	2.69	1.33	2.54	1.92	2.48	0.7	2.39	7.4	6.54	2.62	2.83	34.99
Ontonogan	2008	3.14	1.59	0.7	2.69	2.75	2.09	4.39	0.87	3.46	2.2	2.38	3.32	29.58
Ontonogan	2009	3.77	1.66	0.81	3.83	0.88	2.87	1.92	6.61	2.09	5.55	1.27	4.23	35.49
Ontonogan	2010	1.95	1.5	0.13	1.19	2.3	3.5	1.31	2.22	5.61	0.94	2.3	2.37	25.32
Ontonogan	Average	2.8	1.5	1.7	2.2	3.0	3.0	3.3	3.0	3.2	3.5	2.6	3.1	33.02
Ontonogan	Max	4.6	4.0	4.4	5.0	5.0	6.8	8.1	6.9	7.4	6.6	6.5	4.8	42.79
Ontonogan	Min	1.5	0.3	0.1	0.5	0.8	0.8	0.7	0.7	0.8	0.9	0.5	1.2	24.71

Average data substituted for missing data

Knight Piésold CONSULTING

Table 4
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Copperwood Estimated Mean Monthly Maximum Temperature (^{o}F)

Station	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ontonogan	1977										57.5	42.1	26.7
Ontonogan	1978	22.7	24.9	38.6	49.5	69.2	75.1	76.2	78.4	70.3	57.8	41.2	24.8
Ontonogan	1979	15.3	21	37	49.4	59.9	73.1	79.2	75.7	69.4	50.6	39.4	33.4
Ontonogan	1980	24.3	25.3	36.2	53.2	70	73.1	79.1	76.1	65.8	51.7	40.6	26.2
Ontonogan	1981	27.2	31.2	41.6	55.5	65.5	73.8	79.2	77.8	66.1	53.1	47.3	29
Ontonogan	1982	18.1	25.7	36.2	49.1	71	69.3	79.9	72.6	66.5	57.8	38.2	31.9
Ontonogan	1983	28.6	33.5	38.1	46.8	61	77.1	83.9	82.3	70.3	56.4	41	18.3
Ontonogan	1984	23.7	36.8	33.6	56.1	64.5	76.8	78.2	79.8	65.8	61	41.8	28.9
Ontonogan	1985	21.5	24.6	42.4	55.5	67.6	72.1	77.5	74.3	67.7	58.6	33.6	19.9
Ontonogan	1986	26.4	27	42.5	57.3	71	75.1	79.9	75.3	65.7	56.5	36	32.6
Ontonogan	1987	30.1	38.4	45.6	63.1	70.4	78.6	81.5	77.4	70.8	51.4	44	33.6
Ontonogan	1988	22.8	24.3	37.8	56.1	74.3	80.5	86.4	79.3	69.2	50.6	39.6	28.4
Ontonogan	1989	31.6	23.3	34.6	50.9	67.7	71.9	81.7	78.3	72.6	60.3	34.1	19.1
Ontonogan	1990	34	33.4	44.5	57.1	62.6	74	78.2	78.7	68.7	54.8	45.2	28.5
Ontonogan	1991	21.5	34	41.6	57.9	70.4	78.3	77.1	80	65.2	53.3	36.5	31
Ontonogan	1992	28.6	32	37.6	48.2	71.4	70.8	71	74.6	69.7	54.4	36.6	29.2
Ontonogan	1993	26.1	29	39.9	47.2	64.1	70.7	76.2	78.7	63	54.5	36.2	28.6
Ontonogan	1994	13.7	23.1	41.2	50.5	66.5	75.8	77.2	78.3	70.1	60.9	45.5	35.7
Ontonogan	1995	26.4	26.6	40.6	45.1	64.7	78.8	79.7	82.6	67.7	55.6	31.6	25.5
Ontonogan	1996	20.7	25.6	32.2	46	62	75.8	73.1	78.5	67.1	58.6	34.2	26.5
Ontonogan	1997	22.8	29.9	36.2	50.7	58.3	78.9	76.9	74.3	70.1	58.2	37.6	34.3
Ontonogan	1998	27.7	40.8	39.7	58.7	72.8	71.4	79.5	81.9	74	60.2	42.7	34.1
Ontonogan	1999	25.1	36.4	42.1	54.9	68.5	74.9	81.6	76.4	69.8	54.6	49.3	33.2
Ontonogan	2000	26	36.8	48	50.7	68	72.4	78.1	78.6	69.5	62.6	41.2	20.8
Ontonogan	2001	31.4	25.3	37.8	55.4	68.2	76	80.3	80.8	68.1	57.2	52.7	35.3
Ontonogan	2002	31.5	35.7	32.5	50.4	60.3	76.6	83.4	77.4	69.4	49	37.3	32.4
Ontonogan	2003	23.2	23.2	39.8	51	66.3	74.3	77.9	79.8	71.1	55.3	39.6	34.1
Ontonogan	2004	18	35.3	40.1	51.7	62.1	71.8	77.4	78.3	77	58	44.3	27.9
Ontonogan	2005	22.5	34.1	39.8	59.3	63.8	80.4	83.5	80.1	77.3	58.9	42.1	28.4
Ontonogan	2006	34.3	28.9	42.2	61.2	65.8	76.9	84.4	79.1	68.4	53	44.4	34.8
Ontonogan	2007	28.4	21.8	44.6	53.2	72.4	79.5	80.9	80.3	71.9	61.3	39.8	27.2
Ontonogan	2008	26.1	27.4	37.4	52.1	60.4	74	78.7	79.8	72.3	57.1	40.5	22.4
Ontonogan	2009	19.8	30.1	40.7	51.4	67.1	72.3	73	75.6	74.5	49.9	48.6	26.2
Ontonogan	2010	26.5	31.1	51.7	62.1	70.1	71.6	81.8	82.8	64.7	60.3	43.7	27.6
Ontonogan	Average	25.0	29.6	39.8	53.3	66.6	74.9	79.2	78.3	69.4	56.2	40.8	28.7
Ontonogan	Max	34.3	40.8	51.7	63.1	74.3	80.5	86.4	82.8	77.3	62.6	52.7	35.7
Ontonogan	Min	13.7	21.0	32.2	45.1	58.3	69.3	71.0	72.6	63.0	49.0	31.6	18.3

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Table 5
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Copperwood Estimated Mean Monthly Minimum Temperature (°F)

Station	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ontonogan	1977										34.6	25.8	14.6
Ontonogan	1978	4.3	-1.4	10.4	29.9	41	47.8	53.8	54	49.6	36.2	22.5	9.4
Ontonogan	1979	-2.6	-5.6	15.8	26.7	36.8	46.7	52.9	52.1	46.6	35.2	25.1	16.7
Ontonogan	1980	7.2	3.3	11.5	32	41.7	45.9	53.7	56	44.7	34.1	27.3	11.2
Ontonogan	1981	7.1	12.8	20	32.5	36.4	50.8	54.4	54.4	43.6	35.7	30.2	16.3
Ontonogan	1982	-3.9	3.9	15.7	27	44.5	43.1	55.3	50.1	46.5	39.3	24.4	20.5
Ontonogan	1983	13	18.5	22.5	27	35.3	49.7	59	57.6	49.4	36.3	28.6	4.4
Ontonogan	1984	1.9	18.6	9.1	31.3	37.6	51.8	52.8	56.7	43.3	40.8	27.6	11.1
Ontonogan	1985	4.9	2.2	23.6	34.1	42.9	46.5	51.2	51.6	47	37.1	22.4	7.5
Ontonogan	1986	9.7	6	17.8	34.7	41.3	47.5	56.4	51.1	47.4	36.9	21.4	14.9
Ontonogan	1987	15.2	16.4	24.8	32.8	42.7	50.9	57.8	54.8	47.2	34.2	28.2	21
Ontonogan	1988	4.4	2	16.8	30.6	43.5	48.5	55.2	55.7	48.4	34.3	28.4	11.3
Ontonogan	1989	12.2	0.7	9.8	28.7	39.4	47.5	55.5	55	46.9	34.6	21.6	3.8
Ontonogan	1990	14.6	6.7	20.3	32.6	35.4	49.8	52.7	52.6	46.1	34.3	27.5	12.5
Ontonogan	1991	6.4	10.1	18.5	34.5	46	51.3	55.9	54.5	45.5	35	19.8	12.9
Ontonogan	1992	12.3	13.8	16.5	30.1	42.4	44.3	49.1	48.4	47.1	36.3	26.3	15.9
Ontonogan	1993	10.7	5	14.6	28.9	40.1	47.5	56.6	56.1	41.7	33.6	22.3	17.5
Ontonogan	1994	-2.2	-2.1	19.9	29.4	39.2	49.9	53.7	54.3	49.6	41	28.6	20.3
Ontonogan	1995	14.8	11.1	22.5	26.7	40.7	53.2	56.3	58.3	44.9	39	20.6	11.3
Ontonogan	1996	1.9	1.1	8.8	22.8	37	50.2	50.6	54	48.3	37.6	22.6	15
Ontonogan	1997	5.9	6.1	12.8	26.5	35	51.2	53.2	50.1	48	37.4	24.4	21.3
Ontonogan	1998	13.7	23.9	20.6	32.2	42	50.6	53.6	55.6	49.8	41	30.5	16.5
Ontonogan	1999	8.3	15.2	20.4	30.9	43.3	52.3	59.1	53.1	47.7	35	31.7	17
Ontonogan	2000	6.7	14	27.8	28.4	43.3	47.9	53.6	54.8	44.2	38.5	28.5	6
Ontonogan	2001	13.8	7.5	15.2	34.6	43.7	51.3	53.9	56.4	46.4	36.5	33.7	23.1
Ontonogan	2002	15.9	17.4	10.5	29.9	37	51.2	58	55.1	47.2	33.8	23.6	18.3
Ontonogan	2003	7.9	1.5	17.4	27.7	38.2	48.2	53.7	55.2	49.3	36.5	26	18.1
Ontonogan	2004	4.7	10.9	23	30	38.2	47	52.4	54.3	52.7	40	27.5	12.5
Ontonogan	2005	6.2	14.9	13.2	33.6	40.8	56.2	55.8	56.5	51.9	40.9	27.3	17.2
Ontonogan	2006	21.8	8.7	18.9	35.4	43.5	49.5	59.4	55	43.5	34.2	29.6	20.7
Ontonogan	2007	13.8	4.7	22.6	28.4	46.3	52.4	54.2	55.5	50.4	42.5	26.6	13.3
Ontonogan	2008	11	3.3	11.1	30.2	36.5	49	56.3	51	49.4	38.4	28.2	9
Ontonogan	2009	-1.7	6.8	17.4	30.7	39.1	47.9	49.9	52.3	49.7	34.9	32.6	13
Ontonogan	2010	13.9	9.4	24.6	35	45.2	51.6	58.9	59.7	44.2	37.2	28.3	14.1
Ontonogan	Average	8.3	8.1	17.4	30.5	40.5	49.4	54.7	54.3	47.2	36.9	26.5	14.4
Ontonogan	Max	21.8	23.9	27.8	35.4	46.3	56.2	59.4	59.7	52.7	42.5	33.7	23.1
Ontonogan	Min	-3.9	-5.6	8.8	22.8	35.0	43.1	49.1	48.4	41.7	33.6	19.8	3.8

Average data substituted for missing data

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Table 6
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Copperwood Estimated Monthly Potential Evaporation (inches)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1977	0.38	1.00	1.37	2.82	5.49	6.47	6.97	6.10	3.14	1.97	0.80	0.32	36.81
1978	0.29	0.50	1.49	2.80	5.86	6.44	6.20	5.78	3.44	2.01	0.89	0.30	36.00
1979	0.14	0.36	1.31	2.85	4.58	6.26	6.89	5.54	3.59	1.61	0.69	0.45	34.26
1980	0.30	0.50	1.43	3.34	5.94	6.27	6.58	5.07	3.19	1.62	0.68	0.30	35.21
1981	0.47	0.71	1.73	3.33	5.43	5.99	6.76	5.53	3.42	1.73	1.01	0.37	36.48
1982	0.18	0.47	1.32	2.84	5.80	5.73	6.80	5.07	3.21	1.87	0.65	0.42	34.38
1983	0.44	0.70	1.34	2.62	4.78	6.88	7.25	6.14	3.43	1.79	0.69	0.18	36.23
1984	0.27	0.82	1.18	3.52	5.33	6.49	6.60	5.67	3.32	2.08	0.73	0.44	36.44
1985	0.31	0.41	1.67	3.50	5.52	5.98	6.75	5.17	3.34	2.00	0.52	0.20	35.36
1986	0.36	0.42	1.90	3.53	6.22	6.58	6.67	5.45	2.95	1.91	0.61	0.43	37.04
1987	0.42	0.90	1.94	4.34	5.87	7.02	6.83	5.43	3.74	1.61	0.85	0.42	39.38
1988	0.32	0.51	1.39	3.55	6.56	7.61	8.21	5.70	3.40	1.59	0.60	0.39	39.83
1989	0.53	0.47	1.16	3.03	5.65	5.96	7.19	5.54	3.97	2.28	0.57	0.20	36.54
1990	0.60	0.72	1.92	3.72	5.04	6.15	6.69	5.86	3.56	1.85	0.91	0.38	37.40
1991	0.28	0.77	1.62	3.60	5.77	6.92	6.07	5.93	3.18	1.73	0.65	0.42	36.94
1992	0.42	0.70	1.48	2.67	6.08	6.19	5.53	5.48	3.58	1.75	0.54	0.34	34.77
1993	0.38	0.58	1.67	2.55	5.02	5.77	5.75	5.53	3.12	1.89	0.65	0.34	33.24
1994	0.12	0.51	1.61	2.89	5.48	6.48	6.46	5.79	3.48	2.09	0.87	0.52	36.29
1995	0.32	0.55	1.61	2.37	5.07	6.86	6.64	6.07	3.52	1.77	0.47	0.31	35.55
1996	0.24	0.48	1.26	2.55	4.91	6.52	5.97	5.67	3.27	2.06	0.56	0.28	33.76
1997	0.28	0.60	1.44	3.16	4.38	7.03	6.37	5.35	3.57	2.14	0.62	0.45	35.37
1998	0.39	0.92	1.53	3.76	6.23	5.52	6.81	6.05	3.94	1.99	0.71	0.50	38.36
1999	0.36	0.83	1.76	3.52	5.50	6.11	6.62	5.40	3.64	1.77	1.01	0.46	36.99
2000	0.36	0.95	2.01	3.06	5.38	6.00	6.61	5.58	3.69	2.20	0.72	0.24	36.80
2001	0.48	0.39	1.52	3.35	5.48	6.45	7.09	5.91	3.37	1.99	1.13	0.45	37.60
2002	0.48	0.80	1.19	2.97	4.64	6.55	7.20	5.40	3.37	1.48	0.65	0.43	35.15
2003	0.33	0.38	1.41	3.11	5.49	6.45	6.53	5.87	3.76	1.89	0.68	0.45	36.34
2004	0.20	0.96	1.49	3.25	4.80	6.01	6.61	6.36	4.11	1.90	0.83	0.33	36.85
2005	0.30	0.74	1.71	3.76	4.90	6.82	7.45	5.87	4.29	1.97	0.77	0.33	38.90
2006	0.50	0.55	1.76	4.06	5.12	6.79	7.31	5.73	3.73	1.79	0.80	0.44	38.59
2007	0.42	0.43	1.87	3.42	5.98	6.95	7.14	6.01	3.60	2.06	0.73	0.33	38.95
2008	0.35	0.58	1.41	3.07	4.64	6.27	6.37	6.18	3.76	1.83	0.70	0.24	35.39
2009	0.22	0.56	1.54	2.98	5.59	6.02	5.91	5.36	4.11	1.44	0.92	0.32	34.97
2010	0.38	0.62	2.43	4.05	5.74	5.44	6.74	5.96	3.16	2.25	0.83	0.34	37.94
Average	0.35	0.63	1.57	3.23	5.42	6.38	6.69	5.69	3.53	1.88	0.74	0.36	36.47
Max	0.60	1.00	2.43	4.34	6.56	7.61	8.21	6.36	4.29	2.28	1.13	0.52	39.83
Min	0.12	0.36	1.16	2.37	4.38	5.44	5.53	5.07	2.95	1.44	0.47	0.18	33.24

Knight Piésold CONSULTING

Table 7
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Copperwood Estimated Monthly Pond Evaporation (inches)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1977	0.25	0.65	0.89	1.83	3.57	4.21	4.53	3.96	2.04	1.28	0.52	0.21	23.93
1978	0.19	0.33	0.97	1.82	3.81	4.19	4.03	3.76	2.24	1.31	0.58	0.19	23.40
1979	0.09	0.23	0.85	1.85	2.97	4.07	4.48	3.60	2.33	1.04	0.45	0.29	22.27
1980	0.19	0.32	0.93	2.17	3.86	4.08	4.28	3.29	2.07	1.05	0.44	0.20	22.89
1981	0.31	0.46	1.12	2.16	3.53	3.89	4.39	3.60	2.22	1.12	0.65	0.24	23.71
1982	0.12	0.31	0.86	1.85	3.77	3.72	4.42	3.30	2.09	1.21	0.42	0.28	22.35
1983	0.28	0.45	0.87	1.70	3.11	4.47	4.72	3.99	2.23	1.17	0.45	0.11	23.55
1984	0.18	0.53	0.76	2.29	3.47	4.22	4.29	3.68	2.15	1.35	0.48	0.29	23.69
1985	0.20	0.27	1.08	2.28	3.59	3.89	4.39	3.36	2.17	1.30	0.34	0.13	22.99
1986	0.24	0.28	1.23	2.30	4.04	4.28	4.33	3.54	1.92	1.24	0.40	0.28	24.08
1987	0.27	0.58	1.26	2.82	3.82	4.56	4.44	3.53	2.43	1.05	0.55	0.28	25.60
1988	0.21	0.33	0.90	2.31	4.27	4.95	5.33	3.71	2.21	1.03	0.39	0.26	25.89
1989	0.35	0.31	0.75	1.97	3.67	3.88	4.67	3.60	2.58	1.48	0.37	0.13	23.75
1990	0.39	0.47	1.25	2.42	3.28	4.00	4.35	3.81	2.31	1.20	0.59	0.25	24.31
1991	0.18	0.50	1.05	2.34	3.75	4.50	3.95	3.85	2.07	1.12	0.42	0.27	24.01
1992	0.27	0.45	0.96	1.74	3.95	4.03	3.59	3.56	2.33	1.14	0.35	0.22	22.60
1993	0.25	0.38	1.08	1.66	3.26	3.75	3.74	3.59	2.03	1.23	0.42	0.22	21.61
1994	0.08	0.33	1.04	1.88	3.56	4.21	4.20	3.76	2.26	1.36	0.57	0.34	23.59
1995	0.21	0.36	1.04	1.54	3.30	4.46	4.31	3.94	2.29	1.15	0.31	0.20	23.11
1996	0.15	0.31	0.82	1.66	3.19	4.24	3.88	3.69	2.12	1.34	0.37	0.18	21.95
1997	0.18	0.39	0.93	2.06	2.85	4.57	4.14	3.48	2.32	1.39	0.40	0.29	22.99
1998	0.25	0.60	1.00	2.44	4.05	3.59	4.43	3.93	2.56	1.30	0.46	0.33	24.93
1999	0.24	0.54	1.15	2.28	3.58	3.97	4.30	3.51	2.37	1.15	0.66	0.30	24.05
2000	0.23	0.62	1.31	1.99	3.50	3.90	4.29	3.63	2.40	1.43	0.47	0.16	23.92
2001	0.31	0.26	0.99	2.17	3.56	4.19	4.61	3.84	2.19	1.29	0.73	0.29	24.44
2002	0.31	0.52	0.77	1.93	3.02	4.25	4.68	3.51	2.19	0.96	0.42	0.28	22.85
2003	0.21	0.25	0.91	2.02	3.57	4.19	4.24	3.81	2.44	1.23	0.44	0.29	23.62
2004	0.13	0.62	0.97	2.12	3.12	3.90	4.29	4.13	2.67	1.24	0.54	0.21	23.96
2005	0.19	0.48	1.11	2.44	3.18	4.44	4.84	3.81	2.79	1.28	0.50	0.22	25.28
2006	0.33	0.36	1.15	2.64	3.33	4.41	4.75	3.72	2.42	1.16	0.52	0.29	25.08
2007	0.28	0.28	1.22	2.22	3.89	4.52	4.64	3.91	2.34	1.34	0.47	0.21	25.32
2008	0.23	0.37	0.92	1.99	3.02	4.08	4.14	4.01	2.44	1.19	0.45	0.16	23.00
2009	0.14	0.36	1.00	1.93	3.64	3.91	3.84	3.48	2.67	0.94	0.60	0.21	22.73
2010	0.24	0.40	1.58	2.63	3.73	3.54	4.38	3.87	2.05	1.46	0.54	0.22	24.66
Average	0.23	0.41	1.02	2.10	3.52	4.15	4.35	3.70	2.29	1.22	0.48	0.24	23.71
Max	0.39	0.65	1.58	2.82	4.27	4.95	5.33	4.13	2.79	1.48	0.73	0.34	25.89
Min	0.08	0.23	0.75	1.54	2.85	3.54	3.59	3.29	1.92	0.94	0.31	0.11	21.61

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Table 8
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Copperwood Estimated Monthly Evaporation from Dry Tailings (inches)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1977	0.38	1.00	0.77	1.39	2.05	1.68	1.27	1.12	0.92	1.10	0.79	0.32	12.80
1978	0.29	0.50	1.49	2.31	2.58	2.30	2.98	1.79	1.32	1.30	0.65	0.30	17.82
1979	0.14	0.36	1.31	2.85	2.41	2.94	1.98	1.54	1.91	1.53	0.69	0.45	18.10
1980	0.30	0.50	1.43	2.46	1.82	2.07	3.05	2.27	3.06	1.24	0.68	0.30	19.17
1981	0.47	0.71	1.71	2.74	2.79	3.62	2.02	1.83	1.46	1.62	0.51	0.37	19.84
1982	0.18	0.47	1.32	2.58	3.10	1.67	2.53	1.98	1.74	1.67	0.65	0.42	18.33
1983	0.44	0.70	1.34	2.24	2.10	2.98	1.59	1.72	1.89	1.46	0.67	0.18	17.31
1984	0.27	0.82	1.18	2.54	2.54	2.35	1.43	1.96	1.91	1.34	0.70	0.44	17.47
1985	0.31	0.41	1.67	3.01	2.53	2.11	1.91	2.06	1.37	1.69	0.52	0.20	17.80
1986	0.36	0.42	1.90	2.43	1.61	1.48	2.62	2.77	1.84	1.40	0.61	0.43	17.88
1987	0.42	0.90	1.32	1.51	1.97	1.49	2.39	1.91	1.74	1.48	0.55	0.42	16.09
1988	0.32	0.51	1.39	2.57	1.86	1.53	1.43	2.95	1.64	1.25	0.60	0.39	16.45
1989	0.53	0.47	1.16	2.22	2.63	3.45	1.16	1.88	1.07	0.79	0.57	0.20	16.14
1990	0.60	0.72	1.92	2.52	1.59	3.02	1.87	0.78	1.59	1.78	0.68	0.38	17.44
1991	0.28	0.77	1.62	2.15	2.56	1.31	3.28	1.43	1.98	1.51	0.65	0.42	17.97
1992	0.42	0.70	1.48	1.88	1.81	1.42	2.34	1.72	1.93	1.14	0.54	0.34	15.72
1993	0.38	0.58	1.67	2.27	2.52	2.65	1.75	2.15	1.69	0.97	0.65	0.34	17.63
1994	0.12	0.51	1.61	1.97	2.34	2.24	2.32	1.69	1.88	1.25	0.60	0.52	17.04
1995	0.32	0.55	1.61	1.62	2.52	1.28	1.98	1.44	1.79	1.77	0.47	0.31	15.66
1996	0.24	0.48	1.26	2.55	2.21	2.79	2.96	1.62	1.51	1.43	0.56	0.28	17.90
1997	0.28	0.60	1.44	1.94	2.40	2.16	2.39	1.88	1.70	1.29	0.62	0.45	17.14
1998	0.39	0.92	1.53	1.61	1.39	2.62	1.87	2.13	1.59	1.51	0.71	0.46	16.72
1999	0.36	0.83	1.66	1.71	2.74	2.22	2.91	2.00	1.51	1.14	0.47	0.46	18.01
2000	0.36	0.95	2.01	2.06	1.72	2.55	1.57	1.55	1.10	0.73	0.58	0.24	15.43
2001	0.48	0.39	1.52	3.35	2.23	2.26	1.19	1.37	1.38	1.70	0.94	0.45	17.28
2002	0.48	0.80	1.19	2.87	1.95	2.35	1.69	1.84	1.70	1.48	0.65	0.43	17.42
2003	0.33	0.38	1.41	2.25	2.29	1.59	2.01	1.44	1.14	1.15	0.68	0.45	15.12
2004	0.20	0.96	1.49	1.91	2.20	1.99	1.70	1.69	1.02	1.39	0.70	0.33	15.57
2005	0.30	0.74	1.71	1.92	2.19	2.15	1.13	0.74	1.65	1.72	0.77	0.33	15.35
2006	0.50	0.55	1.76	1.43	2.47	1.88	1.91	1.54	0.97	1.31	0.80	0.44	15.58
2007	0.42	0.43	1.87	2.02	2.00	2.07	0.91	1.02	2.82	2.06	0.73	0.33	16.69
2008	0.35	0.58	1.41	3.07	2.05	1.84	2.24	1.10	1.70	1.15	0.67	0.24	16.38
2009	0.22	0.56	1.54	2.69	1.87	1.61	1.40	1.66	0.90	1.44	0.90	0.32	15.12
2010	0.38	0.62	2.10	1.04	2.05	2.30	1.46	1.71	2.04	0.81	0.69	0.34	15.53
Average	0.35	0.63	1.52	2.23	2.21	2.18	1.98	1.71	1.63	1.37	0.65	0.36	16.82
Max	0.60	1.00	2.10	3.35	3.10	3.62	3.28	2.95	3.06	2.06	0.94	0.52	19.84
Min	0.12	0.36	0.77	1.04	1.39	1.28	0.91	0.74	0.90	0.73	0.47	0.18	12.80

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Table 9
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Maximum 24-Hour Precipitation Values Used in Frequency Analysis (Partial Duration Series)
(inches)

January		February		March		April		May		June		July		August		September		October		November		December		Annual	
Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value	Year	Value
1996	1.64	1984	1.13	1996	2.83	1994	1.79	2008	1.72	1986	2.28	1987	2.84	1978	4.41	1983	2.61	2005	1.98	1991	2.15	1998	1.10	1978	4.41
1997	0.90	1999	0.76	1998	1.36	1984	1.70	2006	1.64	2006	1.94	1991	2.78	1980	3.33	1984	2.09	2002	1.92	1988	1.77	1987	1.08	1980	3.33
1980	0.88	1984	0.70	2005	1.36	2004	1.70	2002	1.56	1989	1.60	1992	2.66	1988	2.40	1985	2.08	1981	1.75	1982	1.70	2006	1.05	1987	2.84
1997	0.88	1996	0.70	2006	1.36	1996	1.64	1978	1.47	1979	1.58	1999	2.40	1994	2.40	2007	2.02	1982	1.70	1985	1.56	1982	0.99	1996	2.83
1982	0.87	2002	0.68	1979	1.33	2009	1.49	1991	1.39	1984	1.57	1980	2.15	2009	2.20	2010	2.00	1983	1.67	1991	1.44	1981	0.87	1991	2.78
1988	0.81	1983	0.62	1983	1.10	2001	1.42	1999	1.39	1990	1.53	1982	1.94	2007	1.95	1980	1.95	1979	1.63	2005	1.36	2004	0.87	1992	2.66
2009	0.79	2007	0.61	1979	1.08	1985	1.30	1993	1.36	1991	1.50	2002	1.84	2009	1.83	2007	1.81	1995	1.63	1987	1.32	2007	0.87	1983	2.61
1982	0.77	1981	0.60	1994	1.07	1982	1.24	1998	1.25	1998	1.48	1990	1.77	1998	1.59	1979	1.73	1990	1.54	1994	1.23	1982	0.85	1991	2.54
1980	0.76	2003	0.58	2000	1.06	1981	1.05	1987	1.24	1990	1.47	1986	1.67	2000	1.50	2008	1.70	1990	1.47	1999	1.07	1996	0.79	2003	2.49
1988	0.76	1995	0.53	1984	0.99	1981	1.04	2004	1.18	1993	1.47	2008	1.57	1988	1.45	1985	1.58	2007	1.45	1998	1.04	1977	0.71	1988	2.40
1989	0.76	2005	0.53	1998	0.88	1982	1.02	1982	1.13	1981	1.42	2003	1.53	1983	1.39	1995	1.50	1992	1.44	1985	0.98	1986	0.64	1995	2.40
1992	0.73	2001	0.51	1988	0.86	1996	1.02	1984	1.13	2007	1.42	2003	1.50	2002	1.39	2005	1.48	1981	1.42	1978	0.93	1984	0.62	1999	2.40
1981	0.68	2001	0.47	1986	0.85	2003	1.02	1982	1.10	1998	1.32	1986	1.41	1985	1.36	2009	1.48	1991	1.36	1996	0.85	1993	0.62	1986	2.28
1986	0.68	2004	0.47	1991	0.85	1995	0.88	1995	1.05	2000	1.30	1987	1.38	1996	1.36	1983	1.47	1995	1.30	2003	0.78	1985	0.60	2009	2.20
2008	0.63	1979	0.46	1984	0.79	2010	0.87	1978	1.04	1979	1.20	2008	1.38	2009	1.30	1985	1.41	1995	1.30	1987	0.77	1985	0.60	1980	2.15
2005	0.60	1996	0.45	1986	0.77	1983	0.84	1983	1.02	1993	1.18	1991	1.36	1982	1.28	1990	1.30	1993	1.24	2008	0.75	1996	0.60	1991	2.15
1985	0.57	1988	0.43	2002	0.77	2007	0.84	1993	1.02	1989	1.15	1988	1.32	1988	1.19	2007	1.27	2006	1.18	1992	0.73	1983	0.59	1984	2.09
1979	0.53	1981	0.42	1985	0.70	1985	0.81	1990	0.94	1996	1.10	2003	1.32	1996	1.13	2010	1.15	1985	1.16	1993	0.73	2009	0.59	1985	2.08
1980	0.51	1981	0.42	1997	0.68	1993	0.79	2001	0.94	1984	1.04	1982	1.31	2009	1.13	1979	1.07	1983	1.12	2010	0.73	1992	0.57	2007	2.02
1988	0.51	1989	0.40	1987	0.66	1986	0.76	1989	0.93	1981	1.02	2009	1.28	1997	1.12	2004	1.01	2002	1.04	1991	0.70	1997	0.57	2010	2.00
1995	0.51	1996	0.40	1998	0.64	2005	0.73	1979	0.90	1990	1.02	1978	1.27	1996	1.11	1992	0.98	1986	1.02	2003	0.68	1989	0.55	1981	1.98
1986	0.49	2000	0.40	1991	0.62	1999	0.72	1985	0.90	1996	0.97	1997	1.27	1985	1.10	1996	0.96	1988	1.02	2005	0.66	2003	0.55	2005	1.98
2007	0.49	2002	0.40	1981	0.61	2001	0.71	1983	0.88	2000	0.97	1983	1.22	1981	1.07	1987	0.88	2007	1.02	1977	0.64	1986	0.54	1980	1.95
1990	0.47	2003	0.40	1985	0.61	2003	0.70	1995	0.87	1995	0.96	2002	1.22	1978	1.05	1980	0.87	1982	1.01	1978	0.64	1998	0.54	2007	1.95
1978	0.46	1981	0.38	1990	0.60	1978	0.68	1984	0.86	1990	0.95	1999	1.15	1987	1.03	2001	0.87	2007	0.99	1993	0.63	2001	0.52	1982	1.94
2001	0.46	1992	0.38	2002	0.58	2009	0.68	1981	0.85	1989	0.94	1996	1.14	2000	1.02	1992	0.85	1980	0.96	1979	0.62	1988	0.51	2006	1.94
1982	0.45	2007	0.38	1989	0.57	2001	0.66	1978	0.78	2008	0.94	1991	1.11	1986	0.98	1980	0.82	1996	0.96	2010	0.62	1988	0.51	2002	1.92
2002	0.45	2004	0.37	1995	0.55	1980	0.64	2003	0.78	2005	0.93	1991	1.11	1986	0.96	1999	0.81	2009	0.96	1985	0.61	2000	0.51	2002	1.84
1994	0.44	2007	0.37	2000	0.54	1984	0.63	1980	0.77	1984	0.90	1987	1.04	1989	0.94	2007	0.81	1987	0.94	1994	0.60	1984	0.50	2009	1.83
1998	0.44	1990	0.36	1983	0.50	2008	0.63			2006	0.90	1978	1.03	1984	0.92	1981	0.80	1986	0.87	2000	0.60	1997	0.50	2002	1.81
2009	0.44	2002	0.36	1985	0.50	1993	0.62			1997	0.87	1981	1.02	1995	0.92	1998	0.80	1986	0.87	1983	0.59	1995	0.49	2005	1.81
1978	0.43	1992	0.35	2000	0.50	1999	0.62			1981	0.85	2004	1.02			2010	0.80	1986	0.85	1998	0.59	1998	0.49	2007	1.81
										1999	0.84	1980	0.97					1987	0.85	2001	0.57	1990	0.47		
																		2007	0.85	2004	0.57	1993	0.47		

Note: All values multiplied by 1.13 to adjust for fixed observational period

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Table 10
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Daily Precipitation Statistics by Month

Description	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1. Avg. non-zero precipitation (in)	0.15	0.14	0.20	0.25	0.30	0.28	0.33	0.33	0.29	0.27	0.20	0.17
2. Std. dev. non-zero precipitation	0.14	0.13	0.27	0.29	0.34	0.33	0.42	0.46	0.35	0.32	0.24	0.15
3. Skew non-zero precipitation	2.84	2.14	3.61	2.36	2.35	2.00	2.34	3.48	2.56	2.18	3.11	1.94
4. Average monthly precipitation (in)	2.80	1.59	1.75	2.25	2.98	3.03	3.28	3.01	3.24	3.45	2.66	3.02
5. Maximum daily precipitation (in)	1.45	1.00	2.50	1.60	2.25	2.02	2.51	3.90	2.31	1.75	1.90	0.97
6. Minimum daily precipitation (in)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7. Avg. days with precipitation	18.1	11.7	8.6	9.0	10.0	10.7	10.0	9.1	11.3	12.8	13.1	17.4
8. Total days of record	986	914	987	987	1023	988	1022	961	958	1054	1019	1049
9. Total days with precipitation	577	378	273	295	329	353	329	282	360	435	444	589
10. Total months of record	32	32	32	33	33	33	33	31	32	34	34	34

Notes:
1. Average daily precipitation for days when precipitation occurred during the period of record.
2. Standard deviation of daily precipitation for days when precipitation occurred during the period of record.
3. Skew of daily precipitation for days when precipitation occurred during the period of record.
4. Average monthly precipitation for period of record
5. Maximum daily precipitation during period of record
6. Minimum daily precipitation during period of record
7. Average number of days during month that had measurable precipitation
8. Total number of days in period of record
9. Total number of days in period of record with measurable precipitation

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Table 11
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Monthly and Annual Precipitation Values (inches) for Selected Durations and Return Periods

Duration/ Return Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2-yr/24-hr[1]	0.61	0.48	0.81	0.94	1.17	1.18	1.43	1.39	1.27	1.20	0.85	0.63	2.21
5-yr/24-hr[1]	0.86	0.65	1.27	1.33	1.63	1.52	1.96	2.17	1.77	1.53	1.27	0.82	2.76
10-yr/24-hr[1]	1.02	0.76	1.57	1.59	1.93	1.75	2.31	2.69	2.11	1.75	1.54	0.94	3.12
25-yr/24-hr[1]	1.22	0.89	1.94	1.92	2.32	2.04	2.74	3.34	2.53	2.03	1.89	1.10	3.57
50-yr/24-hr[1]	1.37	1.00	2.23	2.16	2.61	2.26	3.07	3.82	2.84	2.24	2.14	1.22	3.91
100-yr/24-hr[1]	1.52	1.10	2.51	2.40	2.89	2.47	3.39	4.30	3.16	2.45	2.40	1.34	4.25
72-hr/half-PMP[2]	5.81	4.21	9.60	9.18	11.05	9.44	12.96	16.44	12.08	9.37	9.18	5.12	16.25
72-hr/PMP[2]	11.62	8.41	19.19	18.35	22.10	18.89	25.92	32.88	24.16	18.74	18.35	10.25	32.50

Notes:

1. 24-hr value from Extreme Value Type I (Gumbel) distribution fit to Ontonogan Station data for years 1977 to 2010 using partial duration series.
2. Annual PMP values were estimated using NOAA Hydrometerological Report No. 51, *Probable Maximum Precipitation Estimates, United States East of the 105th Meridian (1978). Monthly PMP values were estimated by assuming that the ratio of the monthly PMP to the annual PMP is the same as the ratio of the monthly 24-hr 100-yr precipitation to the annual 24-hour 100-yr precipitation.*

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Table 12
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Maximum Daily Snow Depth (inches) at Copperwood (Ontonogan Station)

Year	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec
1977	--[1]	--	--	--	--	0	7	14
1978	25	26	25	7	0	0	12	22
1979	38	36	42	18	0	5	10	10
1980	25	26	25	8	0	0	6	18
1981	28	28	15	5	0	4	6	21
1982	35	35	26	12	0	6	10	16
1983	20	32	15	5	0	0	11	22
1984	24	24	23	7	7	1	2	13
1985	28	28	17	8	0	0	13	29
1986	32	34	35	2	0	0	8	12
1987	14	18	16	8	0	0	2	12
1988	25	28	31	9	0	0	10	20
1989	30	30	32	9	1	1	8	22
1990	21	21	14	2	1	1	3	12
1991	18	17	11	3	0	0	21	21
1992	25	27	24	4	0	1	8	15
1993	21	18	17	3	0	4	9	15
1994	23	25	11	8	0	0	8	4
1995	13	21	26	2	0	1	9	18
1996	31	33	33	28	2	2	7	22
1997	33	31	32	15	10	1	8	12
1998	20	18	7	0	0	0	2	17
1999	--	27	22	0	0	0	1	14
2000	24	23	7	1	0	0	11	26
2001	24	30	30	10	0	0	7	22
2002	18	18	24	12	0	2	12	11
2003	17	21	--	5	0	0	6	14
2004	27	27	18	0	0	0	4	15
2005	20	16	17	0	0	0	9	12
2006	12	15	15	0	0	9	3	8
2007	12	20	22	8	0	0	7	10
2008	19	23	20	18	0	0	4	17
2009	34	27	18	8	0	2	0	13
2010	15	20	18	0	0	0	4	11
Average	23.5	24.9	21.5	6.8	0.6	1.2	7.3	15.9

Notes:

1. Dashed entry signifies that no data was available.

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Table 13
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Maximum Daily Mean Air Temperature (°F) at Copperwood (Ontonogan Station)

Year	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec
1977	--(1)	--	--	--	--	57	60	39
1978	30	25	43	53	78	67	56	29
1979	24	34	47	55	68	60	48	39
1980	34	33	42	70	72	60	48	37
1981	44	49	49	59	70	59	55	35
1982	21	37	47	66	72	58	55	50
1983	34	44	46	53	64	65	51	27
1984	32	45	37	62	67	64	51	39
1985	28	39	48	68	75	62	48	28
1986	35	33	54	67	72	59	44	33
1987	35	37	58	77	73	61	58	36
1988	34	38	43	56	77	61	45	39
1989	39	30	54	60	70	68	44	24
1990	37	36	57	74	60	60	61	39
1991	35	46	48	65	78	64	46	37
1992	36	31	41	58	76	64	47	36
1993	39	31	45	51	74	59	40	40
1994	22	48	45	60	72	67	50	41
1995	35	34	56	44	67	73	41	35
1996	31	38	49	55	69	62	47	33
1997	34	36	44	58	64	71	48	40
1998	36	46	52	67	73	65	46	46
1999	--	38	59	51	70	58	59	39
2000	33	50	57	59	76	71	60	30
2001	35	28	41	71	67	62	60	44
2002	43	40	37	68	68	66	42	39
2003	39	32	--	67	66	68	46	43
2004	32	41	47	59	66	65	49	37
2005	29	40	55	66	68	75	50	36
2006	45	34	51	64	83	65	51	40
2007	38	36	59	68	78	71	50	36
2008	37	30	43	60	59	70	66	35
2009	24	44	50	59	69	59	50	36
2010	36	32	63	71	81	60	57	36
Average	33.9	37.4	49.0	61.8	71.0	64.0	50.9	36.9

Notes:

1. Dashed entry signifies that no data was available.

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Table 14
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Estimated Maximum Daily Snow Depth and Maximum Daily Mean Air Temperature at Copperwood for Selected Return Periods(1)

	Return Period (years)							
	2	**5**	**10**	**25**	**50**	**100**	**500**	**1,000**
Snow Depth (in)								
January	22	29	34	40	44	49	59	63
February	24	30	34	39	42	46	54	58
March	20	29	34	41	47	52	64	69
April	6	12	16	22	26	30	39	43
May	0	2	4	6	7	8	11	13
October	1	3	4	6	7	9	12	13
November	7	11	14	17	20	22	28	31
December	15	21	24	29	32	35	43	47
Air Temperature (^{o}F)								
January	33	39	43	48	51	55	63	67
February	36	43	47	53	57	60	70	74
March	48	55	59	65	69	73	83	87
April	61	68	73	79	84	89	99	104
May	70	76	80	84	88	91	99	103
October	63	68	71	75	78	81	88	91
November	50	56	61	66	70	74	83	87
December	36	41	45	49	53	56	63	67

Notes:
(1) Extreme Value Type I (Gumbel) distribution fit to data.

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Table 15
Orvana Resources U.S. Corporation
Copperwood Project
Tailings Disposal Facility and Ancillary Structures
Pre-Feasibility Study - Climatic Data Report

Monthly Rain-on-Snow Depths for the 100-yr/24-hr, 72-hr/PMP, and 72-hr/half-PMP Storm Events

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Snow Depth (in) - 10-yr(1)	34	34	34	16	4	0	0	0	0	4	14	24
Snow Water Depth (in)(2)	3.4	3.4	3.4	1.6	0.4	0	0	0	0	0.4	1.4	2.4
Air Temperature (°F) - 10-yr(3)	43	47	59	73	80	--	--	--	--	71	61	45
Daily Precipitation Rate (in/day)												
100-yr/24-hr storm	1.5	1.1	2.5	2.4	2.9	2.5	3.4	4.3	3.2	2.5	2.4	1.3
72-hr/half-PMP storm	5.8	4.2	9.6	9.2	11.1	9.4	13.0	16.4	12.1	9.4	9.2	5.1
72-hr/PMP storm	11.6	8.4	19.2	18.4	22.1	18.9	25.9	32.9	24.2	18.7	18.4	10.2
Snowmelt during Rain (in/day)(5)												
100-yr/24-hr storm	1.4	1.9	3.4(7)	1.6(7)	0.4(7)	--	--	--	--	0.4(7)	1.4(7)	1.7
72-hr/half-PMP storm	1.8	2.2	3.4(7)	1.6(7)	0.4(7)	--	--	--	--	0.4(7)	1.4(7)	2.0
72-hr/PMP storm	2.2	2.7	3.4(7)	1.6(7)	0.4(7)	--	--	--	--	0.4(7)	1.4(7)	2.4(7)
Rain on Snow (in/day)												
100-yr/24-hr storm	2.9	3.0	5.9	4.0	3.3	2.5(8)	3.4(8)	4.3(8)	3.2(8)	2.9	3.8	3.0
72-hr/half-PMP storm	7.6	6.4	13.0	10.8	11.5	9.4(8)	13.0(8)	16.4(8)	12.1(8)	9.8	10.6	7.1
72-hr/PMP storm	13.9	11.1	22.6	20.0	22.5	18.9(8)	25.9(8)	32.9(8)	24.2(8)	19.1	19.8	12.6

Notes:
(1) 10-yr/24-hr value from Extreme Value Type I (Gumbel) distribution fit to site data.
(2) Assumes 1 inch of water per 10 inches of snow.
(3) Maximum daily mean air temperature with 10-yr return period from Extreme Value Type I (Gumbel) distribution fit to site data
(4) 100-yr/24-hr value from Extreme Value Type I (Gumbel) distribution fit to site data.
(5) Assumes a constant wind velocity of 10 mph and a basin exposure constant of 1.0 (open areas). Rate is based on the USACE (1998) formula. Daily melt is limited to snow depth/10 inches of snow per inch of water.
(6) Estimated using NOAA Hydrometerological Report No. 51, *Probable Maximum Precipitation Estimates, United States East of the 105th Meridian* (1978).
(7) Limited by available snow on ground.
(8) Runoff due to rain only

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Appendix B

***Orvana Resources U.S. Corporation, Copperwood Project, Coleman Engineering Company 2011 Geotechnical Site Investigation*, prepared by Knight Piésold and Co., July, 2011**

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Orvana Resources U.S. Corporation
Copperwood Project
Coleman Engineering Company
2011 Site Investigation

July 29, 2011

prepared for:
Orvana Resources U.S. Corporation
10199 Lake Rd.
Ironwood, MI 49928
Telephone: (906) 364-7577
Facsimile: (906) 364-7579

prepared by:

Knight Piésold and Co.

1580 Lincoln Street, Suite 1000
Denver, Colorado 80203-1512 USA
Telephone: (303) 629-8788
Facsimile: (303) 629-8789
E-mail: *denver@knightpiesold.com*

KP Project No. DV101.00429.02

Rev. No.	Date	Description	Knight Piésold	Client
A-DRAFT	June 13, 2011	Issued for Review/Comment	Jeff Coffin/Jason Reiva	Bill Williams
A	July 29, 2011	Issued for TDF PFS Appendix	Tom Kerr	Bill Williams

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Orvana Resources U.S. Corporation
Copperwood Project
Coleman Engineering Company
2011 Site Investigation Report

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Orvana Resources U.S. Corporation
Copperwood Project
Coleman Engineering Company
2011 Site Investigation Report

Section 1.0 - Introduction

1.1 Project Description

Orvana Resources U.S. Corporation (Orvana) is planning to develop the Copperwood Project located at the western end of Michigan's Upper Peninsula, straddling Ironwood and Wakefield Townships in Gogebic County. The copper deposit and site are located approximately 10 miles north of Wakefield, Michigan, 1- to 2-miles southeast of Lake Superior, and 16 miles northeast of Ironwood, Michigan. The project area and site investigation details are shown on Figure 1.

Mining at the site currently considers both conventional drill-and-blast and underground room–and-pillar methods. The copper bearing ore will be delivered to a nearby plant to be crushed, milled, and processed by flotation methods to recover the copper. The waste tailings will be pumped as slurry to a disposal facility located to the southeast of the process plant. During the planned 14.25-year mine life, approximately 32.3 Million dry tons (Mt) of tailings will be deposited within the Tailings Disposal Facility (TDF).

1.2 Site Investigation Objectives

A geotechnical investigation of the area under and closely surrounding the TDF site was conducted in early 2011 as part of the project pre-feasibility study (PFS) to support the design of the TDF. The site investigation was completed by Coleman Engineering Company (Coleman) under the direction and partial supervision of Knight Piésold, while laboratory testing was primarily conducted by Coleman with some test conducted by Knight Piésold. In general, the work included: (1) gaining an understanding of the subsurface conditions (soil types, depths, and consistencies/densities, as well as the depth and condition of the underlying bedrock), (2) evaluating the in-situ soil and bedrock permeability, and (3) obtaining soil and rock samples for laboratory testing.

The geotechnical investigations completed to date includes the following:

- Excavation and sampling of 26 test pits
- Geotechnical drilling and sampling of 12 boreholes
- One-hundred fifty-nine Standard Penetration Tests (SPT)
- Shelby Tube (ST) sampling from 40 locations
- In-situ permeability testing at 18 locations within the glacial till and 6 locations within the bedrock
- Piezometer installation and monitoring
- Laboratory Testing

Test pit logs and test pit photographs are included in Appendices A and B, respectively. Boring logs, core box photographs, and in-situ permeability test logs comprise Appendices C, D, and E, respectively. Detailed geotechnical laboratory results are contained in Appendix F. Information related to previous site investigations conducted at the Copperwood site are provided in Appendix G.

1.3 Limitations and Disclaimer

This report titled *Coleman Engineering Company 2011 Site Investigation Report* has been prepared by Knight Piésold and Co. (Knight Piésold) for the exclusive use of Orvana. No other party is an intended beneficiary of this report or the information, opinions, and conclusions contained herein. Any use by any party other than Orvana of any of the information, opinions, or conclusions is the sole responsibility of said party. The use of this report shall be at the sole risk of the user regardless of any fault or negligence of Orvana or Knight Piésold.

The information and analyses contained herein have been completed to a level of detail commensurate with the objectives of the assignment and in light of the information made available to Knight Piésold at the time of preparation. This report and its supporting documentation have been reviewed and/or checked for conformance with industry-accepted norms and applicable government regulations. Calculations and computer simulations have been checked and verified for reasonableness, and the content of the report has been reviewed for completeness, accuracy, and appropriateness of conclusions. To the best of the information and belief of Knight Piésold, the information presented in this report is accurate to within the limitations specified herein.

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1.4 Contributors and Contacts

This report was prepared, reviewed, and approved by the undersigned.

Prepared by:

Jeffrey G. Coffin, Ph.D.
Project Engineer

Reviewed by:

Jason Reiva, P.E.
Senior Engineer

Approved by:

Thomas F Kerr, P.E.
President

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Section 2.0 - Site Description

2.1 Regional Geology

The Copperwood project site is located south of Lake Superior in the Upper Peninsula of Michigan, in the area of Ancestral Lake Superior. This area was once glaciated and has been established by glacial deposition and retreat, and more recently by fluxuations in the surface elevation of the lake. The area around the Copperwood project is relatively flat with a general ground sloping to the north toward the lake. Several streams and tributaries run through and around the potential TDF location.

2.2 Site Geology

The Copperwood TDF is located on the old lakebed of Lake Superior and has been formed by glacial deposition of materials as the glacier retreated and formed Lake Superior. Additional fluxuations of the lake surface elevation and exposed beach areas has interlaid numerous thin, non-continuous sandy layers within the overburden soil. The geologic units include the glacial till above bedrock which consists of the Copper Harbor Conglomerate and Nonesuch Shale formations.

2.2.1 Bedrock

Bedrock beneath the project site was examined in more than 100 borings (both environmental and exploration) advanced in 2008 and 2009 by AECOM; although these borings were conducted on a more widespread basis for the previously considered mine site slightly northwest of the currently proposed TDF location. A total of 11 additional borings, specific to the current TDF site, were completed as part of the 2011 geotechnical site investigation. The top of the bedrock surface is variable, reflecting the presence of transitional materials including boulders, likely dislodged and transported by glacial movement, and a zone of weathered bedrock at the surface. The bedrock generally slopes downward to the northwest in the same general direction as, but at a steeper slope than, the overlying ground surface. This typically results in larger depths of glacial overburden under the northern side of the TDF, and shallower depths under the southern side. Bedrock is exposed at the ground surface to the southeast of the proposed TDF site, and in localized areas within the Namebinag Creek. The Copperwood Project site is underlain by two bedrock formations, with the TDF founded above the Copper Harbor Conglomerate and the Nonesuch Shale overlying the Copper Harbor Conglomerate north of the TDF.

The Nonesuch Shale formation classifies as shale to siltstone with the later existing above the shale. The intersection between with Nonesuch Shale is sharp and irregular, and no Nonesuch Shale was found during this phase of exploration. The Copper Harbor Conglomerate formation consists of conglomerate and sandstone bedrock material.

2.2.2 Glacial Till Deposits

Summary information in this section is partially comprised of selected excepts from AECOM's preliminary draft document titled *Copperwood Project, Ironwood Township, Gogebic County, MI, Environmental Impact Assessment, Draft Summary Report(Draft Summary Report)*, prepared in November, 2009.

> (The glacial overburden consists) *primarily of a reddish-brown glacial till. The material was described in the field during the soil boring program as several variations of a silty clay. Slight variations in the observed portions of silt, clay, and sand, brought about descriptions ranging from silt, clay, silty clay, clayey silt, silty sand, and sandy silt. The till was found to contain trace (1-9%) to little (10-19%) to some (20-34%) amounts of sand and gravel.*

Gravel size particles in the till are predominantly comprised of dark, reddish-brown sandstone likely from the Freda Sandstone, a unit which overlies the Nonesuch Shale and was eroded by the glaciers in the vicinity of the site.

> (The glacial overburden) *was described as a massive matrix-supported diamicton. A diamicton is a descriptive term for poorly sorted deposits composed of gravel clasts within a finer-grained matrix, and is an important term in the description of glacial sediments. Based on the lack of structure observed within the material, a possible classification of the site glacial materials is a subglacial diamicton (Kemmis, 2008), meaning that it was deposited beneath the glacial ice.*

The section of site glacial overburden was generally described as "slightly coarser with depth, being more clay-rich at the surface and more silt-rich at depth." Specific to the current TDF location, the glacial till thickness was estimated to vary from approximately 20 to 120 ft across the site. While the thickness of the material may vary across the site, AECOM has suggested that it was found to be present and consistent over an area of several square miles surrounding the project.

> *Layers of coarser (non-cohesive) material were observed throughout the site in various borings. These soil types generally consisted of fine to medium sand with varying amounts of silt and clay. Granular deposits appear to be thin and isolated. No granular deposits thicker than 10 feet were observed at the site. In fact, the average thickness of the granular deposits is less than 1 to 3 feet thick. The cleanest (i.e. well sorted) sand layer within the glacial materials was observed at boring CW-08-12, at a depth between 62 and 72 feet below ground surface. These granular deposits, when encountered, do not appear laterally extensive, and for the most part, cannot be correlated between adjacent borings. These deposits are considered to be intra-till sands or subglacial meltwater deposits. Based on descriptions of the glacial section by Hack (1965), these coarser-grained deposits may represent lacustrine deposits deposited within lakes which existed between different glacial advances, but no clear evidence was observed to support a lacustrine origin of these layers.*

AECOM has also identified several shoreline features across the site, believed to have been formed by glacial Lake Duluth.

The site overburden has been compared to subglacial deposits that have elsewhere been described as "drumlinized and fluted glacial deposits" (after Peterson, et. al., 1986). These landforms are streamlined features that are typically formed in till by the movement of the overlying glacier (drumlin) and by processes including subglacial flow of meltwater (fluting). While drumlins and fluted landforms were not observed at the project site AECOM suggested that the fluted features may have been the cause of the distinct drainage patterns exhibited at the Copperwood site.

AECOM previously considered subdividing the site glacial deposits into three subunits, as has been done elsewhere in the region (Hack, 1965, reported in AECOM); AECOM also developed geologic cross-sections for the site that contain three subdivided till layers. However, more recently, in AECOM's memorandum titled *Glacial Overburden Material at Copperwood*, dated November 3, 2010, AECOM identified the upper till unit of Hack (1965) as most closely matching the entire site glacial section.

> *The upper unit is described as a clayey till that is much less stony than either of the lower units. This reference (which was identified by AECOM after the drilling program was completed), closely matches the glacial section described by AECOM geologists.*

The AECOM geologic cross-sections from 2009 are therefore not further used in this study. Also from AECOM's 2010 memorandum, it suggests a final conclusion that the overburden material at Copperwood is of sub-glacial till origin.

> *It is unlikely that the Copperwood material is a water-laid till (rain-out deposit or debris flow into glacial lake) because it lacks vague horizontal layering and multiple coarsening or fining sequences and it covers much larger areas than water-laid till.*

Significance of Sub-glacial Till

We (AECOM, 2010) *think that the sub-glacial till origin to be correct as well as an advantage for site permit approval because:*

- *Sub-glacial till is more uniform over larger areas and greater thicknesses than lacustrine deposits,*
- *Sub-glacial till is massive, lacking the bedding that lacustrine deposits have which lowers shear strength and increases bulk hydraulic conductivity,*
- *Sub-glacial till is overconsolidated, and hence denser, resulting in lower hydraulic conductivity, higher bearing capacity, and* greater shear strength.

It is noted that the extremely fine-grained and relatively well-sorted character of the subglacial till has led to confusion in the past. For example, a recent U.S. Geological Survey publication (Hoard and Westjohn, 2001) describes how a thick (>50 ft in thickness) layer of dense, clay-rich basal lodgment till (i.e., ground moraine) was previously mapped as lacustrine sediments on the State Quaternary geologic map (Farrand and Bell, 1982).

Section 3.0 - Field Investigations and In-Situ Testing

The geotechnical site investigation for the PFS was conducted between January and April of 2011. The investigation consisted of excavating 26 test pits and advancing 10 boreholes in the area of the TDF. Figure 1 presents the location of these investigations within the area of the TDF.

3.1 Previous Site Investigations

Previous site investigations were performed by Coleman around the Copperwood Project site and included a number of test pits and boreholes. The information pertaining to this information was provided to Knight Piésold as part of the PFS Request for Proposal (RFP). A total of eleven test pits and four boreholes from the previous investigation are located within the area of the 2011 geotechnical site investigation for the currently proposed TDF. The pertinent test pit and borehole logs, and laboratory test data sheets, from the previous site investigations are included in Appendix G.

3.2 2011 Test Pits

Test pits in the locations proposed by Knight Piésold were excavated by Coleman during February of 2011. The test pits were typically advanced to the maximum depths achievable by the excavator and varied between 10 and 17 feet (ft) in depth. The test pit soils were logged based on materials excavated from the test pit walls. Large disturbed samples and undisturbed block samples were collected, with select samples noted for laboratory testing. A summary of the test pits excavated in the area of the TDF as part of the 2011 site investigation is shown in Table 1. Detailed test pit logs are included in Appendix A, while photographs of the test pit are provided in Appendix B.

Upon completion of the sampling, the test pits were backfilled with excavated material and compacted with the excavator bucket. Each backfilled test pit was graded to match the original topography of the area.

3.3 2011 Boreholes

3.3.1 Rotosonic Drilling

Geotechnical and geological drilling at the locations proposed by Knight Piésold was conducted from January to April 2011 by Coleman to explore the overburden and bedrock materials underlying the proposed TDF. In-situ and laboratory testing was used to evaluate material properties as a basis for the TDF design. Boring depths ranged from 30.2 to 148.5 ft. Coleman utilized both Diedrich D-50 Truck-mounted and D120 ATV-mounted rigs with a variety of drilling techniques including the use of roller bits, NQ rock coring bits, solid stem auger bits, and drag bits. A summary of the 2011 borings completed for the Copperwood project is presented in Table 2.

SPT and ST sampling were completed in order to obtain representative soil samples and to provide a measure of soil consistency. Disturbed samples were recovered from the split-barrel sampler with a 2inch outer diameter. Undisturbed soil samples were recovered utilizing a lined 3 inch ST barrel. After recording sample recovery and classification data for the SPT samples, the samples were labeled, capped and sealed or bagged, and stored for shipment to the Coleman geotechnical laboratory for testing. A summary of SPT blow-count results is included in Table 3.

Rock samples were recovered from the borings utilizing a wireline system and placed in cardboard core boxes for protection during storage and shipping to the Coleman geotechnical laboratories. Detailed boring logs are shown in Appendix C, while photos of the rock core boxes and disturbed samples recovered from SPT testing are provided in Appendix D.

Upon completion, the boreholes were backfilled with grout to the original ground surface.

3.3.2 Packer Testing

Permeability testing was performed by Coleman under the direction of Knight Piésold. During the site investigation, in-situ Packer permeability testing was conducted in the bedrock layer of six boreholes using an inflatable down-hole packer system. Permeability measurements obtained are presented in Table 4. Detailed results from the in-situ Packer permeability testing are provided in Appendix E.

3.3.3 Falling Head Permeability Testing

Open standpipe piezometers were installed near six borehole locations and three standpipes were installed within each location to evaluate the permeability at various depth intervals in the overburden soils below the TDF. These were installed in parallel boreholes due to the drilling methods used not being conducive to installing piezometers in the initial boreholes. Detailed results from the falling head permeability tests are provided in Appendix E and summarized in Table 4.

Standpipe piezometers installed during the geotechnical investigation consisted of 1 inch (schedule 40) PVC pipe. The lower 24 inches of the piezometer were slotted with size 10 slots and prior to installation the lower ends of the piezometers were fitted with plastic end caps. Red flint well sand was placed as backfill from 1 ft below to 1 ft above the slotted screen. Bentonite pellets were used to seal the top and bottom of the interval to be tested and the pellets were hydrated during installation either by contact with water present in the borehole or by manual addition of water. The remainder of the borehole above the test interval was backfilled with a grout mixture.

Section 4.0 - Laboratory Testing

After the samples from the 2011 geotechnical investigation were received by the Coleman geotechnical laboratory, they were inventoried and specific testing was assigned. Index and moisture content testing were performed on disturbed samples obtained from select soil layers encountered in test pits and boreholes. Proctor compaction testing was completed on disturbed bulk samples from the test pits. Additionally permeability, consolidation, and triaxial testing was performed on select undisturbed samples from the test pits and boreholes. Index testing on potential sand borrow source materials provided by Orvana was performed at the Knight Piésold geotechnical laboratory in Denver, Colorado. Each test was conducted in accordance with the appropriate American Society for Testing and Materials (ASTM) standard as indicated in the following sections.

4.1 Previous Site Investigation Testing

Previous site investigations included sampling and testing from test pits and boreholes in the area of the currently proposed TDF. Index, natural moisture content, and moisture-density testing were performed to evaluate the mechanical properties of the in-situ materials. As was typically done with samples from the 2011 site investigation, the testing was performed by Coleman under the standards and procedures outlined in the following sections. Details of the laboratory testing from the previous site investigations are provided in Appendices G-4 through G-6.

4.2 2011 Index Testing

Sieve and hydrometer analyses (ASTM D422) were conducted on a total of 44 samples collected from the test pits and boreholes and three samples from local rock quarries, of which 28 of the samples were also tested to determine Atterberg limits (ASTM D 4318). These index tests were used to classify the soils according to the Unified Soil Classification System (USCS) (ASTM D 2487), which is commonly used to group soils that exhibit similar engineering properties and behavior. Details of the index tests from the 2011 site investigation are contained in Appendices F-1 and F-2.

4.3 2011 Natural Moisture Content Testing

Natural moisture contents (ASTM D 2216) were determined for 56 samples obtained from the test pits and 65 samples obtained from the boreholes. Details of the moisture content tests from the 2011 site investigation are contained in Appendix F-3.

4.4 2011 Specific Gravity

Specific gravity (ASTM D 854) was measured for three samples from the boreholes, four samples from the test pits, and three samples from the potential gravel borrow sources. Likewise, three samples from potential sand borrow sources were measured for specific gravity. Details of the specific gravity tests from the 2011 site investigation are contained in Appendix F-4.

4.5 2011 Moisture-Density Testing

Standard and Modified Proctor Testing (ASTM D 698 and D 1557, respectively) was performed to evaluate the Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) of 21 samples obtained from the test pits. These samples were tested to evaluate borrow material sources for embankment construction. Both tests were performed to estimate the effect of different compaction efforts which may be anticipated in the field with typical construction equipment. Details of the moisture-density tests from the 2011 site investigation are provided in Appendix F-5.

4.6 2011 Permeability Testing

Flexible wall, constant head permeability testing (ASTM D 2434) was performed on one undisturbed sample from the boreholes and two undisturbed samples from the test pits. The materials were tested under stresses which will give an indication of the foundation materials' saturated hydraulic conductivity as it is subjected to loading in the field. It should be noted two additional tests were scheduled to be performed on different, granular material types from the boreholes; however, due to the granular nature of these samples, preparation within the membrane was difficult and the testing was not completed. Details of the permeability tests from the 2011 site investigation are provided in Appendix F-6.

4.7 2011 Compressibility Testing

Oedometer testing (ASTM D 2435) was performed on five undisturbed samples from the test pits. The materials were tested under various effective stresses per testing protocol. This variability will better estimate the consolidation characteristics as the materials are subjected to different loads over time in the field. Details of the Oedometer tests from the 2011 site investigation are provided in Appendix F-7.

4.8 2011 Shear Strength Testing

Unconsolidated, undrained (UU) triaxial; isotropically consolidated undrained (ICU) triaxial; and direct shear testing (ASTM D 2850, D 4767, and D 6528, respectively) were performed on undisturbed samples from the boreholes. Nine UU tests, three ICU test, and three direct shear tests were performed to assess the shear strength of the foundation materials. Pore pressure measurements were not taken during the UU testing, and only total stress shear strength parameters were able to be developed. Measurements were taken during the ICU testing to monitor the generation of pore pressure during shearing in order to evaluate the effective shear strength parameters. The direct shear testing will be used to assess the undrained shear strength of the foundation and embankment borrow material as well. Details of the shear strength testing from the 2011 site investigation are provided in Appendix F-8.

Section 5.0 - Subsurface Conditions

The following sections discuss the design considerations for the Copperwood TDF as they relate to the geologic and geotechnical conditions of the site.

5.1 Design Considerations

5.1.1 Embankment Foundations

The current design concept is to found the TDF embankment on the glacial till deposit. These materials will need to provide adequate support for the embankment and are expected to have limited compression causing differential settlement of these footprints. The thickness of this material gradually increases from the southern embankment to the north from roughly 20 to 120 ft.

5.1.2 Foundation Preparation

Foundation preparation in the dam footprint bottom will primarily involve removal of topsoil and organics to expose the glacial tills. Dewatering and water diversion may be needed to permit construction to be accomplished in a dry condition.

5.1.3 Basin Preparation

Material from within the basin will be excavated to produce borrow material for embankment construction during early stages of the project life. The topsoil and organics from this area will be disposed of accordingly. It is likely that dewatering will be necessary for the excavation currently expected within the tailings basin area.

5.2 Subsurface Conditions

5.2.1 Test Pit Investigation

A total of 26 test pits were advanced in the area of the Copperwood TDF as shown on Figure 1. Soils encountered in the test pits predominantly consisted of a thin layer of topsoil and organic matter overlying stiff, lean clay (CL). Some test pitting and sampling was performed in areas thought to have suitable borrow material for the drainage aggregate to be used in the chimney and blanket drains. This material generally classified as silty sand (SM). However, it is assumed that there will be insufficient free draining material onsite to be used for the drainage aggregate. Bedrock was not encountered in the test pits indicating that depth to bedrock in these areas is deeper than the extent of the excavators reach. The eleven test pits performed during previous site investigations produced similar information in classifying the subsurface materials.

5.2.2 Geotechnical Drilling

A total of eleven borings were drilled in the area of the Copperwood TDF during the 2011 site investigation. A twelfth borehole was proposed in the southeast corner of the proposed site; however, this borehole was abandoned due to poor access for the drill rigs. Soils encountered during drilling consisted predominantly of the glacial till deposit. This extensive glacial till deposit consisted of dense, stiff lean clays (CL). Interbedded within this deposit were few, thin layers of silty sand (SM) with trace gravel. These layers were typically on the order of 1- to 2-ft thick and were only observed in a few boreholes. All ten of these boreholes were extended to the bedrock horizon with eight of these advanced into competent bedrock described as Copper Harbor Conglomerate which ranged in depth between roughly 20 and 130 ft. The four boreholes from the previous site investigations show very similar subsurface conditions with a depth to bedrock ranging from 48 to 121 ft. It should be noted that two of these boreholes were extended to bedrock described as Copper Harbor Conglomerate at a depths of 48 and 96 ft. The other two holes were extended to bedrock described as Nonesuch Shale at depths of 118

and 121 ft. One of these holes was advanced to a depth of over 300 ft, intersecting the Nonesuch Shale - Copper Harbor Conglomerate horizon at a depth of 293 ft. Both of the boreholes intersecting the Nonesuch Shale were drilled just north of the current boring investigation.

SPT and ST testing and sampling within the glacial till provided fairly uniform results throughout the TDF area. SPT values at the surface of showed N-values generally around 5. These were shown to increase with depth until refusal was measured near the bottom of the borehole. It should be noted that these values increased more quickly at shallower depths for boreholes BH-11 and BH-12, where bedrock was encountered at roughly 20 ft. N-values at depths between 10 and 60 ft were generally on the order of 20. N-value is defined as the summation of the blow counts required to drive the SPT sampler through the second (6 to 12 inches) and third (12 to 18 inches) test intervals. Refusal is considered when blow counts exceed a value of 50 without the completion of a given interval. No in-situ strength testing data was available from the previous site investigations. Results of the SPT testing are shown on Table 3.

In-situ permeability testing was completed within the glacial till and bedrock, using falling head tests performed in open standpipe piezometers and packer testing, respectively. Measured permeability values ranged from 9.8e-8 to 3.5e-9 cm/s, with an average value of 1.9e-8 cm/s. Within this bedrock, measured permeability values ranged from 4.9E-6 to 1.5e-7 cm/s, with an average value of 2.0e-6 cm/s. No in-situ permeability testing data was available from the previous site investigations. Results of the in-situ permeability testing are shown on Table 4.

Section 6.0 - Material Characteristics

The following section provides a discussion of the engineering properties of the glacial till which will remain within the foundation of the dam and will also be used as a construction material for the embankment structural zones. Engineering properties of samples obtained from the potential sand and gravel borrow sources will also be discussed to the extent that they were subjected to testing.

6.1 Classification

Samples collected from the test pits and boreholes were predominantly obtained from the glacial till deposits. These samples classify mainly as a lean clay with some sand and/or trace gravel (CL) according to the USCS. Several samples were collected in potential borrow areas and from interbedded sand seems within the glacial till strata. These materials classified as generally silty sand with some gravel (SM). A summary of the laboratory index testing of the samples is included in Table 5. This is consistent with previous site investigations.

The three potential gravel and drainage aggregate sources classified as a poorly-graded sand (SP) according to the USCS. These materials were generally uniformly graded with some gravel and fines.

6.2 Natural Moisture Content

Samples tested from the glacial till deposit ranged in natural moisture content from 3.6 to 30.7 percent. However, they were generally between 10.0 and 15.0 percent natural moisture content, with an average of 13.3 percent. A summary of the natural moisture content testing of the samples is included in Table 6.

6.3 Specific Gravity

Several samples from the glacial till were tested to estimate the specific gravity of the soil solids. These tests estimated the specific gravity of the soils to range between 2.63 and 2.67 with an average of 2.64. A summary of the specific gravity testing of the samples is included in Table 7.

The three potential sand aggregate sources were evaluated to have a specific gravity of ranging from 2.68 to 2.73, with an average 2.7.

6.4 Proctor Compaction

Standard and Modified Proctor testing was performed to evaluate the MDD and the OMC of the glacial till materials. Based on the testing, the MDD was evaluated at an average of 120.9 and 133.4 pounds per cubic foot (pcf) with an average OMC of 12.5 and 8.8 percent, for the Modified and Standard Proctor tests, respectively. Results of the compaction testing are shown on Table 8. It should be noted that the OMC is below the average natural moisture content which means that the construction materials will either need to be dried or placed at wet of optimum.

6.5 Permeability

Permeability testing was performed under a single, 55 pounds per square inch (psi), confining stress to understand the saturated hydraulic conductivity of the glacial till material under a static load. The glacial till was tested from undisturbed Shelby Tube samples from the boreholes and undisturbed block samples, which were subsequently trimmed, from the test pits. In general, the permeability of the foundation material was low, ranging from approximately 2.5e-8 and 5.9e-9 centimeters per second (cm/s). Two other permeability tests were proposed; however, due to the granular nature of these other samples, placing them within the membrane proved difficult. Results for the laboratory permeability testing can be seen in Table 8. It should be noted that these values are consistent with the falling head tests performed

in-situ within the installed open standpipe piezometers. The results of the in-situ testing can be seen in Table 4.

6.6 Compressibility

Compressibility of the foundation materials were evaluated in Oedometer tests on undisturbed block samples from the test pits. These tests were performed to estimate the compressibility characteristics of the materials under loads which are to be expected due to the construction of the TDF embankments. The material properties of interest include the coefficient of compressibility (a_v), coefficient of volume compressibility (m_v), coefficient of consolidation (c_v), hydraulic conductivity (k) and compression index (Cc). These parameters are a function of the stresses applied or the entire stress range for the whole test, considering the compression index, and a summary of the testing results are is shown on Table 10. It should be noted that the hydraulic conductivity is determined as the ratio of and is not a direct measurement from the testing procedure. The calculated hydraulic conductivity values are consistent with both the in-situ permeability testing of the glacial till as well as the flexible wall permeability testing results. From this testing, it was also observed that the over-consolidation ratio (OCR) ranged from 1.7 to 2.4, with an average of 2.0. This is consistent with a slightly over-consolidated material. It should be noted that these values were estimated through reconstructed void ratio vs. effective stress plots, and should be used as a first order estimate of the OCR.

6.7 Shear Strength

Shear strength of the fill and foundation materials were evaluated in triaxial tests under unconsolidated, undrained and isotropically consolidated undrained conditions. Direct shear testing was also conducted to evaluate the shear strength of these materials. Interpretations of the Mohr-Coulomb failure envelopes for the different tests are shown in Appendix F-8. From these interpretations shear strength parameters were estimated.

For the unconsolidated, undrained tests, no pore pressure readings were taken. Therefore, results from these tests are presented as the undrained (total stress) friction angle (φ_u) and the undrained (total stress) cohesion (c_u). The undisturbed samples from the test pits, block samples, and boreholes, ST samples, showed an undrained shear strength which ranged between 0.75 and 3 tsf. Generally, the undrained strength parameters could be bounded into three subsurface layers. The top 5 ft is assumed to be desiccated and has an undrained shear strength of approximately 1.6 tsf. From 5 to 35 ft, the material is generally moister, less stiff, and has an undrained shear strength of approximately 1.25 tsf. Below this, the material becomes increasingly stiff and a shear strength value of 1.6 tsf was estimated from the testing for modeling purposes. It should be noted that all nine of these tests were performed on samples which classify as lean clay (CL). A summary of the unconsolidated, undrained testing results can be seen on Table 11.

During the isotropically consolidated, undrained tests, pore pressure readings were taken. Therefore, results from these tests are presented as both the undrained (total stress) and drained (effective stress) friction angle and cohesion. Two material types were tested, lean clay (CL), representative of a majority of the overburden material, and silty sand (SM), representative of the pockets of this material throughout the overburden soil mass. The lean clay produced average undrained strength parameters of 13.5 degrees and 0.73 tsf, for the friction angle and cohesion, respectively. The average drained friction angle was estimated to be 25.6 degrees. The silty sand is estimated to have undrained strength parameters of 36 degrees and 2.5 tsf; with drained strength parameters of 37 degrees and 0 tsf, considering the friction angle and cohesion, respectively. It should be noted that it is Knight Piésold's opinion that these tests were run too quickly; meaning the rate of compression was too high. This may lead to generated pore pressures developing along the shear plane that do not equilibrate throughout the sample and are, therefore, not observed in the pore pressure readings. This may lead to lower effective strength parameters being estimated than may be representative of the material. A summary of the isotropically consolidated, undrained testing results can be seen on Table 11.

Direct shear tests were performed on three samples which all classified as lean clay (CL). These tests were performed in the undrained condition as is expected for such tests. The average undrained shear strength parameters were estimated to be 25.4 degrees and 0.27 tsf, considering the friction angle and cohesion, respectively. A summary of the direct shear testing results can be seen on Table 11.

Section 7.0 - Recommendations

A significant amount of data has been collected during the 2011 Copperwood Project geotechnical investigation. This information will be used to facilitate characterization of the geotechnical conditions of the TDF foundation. However, additional information should be collected during subsequent design phases such that detailed level designs can be completed. The following investigations are recommended with respect to the investigations needed to complete the detailed design of the Copperwood TDF.

- Mapping and evaluation of sand seams throughout the foundation. It is understood that these seams are thin, 1- to 2 ft in thickness, and it is assumed that they are non-continuous. However, this will need to be assessed in future studies to better establish potential ground water flow pathways and conditions.
- Excavation of test pits away from the TDF site to evaluate potential borrow sources. This will include identifying sources for drainage aggregate, shell material, and core material. Although some of this fill will come from excavation within the TDF basin, additional materials, included dedicated drainage aggregate sources, will need to be identified.
- Laboratory Testing on the following materials:
  - Glacial till to be used for construction of the core and shells. This should include permeability and shear strength testing of remolded samples compacted to 95 percent of the MDD.
  - Drainage aggregate to be used for construction of the embankment drain and the underdrain system within the TDF basin. This should include permeability and shear strength testing of remolded samples.
- A full geologic study including mapping and interpretation.
- Monitoring of water levels in the installed piezometers such that groundwater information can be obtained for design and construction planning purposes.
- Perform additional ICU triaxial tests at a lower compression rate to confirm material properties or more accurately estimate the pore pressure generation within the sample during shearing.

Section 8.0 - Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
cm/s	centimeters per second
ICU	isotropically consolidated undrained
Knight Piésold	Knight Piésold and Co.
MDD	maximum dry density
OCR	over-consolidation ratio
OMC	optimum moisture content
Orvana	Orvana Resources U.S. Corporation
pcf	pounds per cubic foot
psi	per square inch
RFP	Request for Proposal
SPT	Standard Penetration Testing
ST	Shelby Tube
TDF	Tailings Disposal Facility
USCS	Unified Soil Classification System
UU	unconsolidated, undrained

Tables

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Table 1
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Test Pit Summary

Test Pit Designation	Northing[1] (ft)	Easting[1] (ft)	Surface Elevation[2] (ft)	Date Excavated	Depth (ft)
TP-01	699,668	25,502,520	888	2/15/11	16.0
TP-02	698,618	25,503,201	927	2/15/11	17.0
TP-03	698,153	25,502,436	939	2/9/11	17.0
TP-04	698,748	25,501,225	914	2/15/11	16.0
TP-05	699,548	25,501,198	886	2/8/11	17.0
TP-06	700,603	25,501,227	869	2/7/11	17.0
TP-07	702,040	25,501,100	849	2/9/11	17.0
TP-08	702,103	25,499,307	824	2/9/11	16.0
TP-09	699,196	25,499,328	886	2/9/11	17.0
TP-10	698,107	25,498,677	936	2/15/11	17.0
TP-11	699,108	25,498,019	884	2/9/11	17.0
TP-12	699,596	25,497,337	869	2/9/11	17.0
TP-13	698,594	25,500,292	913	2/25/11	10.0
TP-14	701,101	25,498,683	836	2/22/11	15.0
TP-15	701,148	25,499,899	849	2/22/11	15.0
TP-16	700,678	25,497,468	839	2/22/11	15.0
TP-17	700,653	25,498,681	845	2/22/11	15.0
TP-18	700,598	25,500,614	865	2/22/11	15.0
TP-19	700,073	25,497,299	855	2/22/11	16.0
TP-20	700,087	25,497,958	857	2/22/11	16.0
TP-21	700,117	25,498,670	859	2/22/11	15.0
TP-22	700,140	25,499,412	863	2/22/11	15.0
TP-23	699,618	25,498,705	875	2/22/11	15.0
TP-24	699,592	25,499,288	877	2/22/11	16.0
TP-25	698,608	25,499,027	904	2/22/11	10.0
TP-26	698,569	25,499,770	915	2/22/11	10.0

Notes:
[1] Coordinates are in International Feet, State Plane/Michigan North Zone, NAD83.
[2] Elevations are in International Feet, NAVD88, and were derived using GEOID03.

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Table 2
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Borehole Summary

Borehole Designation	Northing[1] (ft)	Easting[1] (ft)	Surface Elevation[2]	Drilling Completion		Number of Tests Performed			Drilling Summary		
				Start Date	End Date	SPT[3]	ST[4]	Packer	Soil (ft)	Rock (ft)	Total (ft)
BH-01	699,716	25,502,906	887	1/11/11	1/18/11	14	6	0	96.8	20.6	117.4
BH-02	699,102	25,503,181	905	3/14/11	3/17/11	12	6	1	86.0	31.4	117.4
BH-04	698,062	25,500,739	936	1/24/11	1/26/11	7	2	0	45.0	21.3	66.3
BH-05	698,602	25,500,587	918	1/25/11	1/26/11	10	3	0	62.1	-	62.1
BH-06	699,666	25,500,573	882	1/18/11	1/18/11	10	6	0	82.4	-	82.4
BH-07	701,115	25,499,121	843	2/17/11	3/11/11	12	6	1	134.0	14.5	148.5
BH-08	701,133	25,497,865	825	2/11/11	3/3/11	13	7	1	117.0	22.5	139.5
BH-09	701,106	25,496,738	821	2/4/11	2/4/11	14	3	0	93.0	-	93.0
BH-10	699,634	25,497,979	870	2/3/11	2/3/11	12	3	1	106.0	18.5	124.5
BH-11	698,603	25,498,027	902	1/27/11	2/1/11	3	0	1	10.5	20.6	31.1
BH-12	698,094	25,497,988	944	1/27/11	1/28/11	3	0	1	9.6	20.6	30.2

Notes:
[1] Coordinates are in International Feet, State Plane/Michigan North Zone, NAD83.
[2] Elevations are in International Feet, NAVD88, and were derived using GEOID03.
[3] SPT is an acronym for Standard Penetration Test. See ASTM D 1586 for details of test equipment and procedures.
[4] "ST" has been used in the geotechnical investigation to abbreviate "Shelby Tube" sampling.

Table 3
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

SPT Test Summary

Boring Designation	Test Interval		Test Summary				Material Type
			Blow Count/6 in Intervals			N-Value[1]	
	From (ft)	To (ft)	0 - 6 in	6 - 12 in	12 - 18 in		
BH-01	0.0	1.5	1	1	3	4	Silty Sand (SM)
	4.5	6.0	14	12	13	25	Silty Sand (SM)
	10.0	11.5	8	17	22	39	Sand (SM)
	20.3	21.8	4	6	9	15	Fat Clay (CH)
	30.3	31.8	5	7	10	17	Fat Clay (CH)
	40.3	41.8	14	24	32	56	Clay (CL)
	45.3	46.8	20	14	16	30	Clay (CL)
	50.3	51.8	6	9	13	22	Clay (CL)
	60.3	61.8	19	16	32	48	Clay (CL)
	70.3	71.8	16	22	28	50	Sandy Clay (CL)
	75.4	76.9	41	66	85	151	Clay (CL)
	80.3	81.8	37	57	56	113	Clay (CL)
	85.3	86.8	27	63	43	106	Clay with some fine Gravel (CL)
	90.3	91.8	80	90	105	195	Clay with some fine Gravel (CL)
BH-02	0.0	1.5	8	4	3	7	Peat (PT) and Lean Clay (CL)
	5.0	6.5	woh[2]	1	2	3	Lean Clay (CL)
	21.2	22.7	7	9	10	19	Lean Clay (CL)
	30.2	31.7	10	11	10	21	Lean Clay with trace fine Gravel (CL)
	40.2	41.7	6	7	9	16	Lean Clay (CL)
	50.2	51.7	17	16	19	35	Lean Clay (CL)
	55.2	56.7	37	22	25	47	Lean Clay (CL)
	60.2	61.7	24	27	31	58	Sand (SM)
	65.2	66.7	35	29	39	68	Lean Clay (CL)
	71.2	73.7	17	34	48	82	Lean Clay (CL)
	79.6	81.0	44	50	50/0.4[3]	Ref[4]	Lean Clay (CL)
	84.5	84.7	50/0.2	-	-	Ref	Cobbles and Boulders
BH-04	0.0	1.5	2	4	5	9	Silty Sand (SM)
	4.5	6.0	6	11	14	25	Clay (CL)
	15.0	16.5	9	16	26	42	Clay (CL)
	25.0	26.5	35	57	50	107	Clay (CL)
	30.0	31.5	35	40	41	81	Silty Sand (SM)
	35.0	36.2	36	106	80/0.2	Ref	Silty Sand (SM)
	45.0	45.2	100/0.2	-	-	Ref	Weathered Bedrock
BH-05	0.0	1.5	21	12	12	24	Clay (CL)
	5.0	6.5	5	7	9	16	Clay (CL)
	10.0	11.5	5	7	8	15	Clay (CL)
	22.0	23.5	4	6	8	14	Clay (CL)
	32.0	33.5	12	13	16	29	Clay with some Sand (CL)
	42.0	43.5	9	14	18	32	Clay (CL)
	47.0	48.5	8	10	14	24	Clay (CL)
	52.0	53.4	71	108	50/0.4	Ref	Clay (CL)
	57.0	58.2	47	101	50/0.2	Ref	Clay (CL)
	62.0	62.1	100/0.1	-	-	Ref	Clay (CL)
BH-06	0.0	1.5	1	3	6	9	Silty Sand (SM)
	5.0	6.5	7	9	13	22	Clay (CL)
	16.2	17.7	6	6	8	14	Clay (CL)
	26.2	27.7	6	7	12	19	Clay with some Sand (CL)
	37.2	38.7	4	7	13	20	Clay with some Sand and Gravel (CL)
	47.2	48.7	9	17	20	37	Clay with some Sand (CL)
	57.2	58.7	9	11	17	28	Clay (CL)
	64.3	65.9	30	29	41	70	Clay (CL)
	70.9	72.4	48	89	141	230	Sandy Clay (CL)
	80.9	82.4	53	77	70	147	Clay (CL)
BH-07	0.0	1.5	3	3	5	8	Lean Clay (CL)
	2.5	4.0	6	7	10	17	Lean Clay (CL)
	5.0	6.5	6	11	17	28	Lean Clay with trace fine Gravel (CL)
	7.5	9.0	6	7	11	18	Lean Clay (CL)
	10.0	11.5	7	9	14	23	Lean Clay (CL)
	20.0	21.5	4	6	14	20	Lean Clay (CL)
	25.0	26.5	5	7	10	17	Lean Clay (CL)
	40.0	41.5	4	5	7	12	Lean Clay (CL)
	50.0	51.5	17	25	38	63	Lean Clay (CL)
	55.0	56.4	14	39	50/0.4	Ref	Lean Clay (CL)
	60.0	61.5	14	22	39	61	Lean Clay (CL)
	92.0	92.5	50	-	-	Ref	Silty Sand (SM)
BH-08	0.0	1.5	11	8	6	14	Lean Clay (CL)
	5.0	6.5	6	6	10	16	Lean Clay (CL)
	54.6	56.1	4	4	8	12	Lean Clay (CL)
	34.6	36.1	7	12	15	27	Lean Clay (CL)
	44.6	46.1	8	12	16	28	Lean Clay (CL)
	49.6	51.1	9	14	16	30	Lean Clay (CL)
	54.6	56.1	32	40	45	85	Lean Clay (CL)
	56.9	61.1	7	12	14	26	Lean Clay (CL)
	64.6	66.1	12	13	16	29	Lean Clay (CL)
	69.6	71.1	22	24	18	42	Lean Clay with Silt (CL)
	79.6	81.0	65	62	50/0.4	Ref	Sand (SM)
	84.6	86.1	24	32	33	65	Lean Clay (CL)
	109.0	110.4	31	106	100/0.4	Ref	Sand (SM)

Table 3
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

SPT Test Summary

Boring Designation	Test Interval		Test Summary				Material Type
			Blow Count/6 in Intervals			N-Value[1]	
	From (ft)	To (ft)	0 - 6 in	6 - 12 in	12 - 18 in		
BH-09	0.0	1.5	4	3	4	7	Lean Clay (CL)
	4.0	5.5	5	7	11	18	Lean Clay with trace fine Sand (CL)
	16.5	18.0	4	5	8	13	Lean Clay (CL)
	31.5	33.0	6	8	14	22	Lean Clay with trace fine Sand (CL)
	36.5	38.0	15	16	23	39	Lean Clay with some fine Sand (CL)
	41.5	43.0	15	16	21	37	Lean Clay (CL)
	46.5	48.0	18	20	25	45	Lean Clay (CL)
	51.5	53.0	17	21	27	48	Lean Clay (CL)
	56.5	58.0	21	32	34	66	Lean Clay (CL)
	61.5	63.0	15	21	27	48	Lean Clay (CL)
	66.5	68.0	14	31	34	65	Lean Clay (CL)
	71.5	71.8	50/0.3	-	-	Ref	Lean Clay (CL)
	81.5	82.8	36	47	50/0.3	Ref	Lean Clay with fine Sand (CL)
	91.5	92.3	36	47	50/0.3	47	Lean Clay (CL)
BH-10	0.0	1.5	12	17	17	34	Clay (CL)
	4.5	6.0	12	18	38	56	Clay (CL)
	9.5	11.0	7	9	14	23	Clay with trace Silt (CL)
	19.5	21.0	10	15	25	40	Clay (CL)
	30.0	31.5	7	11	18	29	Clay (CL)
	40.0	41.5	12	17	25	42	Clay (CL)
	45.0	46.5	11	25	37	62	Clay (CL)
	50.0	51.5	18	38	38	76	Clay with some Gravel (CL)
	55.0	56.5	41	52	58	110	Clay with some Sand (CL)
	65.0	65.8	80	80/0.3	-	Ref	Lean Clay (CL)
	70.0	70.9	88	100/0.4	-	Ref	Lean Clay (CL)
	100.0	101.5	29	52	70	122	Lean Clay (CL)
BH-11	0.0	1.5	1	1	3	4	Silty Sand (SM)
	5.0	6.5	22	32	37	69	Silty Sand (SM)
	10.0	10.4	50/0.4	-	-	Ref	Silty Sand (SM)
BH-12	0.0	1.5	2	6	9	15	Topsoil and Silty Sand (SM) and Clay (CL)
	4.5	6.0	11	16	26	42	Clay (CL)
	90.5	90.7	80/0.2	-	-	Ref	Weathered Bedrock

Notes:
(1) The term N-value is given to the sum of the second and third inverval of blow counts. The values are presented in the format: number of blows per final 12 inches of testing.
(2) "woh" refers to "weight of hammer", meaning that the static weight of the hammer was enough to advance the sampler 6 inches.
(3) Values presented in the format: number of blows/distance driven refer to cases where refusal was reached. The driving distance is shown as the distance driven (in feet) at refusal before reaching 6 inches.
(4) "Ref" refers to refusal of the SPT sampler.

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Table 4
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Packer (Rock Permeability) Test Summary

Borehole Designation	Test Interval		Test Type	Permeability	Material Type
	From (ft)	To (ft)		(cm/s)	
BH-02	107.4	117.4	Packer	1.5E-07	Copper Harbor Conglomerate
BH-07	137.3	148.5	Packer	1.6E-06	Copper Harbor Conglomerate
BH-08	129.1	139.5	Packer	4.9E-06	Copper Harbor Conglomerate
BH-10	116.0	124.5	Packer	8.1E-07	Copper Harbor Conglomerate
BH-11	22.5	31.1	Packer	No Take*	Copper Harbor Conglomerate
BH-12	20.9	30.3	Packer	2.3E-06	Copper Harbor Conglomerate

* Note: "No Take" refers to a condition where no water was receieved within the soil layer during the five minute test interval.

Falling Head (Overburden Soil Permeability) Test Summary

Borehole Designation	Test Interval		Test Type	Permeability	Material Type
	From (ft)	To (ft)		(cm/s)	
BH-02	20.0	24.0	Falling Head	7.0E-09	Lean Clay (CL)
	40.0	44.0	Falling Head	2.2E-08	Lean Clay (CL)
	70.0	74.0	Falling Head	6.0E-09	Lean Clay (CL)
BH-04	20.0	24.0	Falling Head	1.1E-08	Clay (CL)
	35.0	39.0	Falling Head	1.1E-08	Silty Sand (SM)
	44.5	48.5	Falling Head	3.5E-09	Weathered Bedrock
BH-06	30.5	34.5	Falling Head	Artesian*	Clay (CL)
	40.0	44.0	Falling Head	1.4E-08	Clay (CL)
	70.0	74.0	Falling Head	2.2E-08	Sandy Clay (CL)
BH-07	20.0	24.0	Falling Head	2.0E-08	Lean Clay (CL)
	40.0	44.0	Falling Head	1.5E-08	Lean Clay (CL)
	70.0	74.0	Falling Head	9.8E-08	Lean Clay (CL)
BH-08	30.0	34.0	Falling Head	1.4E-08	Lean Clay (CL)
	50.0	54.0	Falling Head	1.7E-08	Lean Clay (CL)
	80.0	84.0	Falling Head	2.6E-08	Sand (SM)
BH-10	25.0	29.0	Falling Head	2.1E-08	Clay (CL)
	40.0	44.0	Falling Head	1.2E-08	Clay (CL)
	60.0	64.0	Falling Head	1.1E-08	Lean Clay (CL)

*Note: Artesian conditions were encountered and upward flow did not cease during drilling. A clay seal zone was placed above and below the artesian zone to confine the layer.

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Table 5
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Laboratory Index Test Summary

Sample Location Designation	Depth Interval		Grain Size Distribution				Atterberg Limits		USCS	USCS Soil Description
	From (ft)	To (ft)	+"3" (%)	Gravel (%)	Sand (%)	Silt/Clay (%)	LL	PI		
BH-01	0.0	3.0	0.0	17.8	69.7	12.5			SM	Sand with Silt and Gravel
	20.3	21.8	0.0	0.0	9.3	90.7	51	33	CH	Fat Clay with some Sand and trace Gravel
BH-02	25.2	27.2	0.0	11.8	20.4	67.8			CL	Lean Clay with Sand and Gravel
BH-04	9.5	11.7	0.0	1.3	16.9	81.8			CL	Clay with Sand and trace Gravel
	20.0	22.5	0.0	3.0	23.7	73.3			CL	Clay with Sand and trace Gravel
	25.0	26.5	0.0	10.8	42.2	47.0	15	3	SM	Silty Sand with some Gravel
BH-07	15.0	17.0	0.0	14.5	20.8	64.7			CL	Lean Clay with Sand and Gravel
	34.0	36.0	0.0	4.2	14.4	81.4			CL	Lean Clay with Sand and trace Gravel
	45.0	47.0	0.0	6.1	22.5	71.4			CL	Lean Clay with Sand and some Gravel
	80.0	82.0	0.0	9.7	49.3	41.0			SM	Silty Sand with some Gravel
BH-08	10.0	12.0	0.0	3.3	18.4	78.3			CL	Lean Clay with Sand and trace Gravel
	19.6	21.8	0.0	4.2	16.6	79.2			CL	Lean Clay with Sand and trace Gravel
	29.6	31.8	0.0	2.9	27.1	70.0			CL	Lean Clay with Sand and trace Gravel
BH-10	9.5	11.0	0.0	1.6	18.7	79.7	34	20	CL	Lean Clay with Sand and trace Gravel
	15.0	17.0	0.0	2.0	21.7	76.3			CL	Lean Clay with Sand and trace Gravel
	25.5	27.5	0.0	2.2	22.7	75.1			CL	Lean Clay with Sand and trace Gravel
TP-01	5.0	16.0	0.0	4.4	29.0	66.6	28	14	CL	Lean Clay with Sand and trace Gravel
TP-02	0.0	5.0	0.0	3.2	9.4	87.4	41	25	CL	Lean Clay with trace Sand and trace Gravel
	10.0	12.0	0.0	3.2	9.4	87.4	52	34	CH	Fat Clay with some Sand and trace Gravel
TP-03	0.0	17.0	0.0	2.0	3.4	94.6	27	13	CL	Lean Clay with trace Sand and trace Gravel
TP-04	0.0	7.0	0.0	11.8	80.6	7.6			SP-SM	Sand with some Gravel and some Silt
	7.0	16.0	0.0	3.5	7.3	89.2	22	9	CL	Lean Clay with some Sand and trace Gravel
TP-05	0.0	17.0	0.0	1.5	20.2	78.3	35	20	CL	Lean Clay with Sand and trace Gravel
TP-06	3.0	17.0	0.0	1.2	20.3	78.5	33	19	CL	Lean Clay with Sand and trace Gravel
TP-07	3.0	17.0	0.0	2.0	26.4	71.6	26	13	CL	Lean Clay with Sand and trace Gravel

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Table 5
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Laboratory Index Test Summary

Sample Location Designation	Depth Interval		Grain Size Distribution				Atterberg Limits		USCS	USCS Soil Description
	From (ft)	To (ft)	+"3" (%)	Gravel (%)	Sand (%)	Silt/Clay (%)	LL	PI		
TP-08	0.0	3.5	0.0	1.8	24.0	74.2	28	14	CL	Lean Clay with Sand and trace Gravel
TP-09	4.0	5.0	0.0	3.7	22.8	73.5	26	12	CL	Lean Clay with Sand and trace Gravel
TP-10	0.0	17.0	0.0	3.0	19.9	77.1	37	22	CL	Lean Clay with Sand and trace Gravel
TP-11	0.0	17.0	0.0	3.0	22.7	74.3	30	16	CL	Lean Clay with Sand and trace Gravel
TP-12	0.0	17.0	0.0	5.5	20.9	73.6	26	11	CL	Lean Clay with Sand and some Gravel
TP-13	-	-	0.0	2.3	92.5	5.2			SP	Sand with some Gravel
TP-14	0.0	15.0	0.0	3.1	24.9	72.0	25	11	CL	Lean Clay with Sand and trace Gravel
TP-15	2.0	15.0	0.0	4.9	23.8	71.3	28	14	CL	Lean Clay with Sand and trace Gravel
TP-16	0.0	15.0	0.0	3.9	28.4	67.7	24	10	CL	Lean Clay with Sand and trace Gravel
TP-17	3.0	15.0	0.0	4.5	25.1	70.4	24	10	CL	Lean Clay with Sand and trace Gravel
TP-18	0.0	15.0	0.0	4.4	18.3	77.3	37	22	CL	Lean Clay with Sand and trace Gravel
TP-19	0.0	16.0	0.0	3.9	22.4	73.7	24	9	CL	Lean Clay with Sand and trace Gravel
TP-20	0.0	16.0	0.0	2.7	22.4	74.9	26	12	CL	Lean Clay with Sand and trace Gravel
TP-21	0.0	12.0	0.0	3.2	22.6	74.2	27	13	CL	Lean Clay with Sand and trace Gravel
TP-22	4.0	15.0	0.0	3.0	25.6	71.4	27	13	CL	Lean Clay with Sand and trace Gravel
TP-23	2.0	15.0	0.0	2.5	24.2	73.3	23	9	CL	Lean Clay with Sand and trace Gravel
TP-24	2.0	16.0	0.0	2.2	23.2	74.6	22	8	CL	Lean Clay with Sand and trace Gravel
TP-26	2.0	3.0	0.0	39.1	53.3	7.6	Non-Plastic		SP-SM	Sand with Gravel and some Silt
MW-7	23.3	25.3	0.0	1.3	14.2	84.5			CL	Lean Clay with Sand and trace Gravel
CP	-	-	0.0	3.5	91.0	5.5	Non-Plastic		SP	Poorly Graded Sand
LP	-	-	0.0	7.2	84.5	8.3	Non-Plastic		SP	Poorly Graded Sand
Connor Pit	-	-	0.0	1.3	94.2	4.5	Non-Plastic		SP	Poorly Graded Sand

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Table 6
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Natural Moisture Content Test Summary

Sample Location	Depth Interval From (ft)	Depth Interval To (ft)	Moisture Content (%)
BH-01	0	1.5	22.5
	4.5	6	7
	10	11.5	10.2
	20.3	21.8	25.9
	30.3	31.8	27.2
	40.3	41.8	11.8
	45.3	46.8	14.3
	50.3	51.8	13.8
	60.3	61.8	17.5
	70.3	71.8	10.5
	75.4	76.9	11.4
	80.3	81.8	9.3
	85.3	86.8	6
	90.3	91.8	9.2
BH-04	0.0	1.5	27.9
	5.0	6.5	12
	9.5	11.7	13.7
	15	16.5	17.6
	20.0	22.5	15
	25.0	26.5	11.8
	30	31.5	6.5
	35.0	36.5	8.9
	45.0	45.2	7.7
BH-05	5.0	6.5	15.7
	10.0	11.5	19.2
	22.0	23.5	19.1
	32.0	33.5	11.6
	42.0	43.5	11.8
	47.5	48.5	18.1
	52.0	53.5	9.6
	57.0	58.5	7.9
BH-06	0.0	1.5	13.3
	5.0	6.5	14.1
	15.0	16.5	20.9
	26.2	27.5	19.1
	37.2	38.7	30.7
	47.2	48.7	18.6
	57.2	58.7	13.3
	64.4	65.4	10.2
	70.9	71.4	11
	80.9	82.4	8.1

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Table 6
Orvana Resources U.S. Corporation
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Natural Moisture Content Test Summary

Sample Location	Depth Interval From (ft)	Depth Interval To (ft)	Moisture Content (%)
BH-09	0.0	1.5	20.2
	4.0	5.5	11.8
	16.5	18.0	16.7
	31.5	33.0	15.4
	36.5	38.0	12.5
	41.5	43.0	10.7
	46.5	48.0	10.9
	51.5	53.0	11.9
BH-10	0.0	1.5	18.4
	4.5	6.0	11
	9.5	11.0	13.2
	19.5	20.5	13.9
	30.0	31.5	16.2
	40.0	41.5	15.9
	45.0	46.5	10.1
	50.0	51.0	11
	70.0	71.5	9.7
	100.0	101.5	10.2
BH-11	0.0	1.5	7.6
	5.0	6.5	7.2
	10.0	11.5	6.1
BH-12	0.0	1.5	25.3
	4.0	6.5	10.8
	9.5	11.0	3.6
TP-01	0.0	3.0	10.8
	13.0	16.0	15.6
TP-02	4.0	4.0	14.3
	10.0	12.0	20.2
	15.0	15.0	23.1
TP-03	0.0	3.0	18
	9.0	12.0	17.3
	13.0	17.0	14.1
TP-04	0.0	7.0	12
	7.0	10.0	14
TP-05	4.0	4.0	12.9
	12.0	12.0	12.8
TP-06	0.0	5.0	13.6
	5.0	10.0	15.4
	10.0	15.0	16.6
TP-07	0.0	5.0	9.3
	5.0	10.0	14.5
	10.0	15.0	10.2

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Table 6
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Natural Moisture Content Test Summary

Sample Location	Depth Interval		Moisture Content (%)
	From (ft)	To (ft)	
TP-08	0.0	5.0	12.7
	5.0	10.0	13.7
	10.0	15.0	20.7
TP-09	0.0	5.0	11.6
	5.0	10.0	12
	10.0	15.0	12.2
TP-10	5.0	5.0	13.6
	10.0	10.0	14.6
	15.0	15.0	20.1
TP-11	5.0	5.0	13.1
	10.0	10.0	11.5
	15.0	15.0	12.9
TP-12	0.0	5.0	9.4
	5.0	10.0	9.6
	10.0	15.0	10.2
TP-14	5.0	5.0	10.3
	11.0	11.0	12.2
TP-15	5.0	5.0	12.3
	13.0	13.0	12.8
TP-16	5.0	5.0	10
	11.0	11.0	12.1
TP-17	9.0	9.0	13.3
	12.0	12.0	10.8
TP-18	5.0	5.0	11.9
	12.0	12.0	13.8
TP-19	9.0	9.0	9.8
	10.0	10.0	12.4
TP-20	6.0	6.0	9.8
	14.0	14.0	15.1
TP-21	5.0	5.0	10.1
	12.0	12.0	10.3
TP-22	6.0	6.0	11.7
	12.0	12.0	14.3
TP-23	5.0	5.0	10.6
	14.0	14.0	11.1
TP-24	5.0	5.0	10.7
	12.0	12.0	8.3
TP-26	2.0	3.0	7.5

Knight Piésold CONSULTING

Table 7
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Specific Gravity Test Summary

Sample Location Designation	Depth Interval		Specific Gravity
	From (ft)	To (ft)	
BH-04	9.5	11.7	2.63
BH-05	22	22	2.65
BH-06	16	16	2.64
TP-03	Composite		2.64
TP-06	5	10	2.62
TP-09	5	10	2.66
TP-12	Composite		2.67
LP	Composite		2.70
CP	Composite		2.73
Conner Pit	Composite		2.68

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Table 8
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Moisture-Density Test Summary

Sample Location Designation	Standard Proctor Test		ModifiedProctor Test	
	MDD (pcf)	OMC (%)	MDD (pcf)	OMC (%)
TP-02	114.0	15.8	127.7	10.6
TP-06	119.6	12.5	132.6	9.0
TP-07	126.4	10.2	137.0	7.9
TP-08	123.0	11.5	135.6	7.8
TP-09	121.6	12.5	134.2	8.7
TP-14	128.3	10.6	-	-
TP-15	-	-	134.1	8.9
TP-16	126.4	10.2	-	-
TP-17	-	-	136.6	7.3
TP-18	117.1	11.3	-	-
TP-19	-	-	133.8	8.9
TP-20	118.7	10.5	-	-
TP-21	-	-	135.1	8.2
TP-22	125.6	10.6	-	-
TP-23	-	-	135.4	8.6
TP-24	127.1	11.7	-	-

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Table 9
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Flexible Wall Permeability Test Summary

Sample Location Designation	Type of Test	Confining Stress (kPa)	Depth Interval		Permeability (cm/s)
			From (ft)	To (ft)	
BH-04	Constant Head	379.2	9.5	11.7	5.9E-09
TP-07	Constant Head	379.2	Block Sample		2.5E-08
TP-09	Constant Head	379.2	Block Sample		1.0E-08

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Table - 10
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Oedometer Test Summary

Test Sample Location	From (ft)	To (ft)	Load Increment (kPa)	Δσ' (kPa)	a_v (Δe/kPa)	m_v (1/kPa)	c_v (cm^2/sec)	K (cm/sec)	C_c	OCR
BH-02	25.2	27.2	9.6	9.6	4.87E-04	3.34E-04	-	-	0.13	2.4
			23.9	14.4	8.15E-05	5.61E-05	-	-		
			47.9	23.9	1.22E-04	8.43E-05	-	-		
			95.8	47.9	1.43E-04	9.85E-05	0.0034	3.3E-08		
			191.5	95.8	1.20E-04	8.35E-05	0.0018	1.5E-08		
			383.0	191.5	8.98E-05	6.31E-05	0.0016	1.0E-08		
			766.1	383.0	7.10E-05	5.05E-05	0.0012	6.1E-09		
			1532.2	766.1	4.91E-05	3.57E-05	0.0011	4.0E-09		
			3064.3	1532.2	2.51E-05	1.84E-05	0.0012	2.2E-09		
BH-04	20.0	22.5	9.6	9.6	1.07E-04	7.68E-05	-	-	0.10	1.7
			23.9	14.4	4.52E-05	3.26E-05	-	-		
			47.9	23.9	1.39E-04	1.01E-04	-	-		
			95.8	47.9	1.39E-04	1.01E-04	0.0021	2.0E-08		
			191.5	95.8	1.34E-04	9.71E-05	0.0010	9.8E-09		
			383.0	191.5	9.54E-05	7.00E-05	0.0010	6.9E-09		
			766.1	383.0	6.10E-05	4.54E-05	0.0008	3.6E-09		
			1532.2	766.1	3.61E-05	2.73E-05	0.0097	2.6E-09		
			3064.3	1532.2	1.88E-05	1.45E-05	0.0012	1.7E-09		
BH-07	23.3	25.3	9.6	9.6	-	-	-	-	0.19	2.0
			23.9	14.4	3.56E-06	2.33E-06	-	-		
			47.9	23.9	3.42E-05	2.23E-05	-	-		
			95.8	47.9	9.40E-05	6.14E-05	0.0010	6.1E-09		
			191.5	95.8	1.39E-04	9.10E-05	0.0010	9.0E-09		
			383.0	191.5	1.70E-04	1.12E-04	0.0004	4.6E-09		
			766.1	383.0	1.34E-04	9.06E-05	0.0003	2.8E-09		
			1532.2	766.1	7.45E-05	5.22E-05	0.0004	2.1E-09		
			3064.3	1532.2	2.95E-05	2.15E-05	0.0005	1.0E-09		
BH-08	19.6	21.8	9.6	9.6	-	-	-	-	0.19	1.9
			23.9	14.4	-	-	-	-		
			47.9	23.9	3.04E-05	1.95E-05	-	-		
			95.8	47.9	1.37E-04	8.80E-05	0.0035	3.1E-08		
			191.5	95.8	1.89E-04	1.22E-04	0.0006	7.7E-09		
			383.0	191.5	1.89E-04	1.23E-04	0.0006	6.8E-09		
			766.1	383.0	1.38E-04	9.25E-05	0.0003	3.2E-09		
			1532.2	766.1	7.74E-05	5.37E-05	0.0003	1.6E-09		
			3064.3	1532.2	3.46E-05	2.50E-05	0.0004	8.9E-10		
BH-10	15.0	17.0	9.6	9.6	1.06E-05	7.00E-06	-	-	0.15	2.2
			23.9	14.4	7.09E-06	4.67E-06	-	-		
			47.9	23.9	5.96E-05	3.92E-05	-	-		
			95.8	47.9	2.19E-04	1.44E-04	0.0015	2.1E-08		
			191.5	95.8	2.13E-04	1.41E-04	0.0006	7.9E-09		
			383.0	191.5	1.70E-04	1.14E-04	0.0004	4.5E-09		
			766.1	383.0	1.04E-04	7.18E-05	0.0004	2.8E-09		
			1532.2	766.1	6.02E-05	4.26E-05	0.0004	1.7E-09		
			3064.3	1532.2	3.08E-05	2.25E-05	0.0004	9.5E-10		

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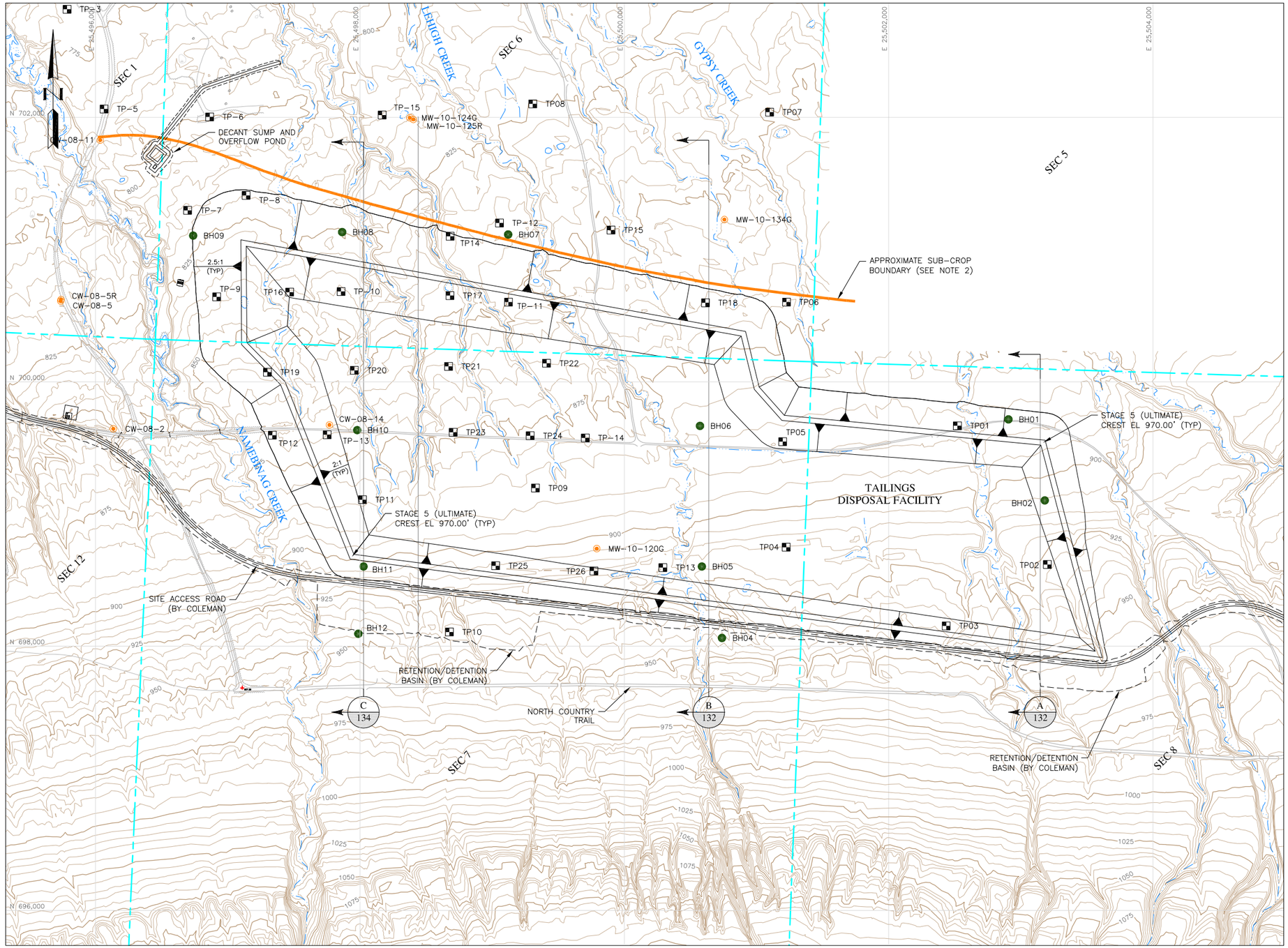
Table - 11
Orvana Resources U.S. Corporation
Copperwood Project Geotechnical Investigation

Shear Strength (UU, ICU, Direct Shear) Test Summary

Test Sample Location	Depth		Unconsolidated Undrained Triaxial Testing	Isotropically Consolidated Undrained Triaxial Testing				Direct Shear Test	
				Effective Stress		Total Stress			
	From	To	s_u	c'	φ'	c	φ	c	φ
	(ft)	(ft)	(kPa)	(kPa)	(deg)	(kPa)	(deg)	(kPa)	(deg)
TP-08			187.7						
BH-02	10	12		0.0	25.1	100.5	13.8		
	14	16	139.4						
	35.2	37.2						35.9	21.4
	45.2	47.2	209.1						
BH-07	15	17	155.5						
	34	36	112.6						
	45	47						16.2	31.5
	80	82		0.0	37.0	242.3	36.0		
BH-08	10	12.2	134.1						
				0.0	25.7	39.3	13.2		
	19.6	21.8						24.8	23.4
	39.6	41.2	321.8						
BH-10	15	17	80.4						
	25.5	27.5	155.5						

Figures



PLAN

400 0 400 800 FEET

1" = 400' AT FULL SIZE (ANSI D)
1" = 800' AT HALF SIZE (ANSI B)

LEGEND:

880	EXISTING GROUND SURFACE CONTOUR AND EL, FEET
	EXISTING DRAINAGE
	SECTION LINE
CW-08-5	AECOM MONITORING WELL (2008)
MW-10-1206	AECOM MONITORING WELL (2010)
BH-01	KNIGHT PIESOLD BOREHOLE (2011)
TP01	KNIGHT PIESOLD TEST PIT (2011)

NOTES:

1. SCALE BAR MEASURES 3" ON A FULL SIZE PLOT (ANSI-D) AND 1.5" ON A HALF SIZE PLOT (ANSI-B).
2. THE SUB-CROP BOUNDARY LINE WAS PROVIDED BY ORVANA ON 2/4/11 AND REPRESENTS THE APPROXIMATE LIMIT BEYOND WHICH SETTLEMENT DUE TO UNDERGROUND MINING ACTIVITIES IS NOT ANTICIPATED.

REFERENCE:
TOPOGRAPHIC MAPPING COMPILED BY AERO-METRIC, INC. FROM AERIAL PHOTOS TAKEN MAY 4, 2009; HORIZONTAL DATUM NAD 83 (96); MICHIGAN STATE PLANE NORTH; VERTICAL DATUM NAVD 88
DATA FILES NAMED: 10904132ft100c, 10904132ft100d, 10904132ft100p, 10904135ft200c, 10904135ft200d, AND 10904135ft200p.dwg RECEIVED FROM ORVANA RESOURCES VIA DISC ON NOVEMBER 19, 2010
SEE G:\101\00429.02\External\2010 1119 - Aerial Data - Disc from Client\CEC Orvana Minerals.dwg
ORVANA DRILL HOLE INFORMATION RECEIVED FROM ORVANA RESOURCES VIA COLEMAN ENGINEERING ON DECEMBER 12, 2010
SEE G:\101\00429.02\External\2010 1214 - TSF Draft Map with Drill Holes

PROJECT	COPPERWOOD PROJECT TAILINGS DISPOSAL FACILITY
TITLE	SITE INVESTIGATION PLAN
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
DRAWN BY	RMG	DV101	00429-02	1	A
ACTIVITY CODE	N/A	XREF NUMBER	N/A		

LAST SAVED BY: JCOFFIN
DRAWING PATH: G:\101\00429.02\CAD\CAD Dept\Figures\2011-0613-SiReport\Fig1.dwg
PRINTED BY: JEFF COFFIN, PRINT TIME: 6/13/2011 8:53 AM

Appendix A

Test Pit Logs

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-1

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 25, 11 REVIEWED BY: W. Rice DATE: 2/15/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(SM) SAND, brown, fine to coarse, with silt, with fine gravel, moist to wet								
				1									
				2					17.8 82.2 12.5	10.8			
				3									
				4									
				5	± 5.0' (CL) CLAY, reddish brown, with sand, trace gravel, moist to wet			a little perched water at 5.0'	4.4 95.6 66.6				
				6									
				7									
				8									
				9									
				10									
				11									
				12									
				13									
				14						15.6	28 14		
				15									
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-1

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-2

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 25, 11 REVIEWED BY: W. Rice DATE: 2/15/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) CLAY, red-brown, trace sand, trace gravel, moist								
				1					0.8 99.2 94.6				3.5 - 4.5
				2									
				3									
				4						14.3	41 16		
				5									
				6									
				7	± 7.0' (CL) CLAY, gray, with small roots								4.5
				8									
				9									
				10									
				11	...(CH) FAT CLAY, brown, some fine to coarse sand, trace fine gravel, highly plastic				3.2 96.8 87.4	20.2	52 18		
				12									
				13									
				14									
				15						23.1			
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-2

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-3

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 25, 11 REVIEWED BY: W. Rice DATE: 2/9/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL to CL-ML) CLAY to SILTY CLAY, reddish brown, lenses of gray silt, trace of sand and gravel, moist								
				1					2.0 98.0 94.6	18.0	27 14		2.0 - 2.5
				2				specific gravity 2.64					
				3									
				4									
				5									
				6									
				7									
				8									
				9									
				10						17.3			
				11									
				12									
				13									
				14									
				15									
				16						14.1			
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-3

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-4

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 25, 11 REVIEWED BY: W. Rice DATE: 2/15/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(SP-SM) SAND, brown, fine to coarse, some fine gravel, some silt, wet								
				1									
				2									
				3									
				4					11.8 88.2 7.9	12.0			
				5									
				6	...6" layer of clay at 5.5'			perched water					
				7	± 7.0' (CL) CLAY, trace gravel, some sand, moist				3.5 96.5 89.2				
				8									
				9						14.0	22 13		
				10									
				11									
				12									
				13									
				14									
				15									
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-4

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-5

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 25, 11 REVIEWED BY: W. Rice DATE: 2/8/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) CLAY, reddish brown, with sand, trace gravel, moist								
				1									>4.5
				2									
				3									
				4						12.9			
				5	± 5.0' (CL) CLAY, reddish brown, trace sand, trace gravel, moist			Note: Atterberg Limits and Gradation determined from a composite sample for the entire test pit	1.5 98.5 78.3		35 15		>4.5
				6	...gray								
				7									
				8									
				9									
				10	...reddish brown								
				11									
				12						12.8			
				13									
				14									
				15									
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-5

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-6

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 26, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/7/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) SANDY CLAY, reddish brown, trace gravel, moist								
				1									
				2									
				3	± 3.0' (CL) CLAY, reddish brown, with sand, trace fine gravel, some cobbles, moist			specific gravity 2.62	1.2 98.8 78.5	13.6	33 14		2.5 - 3.0
				4									
				5									
				6									
				7									
				8						15.4			
				9									
				10									
				11									
				12									
				13									
				14						16.6			
				15									
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-6

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-7

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: Offset approx. 100' W. of stake

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 26, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/9/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) SANDY CLAY, red-brown, trace gravel, firm, crumbly								
				1									
				2									
				3	± 3.0' (CL) CLAY, red-brown, cobbles, stiff, moist				2.0 98.0 71.6	9.3			>4.5
				4									
				5									
				6									
				7									
				8						14.5			
				9									
				10									
				11									
				12									
				13						10.2	26 13		
				14									
				15									
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

[I] -AS-Auger Sample
[B] -BS-Bag Sample
[I] -RC-Rock-Core
[G] -GS-Grab Sample
[P] -PS-Piston Tube
[X] -2SS-2" Split Spoon
[/] -3SS-3" Split Spoon
[◢] -2ST-2" Shelby Tube
[◤] -3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▼ after hours

BORING NO.: TP-7

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-8

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Jan 26, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/9/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL-ML) SILTY CLAY, some sand, crumbly, moist								
				1					1.8 98.2 74.2	12.8	28 14		4.0
				2									
				3									
					± 3.5' (CL) CLAY, red-brown, firm, with cobbles								>4.5
				4									
				5									
				6									
				7									
				8						13.7			
				9									
				10									
				11									
				12						20.7			
				13	...sand seam 12.5' to 13.2'			Water was bleeding from the sand seam					
				14									
				15									
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-8

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-9

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 26, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/9/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(SM) SILTY SAND, fine to medium, organics in the upper 4 inches								
				1									
				2									
				3									
				4	± 4.0' (CL-ML) SILTY CLAY, red-brown, crumbly			specific gravity 2.66	3.7 96.3 73.5	11.6	26 14		
				5	± 5.0' (CL) CLAY, red-brown, with cobbles, firm								
				6									
				7									
				8						12.0			
				9									
				10									
				11									
				12									
				13									
				14						12.2			
				15									
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-9

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-10

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 27, 11 DATE COMPLETED: Jan 27, 11 REVIEWED BY: W. Rice DATE: 2/15/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) CLAY, reddish brown, some silty sand seams, some cobbles, trace gravel								
				1					3.0 97.0 77.1		37 15		>4.5
				2				Note: Atterberg Limits and Gradation determined from a composite sample for the entire test pit					
				3									
				4	...small pocket of perched water at ±4.0'								
				5						13.6			
				6	± 6.0' (CL) LEAN CLAY, reddish brown, gray mottling, trace of fine gravel, with fine to coarse sand, some cobbles, root structures								>4.5
				7									
				8									
				9									
				10					1.6 98.4 79.7	14.6			
				11									
				12									
				13									
				14									
				15						20.1			
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-10

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-11

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 17.0

DATE STARTED: Jan 27, 11 DATE COMPLETED: Jan 27, 11 REVIEWED BY: W. Rice DATE: 2/9/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) CLAY, reddish brown, with gray mottling, trace sand, fine root structure, crumbly								
				1					3.0 97.0 74.3		30 14		2.5 - 3.5
				2									
				3									
				4									
				5	...blocky					13.1			
				6									
				7									
				8									
				9									
				10						11.5			
				11									
				12									
				13									
				14									
				15						12.9			
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-11

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-12

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked ELEV.:

RIG TYPE: John Deere 992E LC Excavator DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated BORING DEPTH: 17.0

DATE STARTED: Jan 27, 11 DATE COMPLETED: Jan 27, 11 REVIEWED BY: W. Rice DATE: 2/9/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL-ML) CLAY, silty, with sand, crumbly, moist								
				1				specific gravity 2.67	5.5 94.5 73.6		26 15		4.0
				2									
				3	± 3.0' (CL) CLAY, red-brown, with cobbles, moist					9.4			>4.5
				4									
				5									
				6									
				7									
				8						9.6			
				9									
				10									
				11									
				12									
				13									
				14									
				15						10.2			
				16									
				17	17.0' End of Test Pit								
				18									
				19									
				20									

AS-Auger Sample; BS-Bag Sample; RC-Rock-Core; GS-Grab Sample; PS-Piston Tube; 2SS-2" Split Spoon; 3SS-3" Split Spoon; 2ST-2" Shelby Tube; 3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▼ after hours

BORING NO.: TP-12

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-13

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 10.0

DATE STARTED: Jan 27, 11 DATE COMPLETED: Jan 27, 11 REVIEWED BY: W. Rice DATE: 2/25/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(SP) SAND, fine to coarse, with seams of clay and silt								
				1									
				2									
				3				Note: Obtained sample at 3.0'					
				4	± 4.0' (SC / CL-ML) Interlayers of CLAYEY SAND and SILTY CLAY								
				5									
				6									
				7									
				8									
				9									
				10	10.0' End of Test Pit								
				11									
				12									
				13									
				14									
				15									
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-13

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-14

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	CLAY, reddish brown, trace sand, trace gravel, perched water in sand pocket just below surface								
				1									
				2									
				3									
				4									
				5						10.3			
				6									
				7									
				8				Q_p > 4.5 tsf					
				9									
				10									
				11						12.2			
				12									
				13									
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-14

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-15

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(SM) SILTY SAND, brown, fine to medium								
				1									
				2	± 2.0' CLAY, reddish brown, trace sand, trace gravel, some cobbles, some mottling								
				3									
				4									
				5						12.3			
				6									
				7									
				8									
				9									
				10									
				11									
				12									
				13						12.8			
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-15

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-16

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	CLAY, reddish brown, trace sand, trace gravel, crumbly 0' to 5.0'								
				1									
				2									
				3									
				4									
				5	...blocky 5.0' to 15.0'					10.0			
				6									
				7									
				8									
				9									
				10				Q_p > 4.5 tsf					
				11	...pocket of sand with perched water at 11.0'					12.1			
				12									
				13									
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-16

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-17

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	SANDY CLAY, reddish brown, trace gravel								
				1									
				2									
				3	± 3.0' (CL) CLAY, reddish brown, trace sand, trace gravel								
				4									
				5									
				6									
				7									
				8									
				9						13.3			
				10	...some mottling at 10.0'								
				11									
				12						10.8			
				13									
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-17

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-18

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	CLAY, reddish brown, trace sand, trace gravel, some gray mottling								
				1									
				2									
				3									
				4									
				5						11.9			
				6									
				7									
				8				Q_p > 4.5 tsf					
				9									
				10									
				11									
				12						13.8			
				13									
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-18

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-19

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	CLAY, reddish brown, some mottling, trace sand, trace gravel, some cobbles, crumbly, hard								
				1									
				2									
				3									
				4									
				5	...blocky								
				6									
				7									
				8				Q_p > 4.5 tsf					
				9						9.8			
				10						12.4			
				11									
				12									
				13									
				14									
				15									
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-19

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-20

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	CLAY, reddish brown, trace gravel, some cobbles								
				1									
				2									
				3									
				4									
				5									
				6						9.8			
				7									
				8				Q_p > 4.5 tsf					
				9									
				10									
				11									
				12									
				13									
				14						15.1			
				15									
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-20

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-21

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	CLAY, reddish brown, trace sand, trace gravel, some cobbles, crumbly, hard								
				1									
				2									
				3									
				4									
				5	...blocky					10.1			
				6									
				7									
				8				Q_p > 4.5 tsf					
				9									
				10									
				11									
				12						10.3			
				13									
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-21

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-22

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	τ (tsf)	q_a (tsf)
				0	(SM) SILTY SAND, brown, fine			Note: Some surface water under the snow running into test pit					
				1									
				2									
				3									
				4	± 4.0' CLAY, reddish brown, trace sand, trace gravel								
				5									
				6						11.7			
				7									
				8									
				9									
				10				Q_p = 4.0 to 4.5 tsf					
				11									
				12						14.3			
				13									
				14									
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-22

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-23

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(SM) SILTY SAND, fine, brown								
				1									
				2	± 2.0' CLAY, reddish brown, mottling, trace sand, trace gravel, some cobbles, little perched water at 2.0'								
				3									
				4									
				5						10.6			
				6									
				7									
				8									
				9									
				10				Q_p > 4.5 tsf					
				11									
				12									
				13									
				14						11.1			
				15	15.0' End of Test Pit								
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-23

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-24

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL								
					0.5' (SM) SILTY SAND, brown, fine (likely fill)								
				1									
				2	± 2.0' CLAY, reddish brown, trace sand, trace gravel, some cobbles, little perched water at 2.0'								
				3									
				4									
				5						10.7			
				6									
				7									
				8									
				9									
				10									
				11									
				12						8.3			
				13									
				14									
				15									
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-24

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-25

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 10.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE									TEST RESULTS				
NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	+4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) CLAY, reddish brown, trace sand, trace gravel, some cobbles								
				1									
				2									
				3									
				4									
				5									
				6									
				7									
				8									
				9									
				10	10.0' End of Test Pit								
				11									
				12									
				13									
				14									
				15									
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-25

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: TP-26

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As staked

ELEV.:

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 10.0

DATE STARTED: Feb 15, 11 DATE COMPLETED: Feb 15, 11 REVIEWED BY: W. Rice DATE: 2/22/11

HOLE CLOSURE: Excavated Soil

SAMPLE									TEST RESULTS				
NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	+4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL								
				1	1.0' SANDY GRAVEL, with clay								
				2	± 2.0' (CL) CLAY, reddish brown					7.5			
				3									
				4									
				5									
				6									
				7									
				8									
				9									
				10	10.0' End of Test Pit								
				11									
				12									
				13									
				14									
				15									
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-26

Appendix B

Test Pit Photos

Copperwood Project
Test Pit Photographs

TP-01 – Full Depth

TP-01 – Bottom of Pit

Copperwood Project
Test Pit Photographs

TP-02 – Surface

TP-02 – Full Depth

Copperwood Project
Test Pit Photographs

TP-03 – Full Depth

TP-03 – Sidewall

Copperwood Project
Test Pit Photographs

TP-04 – Full Depth

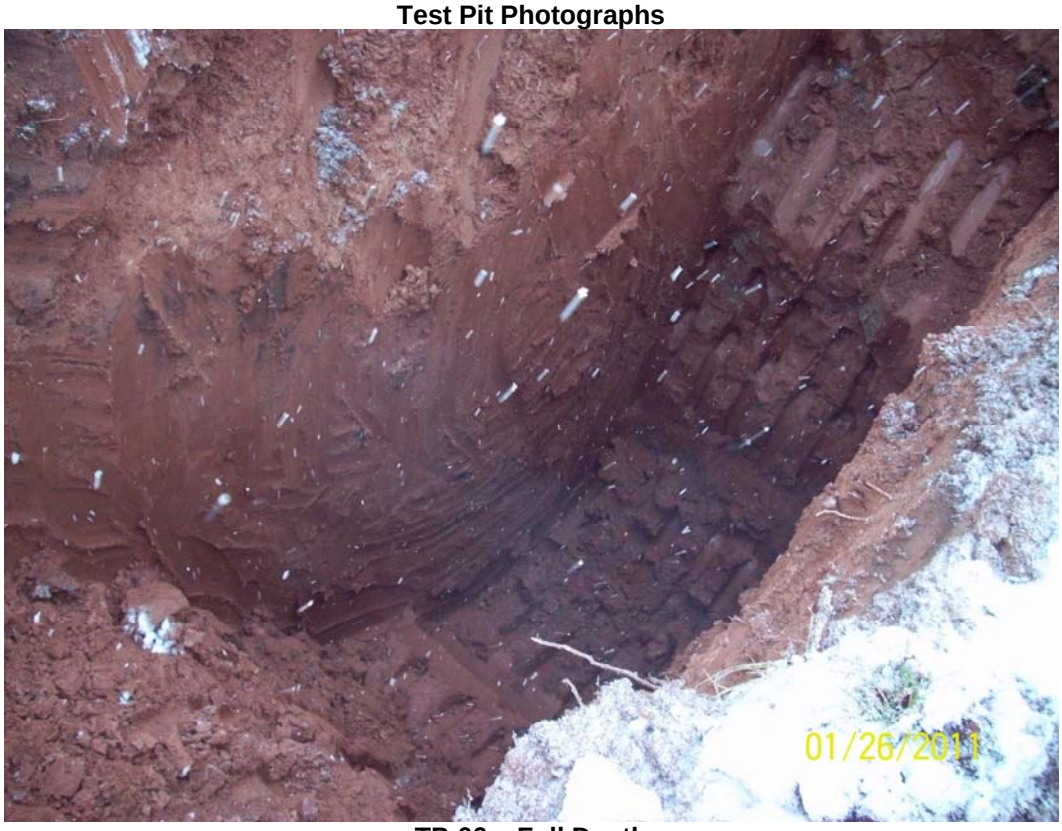
TP-04 – Sidewall

Copperwood Project
Test Pit Photographs

TP-05 – Full Depth

TP-05 – End-wall

Copperwood Project
Test Pit Photographs



TP-06 – Full Depth

TP-06 – Sidewall

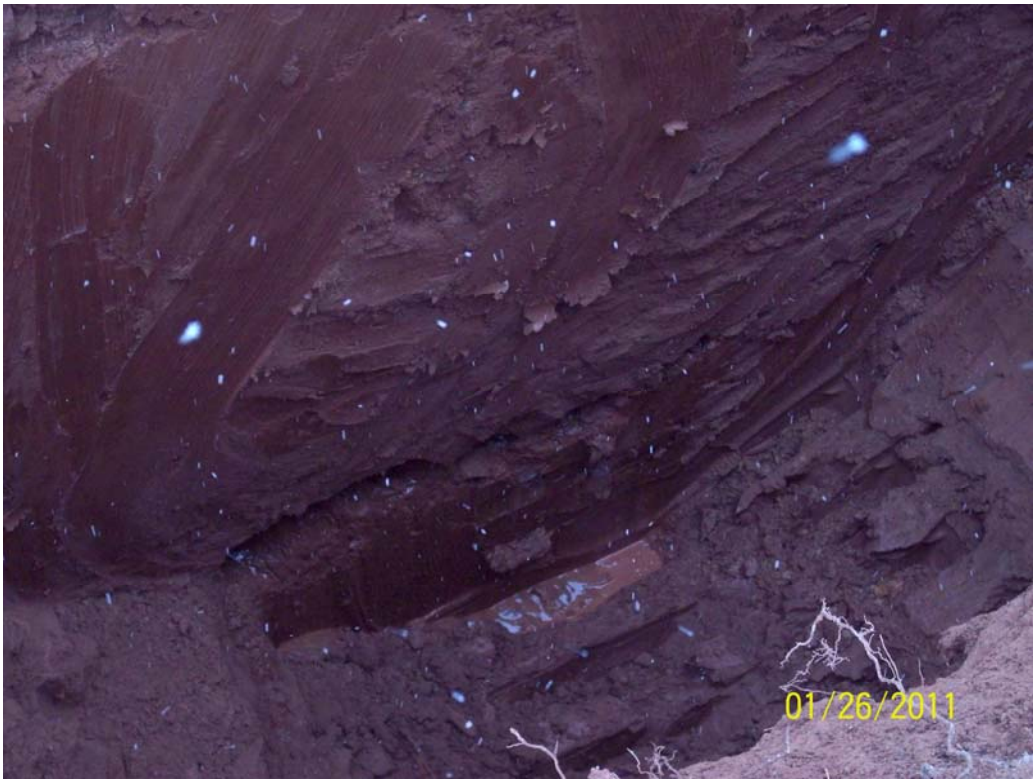
Copperwood Project
Test Pit Photographs

TP-07 – Full Depth

TP-07 – Surface Material

Copperwood Project
Test Pit Photographs

TP-08 – Full Depth



TP-08 – Sidewall

Copperwood Project
Test Pit Photographs

TP-09 – Full Depth

TP-09 – Sidewall

Copperwood Project
Test Pit Photographs

TP-10 – Full Depth

TP-10 – Sidewall

Copperwood Project
Test Pit Photographs

TP-11 – Full Depth

TP-11 – Sidewall

Copperwood Project
Test Pit Photographs

TP-12 – Full Depth

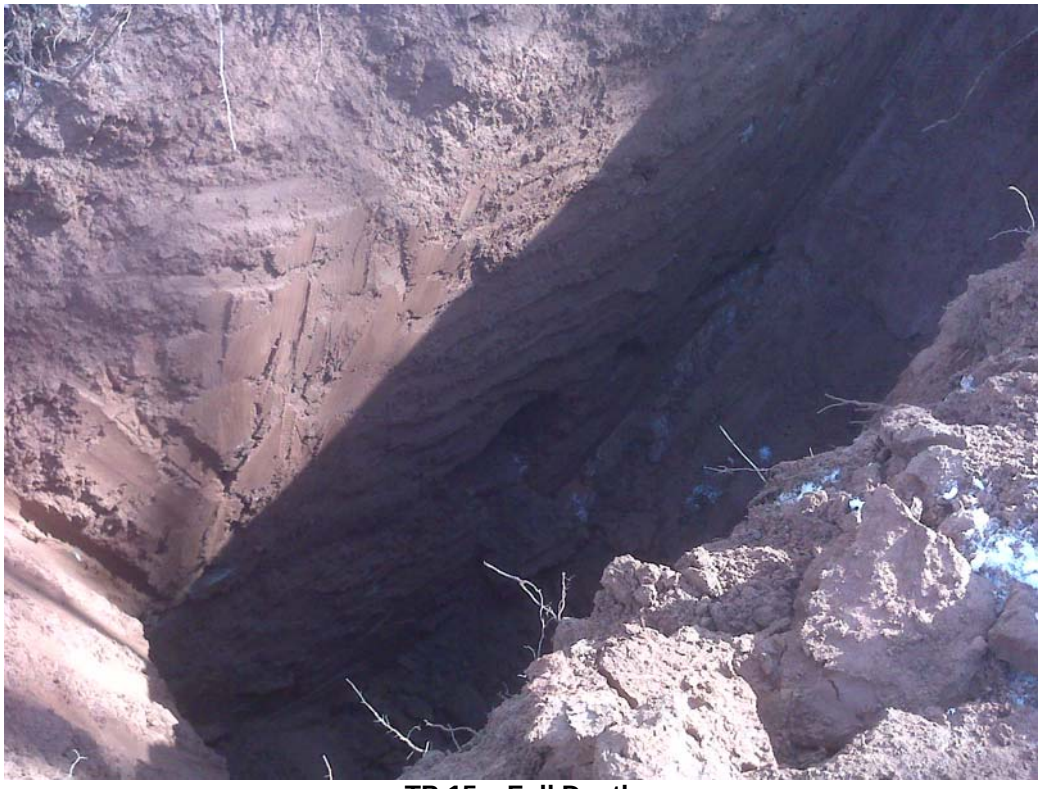
TP-12 – Surface Material

Copperwood Project
Test Pit Photographs

TP-14 – Full Depth

TP-14 – Surface Material

TP-15 – Full Depth



TP-15 – Full Depth

Copperwood Project
Test Pit Photographs

TP-17 – Full Depth

TP-17 – Surface Material

Copperwood Project
Test Pit Photographs

TP-18 – Full Depth

TP-18 – Sidewall

Copperwood Project
Test Pit Photographs

TP-19 – Full Depth

TP-19 – Surface Materials

Copperwood Project
Test Pit Photographs

TP-20 – Full Depth

TP-20 – Sidewall

Copperwood Project
Test Pit Photographs

TP-21 – Full Depth

TP-21 – Sidewall

Copperwood Project
Test Pit Photographs

TP-22 – Full Depth

TP-23 – Full Depth

Copperwood Project
Test Pit Photographs

TP-23 – Sidewall

TP-24 – Full Depth

Copperwood Project
Test Pit Photographs

TP-24 – Sidewall

TP-25 – Full Depth

Copperwood Project
Test Pit Photographs

TP-26 – Full Depth

Appendix C

Borehole Logs

Borehole
BH-01

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-01

CLIENT: Orvana Resources U.S. Corporation — 1 OF 6

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core — BORING DEPTH: 117.4

DATE STARTED: Jan 11, 11 — DATE COMPLETED: Jan 18, 11 — REVIEWED BY: W. Rice — DATE: 2/18/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	1-1-3 (4)	1.1		0	(SM) SILTY SAND, dark brown, fine to medium, trace fine gravel, some rootlets, moist, loose			5" Solid Stem Auger 0.0' to 10.0' 2" SPT Sampling 140# wt., 30" drop 4" casing 0.0' to 17.0'		22.5			
				1				Frost 0.5' deep					
				2									
				3				Driller's note: Water at 3.0' likely perched in sand					
				4									
2	14-12-13 (25)	1.3		5	...red-brown					7.0			
					5.5' (CL) CLAY, red-brown, some fine sand, trace fine gravel, slightly plastic, moist, stiff								
				6									
				7									
				8									
				9									
3	(-)	0.4			9.8' (SM) SAND, red-brown, fine to coarse, with silt, some fine gravel, wet, dense								
4	8-17-22 (39)	1.4		10				3-7/8" Roller Bit with Quickgel drilling mud 10.0' to 98.9'		10.2			
				11									
				12				Driller's note: Cobbles and/or boulders 12.0' to 13.0'					
				13	± 13.0' (CL) CLAY, red-brown, some fine sand, plastic, wet, stiff								
				14									
				15									
5	(-)	1.5		16								0.89	2.0
				17									
				18									
				19									
				20									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-01

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-01

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 117.4

DATE STARTED: Jan 11, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/18/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20	(CH) FAT CLAY, red-brown, some fine to coarse sand, trace fine gravel, plastic, wet, stiff								
6	4-6-9 (15)	1.5		21					0.6 99.4 89.6	25.9	51 18	0.7	1.0
				22									
				23									
				24									
				25									
7	(-)	1.7		26								0.9	1.5
				27									
				28									
				29									
				30									
8	5-7-10 (17)	1.5		31						27.2		0.89	1.5
				32									
				33									
				34									
				35									
9	(-)	2.0		36								0.9	1.5
				37									
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-01

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-01

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 117.4

DATE STARTED: Jan 11, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/18/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				40									
10	14-24-32 (56)	1.4			(CL) CLAY, red-brown, trace fine gravel, with fine sand, hard			Note: Sample crumbly when measuring T.		11.8		0.5	>4.5
				41									
				42									
				43									
				44									
				45									
11	20-14-16 (30)	1.5			...some fine sand, stiff to hard			Driller's note: Attempted TWT at 45.0'; only pushed 0.2'		14.3		0.55	0.5
				46									
				47									
				48									
				49									
				50				Driller's note: Gravel 49.8' to 51.2'					
12	6-9-13 (22)	1.5								13.8		0.63	0.8
				51									
				52									
				53									
13	(-)	1.9										0.9	1.6
				54									
				55									
				56									
				57									
				58									
				59									
				60									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-01

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-01

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 117.4

DATE STARTED: Jan 11, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/18/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				60	(CL) CLAY, red-brown, with fine sand, hard, layer of sand at 60.0'								
14	19-16-32 (48)	1.5		61						17.5		0.54	2.0
				62									
				63									
				64									
				65									
15	(-)	1.7		66									
				67									
				68									
				69									
				70									
16	16-22-28 (50)	1.4		71	...sandy					10.5			
				72				Driller's note: Cobbles and/or boulders 72.0' to 72.2'					
				73									
				74									
				75				Driller's note: Attempted TWT at 75.0'; only pushed 0.1' (ML)					
17	41-66-85 (151)	1.4		76						11.4			
				77									
				78									
				79									
				80									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-01

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-01

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 117.4

DATE STARTED: Jan 11, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/18/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				80	(CL) CLAY, red-brown, sandy, trace fine gravel, hard								
18	37-57-56 (113)	1.3		81						9.3			
				82									
				83									
				84									
				85									
19	27-63-43 (106)	1.3		86	...some fine gravel ...weathered rock at 86.2', sand layer 0.1' thick at 86.5'					6.0			
				87									
				88									
				89				Driller's note: Rig chattering and hard drilling 89.0' to 96.8'					
				90									
20	80-90-105 (195)	1.3		91	...some fine to coarse gravel (piece of shale in sampler tip)					9.2			
				92									
				93									
				94									
				95									
				96									
				97	96.8' WEATHERED BEDROCK								
				98				NQ Rock Core 98.9' to 117.4'					
21	Run 1	2.1		99	98.9' BEDROCK			Run 1: 98.9' to 102.4' Drill: 3.5' Recover: 2.1' RQD: 44					
				100									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-01

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-01

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 117.4

DATE STARTED: Jan 11, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/18/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				100	BEDROCK, sandstone, brown, fine to medium grained, fine to medium bedded at about 15°, occasional joints parallel to bedding (Copper Harbor Conglomerate)								
				101									
				102									
22	Run 2	5.0		103				Run 2: 102.4' to 107.4' Drill: 5.0' Recover: 5.0' RQD: 83					
				104									
				105									
				106									
				107									
23	Run 3	5.0		108				Run 3: 107.4' to 112.4' Drill: 5.0' Recover: 5.0' RQD: 33					
				109									
				110									
				111									
				112									
24	Run 4	5.0		113				Run 4: 112.4' to 117.4' Drill: 5.0' Recover: 3.9' RQD: 87					
				114									
				115									
				116									
				117	117.4'								
				118	End of Boring								
				119									
				120									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-01

Borehole
BH-02

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ
BORING NO.: BH-02

PROJECT: Copperwood Project, Wakefield Township, MI
CLIENT: Orvana Resources U.S. Corporation
BORING LOCATION: Offset approx. 6' N. of stake ELEV.:
RIG TYPE: Diedrich D-120 ATV Mount DRILL CREW: J. Lantagne / J. Frappler
DRILLING METHOD: 4-1/4" SSA & 3-7/8" RB BORING DEPTH: 117.4
DATE STARTED: Mar 14, 11 DATE COMPLETED: Mar 17, 11 REVIEWED BY: W. Rice DATE: 3/24/11
HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	8-4-3 (7)	1.0		0	(PT) PEAT 0.6'			4-1/4" Hollow Stem Auger 0.0' to 5.0'					
				1	(CL) LEAN CLAY, red-brown, plastic, some fine to medium sand, moist, medium stiff			2" SPT Sampling 140# wt., 30" drop 4" casing 0.0' to 8.8'					
								3-7/8" Roller Bit 0.0' to 79.7'					
				2									
				3									
				4									
2	woh-1-2 (3)	0.9		5	...soft							0.26	0.75
				6									
				7									
				8									
				9									
3		2.1		10								0.29	1.25
				11									
4		1.7		12								0.62	2.0
				13									
5		2.0		14								0.67	2.3
				15									
				16									
				17									
				18									
				19									
				20									

AS-Auger Sample; BS-Bag Sample; RC-Rock-Core; GS-Grab Sample; PS-Piston Tube; 2SS-2" Split Spoon; 3SS-3" Split Spoon; 2ST-2" Shelby Tube; 3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▽ after hours

BORING NO.: BH-02

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-02

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset approx. 6' N. of stake ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount DRILL CREW: J. Lantagne / J. Frappler

DRILLING METHOD: 4-1/4" SSA & 3-7/8" RB BORING DEPTH: 117.4

DATE STARTED: Mar 14, 11 DATE COMPLETED: Mar 17, 11 REVIEWED BY: W. Rice DATE: 3/24/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20	(CL) LEAN CLAY, red-brown, plastic, some fine to medium sand, moist, soft								
				21									
6	7-9-10 (19)	1.2		22	...very stiff							0.55	2.0
				23									
				24									
				25									
7		2.0		26								0.71	3.5
				27									
				28									
				29									
				30									
8	10-11-10 (21)	0.7		31	...sandy, trace fine gravel								
				32									
				33									
				34									
				35									
9		2.0		36								0.61	2.1
				37									
				38									
				39									
				40									

-AS-Auger Sample -GS-Grab Sample -3SS-3" Split Spoon
-BS-Bag Sample -PS-Piston Tube -2ST-2" Shelby Tube
-RC-Rock Core -2SS-2" Split Spoon -3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-02

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-02

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset approx. 6' N. of stake ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount DRILL CREW: J. Lantagne / J. Frappier

DRILLING METHOD: 4-1/4" SSA & 3-7/8" RB BORING DEPTH: 117.4

DATE STARTED: Mar 14, 11 DATE COMPLETED: Mar 17, 11 REVIEWED BY: W. Rice DATE: 3/24/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
10	6-7-9 (16)	1.1		40	(CL) LEAN CLAY, red-brown, plastic, some fine to coarse sand, trace fine to coarse gravel, moist, very stiff							0.75	4.5
				41									
				42									
				43									
				44									
				45									
11		2.0		46								0.7	2.6
				47									
				48									
				49									
				50									
12	17-16-19 (35)	1.0		51	...with fine to coarse sand, trace fine gravel, hard							0.86	>4.5
				52									
				53									
				54									
				55									
13	37-22-25 (47)	0.9		56	...wet							0.76	3.3
				57									
				58	± 58.0' (SM) SAND, brown, fine to coarse, with silt, trace fine gravel, wet, very dense								
				59									
				60									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-02

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ
PROJECT: Copperwood Project, Wakefield Township, MI
BORING NO.: BH-02
CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset approx. 6' N. of stake
ELEV.:
RIG TYPE: Diedrich D-120 ATV Mount
DRILL CREW: J. Lantagne / J. Frappier
DRILLING METHOD: 4-1/4" SSA & 3-7/8" RB
BORING DEPTH: 117.4
DATE STARTED: Mar 14, 11
DATE COMPLETED: Mar 17, 11
REVIEWED BY: W. Rice
DATE: 3/24/11
HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	τ (tsf)	q_a (tsf)
14	24-27-31 (58)	1.0		60	(SM) SAND, brown, fine to coarse, with silt, trace fine gravel, wet, very dense								
				61									
				62									
				63	± 63.5'								
				64	(CL) LEAN CLAY, red-brown, slightly plastic, sandy, some fine gravel, wet, hard								
				65									
15	35-29-39 (68)	1.2		66								0.35	2.75
				67									
				68									
				69									
				70									
				71									
16	17-34-48 (82)	1.1		72								0.34	4.25
				73									
				74									
				75									
				76									
				77									
				78									
				79									
				80									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube
while drilling
after drilling
after hours

BORING NO.: BH-02

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ
BORING NO.: BH-02

PROJECT: Copperwood Project, Wakefield Township, MI
CLIENT: Orvana Resources U.S. Corporation
BORING LOCATION: Offset approx. 6' N. of stake ELEV.:
RIG TYPE: Diedrich D-120 ATV Mount DRILL CREW: J. Lantagne / J. Frappler
DRILLING METHOD: 4-1/4" SSA & 3-7/8" RB BORING DEPTH: 117.4
DATE STARTED: Mar 14, 11 DATE COMPLETED: Mar 17, 11 REVIEWED BY: W. Rice DATE: 3/24/11
HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
17	44-50-50/0.4' (-)	1.0		80	(CL) LEAN CLAY, red-brown, slightly plastic, sandy, some fine gravel, wet, hard			3-7/8" Roller Bit 79.7' to 100.0'				0.6	>4.5
				81				85' of 3" casing to 80.9' on 3/16/11					
				82									
				83									
				84	± 84.5'								
18	50/0.2'- (-)	NR		85	COBBLES AND BOULDERS, mixture of granite, basalt, and sandstone cobbles and pieces (probable till)								
19		0.3		86				90' of 3" casing to 80.9' on 3/16/11					
				87									
				88									
20		0.5		89									
				90									
				91									
				92									
				93									
21		0.3		94									
				95									
				96									
				97									
				98									
22	50/0.1'- (-)	NR		99									
				100	± 100.0'								

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▼ after hours

BORING NO.: BH-02

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-02

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset approx. 6' N. of stake

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / J. Frappier

DRILLING METHOD: 4-1/4" SSA & 3-7/8" RB

BORING DEPTH: 117.4

DATE STARTED: Mar 14, 11 DATE COMPLETED: Mar 17, 11 REVIEWED BY: W. Rice DATE: 3/24/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
23	Run 1	1.4		100	BEDROCK, sandstone, gray, fine- to medium-grained, fine-bedded to massive, generally slightly weathered, hard			NQ Rock Core 100.0' to 117.4'					
				101	Conglomerate below 108.0', clayey joint at 112.5', some weathering around cobbles (Copper Harbor Conglomerate)			Run 1: 100.0' to 103.3' Drill: 3.3' Recover: 1.4' RQD: 100					
				102				106' of 3" casing to 101.9' on 3/16/11					
				103									
24	Run 2	5.0		104				Run 2: 103.3' to 108.3' Drill: 5.0' Recover: 5.0' RQD: 78					
				105									
				106									
				107				Core block at 106.8'					
				108									
25	Run 3	4.6		109				Run 3: 108.3' to 113.3' Drill: 5.0' Recover: 4.6' RQD: 68					
				110									
				111									
				112									
				113									
26	Run 4	3.8		114				Run 4: 113.3' to 117.4' Drill: 4.1' Recover: 3.8' RQD: 61					
				115									
				116									
				117	117.4' End of Boring								
				118									
				119									
				120									

AS-Auger Sample | BS-Bag Sample | RC-Rock-Core | GS-Grab Sample | PS-Piston Tube | 2SS-2" Split Spoon | 3SS-3" Split Spoon | 2ST-2" Shelby Tube | 3ST-3" Shelby Tube

while drilling | after drilling

after hours

BORING NO.: BH-02

Borehole
BH-04

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-04

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: S. Strigel / C. Rasmussen

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 66.3

DATE STARTED: Jan 24, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Neat Cement and Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	2-4-5 (9)	1.5		0	(SM) SILTY SAND, red-brown, fine, trace rootlets, moist, loose			5" Solid Stem Auger 0.0' to 9.5' 2" SPT Sampling 140# wt., 30" drop 4" casing 0.0' to 7.5'		27.9			
				1				Frost 0.2' deep					
				2									
				3	± 3.0' (CL) CLAY, red-brown, some fine sand, trace fine gravel, slightly plastic, moist, very stiff								
				4									
2	6-11-14 (25)	1.5		5						12.0		0.9	4.5
2A				6									
				7									
				8									
				9									
3	(-)	1.3		10				3-7/8" Roller Bit with Quickgel drilling mud 9.5' to 52.0'				0.9	2.0
				11									
				12									
				13									
				14									
4	9-16-26 (42)	1.0		15	...plastic (pushed a rock)					17.6			
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling 25.0
after drilling

after hours

BORING NO.: BH-04

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-04

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: S. Strigel / C. Rasmussen

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 66.3

DATE STARTED: Jan 24, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Neat Cement and Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
5	(-)	2.0		20	(CL) CLAY, red-brown, some fine sand, trace fine gravel, plastic, moist, very stiff							0.58	2.0
				21									
				22									
				23	± 23.0' (ML) SANDY SILT, brown, fine to coarse sand, some fine gravel, slightly plastic, hard			Driller's note: Intermittent gravel 23.5' to 36.0'					
				24									
6	35-57-50 (107)	1.4		25		▽		Driller's note: Samples wet 25.0' to 36.5'	10.8 89.2 47.4	11.8	15 12		
6A				26									
				27									
				28	± 28.0' (SM) SILTY SAND, red-brown, with fine gravel, wet, very dense								
				29									
7	35-40-41 (81)	0.9		30						6.5			
7A				31									
				32									
				33									
				34									
8	36-106-80/0.2' (-)	0.9		35						8.9			
8A				36				Driller's note: Hard drilling 36.0' to 42.0'					
				37									
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

▽ while drilling 25.0
▼ after drilling

▽ after hours

BORING NO.: BH-04

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-04

CLIENT: Orvana Resources U.S. Corporation — 3 OF 4

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: S. Strigel / C. Rasmussen

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core — BORING DEPTH: 66.3

DATE STARTED: Jan 24, 11 — DATE COMPLETED: Jan 26, 11 — REVIEWED BY: W. Rice — DATE: 2/21/11

HOLE CLOSURE: Neat Cement and Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
9 10	100/0.1'-WASH	NR		40	(SM) SILTY SAND, red-brown, with fine gravel, wet, very dense								
				41									
				42				Driller's note: Medium drilling 42.0' to 45.0'					
11	WASH			43									
				44									
12	100/0.2'-(-)	0.1		45	± 45.0' Probable WEATHERED BEDROCK, very hard drilling			Driller's note: Very hard drilling 45.0' to 47.5'		7.7			
				46									
				47									
				48				Driller's note: Medium hard drilling 47.5' to 48.0' Driller's note: Very hard drilling 48.0' to 52.0'					
13	WASH			49									
				50									
				51									
Run 1				52	52.0' BEDROCK, sandstone, brown to red-brown, fine to medium grained, crossbedded about 15° from horizontal, occasional joint, weathered, thin zones of small conglomerate at 58.0', 59.8', 61.5' (Pre-Cambrian Copper Harbor Conglomerate)			NQ Rock Core 52.0' to 66.3' Run 1: 52.0' to 57.0' Drill: 5.0' Recover: 4.3' RQD: 69					
				53									
				54									
				55									
				56									
Run 2				57				Run 2: 57.0' to 61.3' Drill: 4.3' Recover: 5.0' RQD: 78					
				58									
				59									
				60									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling 25.0; after drilling; after hours

BORING NO.: BH-04

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-04

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: S. Strigel / C. Rasmussen

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 66.3

DATE STARTED: Jan 24, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Neat Cement and Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				60	BEDROCK, Pre-Cambrian Copper Harbor Conglomerate								
				61									
Run 3				62				Run 3: 61.3' to 66.3' Drill: 5.0' Recover: 4.0' RQD: 88					
				63									
				64									
				65									
				66	66.3'			Driller's note: Bottom 1.0' of core not recovered from boring					
					End of Boring								
				67									
				68									
				69									
				70									
				71									
				72									
				73									
				74									
				75									
				76									
				77									
				78									
				79									
				80									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling 25.0
after drilling

after hours

BORING NO.: BH-04

Borehole
BH-05

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-05

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA & 3-7/8" RB

BORING DEPTH: 62.1

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	21-12-12 (24)	0.6		0	(CL) CLAY, red-brown, some fine sand, trace fine gravel, plastic, moist, very stiff			5" Solid Stem Auger 0.0' to 10.0' 2" SPT Sampling 140# wt., 30" drop 4" casing 0.0' to 8.1' Frost 0.3' deep					
				1									
				2									
				3									
				4									
2	5-7-9 (16)	1.2		5						15.7		0.88	4.5
				6									
				7									
				8									
				9									
3	5-7-8 (15)	1.5		10				3-7/8" Roller Bit with Quickgel drilling mud 10.0' to 62.1'		19.2		0.9	2.0
				11									
				12									
				13									
				14									
				15									
				16									
4	(-)	1.4		17								0.9	2.0
				18									
				19									
				20									

AS-Auger Sample; BS-Bag Sample; RC-Rock-Core; GS-Grab Sample; PS-Piston Tube; 2SS-2" Split Spoon; 3SS-3" Split Spoon; 2ST-2" Shelby Tube; 3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▼ after hours

BORING NO.: BH-05

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-05

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA & 3-7/8" RB

BORING DEPTH: 62.1

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20	(CL) CLAY, red-brown, some fine sand, trace fine gravel, plastic, moist, very stiff								
				21									
5	4-6-8 (14)	1.5		22						19.1		0.84	1.6
				23				Driller's note: Cobbles and/or boulders 23.0' to 25.0'					
				24									
				25									
				26									
6	(-)	1.5		27								0.9	3.5
				28									
				29									
				30									
				31									
7	12-13-16 (29)	1.0		32	...some sandy layers with silt					11.6		0.82	3.7
				33									
				34									
				35									
				36									
8	(-)	1.6		37	...some fine to coarse gravel			Driller's note: Sample too stony to measure T.					>4.5
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-05

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-05

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA & 3-7/8" RB

BORING DEPTH: 62.1

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				40	(CL) CLAY, red-brown, some fine sand, some fine to coarse gravel, plastic, moist, very stiff								
				41									
9	9-14-18 (32)	1.2		42						11.8		0.9	3.5
				43									
				44									
				45									
				46									
10	8-10-14 (24)	1.2		47	...trace fine gravel					18.1		0.9	2.2
				48									
				49									
				50									
				51									
11	71-108-50/0.4' (-)	1.0		52						9.6			
				53	...sandy, slightly plastic			Driller's note: Hard drilling 53.0' to 55.5'					
				54									
				55									
				56				Driller's note: Medium drilling 55.5' to 56.5'					
12	47-101-50/0.2' (-)	0.8		57				Driller's note: Hard drilling 56.5' to 57.0'		7.9			
				58									
				59									
				60									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-05

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-05

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 5" SSA & 3-7/8" RB

BORING DEPTH: 62.1

DATE STARTED: Jan 25, 11 DATE COMPLETED: Jan 26, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Cement/Bentonite

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				60	(CL) CLAY, red-brown, sandy, trace fine gravel, slightly plastic, moist, very stiff ± 60.5'								
				61	Probable WEATHERED BEDROCK, solid at 62.1'			Driller's note: Very hard drilling 60.8' to 62.0'					
13	100/0.1'- (-)	NR		62	62.1' End of Boring								
				63									
				64									
				65									
				66									
				67									
				68									
				69									
				70									
				71									
				72									
				73									
				74									
				75									
				76									
				77									
				78									
				79									
				80									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-05

Borehole
BH-06

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-06

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 16' S., 16' W. of stake

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 82.4

DATE STARTED: Jan 18, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	1-3-6 (9)	1.3		0	(SM) SILTY SAND, red-brown, fine to medium, trace rootlets, moist, loose			3-7/8" Drag Bit with drilling mud 2" SPT Sampling 140# wt., 30" drop 3" casing 0.0' to 10.0'		13.3			
				1									
				2									
				3	± 3.0' (CL) CLAY, red-brown, some sand, trace fine gravel, slightly plastic, moist, very stiff								
				4									
2	7-9-13 (22)	1.3		5						14.1		0.82	3.85
				6									
				7									
				8									
				9									
3	(-)	2.0		10								0.77	1.5
				11									
				12									
				13									
				14									
				15									
				16									
4	6-6-8 (14)	1.5		17	...trace fine sand, trace fine gravel, moderately plastic					20.9		0.5	0.5
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-06

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-06

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 16' S., 16' W. of stake

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 82.4

DATE STARTED: Jan 18, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20	(CL) CLAY, red-brown, trace fine sand, trace fine gravel, moderately plastic, moist, very stiff								
5	(-)	1.7		21	...plastic, wet							0.36	0.5
				22									
				23									
				24									
				25									
				26									
6	6-7-12 (19)	1.5		27	...sand seam at 26.2' and 27.4' to 27.6'					19.1		0.75	1.25
				28									
				29									
				30									
				31									
				32									
7	(-)	1.4		33								0.6	0.5
				34									
				35									
				36									
				37									
8	4-7-13 (20)	1.4		38	...moderately plastic, some fine sand, some fine gravel					30.7		0.57	4.0
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-06

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-06

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 16' S., 16' W. of stake

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 82.4

DATE STARTED: Jan 18, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				40	(CL) CLAY, red-brown, some fine sand, some fine gravel, moderately plastic, moist, very stiff								
				41									
				42									
9	(-)	1.7		43								0.77	4.5
				44									
				45									
				46									
				47									
10	9-17-20 (37)	1.3		48	...sand seam 48.3' to 48.7'					18.6			
				49									
				50									
				51									
				52									
11	(-)	1.4		53	...trace fine gravel, slightly plastic, wet, very stiff							0.76	2.8
				54									
				55									
				56									
				57									
12	9-11-17 (28)	1.4		58						13.3			
				59									
				60									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-06

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-06

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 16' S., 16' W. of stake

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 82.4

DATE STARTED: Jan 18, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				60	(CL) CLAY, red-brown, some fine sand, trace fine gravel, slightly plastic, wet, very stiff								
				61									
				62									
13	(-)	0.9			...with fine sand, some fine gravel, moderately plastic							0.66	>4.5
				63									
				64									
14	30-29-41 (70)	1.5		65	...hard					10.2			
				66									
				67									
				68									
				69									
				70									
15	48-89-141 (230)	1.5		71	...sandy, slightly plastic			Note: Material was crumbly when testing for T.		11.0		0.1	>4.5
				72									
				73									
				74									
				75									
				76									
				77									
				78									
				79									
				80									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-06

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-06

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 16' S., 16' W. of stake

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 82.4

DATE STARTED: Jan 18, 11 DATE COMPLETED: Jan 18, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				80	(CL) CLAY, red-brown, sandy, some fine gravel, slightly plastic, wet, hard								
16	53-77-70 (148)	1.5	X	81						8.1		0.56	>4.5
				82	82.4'								
					End of Boring								
				83									
				84									
				85									
				86									
				87									
				88									
				89									
				90									
				91									
				92									
				93									
				94									
				95									
				96									
				97									
				98									
				99									
				100									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-06

Borehole
BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core

BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 DATE COMPLETED: Mar 11, 11 REVIEWED BY: W. Rice DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	3-3-5 (8)	0.9		0	(CL) LEAN CLAY, red-brown, plastic, some silt, some fine sand, moist, stiff			4-1/4" Hollow Stem Auger 0.0' to 10.0' 2" SPT Sampling 140# wt., 30" drop 3" casing 0.0' to 12.0' 4" casing 0.0' to 13.0' 2-7/8" Roller Bit 0.0' to 34.0'					
				1									
				2									
2	6-7-10 (17)	1.2		3	...very stiff							1.53	4.3
				4									
3	6-11-17 (28)	1.5		5	...trace fine gravel							1.53	4.5
				6									
				7									
4	6-7-11 (18)	1.5		8								1.43	4.5
				9									
5	7-9-14 (23)	1.5		10								1.1	1.5
				11									
				12									
				13									
				14									
6		1.9		15									
				16									
				17									
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 2 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
7	4-6-14 (20)	1.2		20	(CL) LEAN CLAY, red-brown, plastic, some silt, some fine sand, trace fine gravel, moist, very stiff							1.23	1.4
				21									
				22									
				23									
				24									
8	5-7-10 (17)	1.3		25								0.65	0.5
				26									
				27									
				28									
				29									
9		0.4		30								0.52	1.25
				31									
10		2.4		32								0.49	1.25
				33									
11		1.9		34								0.73	1.25
				35									
				36									
				37				Driller's note: Cobbles and/or boulders 36.5' to 37.0'					
				38									
				39									
				40									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling; after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 3 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
12	4-5-7 (12)	1.5		40	(CL) LEAN CLAY, red-brown, plastic, some silt, some fine sand, trace fine gravel, moist, very stiff							0.64	1.5
				41									
				42									
				43									
				44									
13		1.9		45								0.77	>4.5
				46									
				47									
				48									
				49									
14	17-25-38 (63)	1.2		50								0.67	>4.5
				51									
				52									
				53									
				54									
15	14-39-50/0.4' (-)	0.7		55								0.65	>4.5
				56									
				57									
				58									
				59									
				60									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 4 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
16	14-22-39 (61)	1.0	X	60	(CL) LEAN CLAY, red-brown, plastic, some silt, some fine sand, trace fine gravel, moist, very stiff							0.88	2.25
				61									
				62									
				63									
				64				Driller's note: Cobbles and/or boulders 64.0' to 65.5'					
				65									
				66									
				67									
				68				Driller's note: Cobbles and/or boulders 68.0' to 71.0'					
				69									
				70									
				71									
				72									
				73									
				74									
				75	± 75.0' (SM) SILTY SAND, red-brown, fine to medium, trace fine gravel, wet								
				76									
				77									
				78									
				79									
				80									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 5 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
17		1.6		80	(SM) SILTY SAND, red-brown, fine to medium, trace fine gravel, wet								
				81									
18	Soil Core	2.5		82	...gravelly, very dense								
				83									
				84									
				85									
				86									
19	Soil Core	NR		87									
				88									
				89									
				90									
				91									
20	50/0.5' (-)	0.2		92	...some fine gravel								
				93									
				94									
				95									
				96				Driller's note: Cobbles and/or boulders 96.0' to 97.5'					
				97									
				98									
				99									
				100									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling; after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 6 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				100	(SM) SILTY SAND, red-brown, fine to medium, some fine gravel, wet, very dense								
				101									
				102									
				103									
				104									
				105									
				106									
				107									
				108									
				109									
21	50/0.4' (-)	NR	☒	110									
				111				Driller's note: Cobbles and/or boulders 111.0' to 111.5'					
				112									
				113									
				114									
				115									
				116									
				117									
				118									
				119									
				120									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

▽ while drilling; ▼ after drilling; ▽ after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 7 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				120	(SM) SILTY SAND, red-brown, fine to medium, some fine gravel, wet, very dense								
				121									
				122									
				123									
				124				Driller's note: Cobbles and/or boulders 124.0' to 125.0'					
				125									
				126									
				127									
				128									
				129									
				130									
				131									
				132									
				133									
				134	Auger Drilling Refusal 134.0'								
22	Run 1	2.0			BEDROCK, sandstone, gray to red-brown, fine to medium grained, fine bedded, unweathered, hard, bedding flat-lying to about 10° from horizontal (Copper Harbor Conglomerate)			NQ Rock Core 134.0' to 148.5' Run 1: 134.0' to 136.0' Drill: 2.0' Recover: 2.0' RQD: 0					
				135									
23	Run 2	2.0		136				Run 2: 136.0' to 138.0' Drill: 2.0' Recover: 2.0' RQD: 71					
				137									
24	Run 3	5.3		138				Run 3: 138.0' to 143.3' Drill: 5.3' Recover: 5.3' RQD: 77					
				139									
				140									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-07

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-07

CLIENT: Orvana Resources U.S. Corporation — 8 OF 8

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount — DRILL CREW: J. Lantagne / J. Peretto

DRILLING METHOD: 4-1/4" HSA, 2-7/8" RB & NQ Rock Core — BORING DEPTH: 148.5

DATE STARTED: Feb 17, 11 — DATE COMPLETED: Mar 11, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				140	BEDROCK, sandstone, gray to red-brown, fine to medium grained, fine bedded, unweathered, hard, bedding flat-lying to about 10° from horizontal (Copper Harbor Conglomerate)								
				141									
				142									
				143									
25	Run 4	5.2		144				Run 4: 143.3' to 148.5' Drill: 5.2' Recover: 5.2' RQD: 100					
				145									
				146									
				147									
				148									
					148.5'								
				149	End of Boring								
				150									
				151									
				152									
				153									
				154									
				155									
				156									
				157									
				158									
				159									
				160									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-07

Borehole
BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation — 1 OF 7

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit — BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 — DATE COMPLETED: Mar 3, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	11-8-6 (14)	1.4		0	(CL) LEAN CLAY, red-brown, plastic, some fine sand, trace fine gravel, moist, stiff			3-7/8" Drag Bit 2" SPT Sampling 140# wt., 30" drop				0.74	2.7
				1				4" casing 0.0' to 6.0'					
				2				Frost 0.8' deep					
				3									
				4									
2	6-6-10 (16)	1.2		5	...very stiff							1.1	>4.5
				6									
				7									
				8									
				9									
3		1.9		10									
				11									
				12									
4		1.8			...with fine to coarse gravel							0.48	3.3
				13									
				14									
5		1.6		15									
				16									
				17				Driller's note: Cobbles and/or boulders 16.8' to 17.8'					
				18									
				19				Driller's note: Cobbles and/or boulders 19.0' to 19.6'					
				20									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation — 2 OF 7

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit — BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 — DATE COMPLETED: Mar 3, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
6		1.9		20	(CL) LEAN CLAY, red-brown, plastic, some fine sand, with fine to coarse gravel, moist, very stiff							0.88	1.3
				21									
				22									
				23									
				24									
7	4-4-8 (12)	1.4		25								1.13	2.0
				26									
				27									
				28									
				29									
8		1.9		30									
				31									
				32									
				33									
				34									
9	7-12-15 (27)	1.0		35								1.55	3.0
				36									
				37									
				38				Driller's note: Cobbles and/or boulders 37.5' to 39.0'					
				39									
				40									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

▽ while drilling; ▼ after drilling

▼ after hours

BORING NO.: BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation — 3 OF 7

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit — BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 — DATE COMPLETED: Mar 3, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
10		1.2		40	(CL) LEAN CLAY, red-brown, plastic, some fine sand, with fine to coarse gravel, moist, very stiff								
				41									
				42									
				43									
				44									
11	8 -12-16 (28)	1.2		45								1.13	>4.5
				46									
				47									
				48				Driller's note: Cobbles and/or boulders 48.0' to 48.5'					
				49									
12	9-14-16 (30)	1.2		50	...hard							1.13	1.8
				51									
				52									
				53									
				54									
13	32-40-45 (85)	1.5		55								0.95	3.9
				56									
				57									
				58									
				59									
				60	...very stiff								

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation — 4 OF 7

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit — BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 — DATE COMPLETED: Mar 3, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
14	7-12-14 (26)	1.5		60	(CL) LEAN CLAY, red-brown, plastic, some fine sand, with fine to coarse gravel, moist, very stiff							1.73	4.25
				61									
				62									
				63									
				64									
15	12-13-16 (29)	1.2		65								0.37	0.2
				66									
				67									
				68	± 68.0' (SM) SAND, brown, fine to coarse, with silt, with fine gravel, wet, very dense								
				69									
16	22-24-18 (42)	1.2		70	...interlayered with 1" silt layers			Driller's note: Sampled with 3-7/8" Roller Bit to 70.0'. Hole collapsing after Roller Bit to 75.0'. Added 3" casing to 75.0'. No returns. 2-7/8" Roller Bit to 79.6'. Samples at 79.6' and 84.6'.					
				71									
				72									
				73									
				74									
				75									
				76									
				77									
				78									
				79									
				80	...silty								

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation — 5 OF 7

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit — BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 — DATE COMPLETED: Mar 3, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
17	65-62-50/0.4' (-)	1.0		80	(SM) SAND, brown, fine to coarse, silty, with fine gravel, wet, very dense								
				81									
				82									
				83	± 83.0' (CL) LEAN CLAY, red-brown, slightly plastic, with fine sand, wet, hard								
				84									
18	24-32-33 (65)	1.3		85								1.1	>4.5
				86									
19		NR		87				Driller's note: Attempted 2" Shelby Tube at 86.1'. Lost tube down hole. Could not pull tube or 3" casing. Advanced 3" casing to 87.0'. Roller bit tube out of way to 94.1'					
				88									
				89									
				90	± 90.0' COBBLES AND BOULDERS, sandstone and granite fragments, some red-brown clay matrix (probable till)								
				91									
20	Soil Core	0.6		92									
				93									
21	Soil Core	0.4		94									
				95									
				96									
				97									
				98									
22	Soil Core	1.9		99									
				100									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI — BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation — 6 OF 7

BORING LOCATION: As staked — ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount — DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit — BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 — DATE COMPLETED: Mar 3, 11 — REVIEWED BY: W. Rice — DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				100	COBBLES AND BOULDERS, sandstone and granite fragments, some red-brown clay matrix (probable till)								
				101									
				102									
				103	...with fine to medium silty sand								
23	Soil Core	0.5		104									
				105									
				106									
				107									
				108									
				109	± 109.0' (SM) SAND, brown, fine to coarse, with silt, some fine gravel, wet, very dense								
24	31-106-100/.4 (-)	1.5		110	...becomes fine to medium, silty at 110.0'								
				111									
				112									
				113									
				114									
				115									
				116									
				117	± 117.0' PROBABLE WEATHERED BEDROCK, dense, hard drilling			Driller's note: Hard drilling 117.0' to 121.0'. Advanced casing to 119.0' and Roller Bit to 120.0'					
				118									
				119									
				120									

-AS-Auger Sample; -BS-Bag Sample; -RC-Rock-Core; -GS-Grab Sample; -PS-Piston Tube; -2SS-2" Split Spoon; -3SS-3" Split Spoon; -2ST-2" Shelby Tube; -3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: BH-08

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-08

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 139.5

DATE STARTED: Feb 11, 11 DATE COMPLETED: Mar 3, 11 REVIEWED BY: W. Rice DATE: 3/17/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
25	Run 1	0.1		120	PROBABLE WEATHERED BEDROCK, dense, hard drilling			NQ Rock Core 120.0' to 139.5' Run 1: 120.0' to 124.5' Drill: 4.5' Recover: 0.1' RQD: 0					
				121									
				122									
				123									
				124	124.4'								
26	Run 2	5.0		125	BEDROCK, sandstone, white and red-brown, fine to medium grained, fine to coarse-bedded, unweathered, hard, bedding angled approx. 10° from horizontal, nearly vertical calcite vein from 120.0' to 125.0' (Copper Harbor Conglomerate)			Run 2: 124.5' to 129.5' Drill: 5.0' Recover: 5.0' RQD: 97					
				126									
				127									
				128									
				129									
27	Run 3	5.0		130				Run 3: 129.5' to 134.5' Drill: 5.0' Recover: 4.7' RQD: 88					
				131									
				132									
				133									
				134									
28	Run 4	5.3		135				Run 4: 134.5' to 139.5' Drill: 5.0' Recover: 5.3' RQD: 90					
				136									
				137									
				138									
				139	End of Boring 139.5'								
				140									

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-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-08

Borehole
BH-09

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-09

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 93.0

DATE STARTED: Feb 4, 11 DATE COMPLETED: Feb 4, 11 REVIEWED BY: W. Rice DATE: 2/24/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	4-3-4 (7)	1.2		0	(CL) LEAN CLAY, brown, with fine sand, trace fine gravel, slightly to moderately plastic, moist, medium stiff			3-7/8" Drag Bit 0.0' to 93.0' 2" SPT Sampling 140# wt., 30" drop 4" casing 0.0' to 6.7'		20.2		0.38	1.4
				1									
				2									
				3									
2	5-7-11 (18)	1.2		4	...red-brown, trace fine sand, very stiff					11.8		0.85	3.0
				5									
				6									
				7									
				8									
3		1.9		9								0.87	2.4
				10				3-7/8" Roller Bit 10.0' to 83.0'					
				11									
				12									
				13									
				14									
				15									
				16									
4	4-5-8 (13)	1.2		17	...plastic, wet, stiff					16.7		0.57	1.5
				18									
				19									
				20									

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-BS-Bag Sample
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-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-09

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-09

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 93.0

DATE STARTED: Feb 4, 11 DATE COMPLETED: Feb 4, 11 REVIEWED BY: W. Rice DATE: 2/24/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20	(CL) LEAN CLAY, red-brown, trace fine sand, trace fine gravel, plastic, wet, stiff								
				21									
5		2.0		22	...with fine sand							0.39	2.2
				23									
				24									
				25									
				26									
6		1.6		27								0.65	2.8
				28									
				29									
				30									
				31									
7	6-8-14 (22)	1.2		32	...trace fine sand, very stiff					15.4		0.45	2.0
				33									
				34									
				35									
				36									
8	15-16-23 (39)	1.5		37	...some fine sand, hard					12.5		0.62	>4.5
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-09

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-09

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 93.0

DATE STARTED: Feb 4, 11 DATE COMPLETED: Feb 4, 11 REVIEWED BY: W. Rice DATE: 2/24/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				40	(CL) LEAN CLAY, red-brown, some fine sand, trace fine gravel, plastic, wet, hard								
				41									
9	15-16-21 (37)	1.4		42						10.7		0.65	2.75
				43									
				44									
				45									
				46									
10	18-20-25 (45)	1.4		47						10.9		0.89	>4.5
				48									
				49									
				50									
				51									
11	17-21-27 (48)	1.4		52						11.9		0.53	3.0
				53									
				54									
				55									
				56									
12	21-32-34 (66)	1.4		57								0.58	3.2
				58									
				59									
				60									

-AS-Auger Sample
-BS-Bag Sample
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-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-09

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-09

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 93.0

DATE STARTED: Feb 4, 11 DATE COMPLETED: Feb 4, 11 REVIEWED BY: W. Rice DATE: 2/24/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				60	(CL) LEAN CLAY, red-brown, some fine sand, trace fine gravel, plastic, wet, hard								
				61									
13	15-21-27 (48)	1.4		62								0.45	2.4
				63									
				64									
				65									
				66									
14	14-31-34 (65)	1.4		67								0.57	4.0
				68									
				69				Driller's note: Hard drilling 68.5' to 91.5'					
				70									
				71									
15	50/0.3'- (-)	0.1		72	...sticky								
				73									
				74									
				75									
				76									
				77									
				78									
				79									
				80									

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-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-09

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-09

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Drag Bit

BORING DEPTH: 93.0

DATE STARTED: Feb 4, 11 DATE COMPLETED: Feb 4, 11 REVIEWED BY: W. Rice DATE: 2/24/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				80	(CL) LEAN CLAY, red-brown, some fine sand, trace fine gravel, sticky, wet, hard								
				81									
16	36-47-50/0.3' (-)	1.3		82	...with fine sand							0.32	>4.5
				83									
				84									
				85									
				86									
				87									
				88									
				89									
				90									
				91									
17	46-50/0.4'- (-)	0.7		92									
				93	93.0' End of Boring								
				94									
				95									
				96									
				97									
				98									
				99									
				100									

-AS-Auger Sample
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-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-09

Borehole
BH-10

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11 DATE COMPLETED: Feb 3, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	12-17-17 (34)	1.5		0	(CL) CLAY, red-brown, some fine sand, some fine gravel, moderately plastic, moist, hard			5" Solid Stem Auger 2" SPT Sampling 140# wt., 30" drop		18.4			
1A				1				Frost 2.0' deep					
				2									
				3									
				4									
2	12-18-38 (56)	1.5		5						11.0		0.9	4.25
2A				6									
				7									
				8									
				9									
3	7-9-14 (23)	1.5		10	...trace light gray silt					13.2	34 14	0.85	>4.5
3A				11									
				12									
				13									
				14									
4		2.0		15									2.75
				16									
				17									
				18									
				19									
				20									

AS-Auger Sample
BS-Bag Sample
RC-Rock-Core
GS-Grab Sample
PS-Piston Tube
2SS-2" Split Spoon
3SS-3" Split Spoon
2ST-2" Shelby Tube
3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11

DATE COMPLETED: Feb 3, 11

REVIEWED BY: W. Rice

DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
5 5A	10-15-25 (40)	1.5		20	(CL) CLAY, red-brown, some fine sand, some fine gravel, trace light gray silt, moderately plastic, moist, hard			At 20.5' to 21.0', q = 0		13.9		0.8	>4.5
				21	...wet at 20.5'								
				22									
				23									
				24									
				25	...cobble 24.5' to 25.5'								
6		1.5		26								0.85	3.75
				27									
				28									
				29									
7	7-11-18 (29)	0.9		30						16.2		0.8	3.0
				31									
				32									
				33									
				34									
8		1.2		35								0.75	3.5
				36									
				37									
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11

DATE COMPLETED: Feb 3, 11

REVIEWED BY: W. Rice

DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
9	12-17-25 (42)	1.4		40	(CL) CLAY, red-brown, some fine sand, some fine gravel, trace light gray silt, plastic, wet, hard			At 41.0' to 41.5', q = 2.75		15.9			4.25
9A				41									
				42									
				43									
				44									
10	11-25-37 (62)	0.5		45				Driller's note: Attempted thin-wall tube sample at 45.0'; could not push		10.1			>4.5
				46									
				47									
				48									
				49									
11	18-38-38 (76)	1.5		50						11.0			>4.5
				51	...gravelly clay layer 51.0' to 51.5'			At 51.0' to 51.5', q = 0					
				52									
				53									
				54									
12	41-52-58 (110)	0.5		55	...sandy, slightly plastic								>4.5
12A				56									
				57									
				58									
				59									
				60									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

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IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11 DATE COMPLETED: Feb 3, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				60	(CL) LEAN CLAY, red-brown, sandy, trace fine gravel, slightly plastic, wet, hard								
				61									
				62				Driller's note: Cobbles and/or boulders 62.0' to 62.5'					
				63									
				64				Driller's note: Hard drilling 64.0' to 109.5'					
13	80-80/0.3'-(-)	0.4		65									
				66									
14	Soil Core	0.5		67	...basaltic rock core pieces, some red-brown sandy clay			Sample #14 (66.5' to 68.4') collected by Soil Core					
				68									
				69									
15	88-100/0.4'-(-)	0.9		70									
				71									
				72									
				73									
				74									
				75									
16	Soil Core	1.4		76				Sample #16 (75.5' to 80.5') collected by Soil Core					
				77									
				78									
				79									
				80									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11

DATE COMPLETED: Feb 3, 11

REVIEWED BY: W. Rice

DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				80	(CL) LEAN CLAY, red-brown, sandy, slightly plastic, wet, hard								
17	Soil Core	5.2		81				Sample #17 (80.5' to 85.5') collected by Soil Core					
				82									
				83									
				84									
				85									
				86									
				87									
				88									
				89									
				90									
				91									
				92									
				93									
				94									
				95									
				96									
				97									
				98									
				99									
				100									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11 DATE COMPLETED: Feb 3, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
18	29-52-70 (122)	1.1		100	(CL) LEAN CLAY, red-brown, sandy, slightly plastic, wet, hard								>4.5
18A				101									
				102									
				103									
				104									
				105									
				106	± 106.0' WEATHERED ROCK								
				107									
				108									
				109	109.5'								
19	Run 1	2.5		110	BEDROCK, sandstone, red-brown, fine to medium grained, mixture of fine and coarse bedding, occasional pebbles (conglomerate), some fine partings, unweathered, durable (Copper Harbor Conglomerate)			NQ Rock Core 109.5' to 124.5' Run 1: 109.5' to 114.5' Drill: 5.0' Recover: 2.5' RQD: 83					
				111									
				112									
				113									
				114									
20	Run 2	5.3		115				Run 2: 114.5' to 119.5' Drill: 5.0' Recover: 5.3' RQD: 90 Note: Packer test conducted 116.0' to 124.5'					
				116									
				117									
				118									
				119									
21	Run 3	5.0		120									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-10

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: Offset 25' N. of stake, on north side of road

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" Solid Stem Auger

BORING DEPTH: 124.5

DATE STARTED: Feb 3, 11

DATE COMPLETED: Feb 3, 11

REVIEWED BY: W. Rice

DATE: 2/21/11

HOLE CLOSURE:

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				120	BEDROCK, sandstone, red-brown, fine to medium grained, mixture of fine and coarse bedding, occasional pebbles (conglomerate), some fine partings, unweathered, durable (Copper Harbor Conglomerate)			Run 3: 119.5' to 124.5' Drill: 5.0' Recover: 5.0' RQD: 78					
				121									
				122									
				123									
				124	124.5'								
				125	End of Boring								
				126									
				127									
				128									
				129									
				130									
				131									
				132									
				133									
				134									
				135									
				136									
				137									
				138									
				139									
				140									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-10

Borehole
BH-11

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-11

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount

DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Roller Bit & NQ Rock Core

BORING DEPTH: 31.1

DATE STARTED: Jan 27, 11 DATE COMPLETED: Feb 1, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	1-1-3 (4)	1.0		0	(SM) SILTY SAND, brown, fine to medium, trace fine gravel, wet, loose			3-7/8" Roller Bit 0.0' to 12.4' 2" SPT Sampling 140# wt., 30" drop		7.6			
				1				4" casing 0.0' to 7.5' 3" casing 0.0' to 17.5'					
				2									
				3									
				4									
				5				Driller's note: Hard drilling 4.5' to 9.5'					
2	22-32-37 (69)	1.2			...very dense					7.2			
				6									
				7									
				8									
				9									
				10				Driller's note: Very hard drilling 9.5' to 12.8' Bentonite drilling mud 10.0' to 11.5'					
3	50/0.4'- (-)	0.4			± 10.5' WEATHERED BEDROCK					6.1			
				11									
				12	± 12.4'								
4	Run 1	1.6		13	BEDROCK, sandstone / conglomerate, brown, fine- to coarse-grained, slightly weathered, bedding about 15° from horizontal, congolmerate zone 13.5' to 13.8', pebbles rounded, max. 1" across (Copper Harbor Conglomerate)			NQ Rock Core 12.4' to 31.1' Cored 12.4' to 14.0' - rig bogging down, core angling and cocked in hole due to poor quality rock. Core barrel broke, spun 3" casing over barrel to free it, set casing to 17.5'					
				14									
				15				Run 1: 12.4' to 14.0' Drill: 1.6' Recover: 1.6' RQD: 44					
				16									
5	Run 2	4.0		17				Run 2: 16.7' to 21.1' Drill: 4.4' Recover: 4.0' RQD: 75					
				18									
				19									
				20									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-11

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-11

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked ELEV.:

RIG TYPE: Diedrich D-120 ATV Mount DRILL CREW: J. Lantagne / B. Bigalke

DRILLING METHOD: 3-7/8" Roller Bit & NQ Rock Core BORING DEPTH: 31.1

DATE STARTED: Jan 27, 11 DATE COMPLETED: Feb 1, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20									
6	Run 3	5.0		21	BEDROCK, slightly conglomeratic 21.1' to 21.3', moderately weathered sandstone to 22.2', then more intact. Predominantly conglomerate below 25.0', pebbles to maximum of 2" across, rounded, rock durable, bedded about 15° from horizontal to about 26.0' deep (Copper Harbor Conglomerate)			Run 3: 21.1' to 26.1' Drill: 5.0' Recover: 5.0' RQD: 62					
				22									
				23									
				24									
				25									
7	Run 4	5.1		26				Run 4: 26.1' to 31.1' Drill: 5.0' Recover: 5.1' RQD: 100					
				27									
				28									
				29									
				30									
				31	31.1'								
					End of Boring								
				32									
				33									
				34									
				35									
				36									
				37									
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: BH-11

Borehole
BH-12

COLEMAN ENGINEERING COMPANY

635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-12

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 30.2

DATE STARTED: Jan 27, 11 DATE COMPLETED: Jan 28, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
1	2-6-9 (15)	0.1		0	TOPSOIL / SILTY SAND, brown, wet, some rootlets, loose ± 0.2'			5" Solid Stem Auger 0.0' to 9.5' 3-7/8" Roller Bit with Quickgel drilling mud 0.0' to 15.5' 2" SPT Sampling 140# wt., 30" drop		25.3			
				1	(CL) CLAY, red-brown, some fine sand, trace fine gravel, trace light tan silt, slightly plastic, moist, hard								
				2				4" casing 0.0' to 7.0' 3" casing 0.0' to 5.5'					
				3									
				4		▽							
2	11-16-26 (42)	1.3		5				Driller's note: Samples wet 4.5' to 6.0'		10.8		0.8	>4.5
2A				6				Driller's note: Felt like weathered rock drilling 6.0' to 8.0' Hard drilling (not cobbles) with solid stem auger to 9.5'					
				7				Hard drilling with roller bit to 12.9'					
				8									
				9									
3	80/0.2'- (-)	NR		10	± 9.6' WEATHERED BEDROCK			Driller's note: Hard drilling with roller bit to 13.2'		3.6			
				11									
				12									
				13	± 13.2' BEDROCK, sandstone / conglomerate, red-brown, fine to medium grained, unweathered, hard, many joints to 19.0', more intact below (Copper Harbor Conglomerate)								
				14									
				15									
4	Run 1	3.1		16				NQ Rock Core 15.5' to 30.2' Run 1: 15.5' to 19.0' Drill: 3.5' Recover: 3.1' RQD: 14					
				17									
				18				Core block at 19.0' Run 2: 19.0' to 22.8' Drill: 3.8' Recover: 3.8' RQD: 82					
5	Run 2	3.8		19	...conglomerate 19.8' to 22.8', rounded cobbles to 2" across								
				20									

[I] -AS-Auger Sample
[B] -BS-Bag Sample
[I] -RC-Rock-Core
[G] -GS-Grab Sample
[P] -PS-Piston Tube
[X] -2SS-2" Split Spoon
[/] -3SS-3" Split Spoon
[◪] -2ST-2" Shelby Tube
[◪] -3ST-3" Shelby Tube

▽ while drilling 4.5
▼ after drilling

▼ after hours

BORING NO.: BH-12

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 11006.GPJ

PROJECT: Copperwood Project, Wakefield Township, MI

BORING NO.: BH-12

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As staked

ELEV.:

RIG TYPE: Diedrich D-50 Truck Mount

DRILL CREW: J. Frappier / C. Rasmussen

DRILLING METHOD: 5" SSA, 3-7/8" RB & NQ Rock Core

BORING DEPTH: 30.2

DATE STARTED: Jan 27, 11 DATE COMPLETED: Jan 28, 11 REVIEWED BY: W. Rice DATE: 2/21/11

HOLE CLOSURE: Soil Cuttings and Neat Cement

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				20	BEDROCK, conglomerate, red-brown, rounded cobbles to 2" across, unweathered, hard (Copper Harbor Conglomerate)								
				21									
				22									
6	Run 3	5.0		23				Run 3: 22.8' to 27.8' Drill: 5.0' Recover: 5.0' RQD: 63					
				24									
				25									
				26									
				27									
7	Run 4	2.4		28				Run 4: 27.8' to 30.2' Drill: 2.4' Recover: 2.4' RQD: 90					
				29	...fine-bedded sandstone 28.8' to 30.2', some cross-bedding								
				30	30.2' End of Boring								
				31									
				32									
				33									
				34									
				35									
				36									
				37									
				38									
				39									
				40									

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling 4.5
after drilling

after hours

BORING NO.: BH-12

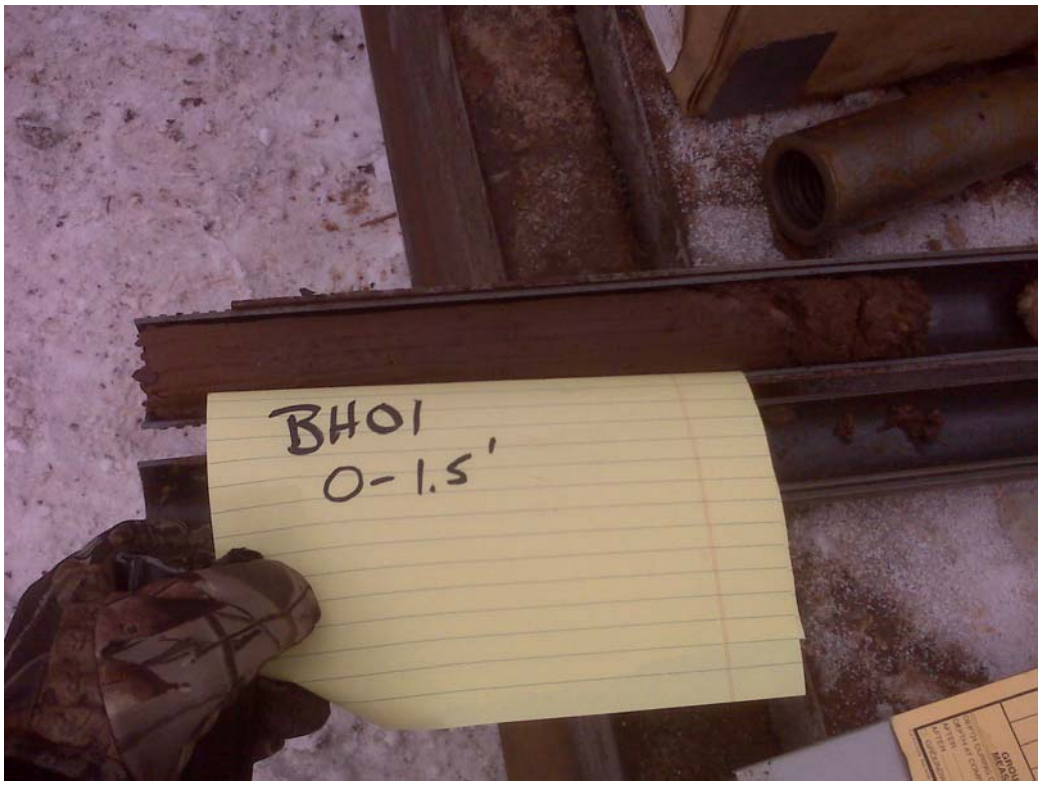
Appendix D

Borehole Photos

Photographs of
Borehole
BH-01

Knight Piésold CONSULTING

Copperwood Project
Borehole Photographs



BH-01 – SPT Recovery, 0-1.5'

BH-01 – SPT Recovery, 4.5-6'

Copperwood Project
Borehole Photographs

BH-01 – SPT Recovery, 10-11.5'

BH-01 – SPT Recovery, 20.5-22'

Copperwood Project
Borehole Photographs

BH-01 – SPT Recovery, 40-41.5'

BH-01 – SPT Recovery, 45-46.5'

Copperwood Project
Borehole Photographs

BH-01 – SPT Recovery, 50-51.5'

BH-01 – SPT Recovery, 60-61.5'

Copperwood Project
Borehole Photographs

BH-01 – SPT Recovery, 75-76.5'

BH-01 – SPT Recovery, 80-81.5'

Copperwood Project
Borehole Photographs

BH-01 – SPT Recovery, 90-91.5'

BH-01 – Rock Core Recovery, 98.9-107.4'

Copperwood Project
Borehole Photographs

BH-01 – Rock Core Recovery, 107.4-117.4'

Photographs of
Borehole
BH-04

Knight Piésold CONSULTING

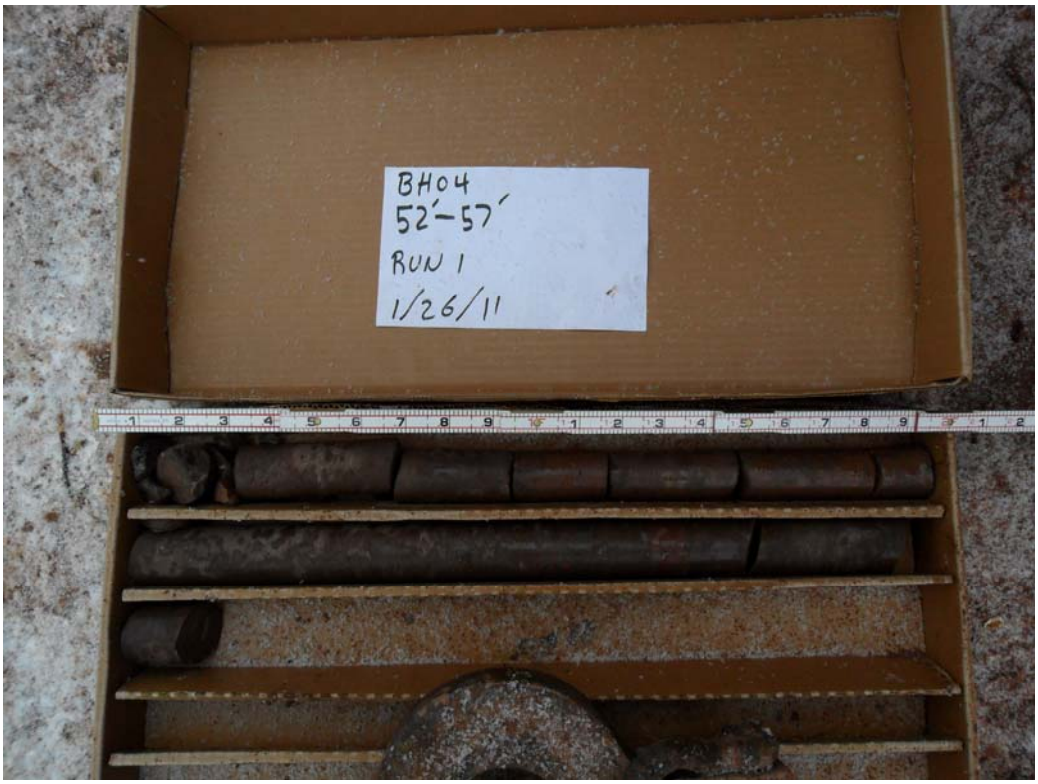
Copperwood Project
Borehole Photographs

BH-04 – SPT Recovery, 25-26.5'

BH-04 – SPT Recovery, 30-31.5'

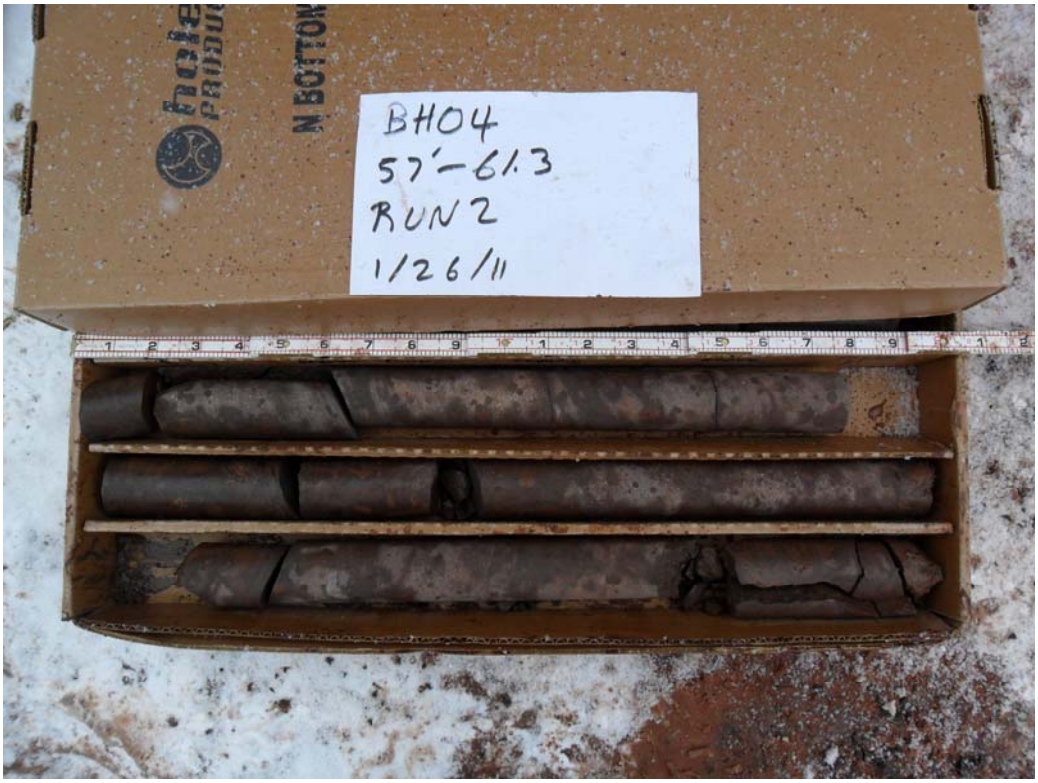
Copperwood Project
Borehole Photographs

BH-04 – SPT Recovery, 35-36.5'



BH-04 – Rock Core Recovery, 52-57'

Copperwood Project
Borehole Photographs



BH-04 – Rock Core Recovery, 57-61.3'

BH-04 – Rock Core Recovery, 61.3-66.3'

Photographs of
Borehole
BH-06

Knight Piésold CONSULTING

Copperwood Project
Borehole Photographs

BH-06 – SPT Recovery, 0-1.5'

BH-06 – SPT Recovery, 5-6.5'

Copperwood Project
Borehole Photographs

BH-06 – SPT Recovery, 15-16.5'

BH-06 – SPT Recovery, 37-38.5'

Copperwood Project
Borehole Photographs

BH-06 – SPT Recovery, 47-48.5'

Photographs of
Borehole
BH-09

Knight Piésold CONSULTING

Copperwood Project
Borehole Photographs

BH-09 – SPT Recovery, 31.5-33'

BH-09 – SPT Recovery, 36.5-38'

Copperwood Project
Borehole Photographs

BH-09 – SPT Recovery, 41.5-43'

BH-09 – SPT Recovery, 46.5-48'

Copperwood Project
Borehole Photographs

BH-09 – SPT Recovery, 56.5-58'

BH-09 – SPT Recovery, 61.5-63'

Copperwood Project
Borehole Photographs

BH-09 – SPT Recovery, 66.5-68'

BH-09 – SPT Recovery, 81.5-83'

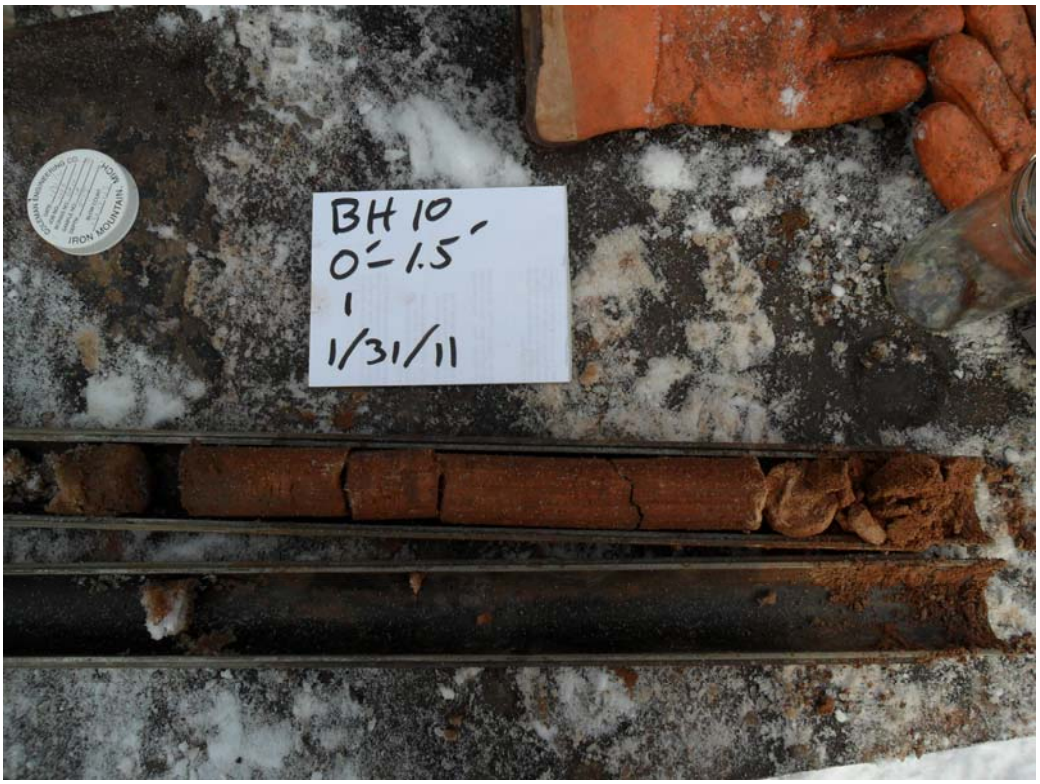
Copperwood Project
Borehole Photographs

BH-09 – SPT Recovery, 91.5-93'

Photographs of
Borehole
BH-10

Knight Piésold
CONSULTING

Copperwood Project
Borehole Photographs

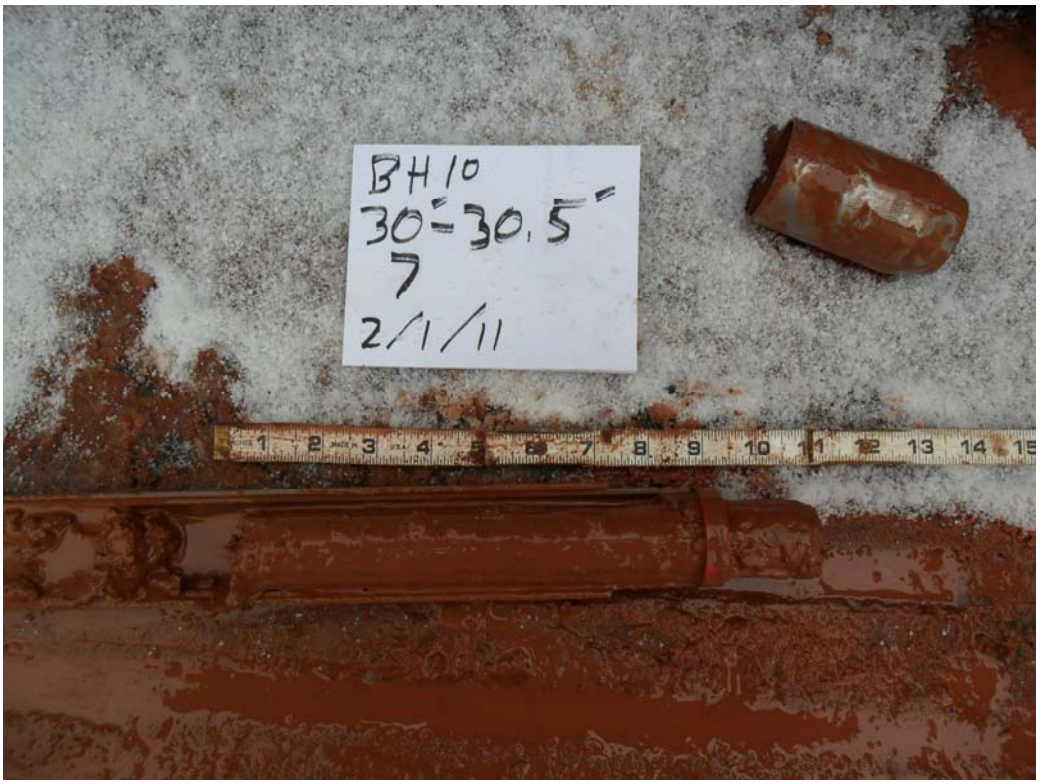


BH-10 – SPT Recovery, 0-1.5'

BH-10 – SPT Recovery, 4.5-6.0'

BH-10 – SPT Recovery, 9.5-11'

BH-10 – SPT Recovery, 19.5-21'



BH-10 – SPT Recovery, 30-31.5'

BH-10 – SPT Recovery, 40-41.5'

BH-10 – SPT Recovery, 45-46.5'

BH-10 – SPT Recovery, 50-51.5'

BH-10 – SPT Recovery, 55-56.5’

BH-10 – SPT Recovery, 65-65.8’

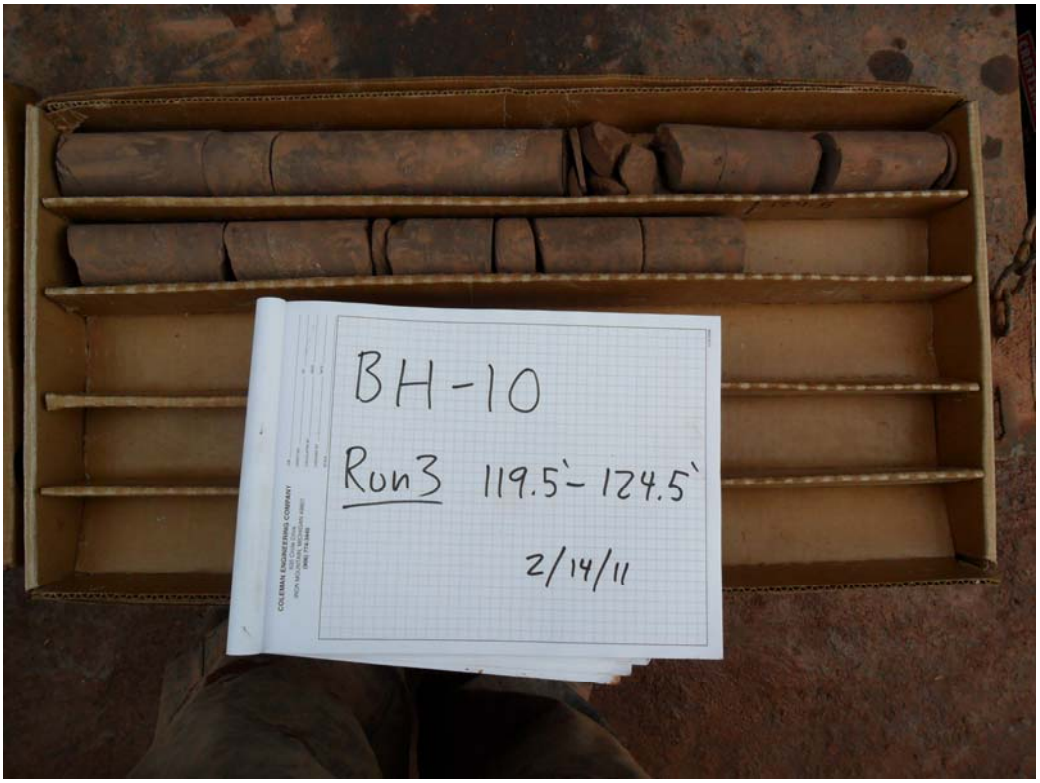
BH-10 – SPT Recovery, 70-71.5'

BH-10 – Soil Core Recovery, 85.5-90.5' (1 of 2)

BH-10 – Soil Core Recovery, 85.5-90.5' (2 of 2)

BH-10 – SPT Recovery, 100-101.5'

BH-10 – Rock Core Recovery, 109.5-119.5'

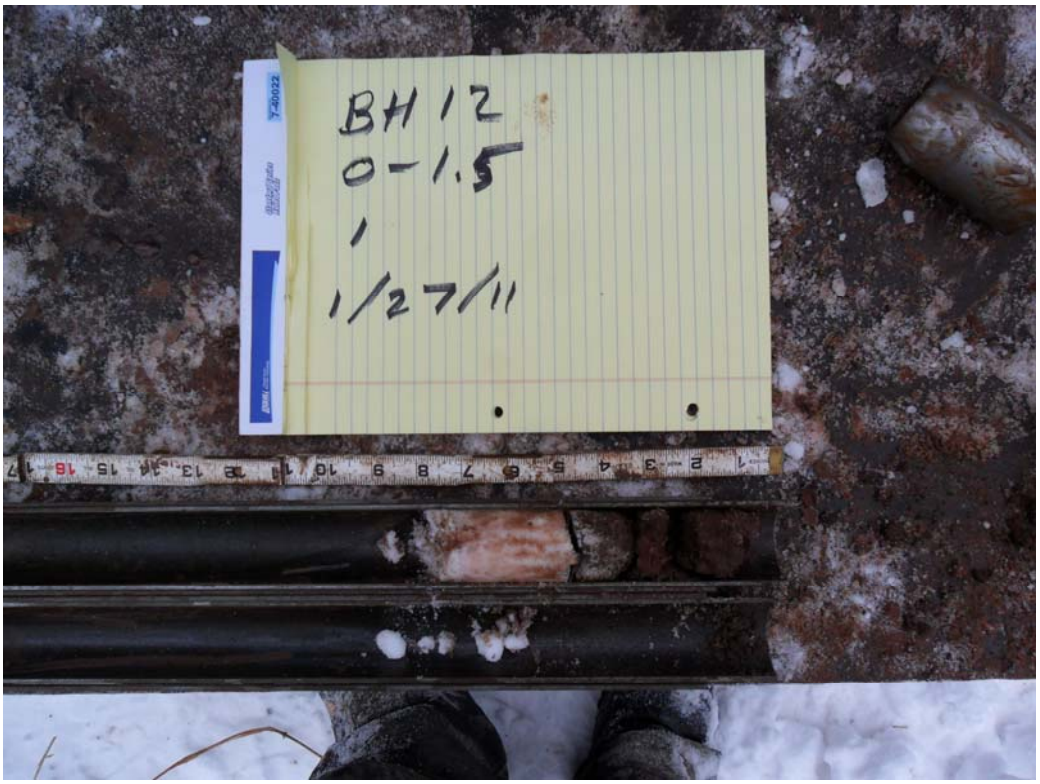


BH-10 – Rock Core Recovery, 119.5-124.5'

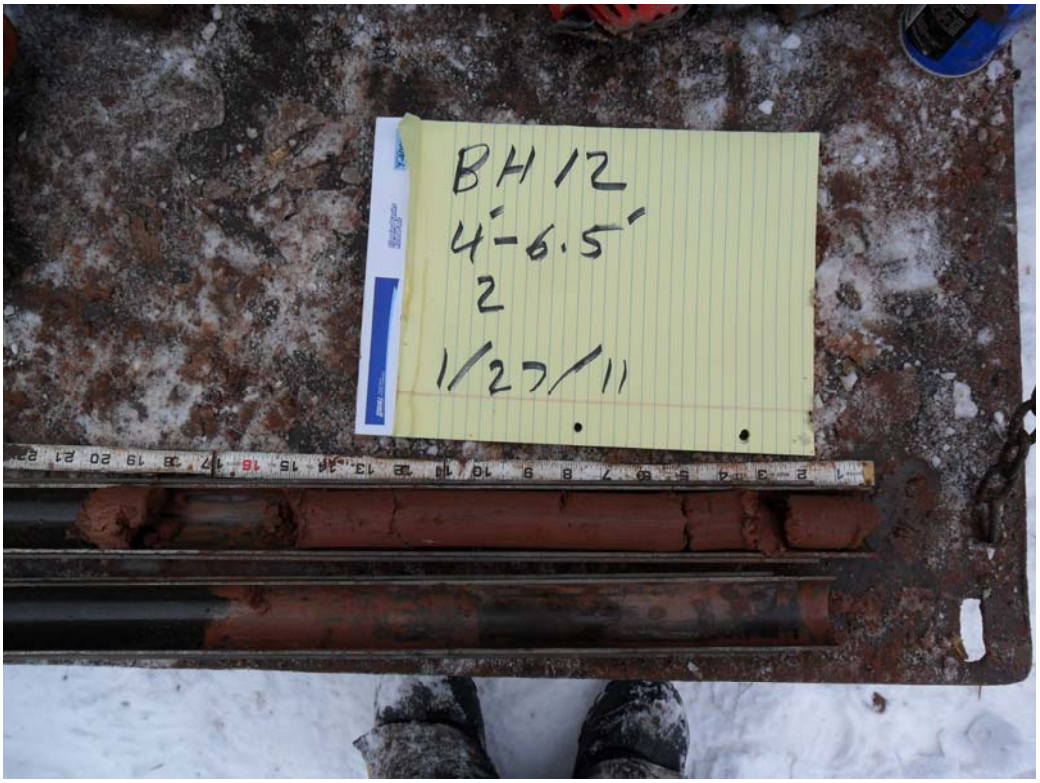
Photographs of
Borehole
BH-12

Knight Piésold CONSULTING

Copperwood Project
Borehole Photographs



BH-12 – SPT Recovery, 0-1.5'



BH-12 – SPT Recovery, 4-6.5'

BH-12 – Rock Core Recovery, 15.5-19'

BH-12 – Rock Core Recovery, 19-22.8'

Copperwood Project
Borehole Photographs

BH-12 – Rock Core Recovery, 22.8-30.2'

Appendix E

In-Situ Permeability Test Data

In Situ Permeability Test Log
Borehole
BH-02

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

Report of: Piezometer Falling Head Permeability

Job Number: GD-11006 Date: 4/20/2011

Project: Copperwood Tailings Facility

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Borehole Number: MW-2

Borehole Diameter: 4 7/8"

Pipe Diameter I.D. : 1.033" ID

Screen Length: 24"

Assumed Isotropic Soil

$$F = \frac{2\pi L}{\ln (L/R)}$$

$$A = \pi r^2$$

$$K = \frac{A}{(F)(t_2 - t_1)}$$

Monitoring Well No.	Middle of Screen Depth (in.)	Water Level (in)	Reading Date	Time	Permeability K (cm/s)
A	264	1.2	3/28	12:39 PM	
A	264	12.8	3/29	3:30 PM	1.5×10^{-8}
A	264	23.3	4/7	9:05 AM	3.0×10^{-9}
A	264	32.5	4/13	12:45 PM	3.0×10^{-9}
B	504	1.2	3/28	12:40 PM	
B	504	72.7	3/29	3:33 PM	5.1×10^{-8}
B	504	111.3	4/7	9:07 AM	9.0×10^{-9}
B	504	113.2	4/13	12:44 PM	6.0×10^{-9}
C	864	1.2	3/28	12:38 PM	
C	864	28.0	3/29	3:36 PM	1.0×10^{-8}
C	864	115.8	4/7	9:09 AM	5.0×10^{-9}
C	864	116.5	4/13	12:42 PM	3.0×10^{-9}

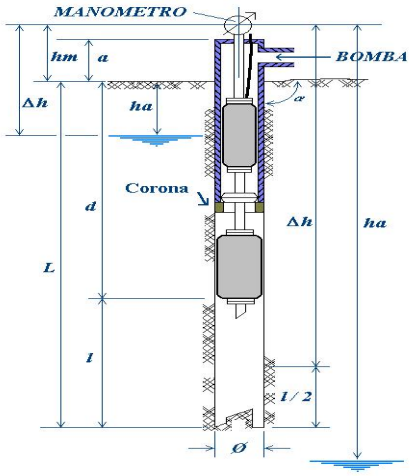
Ref. NAVFAC DM7, 7.1-104

Submitted By Chris Rasmussen

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 107.4 TO 117.4 ft	***BORING Nº*** ***BH-2***
AREA :	**Tailings Facility**	DATE : 3/17/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

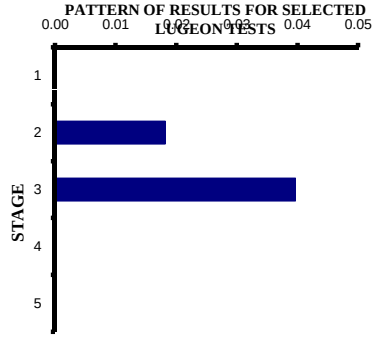


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	112.4	34.28	*m*
d	=	PACKER DEPTH	107.4	32.76	*m*
L	=	DEPTH OF HOLE	117.4	35.81	*m*
a	=	HORIZONTAL INCLINATION	90.0	90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		34.28	*m*
l	=	LENGTH OF TEST INTERVAL	5.0	3.05	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	19	*Kg/cm2*	37	*Kg/cm2*	56	*Kg/cm2*	37	*Kg/cm2*	19	*Kg/cm2*
	P_M =	1.33	P_M =	2.59	P_M =	3.92	P_M =	2.59	P_M =	1.33
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	68.20		69.8		70.1		71.3		71.3	
1	68.20	0.0	69.8	0.0	70.10	0.00	71.30	0.00	71.30	0.00
2	68.20	0.0	70.1	0.3	70.50	0.40	71.30	0.00	71.30	0.00
3	68.20	0.0	70.1	0.0	70.90	0.40	71.30	0.00	71.30	0.00
4	68.20	0.0	70.1	0.0	70.90	0.00	71.30	0.00	71.30	0.00
5	68.20	0.0	70.1	0.0	70.90	0.00	71.30	0.00	71.30	0.00
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		0.0		0.3		0.8		0.0		0.0
q p (l/min)		0.0		0.0		0.1		0.0		0.0
Q (l/min/m)		0.0		0.0		0.0		0.0		0.0
Δp (kg/cm^2)		0.0		0.0		0.0		0.0		0.0
P_{EF} (kg/cm^2)		4.8		6.0		7.3		6.0		4.8
U L		**0.00**		**0.02**		**0.04**		**0.00**		**0.00**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

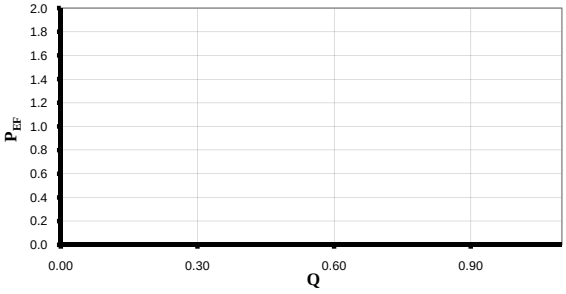
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.01** *U L*

K (PERMEABILITY) : **1.5E-07** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = *150 psi*

Knight Piésold

Chris Rasmussen

Coleman Eng.

Coleman Engineering Company
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PACKER PERMEABILITY PRESSURE DROP TEST

Project Name: Copperwood Wakefield, Michigan
Client: Orvana
Boring: BH-2
Depth: 107.4-117.4

Job No. GD-11006
Date: 3/17/2011

TIME (minutes)	PRESSURE 19 (psi)	PRESSURE 37 (psi)	PRESSURE 56 (psi)	PRESSURE 37 (psi)	PRESSURE 19 (psi)
0	19	37	56	37	19
1	18.5	37	56	37	19
2	18.5	37	56	37	19
3	18.0	37	56	37	18.5
4	18.0	37	56	37	18.5
5	18.0	37	56	36.5	18.5
10	18.0	37	55	36.5	18
15	18.0	37	54	36	18
20	17.5	36.5	54	36	17.5

In Situ Permeability Test Log
Borehole
BH-04

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

Report of: Piezometer Falling Head Permeability

Job Number: GD-11006 Date: 4/20/2011

Project: Copperwood Tailings Facility

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Borehole Number: MW-4

Borehole Diameter: 4 7/8"

Pipe Diameter I.D. : 1.033" ID

Screen Length: 24"

Assumed Isotropic Soil

$$F = \frac{2\pi L}{\ln (L/R)}$$

$$A = \pi r^2$$

$$K = \frac{A}{(F)(t_2 - t_1)}$$

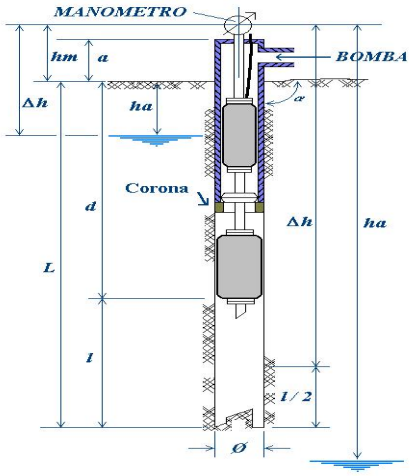
Monitoring Well No.	Middle of Screen Depth (in.)	Water Level (in)	Reading Date	Time	Permeability K (cm/s)
A	264	24.0 (frozen)	3/28		
A	264	24.0 (frozen)	3/29		
A	264	24.0 (frozen)	4/7	9:30 AM	
A	264	1.2	4/12	12:45 PM	
A	264	11.9	4/13	2:16 PM	$1.5X10^{-8}$
A	264	32.3	4/20	1:11 PM	$6.0X10^{-9}$
B	444	24.0 (frozen)	3/28		
B	444	24.0 (frozen)	3/29		
B	444	24.0 (frozen)	4/7	9:30 AM	
B	444	1.2	4/12	12:40 PM	
B	444	23.2	4/13	2:08 PM	$1.8X10^{-8}$
B	444	26.5	4/20	1:13 PM	$3.0X10^{-9}$
C	558	24.0 (frozen)	3/28		
C	558	24.0 (frozen)	3/29		
C	558	24.0 (frozen)	4/7	9:30 AM	
C	558	1.2	4/12	12:30 PM	
C	558	10.4	4/13	2:20 PM	$6.0X10^{-9}$
C	558	18.6	4/20	1:15 PM	$1.0X10^{-9}$

Ref. NAVFAC DM7, 7.1-104 Submitted By Chris Rasmussen

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 47.40 TO 57.4 ft	*BORING Nº* **BH-4**
AREA :	**Tailings Facility**	DATE : 3/22/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

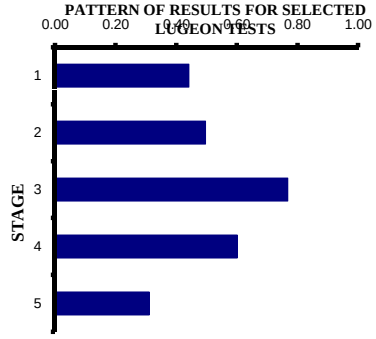


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	52.4	15.98	*m*
d	=	PACKER DEPTH	47.4	14.46	*m*
L	=	DEPTH OF HOLE	57.4	17.51	*m*
a	=	HORIZONTAL INCLINATION	90.0	90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		15.98	*m*
l	=	LENGTH OF TEST INTERVAL	10.0	3.05	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	9	*Kg/cm2*	17	*Kg/cm2*	26	*Kg/cm2*	17	*Kg/cm2*	9	*Kg/cm2*
	P_M =	0.63	P_M =	1.19	P_M =	1.82	P_M =	1.19	P_M =	0.63
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	31.70		34.4		40.1		48.4		53.0	
1	32.10	0.4	35.1	0.7	40.80	0.70	49.20	0.80	53.40	0.40
2	32.80	0.7	35.5	0.4	42.30	1.50	50.30	1.10	53.70	0.30
3	33.20	0.4	36.3	0.8	44.20	1.90	51.10	0.80	54.10	0.40
4	34.00	0.8	37.4	1.1	46.10	1.90	51.80	0.70	54.50	0.40
5	34.40	0.4	38.2	0.8	47.30	1.20	53.00	1.20	54.90	0.40
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		2.7		3.8		7.2		4.6		1.9
q p (l/min)		0.3		0.4		0.8		0.5		0.2
Q (l/min/m)		0.1		0.1		0.3		0.2		0.1
Δp (kg/cm^2)		0.0		0.0		0.0		0.0		0.0
P_{EF} (kg/cm^2)		2.2		2.8		3.4		2.8		2.2
U L		**0.44**		**0.50**		**0.77**		**0.60**		**0.31**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

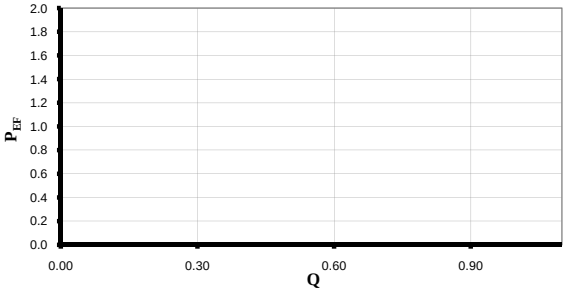
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.52** *U L*

K (PERMEABILITY) : **6.8E-06** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = *150 psi*

Knight Piésold

Chris Rasmussen

Coleman Eng.

Coleman Engineering Company
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PACKER PERMEABILITY PRESSURE DROP TEST

Project Name: Copperwood Wakefield, Michigan
Client: Orvana
Boring: BH-4
Depth: 47.4' - 57.4'

Job No. GD-11006
Date: 3/22/2011

TIME (minutes)	PRESSURE 9 (psi)	PRESSURE 17 (psi)	PRESSURE 26 (psi)	PRESSURE 17 (psi)	PRESSURE 9 (psi)
0	9	17	26	17	9
1	9	17	25.5	17	9
2	8.5	17	25.5	16	9
3	8	16	25	15.5	8.5
4	8	15.5	25	15.5	8.5
5	7.5	15.5	24.5	15	8
10	7	15	24	13.5	7.5
15	6	14	22.5	13	7
20	4.5	13	21	12	6

In Situ Permeability Test Log
Borehole
BH-06

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

Report of: Piezometer Falling Head Permeability

Job Number: GD-11006 Date: 4/20/2011

Project: Copperwood Tailings Facility

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Borehole Number: MW-6

Borehole Diameter: 4 7/8"

Assumed Isotropic Soil

Pipe Diameter I.D. : 1.037" ID

Screen Length: 24"

$$F = \frac{2\pi L}{\ln (L/R)}$$

$$A = \pi r^2$$

$$K = \frac{A}{(F)(t_2 - t_1)}$$

Monitoring Well No.	Middle of Screen Depth (in.)	Water Level (in)	Reading Date	Time	Permeability K (cm/s)
A	390	Froze @ top	3/28		
A	390	Froze @ top	3/29		
A	390	Artesian	4/7	9:48 AM	
A	390	Artesian	4/13	1:48 PM	
B	504	1.2	3/28	11:52 AM	
B	504	36.4	3/29	3:06 PM	2.4×10^{-8}
B	504	120.7	4/7	9:50 AM	1.0×10^{-8}
B	504	137.6	4/13	1:46 PM	7.0×10^{-9}
C	864	1.2	3/28	11:54 AM	
C	864	104.0	3/29	3:08 PM	4.2×10^{-8}
C	864	272.3	4/7	9:42 PM	1.4×10^{-8}
C	864	279.2	4/13	1:45 PM	9.0×10^{-9}

Ref. NAVFAC DM7, 7.1-104 Submitted By Chris Rasmussen

*Top of Pipe

In Situ Permeability Test Log
Borehole
BH-07

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

Report of: Piezometer Falling Head Permeability

Job Number: GD-11006 Date: 4/20/2011

Project: Copperwood Tailings Facility

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Borehole Number: MW-7

Borehole Diameter: 4 7/8"

Pipe Diameter I.D. : 1.033" ID

Screen Length: 24"

Assumed Isotropic Soil

$$F = \frac{2 \pi L}{\ln (L/R)}$$

$$A = \pi r^2$$

$$K = \frac{A}{(F)(t_2 - t_1)} \left[\ln (h_1/h_2) \right]$$

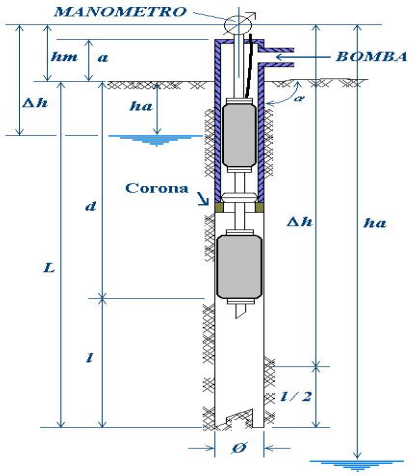
Monitoring Well No.	Middle of Screen Depth (in.)	Water Level (in)	Reading Date	Time	Permeability K (cm/s)
A	264	1.2	3/28	11:01 AM	
A	264	32.2	3/29	2:53 PM	4.0×10^{-8}
A	264	75.7	4/7	10:24 AM	1.2×10^{-8}
A	264	83.9	4/13	1:15 PM	9.0×10^{-9}
B	504	1.2	3/28	11:00 AM	
B	504	40.7	3/29	2:55 PM	2.6×10^{-8}
B	504	127.8	4/7	10:29 AM	1.1×10^{-8}
B	504	161.6	4/13	1:17 PM	9.0×10^{-9}
C	864	1.2	3/28	10:59 AM	
C	864	456.1	3/29	2:58 PM	2.3×10^{-7}
C	864	534.5	4/7	10:28 AM	3.5×10^{-8}
C	864	535.4	4/13	11:18 AM	2.2×10^{-8}

Ref. NAVFAC DM7, 7.1-104 Submitted By Chris Rasmussen

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 137.3' TO 148.5 ft	*BORING Nº* ***BH-7 (rev)***
AREA :	**Tailings Facility**	DATE : 3/14/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

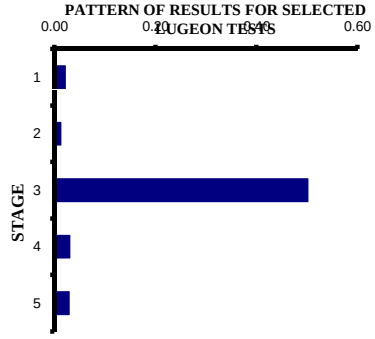


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	142.9	43.58	*m*
d	=	PACKER DEPTH	137.3	41.88	*m*
L	=	DEPTH OF HOLE	148.5	45.29	*m*
a	=	HORIZONTAL INCLINATION		90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		43.58	*m*
l	=	LENGTH OF TEST INTERVAL	5.6	3.42	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	23	*Kg/cm2*	47	*Kg/cm2*	71	*Kg/cm2*	47	*Kg/cm2*	23	*Kg/cm2*
	P_M =	1.61	P_M =	3.29	P_M =	4.97	P_M =	3.29	P_M =	1.61
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	87.70		88.1		334.0		342.8		343.2	
1	87.70	0.0	88.1	0.0	338.20	4.20	342.80	0.00	343.20	0.00
2	88.10	0.4	88.1	0.0	339.70	1.50	343.20	0.40	343.50	0.30
3	88.10	0.0	88.4	0.3	340.50	0.80	343.20	0.00	343.50	0.00
4	88.10	0.0	88.4	0.0	341.30	0.80	343.20	0.00	343.50	0.00
5	88.10	0.0	88.4	0.0	342.00	0.70	343.20	0.00	343.50	0.00
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		0.40		0.30		8.00		0.40		0.30
q p (l/min)		0.04		0.03		1.60		0.08		0.06
Q (l/min/m)		0.01		0.01		0.47		0.02		0.02
Δp (kg/cm^2)		0.00		0.00		0.00		0.00		0.00
P_{EF} (kg/cm^2)		5.97		7.65		9.33		7.65		5.97
U L		**0.02**		**0.01**		**0.50**		**0.03**		**0.03**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

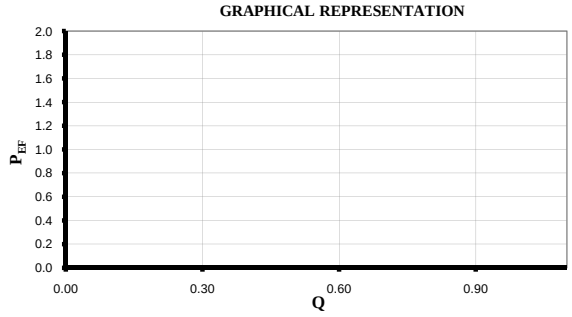
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.12** *U L*

K (PERMEABILITY) : **1.6E-06** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = *145 psi*

Knight Piésold

Chris Rasmussen

Coleman Eng.

In Situ Permeability Test Log
Borehole
BH-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

Report of: Piezometer Falling Head Permeability

Job Number: GD-11006 Date: 4/20/2011

Project: Copperwood Tailings Facility

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Borehole Number: MW-8

Borehole Diameter: 4 7/8"

Assumed Isotropic Soil

Pipe Diameter I.D. : 1.033"

Screen Length: 24"

$$F = \frac{2\pi L}{\ln (L/R)}$$

$$A = \pi r^2$$

$$K = \frac{A}{(F)(t_2 - t_1)}$$

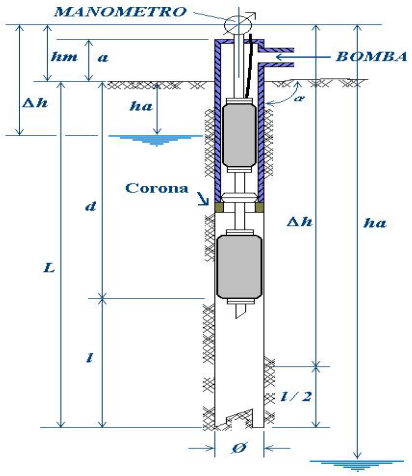
Monitoring Well No.	Middle of Screen Depth (in.)	Water Level (in)	Reading Date	Time	Permeability K (cm/s)
A	384	5.4	3/28	10:42 AM	
A	384	40.1	3/29	2:41 PM	3.0×10^{-8}
A	384	100.1	4/7	10:06 AM	1.1×10^{-8}
A	384	123.6	4/13	1:01 PM	1.1×10^{-9}
B	624	6.0	3/28	10:41 AM	
B	624	58.2	3/29	2:43 PM	2.8×10^{-8}
B	624	180.24	4/7	10:09 AM	1.2×10^{-8}
B	624	221.3	4/13	1:03 PM	1.0×10^{-8}
C	984	Top of Pipe	3/28	10:40 AM	
C	984	136.9	3/29	2:45 PM	4.8×10^{-8}
C	984	375.5	4/7	10:11 AM	1.8×10^{-8}
C	984	376.3	4/13	1:04 PM	1.1×10^{-8}

Ref. NAVFAC DM7, 7.1-104 Submitted By Chris Rasmussen

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 129.1 ft TO 139.5 ft	***BORING Nº*** ***BH-8***
AREA :	**Tailings Facility**	DATE : 3/3/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

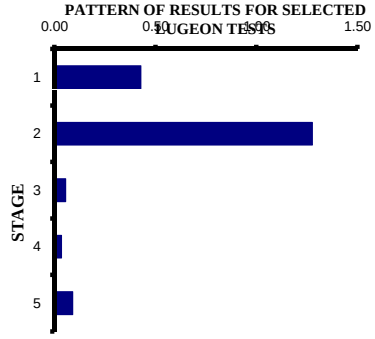


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	134.3	40.96	*m*
d	=	PACKER DEPTH	129.1	39.38	*m*
L	=	DEPTH OF HOLE	139.5	42.55	*m*
a	=	HORIZONTAL INCLINATION	90.0	90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		40.96	*m*
l	=	LENGTH OF TEST INTERVAL	10.4	3.17	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	21	*Kg/cm2*	43	*Kg/cm2*	54	*Kg/cm2*	43	*Kg/cm2*	21	*Kg/cm2*
	P_M =	1.47	P_M =	3.01	P_M =	3.78	P_M =	3.01	P_M =	1.47
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	151.30		170.6		202.2		202.9		203.7	
1	153.20	1.9	172.5	1.9	202.60	0.40	202.90	0.00	204.10	0.40
2	154.30	1.1	181.7	9.2	202.60	0.00	203.30	0.40	204.10	0.00
3	155.80	1.5	186.6	4.9	202.90	0.30	203.30	0.00	204.10	0.00
4	157.00	1.2	191.5	4.9	202.90	0.00	203.30	0.00	204.50	0.40
5	158.10	1.1	196.5	5.0	202.90	0.00	203.30	0.00	204.50	0.00
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		6.80		25.90		0.70		0.40		0.80
q p (l/min)		0.76		2.88		0.14		0.08		0.16
Q (l/min/m)		0.24		0.91		0.04		0.03		0.05
Δp (kg/cm^2)		0.00		0.00		0.00		0.00		0.00
P_{EF} (kg/cm^2)		5.57		7.11		7.88		7.11		5.57
U L		**0.43**		**1.28**		**0.06**		**0.04**		**0.09**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

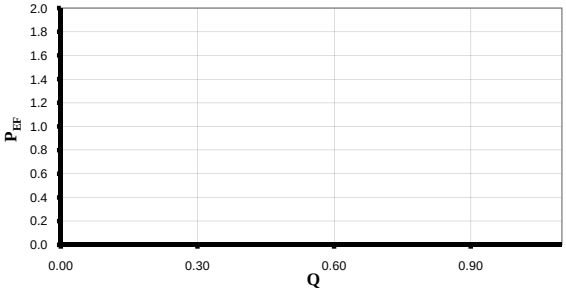
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.38** *U L*

K (PERMEABILITY) : **4.9E-06** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = *145 psi*

Knight Piésold

Chris Rasmussen

Coleman Eng.

In Situ Permeability Test Log
Borehole
BH-10

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

Report of: Piezometer Falling Head Permeability

Job Number: GD-11006 Date: 4/20/2011

Project: Copperwood Tailings Facility

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Borehole Number: MW-10

Borehole Diameter: 4 7/8"

Assumed Isotropic Soil

Pipe Diameter I.D. : 1.033" ID

Screen Length: 24"

$$F = \frac{2 \pi L}{\ln (L/R)}$$

$$A = \pi r^2$$

$$K = \frac{A}{(F)(t_2 - t_1)}$$

Monitoring Well No.	Middle of Screen Depth (in.)	Water Level (in)	Reading Date	Time	Permeability K (cm/s)
A	324	1.8	3/28	9:52 AM	
A	324	48.2	3/29	2:26 PM	4.9×10^{-8}
A	324	63.4	4/7	10:45 AM	8.0×10^{-9}
A	324	62.5	4/13	1:33 PM	5.0×10^{-9}
B	504	1.8	3/28	9:51 AM	
B	504	47.9	3/29	2:27 PM	2.9×10^{-8}
B	504	64.2	4/7	10:47 AM	5.0×10^{-9}*
B	504	62.5	4/13	1:34 PM	3.0×10^{-9}
C	744	2.4	3/28	9:50 AM	
C	744	59.6	3/29	2:29 PM	3.0×10^{-9}
C	744	257.2	4/7	10:49 AM	1.6×10^{-8}
C	744	320.9	4/13	1:35 PM	1.3×10^{-8}

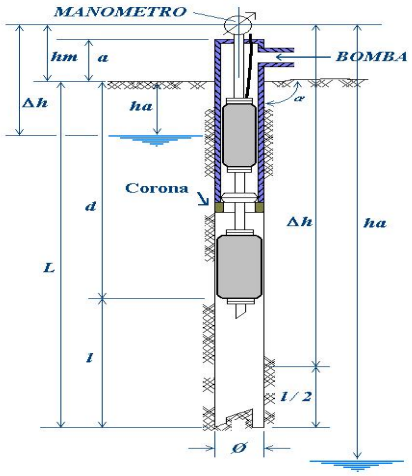
Ref. NAVFAC DM7, 7.1-104 Submitted By Chris Rasmussen

*Anomaly

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 116.0 ft TO 124.5 ft	***BORING Nº*** ***BH-10***
AREA :	**Tailings Facility**	DATE : 2/14/2011 - 2/15/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

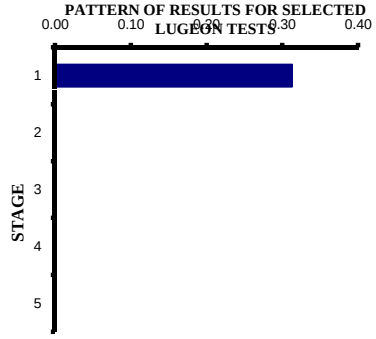


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	120.2	36.66	*m*
d	=	PACKER DEPTH	116.0	35.38	*m*
L	=	DEPTH OF HOLE	124.5	37.97	*m*
a	=	HORIZONTAL INCLINATION	90.0	90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		36.66	*m*
l	=	LENGTH OF TEST INTERVAL	8.5	2.59	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	22	*Kg/cm2*	41	*Kg/cm2*	61	*Kg/cm2*	41	*Kg/cm2*	22	*Kg/cm2*
	P_M =	1.54	P_M =	2.87	P_M =	4.27	P_M =	2.87	P_M =	1.54
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	86.70		152.9		0.0		296.4		296.8	
1	89.00	2.3	152.9	0.0	0.00	0.00	296.40	0.00	296.80	0.00
2	89.70	0.7	152.9	0.0	0.00	0.00	296.40	0.00	296.80	0.00
3	90.50	0.8	152.9	0.0	0.00	0.00	296.40	0.00	296.80	0.00
4	90.50	0.0	152.9	0.0	0.00	0.00	296.40	0.00	296.80	0.00
5	90.50	0.0	152.9	0.0	0.00	0.00	296.40	0.00	296.80	0.00
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		3.8		0.0		0.0		0.0		0.0
q p (l/min)		0.4		0.0		0.0		0.0		0.0
Q (l/min/m)		0.2		0.0		0.0		0.0		0.0
Δp (kg/cm^2)		0.0		0.0		0.0		0.0		0.0
P_{EF} (kg/cm^2)		5.2		6.5		7.9		6.5		5.2
U L		**0.31**		**0.00**		**0.00**		**0.00**		**0.00**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

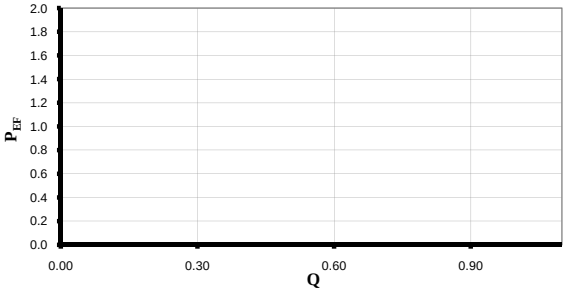
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.06** *U L*

K (PERMEABILITY) : **8.1E-07** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = *145 psi*

notes:

packer would not hold/seal with water pump pressure above 45 psi +/-

air temperature 50 degrees F

Knight Piésold

Chris Rasmussen

Coleman Eng.

Coleman Engineering Company
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PACKER PERMEABILITY PRESSURE DROP TEST

Project Name: Copperwood Wakefield, Michigan
Client: Orvana
Boring: BH-10
Depth: 116.0 - 124.5

Job No. GD-11006
Date: 2/16/2011

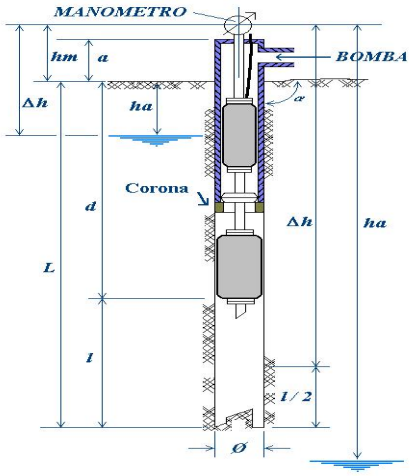
TIME (minutes)	PRESSURE 22 (psi)	PRESSURE 42 (psi)	PRESSURE 61 (psi)	PRESSURE 42 (psi)	PRESSURE 22 (psi)
0					
1		40 1/2		28	12
2		40		25	10 1/2
3		39		22	9 1/2
4		38		19 1/2	8
5		38		16	8
10		36		11	4 1/2
15		33		Battery went dead on stopwatch	3
20		32			

In Situ Permeability Test Log
Borehole
BH-11

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 22.5 ft TO 31.1 ft	***BORING Nº*** ***BH-11***
AREA :	**Tailings Facility**	DATE : 2/2/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

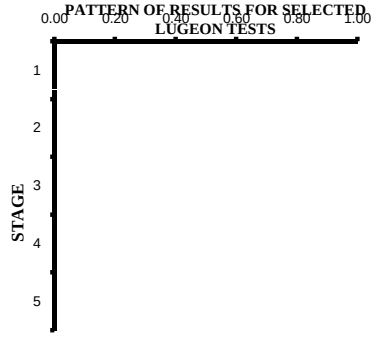


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	28.1	8.57	*m*
d	=	PACKER DEPTH	25.2	7.69	*m*
L	=	DEPTH OF HOLE	31.1	9.49	*m*
a	=	HORIZONTAL INCLINATION	90.0	90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		8.57	*m*
l	=	LENGTH OF TEST INTERVAL	5.9	1.80	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	5	*Kg/cm2*	9	*Kg/cm2*	13	*Kg/cm2*	9	*Kg/cm2*	5	*Kg/cm2*
	P_M =	0.35	P_M =	0.63	P_M =	0.91	P_M =	0.63	P_M =	0.35
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	51.10		51.1		51.1		51.1		51.1	
1	51.10	0.0	51.1	0.0	51.10	0.00	51.10	0.00	51.10	0.00
2	51.10	0.0	51.1	0.0	51.10	0.00	51.10	0.00	51.10	0.00
3	51.10	0.0	51.1	0.0	51.10	0.00	51.10	0.00	51.10	0.00
4	51.10	0.0	51.1	0.0	51.10	0.00	51.10	0.00	51.10	0.00
5	51.10	0.0	51.1	0.0	51.10	0.00	51.10	0.00	51.10	0.00
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		0.0		0.0		0.0		0.0		0.0
q p (l/min)		0.0		0.0		0.0		0.0		0.0
Q (l/min/m)		0.0		0.0		0.0		0.0		0.0
Δp (kg/cm^2)		0.0		0.0		0.0		0.0		0.0
P_{EF} (kg/cm^2)		1.2		1.5		1.8		1.5		1.2
U L		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

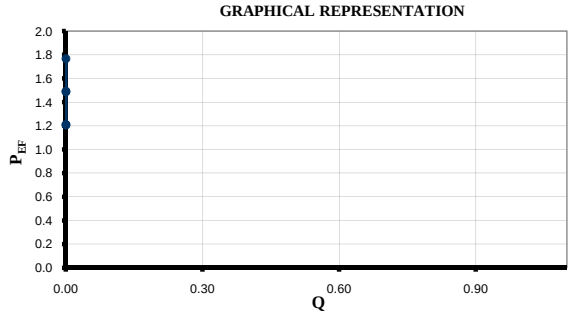
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.00** *U L*

K (PERMEABILITY) : **0.0E+00** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = 125 psi

To confirmed pump and water in line
did not freeze …. immediately after last reading released pressure in packer and observed
water flowing out of casing and water meter operating properly.
no pressure drop test
Air Temp low/high 15/23 degrees F.

Knight Piésold

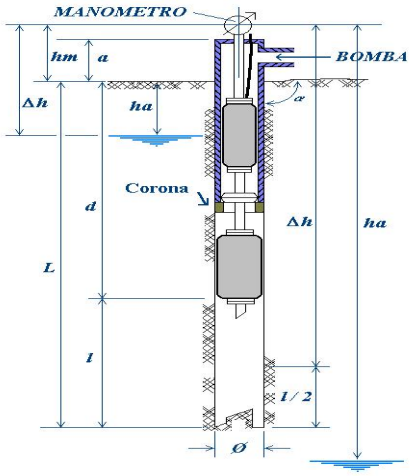
Chris Rasmussen
Coleman Eng.

In Situ Permeability Test Log
Borehole
BH-12

Single Packer Permeability Test
PERMEABILITY TESTING

Knight Piésold CONSULTING

PROJECT :	**Copperwood Wakefield Mi.**	TESTING DEPTH FROM : 20.9 ft TO 30.3 ft	***BORING Nº*** ***BH-12***
AREA :	**Tailings Facility**	DATE : 1/28/2011 TIME BEGIN: END :	TRIAL Nº
		LITHOLOGY : Copper Harbor Conglomerate	

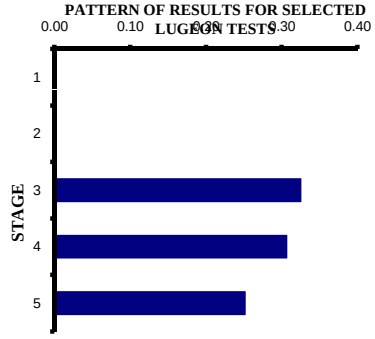


hm	=	MANOMETER HEIGHT			*m*
a	=	HEIGHT ABOVE GROUND LEVEL			*m*
ha	=	DEPTH OF PHREATIC SURFACE			*m*
Δh	=	HEAD	25.6	7.81	*m*
d	=	PACKER DEPTH	20.9	6.37	*m*
L	=	DEPTH OF HOLE	30.3	9.24	*m*
a	=	HORIZONTAL INCLINATION	90.0	90	°
Δh'	=	Dh CORRECTED = *Sen a x Δh*		7.81	*m*
l	=	LENGTH OF TEST INTERVAL	9.4	2.87	*m*
Ø	=	HOLE DIAMETER	NQ3	7.60	*cm*
PM	=	GAUGE PRESSURE			
PEF	=	EFFECTIVE PRESSURE ON MIDPOINT OF INTERVAL			
Δp	=	HEAD LOSS			
q	=	WATER VOLUME DURING TEST (L/min)			
qt	=	TOTAL VOLUME FOR EACH STAGE (L)			
G	=	FLOW FOR EACH STAGE (L/min)			
Q	=	FLOW PER METER OF TEST SPAN (L/min)			
UL	=	LUGEON UNIT (Q x 10 / P_{EF})			

	32	*Kg/cm2*	36	*Kg/cm2*	44	*Kg/cm2*	36	*Kg/cm2*	32	*Kg/cm2*
	P_M =	2.24	P_M =	2.52	P_M =	3.08	P_M =	2.52	P_M =	2.24
TIME IN MINUTES	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*	FLOW READING	*q (l)*
0	0.00		0.0		0.0		0.0		0.0	
1	0.00	0.0	0.0	0.0	0.38	0.38	0.29	0.29	0.22	0.22
2	0.00	0.0	0.0	0.0	0.72	0.34	0.58	0.29	0.44	0.22
3	0.00	0.0	0.0	0.0	1.08	0.36	0.87	0.29	0.65	0.21
4	0.00	0.0	0.0	0.0	1.44	0.36	1.16	0.29	0.87	0.22
5	0.00	0.0	0.0	0.0	1.80	0.36	1.45	0.29	1.09	0.22
6										
7	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
q t (l)		0.00		0.00		1.80		1.45		1.09
q p (l/min)		0.00		0.00		0.36		0.29		0.22
Q (l/min/m)		0.00		0.00		0.13		0.10		0.08
Δp (kg/cm^2)		0.00		0.00		0.00		0.00		0.00
P_{EF} (kg/cm^2)		3.02		3.30		3.86		3.30		3.02
U L		**0.00**		**0.00**		**0.33**		**0.31**		**0.25**
		1		2		3		4		5

$P_{EF} = P_M - Dp + Dh / 10$

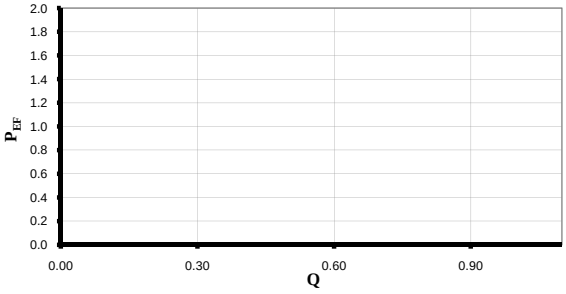
GRAPHICAL REPRESENTATION OF PATTERN OF RESULTS FOR SELECTED LUGEON TESTS



LUGEON UNIT SELECTED **0.18** *U L*

K (PERMEABILITY) : **2.3E-06** *cm/s*

GRAPHICAL REPRESENTATION



OBSERVATIONS

PACKER PRESSURE = *100 psi*

Knight Piésold

Chris Rasmussen

Coleman Eng.

Knight Piésold CONSULTING

Appendix F

Laboratory Test Data

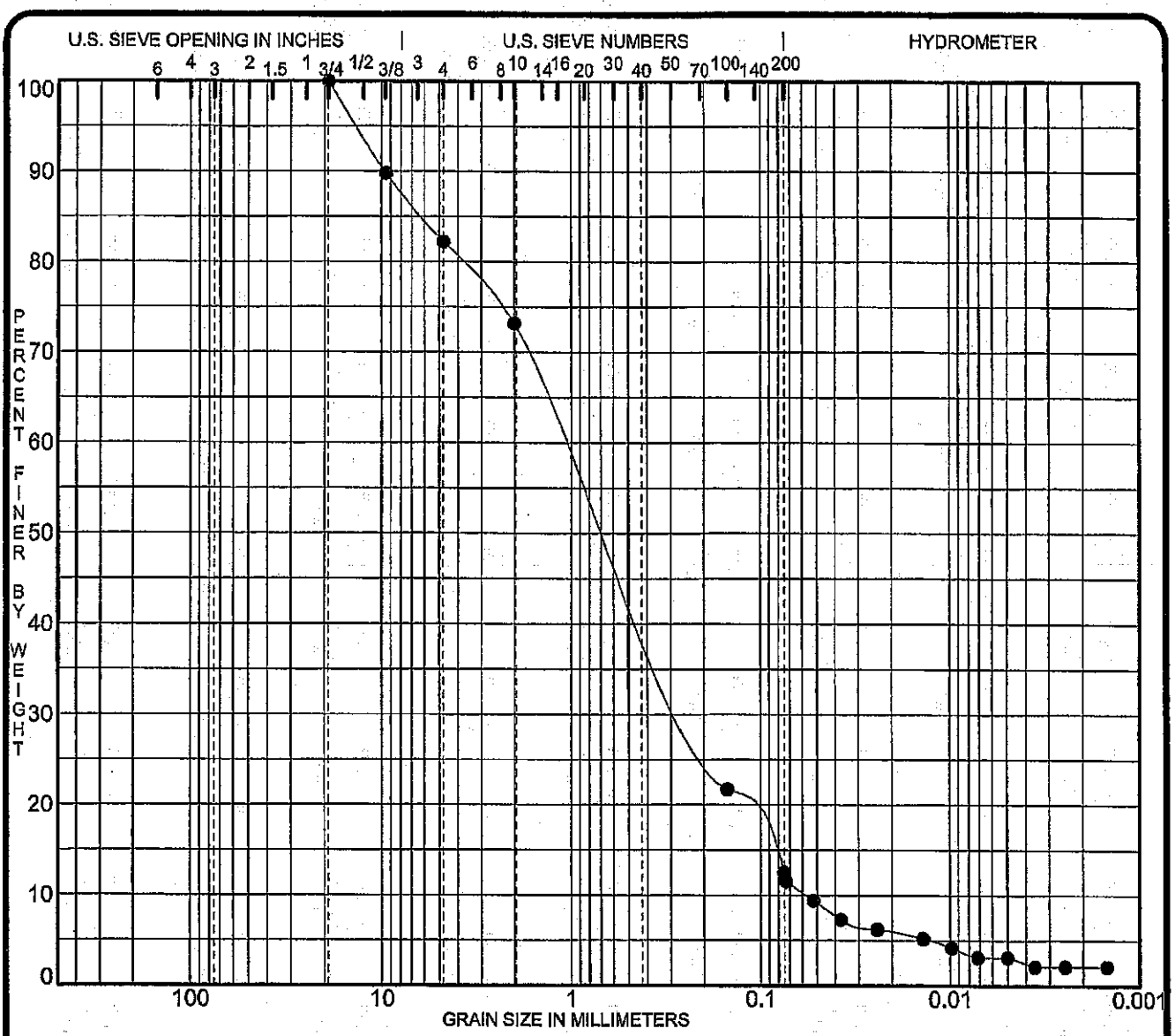
F-1 Laboratory Test Data – Particle Size Distribution Data (Test Pits, Boreholes, and Sand Pits)
F-2 Laboratory Test Data – Atterberg Limits Data (Test Pits and Boreholes)
F-3 Laboratory Test Data – Natural Moisture Content Data (Test Pits and Boreholes)
F-4 Laboratory Test Data – Specific Gravity Data (Test Pits, Boreholes, and Sand Pits)
F-5 Laboratory Test Data – Moisture Density Data (Test Pits)
F-6 Laboratory Test Data – Permeability Data (Test Pits and Boreholes)
F-7 Laboratory Test Data – Oedometer Data (Boreholes)
F-8 Laboratory Test Data – Shear Strength Data (Test Pits and Boreholes)

Knight Piésold CONSULTING

Appendix F-1

Laboratory Test Data - Particle Size Distribution Data (Test Pits, Boreholes, and Sand Pits)

TP-1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-1 0'-3'	(SM) SAND, brown, fine to coarse, with silt, with fine gravel					0.87	17.9

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-1 0'-3'	19.00	1.03	0.623	0.228	0.0576	17.8	69.7	9.4	3.1

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (SM) SAND, brown, f-c, with silt, with fine gravel **Boring No.** TP-1

Shape: **Hardness:** **Sample No.**

Remarks: **Depth:** 0' - 3'

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2	-	-	-
	2"	50.8	-	-	-
	1 1/2"	37.5	-	-	-
	1	25.4	-	-	
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	13.10	10.2	89.8
	4M	4.76	9.78	7.6	82.2
	10M	2.00	11.55	9.0	73.2
MECHANICAL ANALYSIS	40M	0.42	18.02	25.6	74.4 /* 54.5
PORTION OF HYDROMETER	100M	0.149	31.49	44.8	29.6 /* 21.7
ANALYSIS	200M	0.074	8.83	12.5	17.1 /* 12.5
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 34.43 gm = 26.8% %

Material passing No. 10 mesh: weight = 93.9 gm = 73.2% %

Weight of Total Sample = 128.33 gm

Tested By: Graham Donahue **Date:** 2/15/2011

Submitted By: Wm D Rich **Date:** 2/15/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-1
Sample No:
Depth: 0-3
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

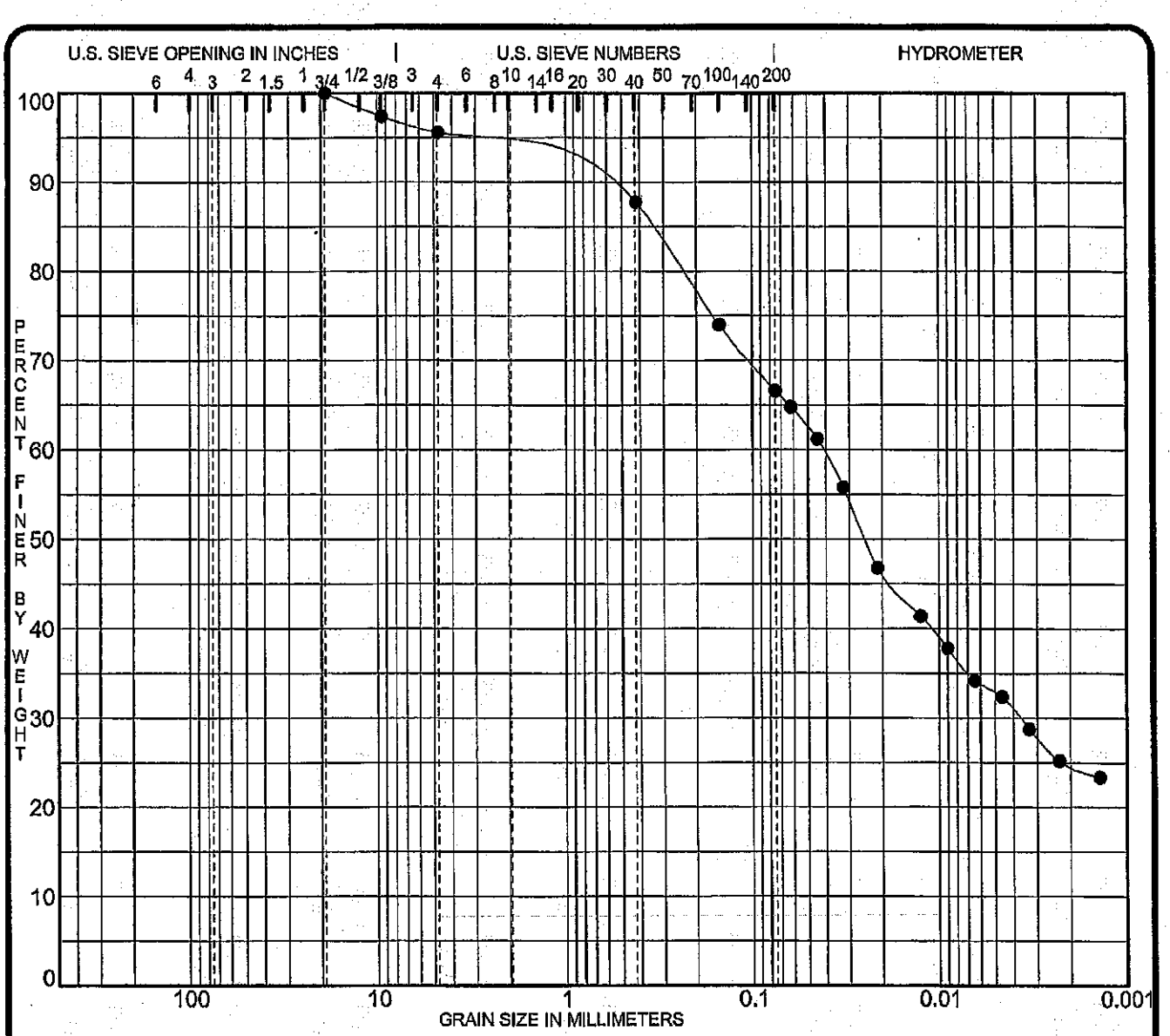
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:15:00

% of Original Sample Used
For Hydrometer Analysis: 73.2 %
Weight of Sample Dispersed: 70.29 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:15:30	0.5	16	18	5	11	15.6	0.01399	13.7	0.0732	11.5
9:16:00	1.0	14	18	5	9	12.8	0.01399	14.0	0.0523	9.4
9:17:00	2.0	12	18	5	7	10.0	0.01399	14.3	0.0374	7.3
9:20:00	5.0	11	18	5	6	8.5	0.01399	14.7	0.0240	6.2
9:30:00	15.0	10	18	5	5	7.1	0.01399	14.7	0.0138	5.2
9:45:00	30.0	9	18	5	4	5.7	0.01399	14.8	0.0098	4.2
10:12:00	57.0	8	18	5	3	4.3	0.01399	15.0	0.0072	3.1
11:14:00	119.0	8	18	5	3	4.3	0.01399	15.0	0.0050	3.1
1:06:00	231.0	7	18	5	2	2.8	0.01399	15.2	0.0036	2.1
5:19:00	484.0	7	18	5	2	2.8	0.01399	15.2	0.0025	2.1
8:46:00	1411.0	7	18	5	2	2.8	0.01399	15.2	0.0015	2.1

Tested By: Bill Rice
Date: 2/10/2011
Submitted By:
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-1 5'-10'	(CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-1 5'-10'	19.00	0.04	0.025	0.004		4.4	29.0	33.7	32.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brn, w/ f-c sand, tr. gravel, medium plastic **Boring No.** TP-1

Shape: **Hardness:** **Sample No.** Composite

Remarks: **Depth:** 5' - 16'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			-
2"	50.8			-
1 1/2"	37.5			-
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	5.14	2.6	97.4
4M	4.76	3.60	1.8	95.6
10M	2.00	4.35	2.2	93.4
40M	0.42	3.09	6.0	94.0 /* 87.8
100M	0.149	7.66	14.8	79.2 /* 74.0
200M	0.074	4.09	7.9	71.3 /* 66.6
Pan				/*

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 13.09 gm = 6.6% %

Material passing No. 10 mesh: weight = 186.56 gm = 93.4% %

Weight of Total Sample = 199.65 gm

Tested By: Graham Donahue **Date:** 2/3/2011

Submitted By: Wm D/ Ard **Date:** 2/3/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI, 49938

Remarks:
Boring No: TP-1
Sample No:
Depth: 5'-16'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:23:00

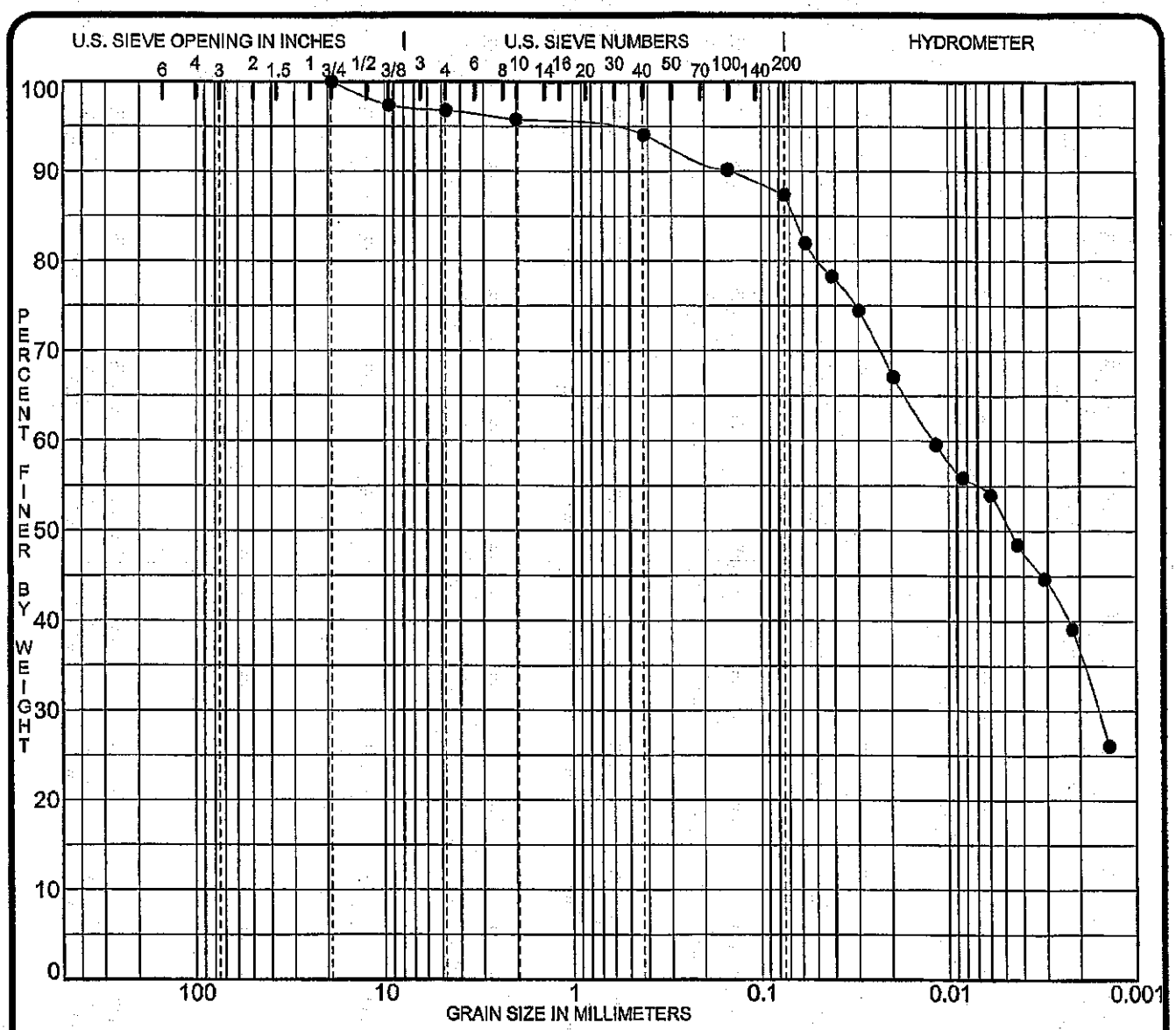
% of Original Sample Used
For Hydrometer Analysis: 93.4 %
Weight of Sample Dispersed: 51.89 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:23:30	0.5	41	17	5	36	69.4	0.01417	9.6	0.0621	64.8
8:24:00	1.0	39	17	5	34	65.5	0.01417	9.9	0.0446	61.2
8:25:00	2.0	36	17	5	31	59.7	0.01417	10.4	0.0323	55.8
8:28:00	5.0	31	17	5	26	50.1	0.01417	11.2	0.0212	46.8
8:38:00	15.0	28	17	5	23	44.3	0.01417	11.7	0.0125	41.4
8:53:00	30.0	26	17	5	21	40.5	0.01417	12.0	0.0090	37.8
9:23:00	60.0	24	17	5	19	36.6	0.01417	12.4	0.0064	34.2
10:23:00	120.0	23	17	5	18	34.7	0.01417	12.5	0.0046	32.4
12:23:00	240.0	21	17	5	16	30.8	0.01417	12.9	0.0033	28.8
16:23:00	480.0	19	17	5	14	27.0	0.01417	13.2	0.0023	25.2
8:23:00	1440.0	18	17	5	13	25.1	0.01417	13.3	0.0014	23.4

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: [signature]
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-2



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-2 0'-5'	(CL) LEAN CLAY, red-brown, trace sand, trace gravel, highly plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-2 0'-5'	19.00	0.01	0.005	0.002		3.2	9.4	36.4	51.0

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Soil Description: (CL) LEAN CLAY, red-brn, tr. sand, tr. gravel, highly plastic **Boring No.** TP-2
Shape: **Hardness:** **Sample No.**
Remarks: **Depth:** 0' - 5'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	0.83	0.4	99.6
4M	4.76	0.79	0.4	99.2
10M	2.00	3.41	1.5	97.7
40M	0.42	1.68	0.8	99.2 /* 97.0
100M	0.149	3.19	1.4	97.8 /* 95.6
200M	0.074	2.40	1.1	96.7 /* 94.6
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:
Material retained on No. 10 mesh: weight = 5.03 gm = 2.2% %
Material passing No. 10 mesh: weight = 218.6 gm = 97.8% %
Weight of Total Sample = 223.63 gm

Tested By: Graham Donahue **Date:** 2/3/2011
Submitted By: [signature] **Date:** 2/3/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-2
Sample No:
Depth: 0' - 5'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

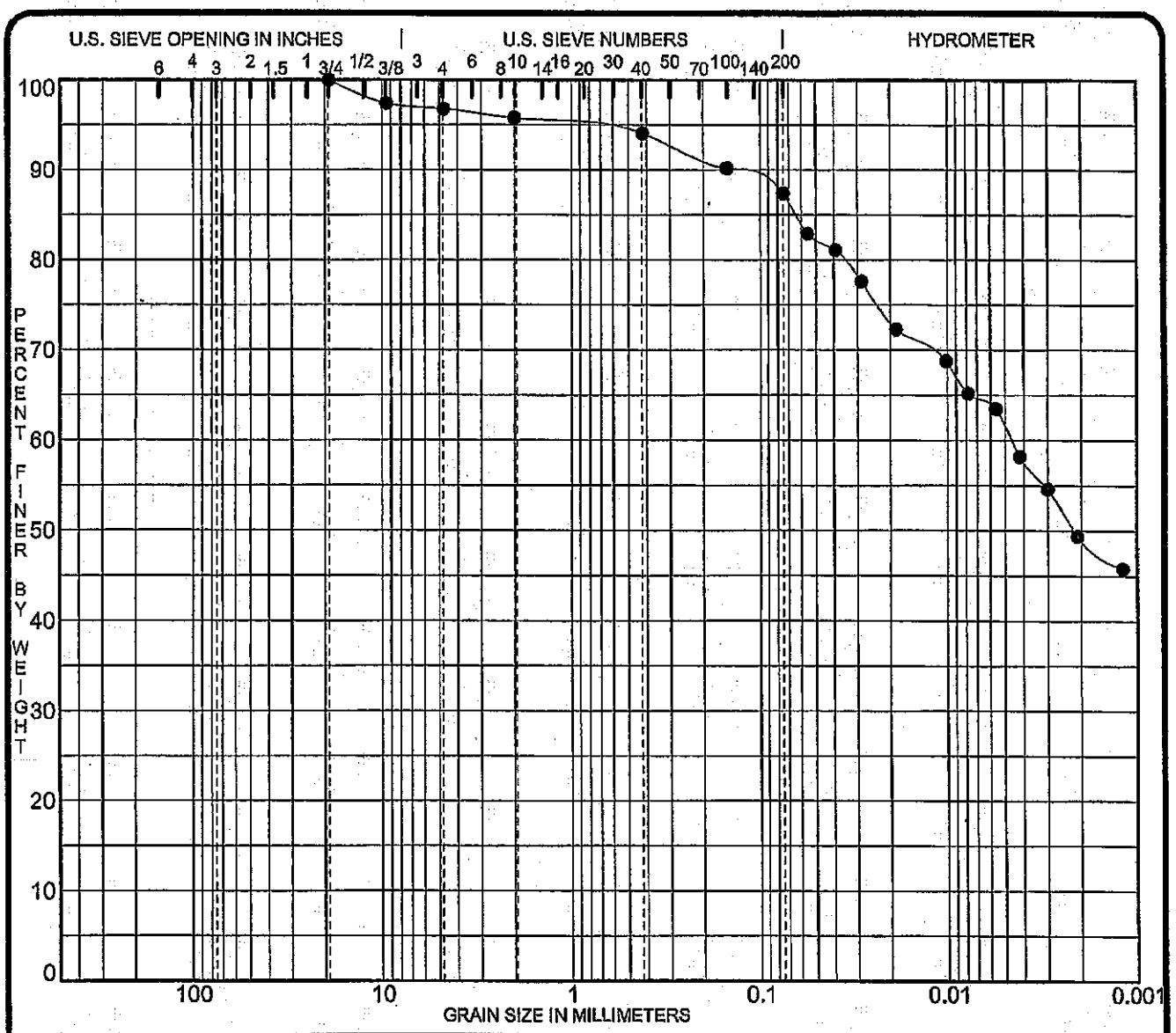
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:27:00

% of Original Sample Used
For Hydrometer Analysis: 97.8 %
Weight of Sample Dispersed: 52.48 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:27:30	0.5	49	17	5	44	83.8	0.01417	8.3	0.0577	82.0
8:28:00	1.0	47	17	5	42	80.0	0.01417	8.6	0.0416	78.3
8:29:00	2.0	45	17	5	40	76.2	0.01417	8.9	0.0299	74.5
8:32:00	5.0	41	17	5	36	68.6	0.01417	9.6	0.0196	67.1
8:42:00	15.0	37	17	5	32	61.0	0.01417	10.2	0.0117	59.6
8:57:00	30.0	35	17	5	30	57.2	0.01417	10.6	0.0084	55.9
9:27:00	60.0	34	17	5	29	55.3	0.01417	10.7	0.0060	54.0
10:27:00	120.0	31	17	5	26	49.5	0.01417	11.2	0.0043	48.5
12:27:00	240.0	29	17	5	24	45.7	0.01417	11.5	0.0031	44.7
16:27:00	480.0	26	17	5	21	40.0	0.01417	12.0	0.0022	39.1
8:27:00	1440.0	19	17	5	14	26.7	0.01417	13.2	0.0014	26.1

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: Wm D Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-2 10'-12'	(CH) FAT CLAY, brown, some fine to coarse sand, trace fine gravel, highly plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-2 10'-12'	19.00	0.00	0.002			3.2	9.4	26.0	61.4

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Soil Description: (CH) FAT CLAY, brown, some fine to coarse ** **Boring No.** TP-2
Shape: **Hardness:** **Sample No.**
Remarks: **sand, trace fine gravel, highly plastic **Depth:** 10' - 12'

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	3"	76.2	-	-	-
	2"	50.8	-	-	-
	1 1/2"	37.5	-	-	-
	1	25.4	-	-	
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	4.02	2.6	97.4
	4M	4.76	0.90	0.6	96.8
	10M	2.00	1.42	1.0	95.8
	40M	0.42	0.92	1.7	98.3 /* 94.1
	100M	0.149	2.27	4.2	94.1 /* 90.2
	200M	0.074	1.62	3.0	91.1 /* 87.4
	Pan				/*

***Percent Based on Total Sample**

Original Sample:
Material retained on No. 10 mesh: weight = 6.34 gm = 4.1% %
Material passing No. 10 mesh: weight = 148.61 gm = 95.9% %
Weight of Total Sample = 154.95 gm

Tested By: Graham Donahue **Date:** 2/15/2011
Submitted By: [signature] **Date:** 2/15/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-2
Sample No:
Depth: 10-12
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

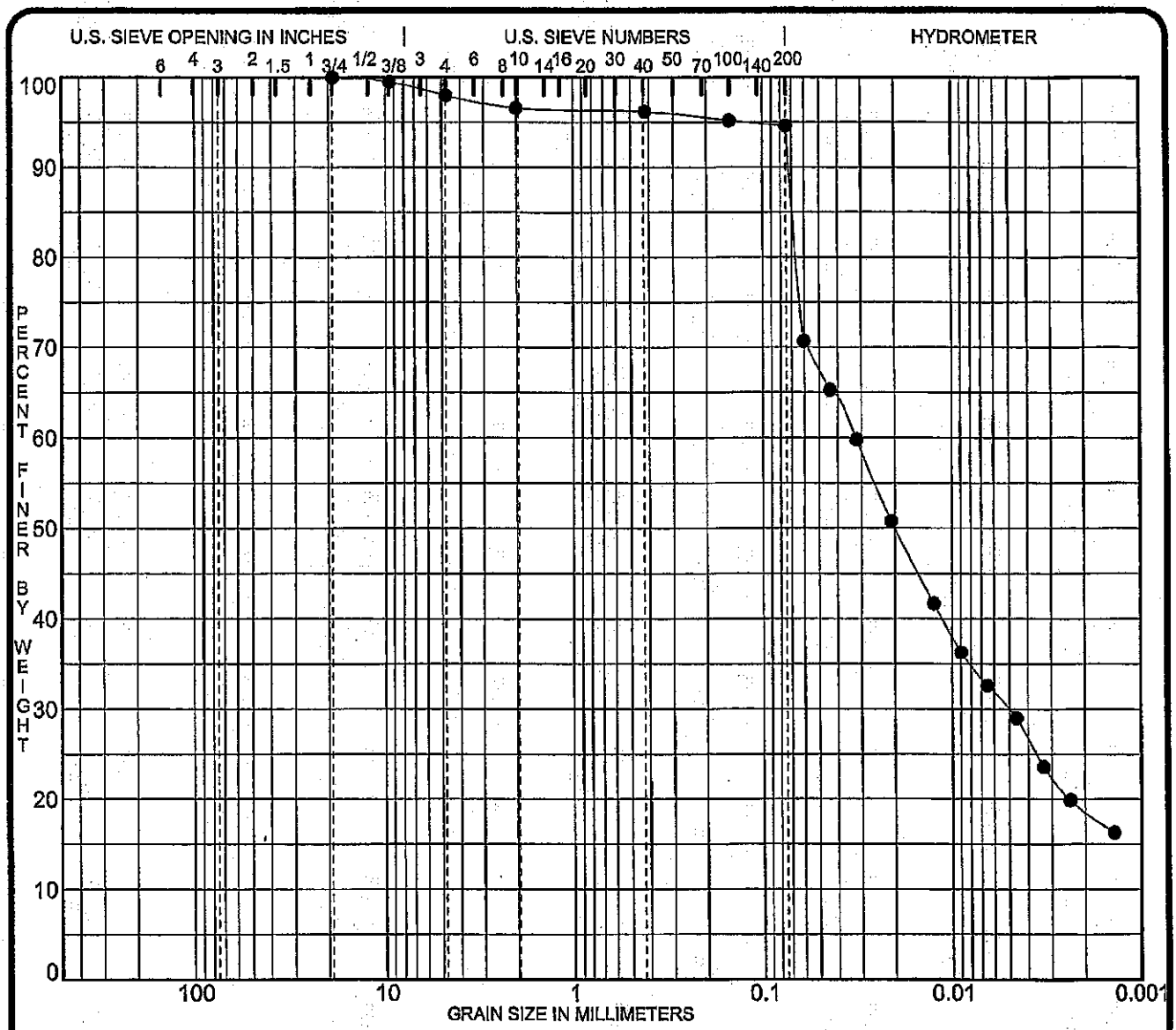
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:27:00

% of Original Sample Used
For Hydrometer Analysis: 95.9 %
Weight of Sample Dispersed: 54.4 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:27:30	0.5	52	18	5	47	86.4	0.01399	7.8	0.0553	82.9
9:28:00	1.0	51	18	5	46	84.6	0.01399	7.9	0.0393	81.1
9:29:00	2.0	49	18	5	44	80.9	0.01399	8.3	0.0285	77.6
9:32:00	5.0	46	18	5	41	75.4	0.01399	8.8	0.0186	72.3
9:44:00	17.0	44	18	5	39	71.7	0.01399	9.1	0.0102	68.8
9:57:00	30.0	42	18	5	37	68.0	0.01399	9.4	0.0078	65.2
10:27:00	60.0	41	18	5	36	66.2	0.01399	9.6	0.0056	63.5
11:18:00	111.0	38	18	5	33	60.7	0.01399	10.1	0.0042	58.2
1:10:00	223.0	36	18	5	31	57.0	0.01399	10.4	0.0030	54.6
5:22:00	475.0	33	18	5	28	51.5	0.01399	10.9	0.0021	49.4
8:51:00	1404.0	31	18	5	26	47.8	0.01399	11.2	0.0012	45.8

Tested By: Bill Rice
Date: 2/10/2011
Submitted By:
Date: 2/4/2011

TP-3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
●	TP-3 0'-17'	(CL) LEAN CLAY, red-brown, trace sand, trace gravel, medium plastic						

	Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	TP-3 0'-17'	19.00	0.03	0.020	0.005		2.0	3.4	64.7	29.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, red-bm, tr. sand, tr. gravel, medium plastic **Boring No.** TP-3

Shape: **Hardness:** **Sample No.** Composite

Remarks: **Depth:** 0' - 17'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	3.10	0.5	99.5
4M	4.76	8.82	1.5	98.0
10M	2.00	8.56	1.4	96.6
40M	0.42	2.34	0.4	99.6 /* 96.2
100M	0.149	6.86	1.1	98.5 /* 95.2
200M	0.074	3.81	0.6	97.9 /* 94.6
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 20.48 gm = 3.4% %

Material passing No. 10 mesh: weight = 580.56 gm = 96.6% %

Weight of Total Sample = 601.04 gm

Tested By: Graham Donahue **Date:** 2/3/2011

Submitted By: [signature] **Date:** 2/3/2011

Form: D422A Revision Date: 04/02/09

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635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-3
Sample No:
Depth: Composite
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:31:00

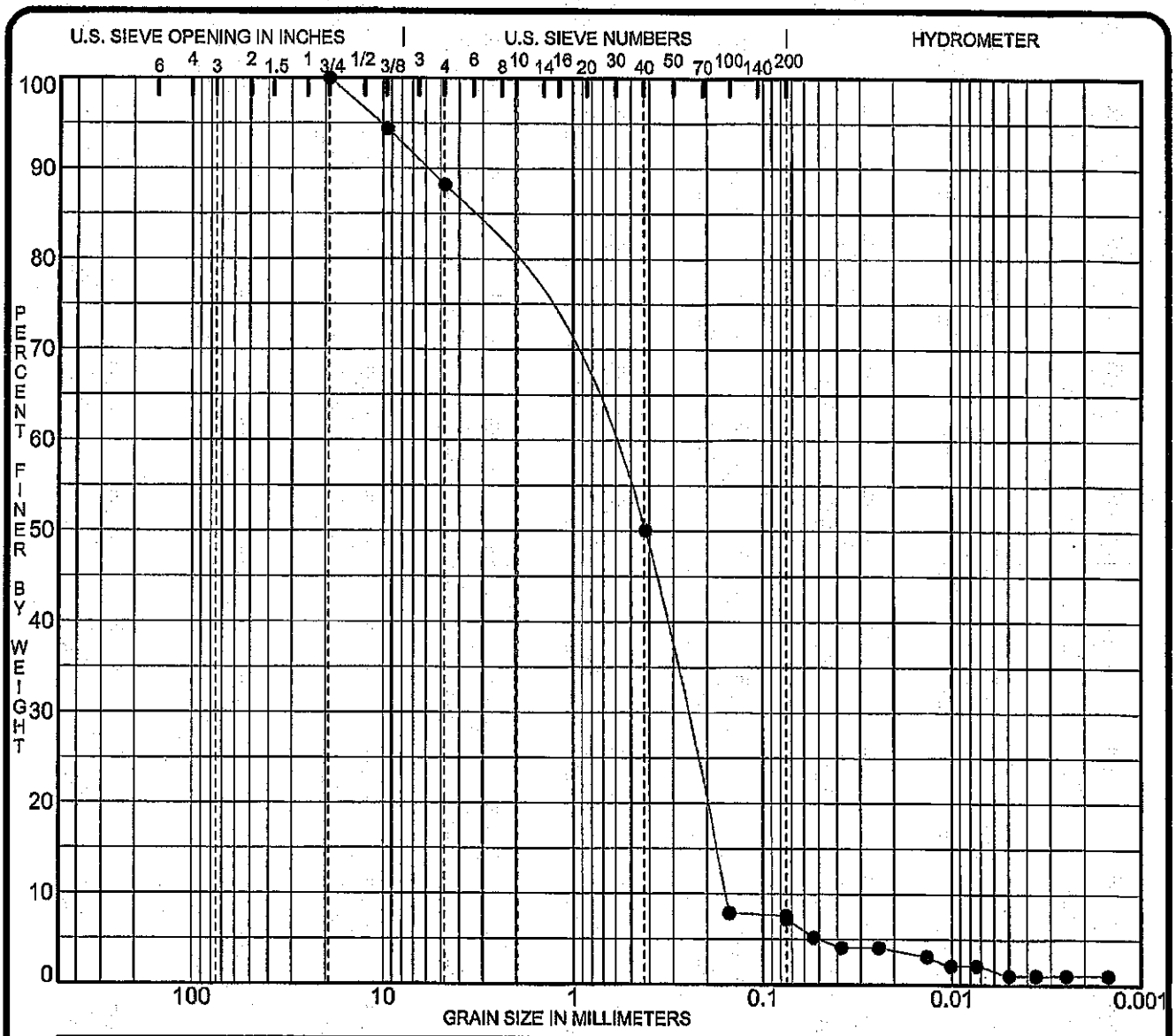
% of Original Sample Used
For Hydrometer Analysis: 96.6 %
Weight of Sample Dispersed: 53.27 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:31:30	0.5	44	17	5	39	73.2	0.01417	9.1	0.0605	70.7
8:32:00	1.0	41	17	5	36	67.6	0.01417	9.6	0.0439	65.3
8:33:00	2.0	38	17	5	33	61.9	0.01417	10.1	0.0318	59.8
8:36:00	5.0	33	17	5	28	52.6	0.01417	10.9	0.0209	50.8
8:46:00	15.0	28	17	5	23	43.2	0.01417	11.7	0.0125	41.7
9:01:00	30.0	25	17	5	20	37.5	0.01417	12.2	0.0090	36.3
9:31:00	60.0	23	17	5	18	33.8	0.01417	12.5	0.0065	32.6
10:31:00	120.0	21	17	5	16	30.0	0.01417	12.9	0.0046	29.0
12:31:00	240.0	18	17	5	13	24.4	0.01417	13.3	0.0033	23.6
16:31:00	480.0	16	17	5	11	20.6	0.01417	13.7	0.0024	19.9
8:31:00	1440.0	14	17	5	9	16.9	0.01417	14.0	0.0014	16.3

Tested By: Graham Doanhue
Date: 2/4/2011
Submitted By: Wm D Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-4



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-4 0'-7'	(SP-SM) SAND, brown, fine to coarse, some fine gravel, some silt					0.53	5.0

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-4 0'-7'	19.00	0.79	0.419	0.257	0.1579	11.8	80.6	6.6	1.0

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Soil Description: (SP-SM) SAND, brown, fine to coarse, some ** **Boring No.** TP-4
Shape: **Hardness:** **Sample No.**
Remarks: ** fine gravel, some silt **Depth:** 0' - 7'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	
3/4	19.1	0.00	0.0	100.0
3/8	9.5	10.36	5.6	94.4
4M	4.76	11.44	6.2	88.2
10M	2.00	18.70	10.1	78.1
40M	0.42	27.02	35.8	64.2 /* 50.1
100M	0.149	38.55	51.1	13.1 /* 10.2
200M	0.074	2.27	3.0	10.1 /* 7.9
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:
Material retained on No. 10 mesh: weight = 40.5 gm = 21.9% %
Material passing No. 10 mesh: weight = 144.4 gm = 78.1% %
Weight of Total Sample = 184.9 gm

Tested By: Graham Donahue **Date:** 2/15/2011
Submitted By: [signature] **Date:** 2/15/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-4
Sample No:
Depth: 0-7
Date Received: 1/27/2011

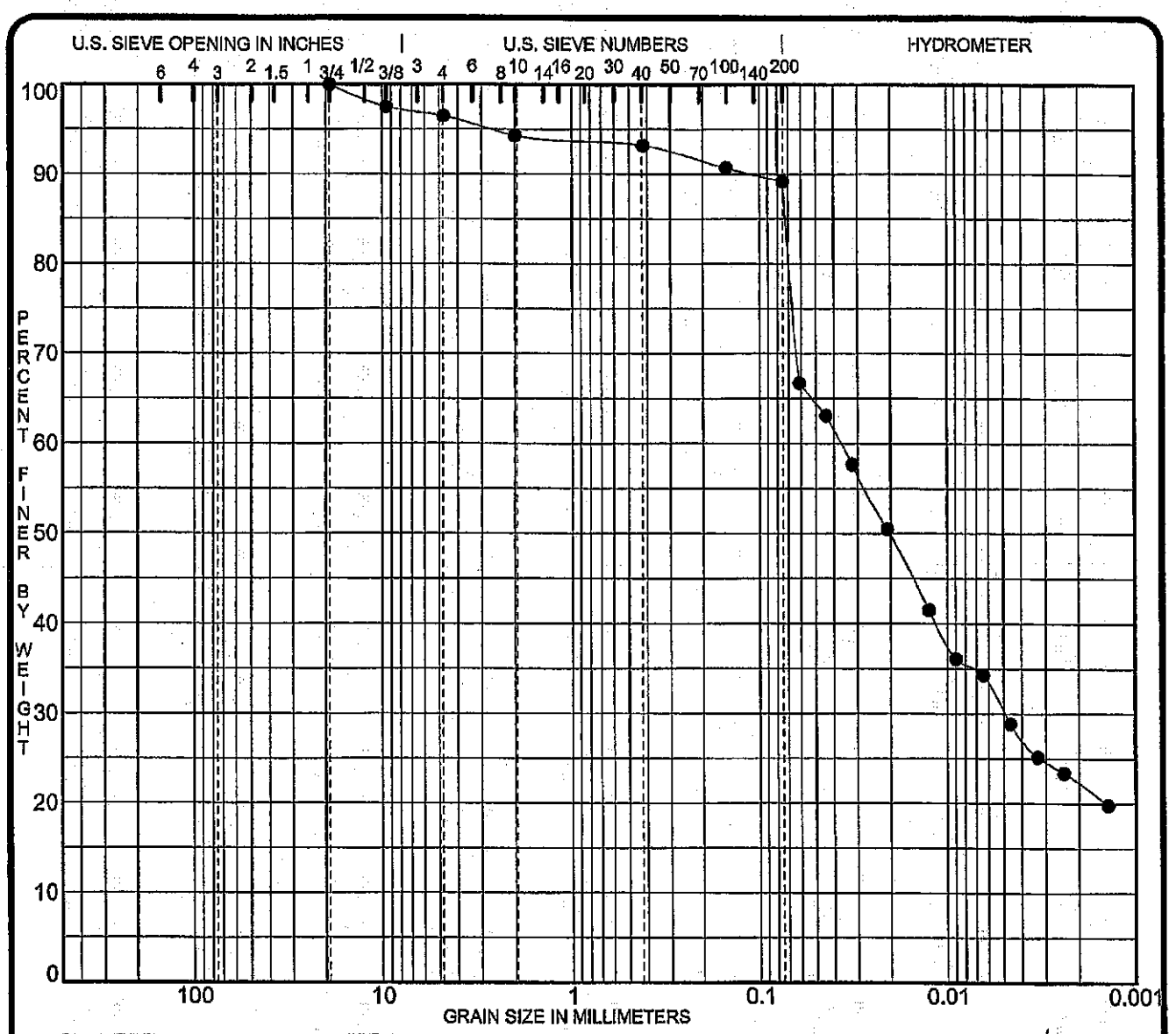
Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:21:00

% of Original Sample Used
For Hydrometer Analysis: 78.1 %
Weight of Sample Dispersed: 75.51 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:21:30	0.5	12	18	5	7	9.3	0.01399	14.3	0.0748	7.2
9:22:00	1.0	10	18	5	5	6.6	0.01399	14.7	0.0536	5.2
9:23:00	2.0	9	18	5	4	5.3	0.01399	14.8	0.0381	4.1
9:26:00	5.0	9	18	5	4	5.3	0.01399	14.8	0.0241	4.1
9:37:00	16.0	8	18	5	3	4.0	0.01399	15.0	0.0135	3.1
9:50:00	29.0	7	18	5	2	2.6	0.01399	15.2	0.0101	2.1
10:15:00	54.0	7	18	5	2	2.6	0.01399	15.2	0.0074	2.1
11:21:00	120.0	6	18	5	1	1.3	0.01399	15.3	0.0050	1.0
1:08:00	227.0	6	18	5	1	1.3	0.01399	15.3	0.0036	1.0
5:21:00	480.0	6	18	5	1	1.3	0.01399	15.3	0.0025	1.0
8:48:00	1407.0	6	18	5	1	1.3	0.01399	15.3	0.0015	1.0

Tested By: Bill Rice
Date: 2/10/2011
Submitted By:
Date: 2/4/2011



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-4 7'-16'	(CL) LEAN CLAY, trace gravel, some fine to coarse sand, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-4 7'-16'	19.00	0.04	0.020	0.005		3.5	7.3	58.9	30.3

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, tr. gravel, some f-c sand** **Boring No.** TP-4

Shape: **Hardness:** **Sample No.** Composite

Remarks: **medium plastic **Depth:** 7' - 16'

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	5.77	2.5	97.5
4M	4.76	2.37	1.0	96.5
10M	2.00	5.10	2.2	94.3
40M	0.42	2.51	1.1	98.9 /* 93.2
100M	0.149	6.07	2.6	96.3 /* 90.7
200M	0.074	3.61	1.6	94.7 /* 89.2
Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 13.24 gm = 5.8% %

Material passing No. 10 mesh: weight = 216.00 gm = 94.2% %

Weight of Total Sample = 229.24 gm

Tested By: Graham Donahue **Date:** 2/3/2011

Submitted By: Wm D Rice **Date:** 2/3/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-4
Sample No:
Depth: 7'-16'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:35:00

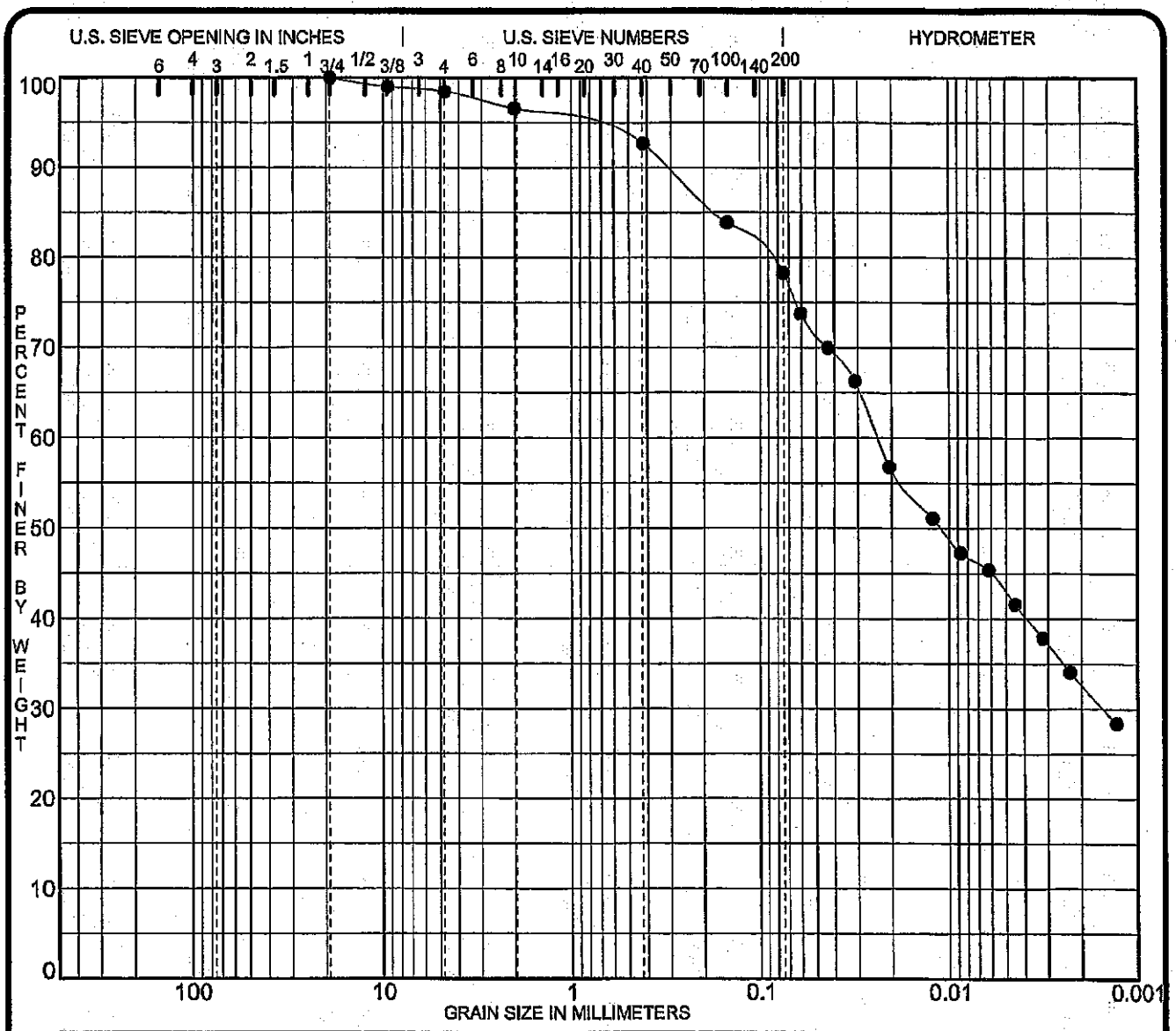
% of Original Sample Used
For Hydrometer Analysis: 94.2 %
Weight of Sample Dispersed: 52.24 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:35:30	0.5	42	17	5	37	70.8	0.01417	9.4	0.0614	66.7
8:36:00	1.0	40	17	5	35	67.0	0.01417	9.7	0.0441	63.1
8:37:00	2.0	37	17	5	32	61.3	0.01417	10.2	0.0320	57.7
8:40:00	5.0	33	17	5	28	53.6	0.01417	10.9	0.0209	50.5
8:50:00	15.0	28	17	5	23	44.0	0.01417	11.7	0.0125	41.5
9:05:00	30.0	25	17	5	20	38.3	0.01417	12.2	0.0090	36.1
9:35:00	60.0	24	17	5	19	36.4	0.01417	12.4	0.0064	34.3
10:35:00	120.0	21	17	5	16	30.6	0.01417	12.9	0.0046	28.9
12:35:00	240.0	19	17	5	14	26.8	0.01417	13.2	0.0033	25.2
16:35:00	480.0	18	17	5	13	24.9	0.01417	13.3	0.0024	23.4
8:35:00	1440.0	16	17	5	11	21.1	0.01417	13.7	0.0014	19.8

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: [signature]
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-5



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
●	TP-5 0'-17'	(CL) LEAN CLAY, reddish brown, with fine to coarse sand, trace fine gravel, medium plastic, moist						

	Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	TP-5 0'-17'	19.00	0.02	0.011	0.002		1.5	20.2	35.5	42.8

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
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Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, reddish brown, with fine to coarse sand** **Boring No.** TP-5

Shape: **Hardness:** **Sample No.** Composite

Remarks: **trace fine gravel, medium plastic, moist **Depth:** 0' - 17'

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2	-	-	-
	2"	50.8	-	-	-
	1 1/2"	37.5	-	-	-
	1	25.4	-	-	-
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	4.66	1.0	99.0
	4M	4.76	2.47	0.5	98.5
	10M	2.00	8.78	1.9	96.6
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.05	4.0	96.0 /* 92.7
	100M	0.149	4.63	9.1	86.9 /* 83.9
	200M	0.074	2.95	5.8	81.1 /* 78.3
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 15.91 gm = 3.4% %

Material passing No. 10 mesh: weight = 455.88 gm = 96.6% %

Weight of Total Sample = 471.79 gm

Tested By: Graham Donahue **Date:** 2/3/2011

Submitted By: [signature] **Date:** 2/3/2011

Form: D422A Revision Date: 04/02/09

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Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-5
Sample No:
Depth: Composite
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:39:00

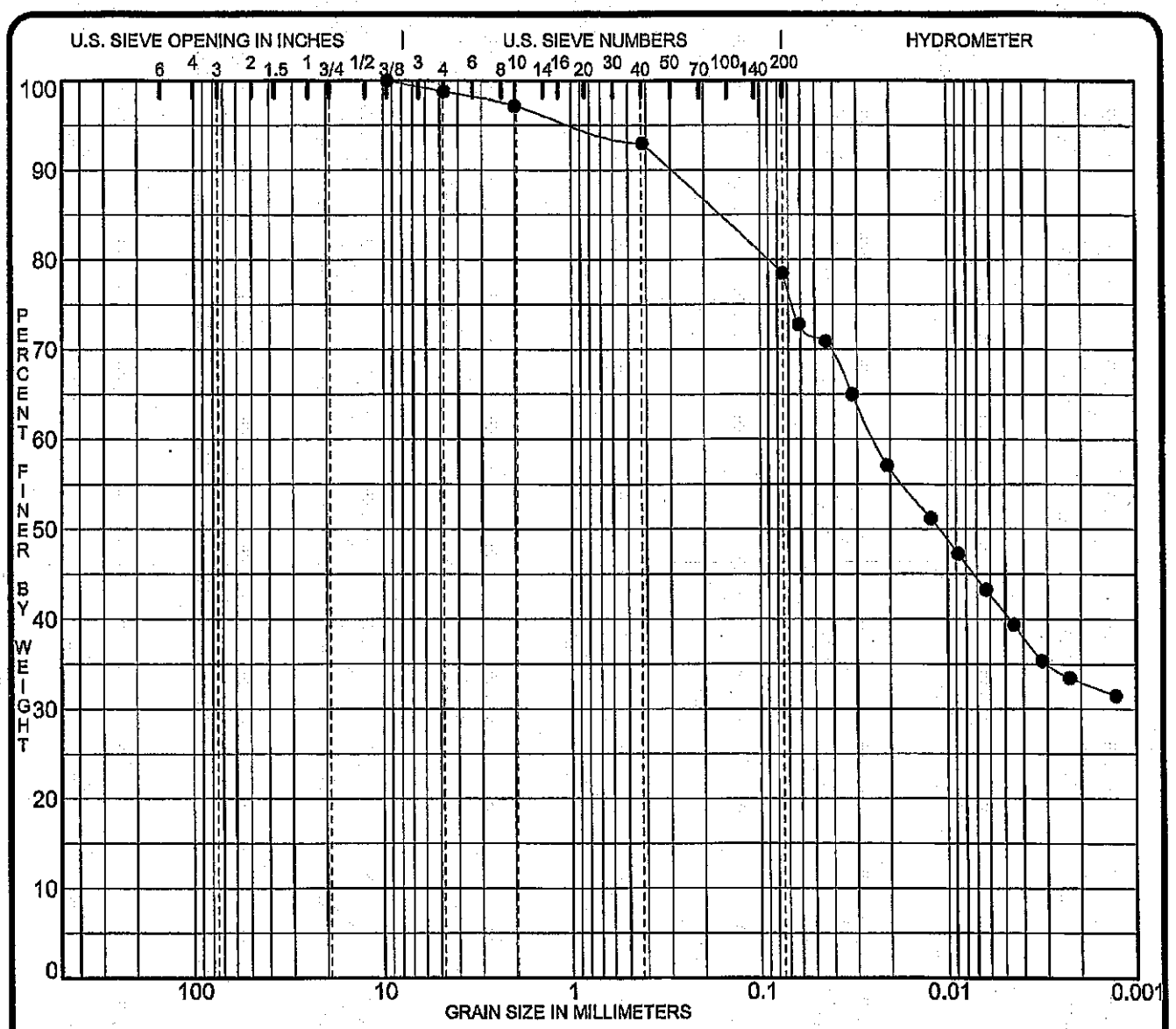
% of Original Sample Used
For Hydrometer Analysis: 96.6 %
Weight of Sample Dispersed: 51.03 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:39:30	0.5	44	17	5	39	76.4	0.01417	9.1	0.0605	73.8
8:40:00	1.0	42	17	5	37	72.5	0.01417	9.4	0.0434	70.0
8:41:00	2.0	40	17	5	35	68.6	0.01417	9.7	0.0312	66.3
8:44:00	5.0	35	17	5	30	58.8	0.01417	10.6	0.0206	56.8
8:54:00	15.0	32	17	5	27	52.9	0.01417	11.1	0.0122	51.1
9:09:00	30.0	30	17	5	25	49.0	0.01417	11.4	0.0087	47.3
9:39:00	60.0	29	17	5	24	47.0	0.01417	11.5	0.0062	45.4
10:39:00	120.0	27	17	5	22	43.1	0.01417	11.9	0.0045	41.6
12:39:00	240.0	25	17	5	20	39.2	0.01417	12.2	0.0032	37.9
16:39:00	480.0	23	17	5	18	35.3	0.01417	12.5	0.0023	34.1
8:39:00	1440.0	20	17	5	15	29.4	0.01417	13.0	0.0013	28.4

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: [signature]
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-6



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-6 3'-17'	(CL) LEAN CLAY, reddish brown, with fine to coarse sand, trace fine gravel, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-6 3'-17'	9.50	0.02	0.011			1.2	20.3	37.9	40.6

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, reddish brown, with f -c sand** **Boring No.** TP-6

Shape: **Hardness:** **Sample No.**

Remarks: **trace fine gravel, medium plastic **Depth:** 3' - 17'

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	-	-	-
3/8	9.5	0.00	0.0	100.0
4M	4.76	3.95	1.2	98.8
10M	2.00	5.20	1.6	97.2
40M	0.42	2.14	4.3	95.7 /* 93.0
100M	0.149	4.64	9.4	86.3 /* 83.9
200M	0.074	2.71	5.5	80.8 /* 78.5
Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 9.15 gm = 2.8% %

Material passing No. 10 mesh: weight = 318.95 gm = 97.2% %

Weight of Total Sample = 328.1 gm

Tested By: Graham Donahue **Date:** 2/3/2011

Submitted By: Wm D Rice **Date:** 2/3/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-6
Sample No:
Depth: 3'-17'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:43:00

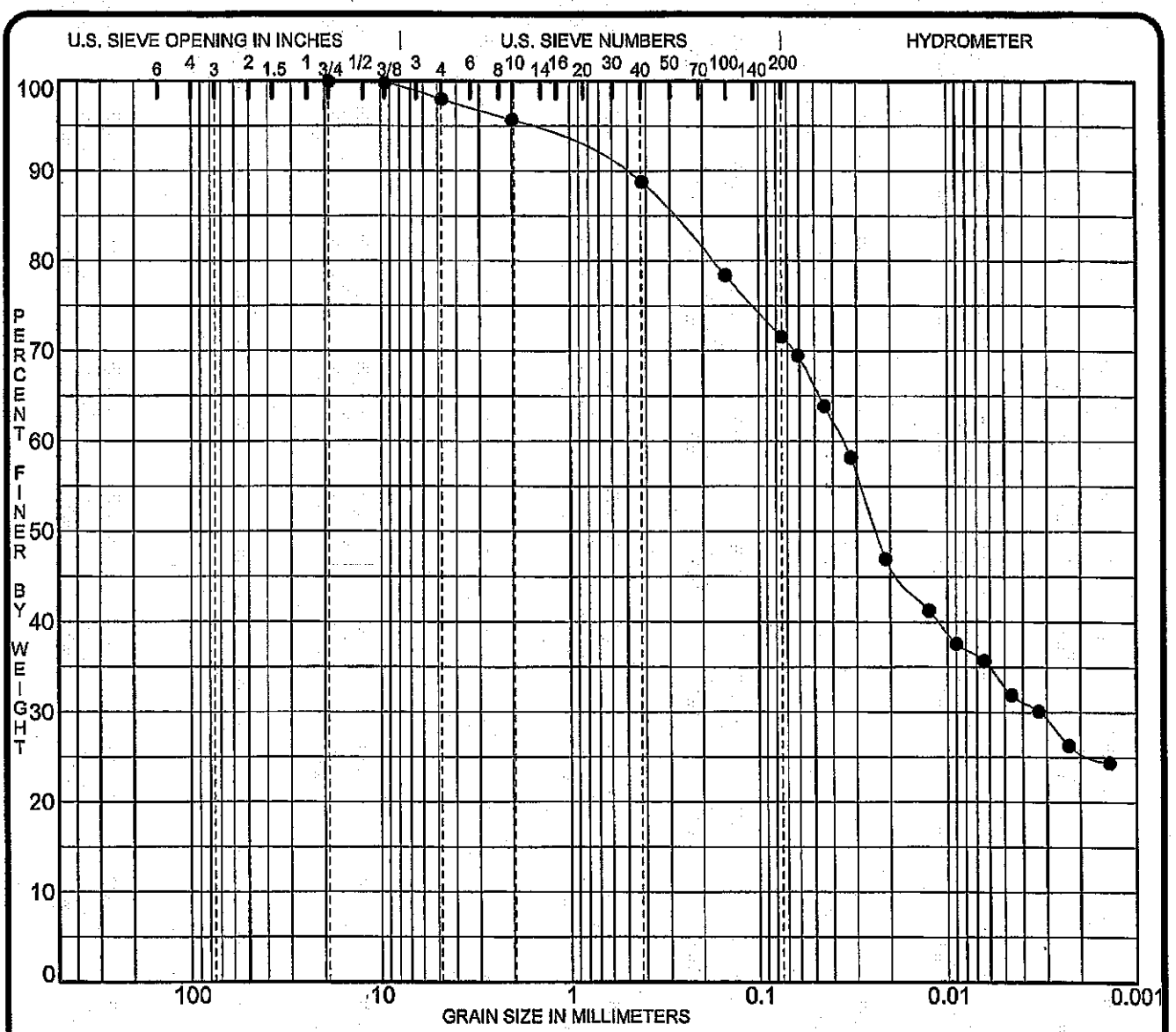
% of Original Sample Used
For Hydrometer Analysis: 97.2 %
Weight of Sample Dispersed: 49.37 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:43:30	0.5	42	17	5	37	74.9	0.01417	9.4	0.0614	72.8
8:44:00	1.0	41	17	5	36	72.9	0.01417	9.6	0.0439	70.9
8:45:00	2.0	38	17	5	33	66.8	0.01417	10.1	0.0318	65.0
8:48:00	5.0	34	17	5	29	58.7	0.01417	10.7	0.0207	57.1
8:58:00	15.0	31	17	5	26	52.7	0.01417	11.2	0.0122	51.2
9:13:00	30.0	29	17	5	24	48.6	0.01417	11.5	0.0088	47.3
9:43:00	60.0	27	17	5	22	44.6	0.01417	11.9	0.0063	43.3
10:43:00	120.0	25	17	5	20	40.5	0.01417	12.2	0.0045	39.4
12:43:00	240.0	23	17	5	18	36.5	0.01417	12.5	0.0032	35.4
16:43:00	480.0	22	17	5	17	34.4	0.01417	12.7	0.0023	33.5
8:43:00	1440.0	21	17	5	16	32.4	0.01417	12.9	0.0013	31.5

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: [signature]
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-7



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
●	TP-7 3'-17'	(CL) LEAN CLAY, red-brown, with fine to coarse sand, trace fine gravel, medium plastic						

	Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	TP-7 3'-17'	19.00	0.04	0.024	0.003		2.0	26.4	38.7	32.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, red-brn, with fine to coarse** **Boring No.** TP-7

Shape: **Hardness:** **Sample No.**

Remarks: **sand, trace fine gravel, medium plastic **Depth:** 3' - 17'

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	0.71	0.2	99.8
4M	4.76	6.72	1.8	98.0
10M	2.00	8.56	2.3	95.7
40M	0.42	3.60	7.1	92.9 /* 88.8
100M	0.149	5.55	10.9	82.0 /* 78.4
200M	0.074	3.61	7.1	74.9 /* 71.6
Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 15.99 gm = 4.4% %

Material passing No. 10 mesh: weight = 351.38 gm = 95.6% %

Weight of Total Sample = 367.37 gm

Tested By: Graham Donahue **Date:** 2/4/2011

Submitted By: [signature] **Date:** 2/4/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-7
Sample No:
Depth: 3'-17'
Date Received: 1/27/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:53:00

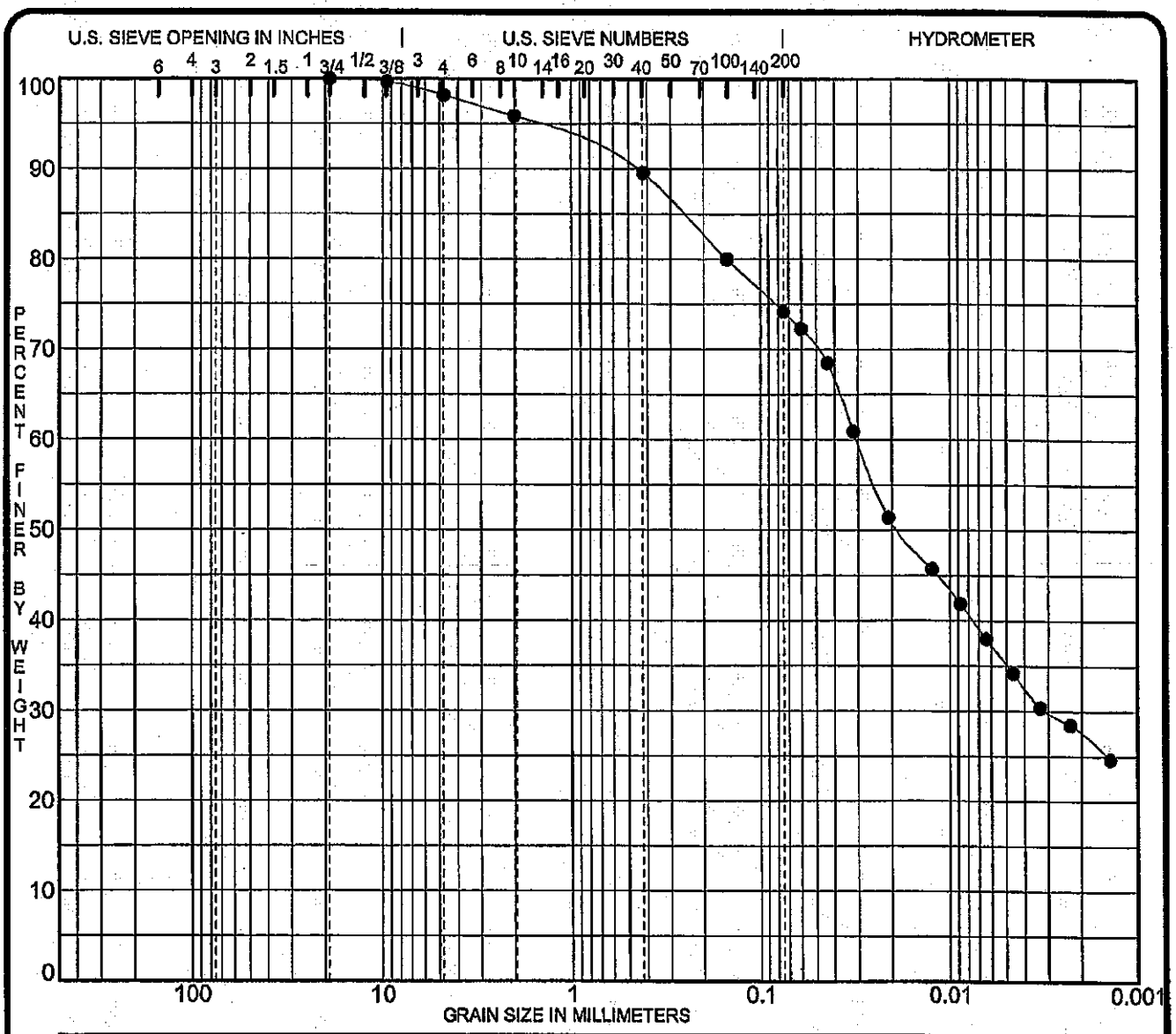
% of Original Sample Used
For Hydrometer Analysis: 95.6 %
Weight of Sample Dispersed: 50.88 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:53:30	0.5	41	18	4	37	72.7	0.01399	9.6	0.0613	69.5
9:54:00	1.0	38	18	4	34	66.8	0.01399	10.1	0.0445	63.9
9:55:00	2.0	35	18	4	31	60.9	0.01399	10.6	0.0322	58.2
9:58:00	5.0	29	18	4	25	49.1	0.01399	11.5	0.0212	47.0
10:08:00	15.0	26	18	4	22	43.2	0.01399	12.0	0.0125	41.3
10:23:00	30.0	24	18	4	20	39.3	0.01399	12.4	0.0090	37.6
10:53:00	60.0	23	18	4	19	37.3	0.01399	12.5	0.0064	35.7
11:53:00	120.0	21	18	4	17	33.4	0.01399	12.9	0.0046	31.9
13:53:00	240.0	20	18	4	16	31.4	0.01399	13.0	0.0033	30.1
17:46:00	473.0	18	18	4	14	27.5	0.01399	13.3	0.0023	26.3
9:53:00	1440.0	17	18	4	13	25.6	0.01399	13.5	0.0014	24.4

Tested By: Graham Donahue
Date: 2/4/2011

Submitted By: [signature]
Date: 2/4/2011

TP-8



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-8 0'-3.5'	(CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-8 0'-3.5'	19.00	0.03	0.018	0.003		1.8	24.0	39.0	35.2

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, with f-c sand** **Boring No.** TP-8

Shape: **Hardness:** **Sample No.**

Remarks: **trace gravel, medium plastic **Depth:** 0' - 3½'

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	1.21	0.3	99.7
4M	4.76	5.39	1.5	98.2
10M	2.00	8.26	2.3	95.9
40M	0.42	3.25	6.5	93.5 /* 89.6
100M	0.149	5.05	10.0	83.5 /* 80.0
200M	0.074	3.01	6.0	77.5 /* 74.2
Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 14.86 gm = 4.2% %

Material passing No. 10 mesh: weight = 337.24 gm = 95.8% %

Weight of Total Sample = 352.11 gm

Tested By: Graham Donahue **Date:** 2/4/2011

Submitted By: [signature] **Date:** 2/4/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-8
Sample No:
Depth: 0'-3.5'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:59:00

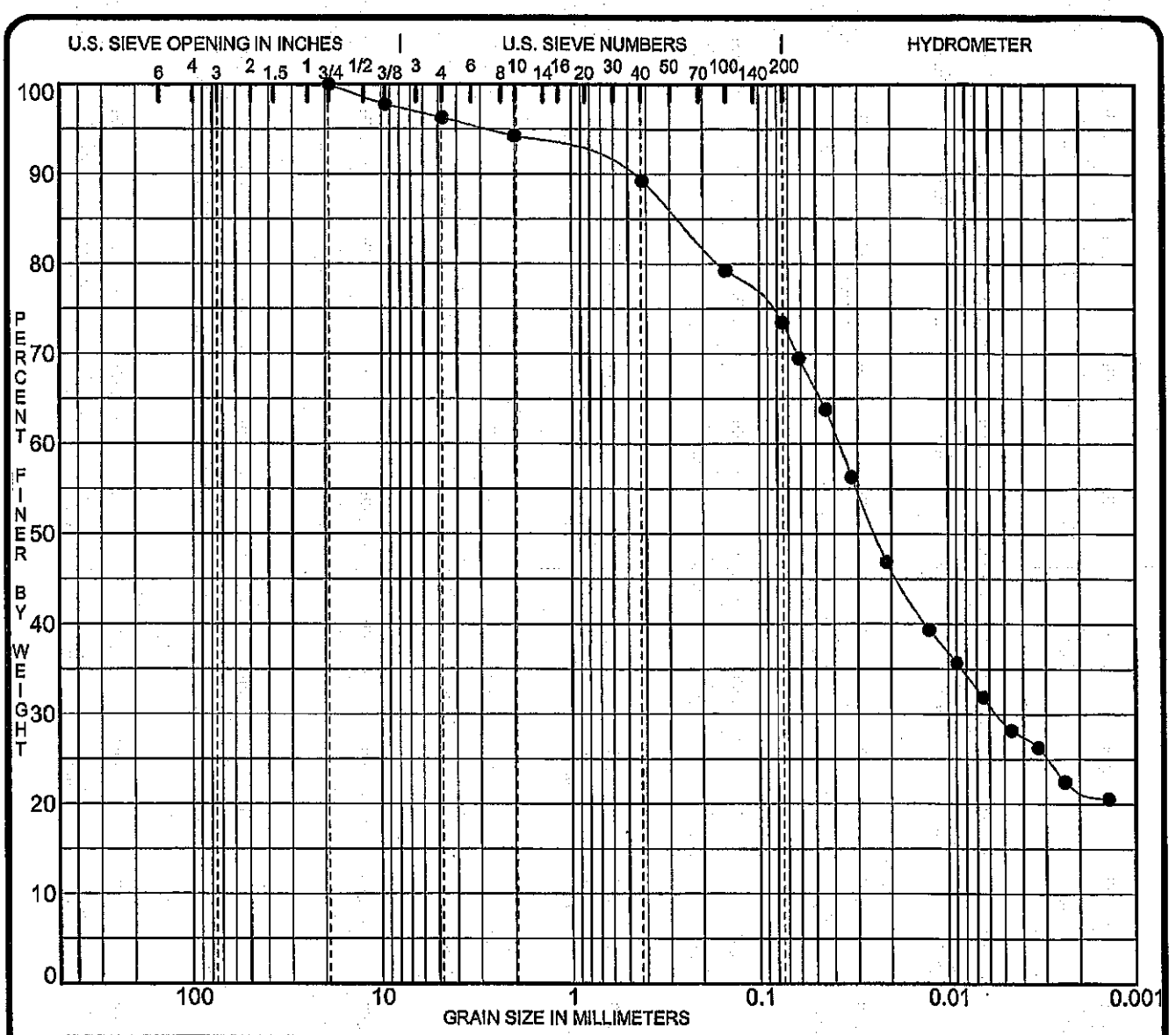
% of Original Sample Used For Hydrometer Analysis: 95.8 %
Weight of Sample Dispersed: 50.36 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:59:30	0.5	42	18	4	38	75.5	0.01399	9.4	0.0607	72.3
10:00:00	1.0	40	18	4	36	71.5	0.01399	9.7	0.0436	68.5
10:01:00	2.0	36	18	4	32	63.5	0.01399	10.4	0.0319	60.9
10:04:00	5.0	31	18	4	27	53.6	0.01399	11.2	0.0209	51.4
10:14:00	15.0	28	18	4	24	47.7	0.01399	11.7	0.0124	45.7
10:29:00	30.0	26	18	4	22	43.7	0.01399	12.0	0.0088	41.9
10:59:00	60.0	24	18	4	20	39.7	0.01399	12.4	0.0064	38.0
11:59:00	120.0	22	18	4	18	35.7	0.01399	12.7	0.0046	34.2
13:59:00	240.0	20	18	4	16	31.8	0.01399	13.0	0.0033	30.4
17:47:00	468.0	19	18	4	15	29.8	0.01399	13.2	0.0023	28.5
9:59:00	1440.0	17	18	4	13	25.8	0.01399	13.5	0.0014	24.7

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: [signature]
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-9



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-9 4'-5'	(CL) LEAN CLAY, red-brown, with fine to coarse sand, trace gravel, medium plastic, crumbly						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-9 4'-5'	19.00	0.04	0.024	0.005		3.7	22.8	44.4	29.1

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, red-brown, with fine to coarse** **Boring No.** TP-9

Shape: **Hardness:** **Sample No.**

Remarks: **sand, trace gravel, medium plastic, crumbly **Depth:** 4' - 5'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	10.25	2.2	97.8
4M	4.76	6.78	1.5	96.3
10M	2.00	9.34	2.0	94.3
40M	0.42	2.61	5.2	94.8 /* 89.3
100M	0.149	5.30	10.6	84.2 /* 79.3
200M	0.074	3.11	6.2	78.0 /* 73.5
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 26.37 gm = 5.8% %

Material passing No. 10 mesh: weight = 431.38 gm = 94.2% %

Weight of Total Sample = 457.75 gm

Tested By: Graham Donahue **Date:** 2/4/2011

Submitted By: [signature] **Date:** 2/4/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-9
Sample No:
Depth: 4'-5'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:47:00

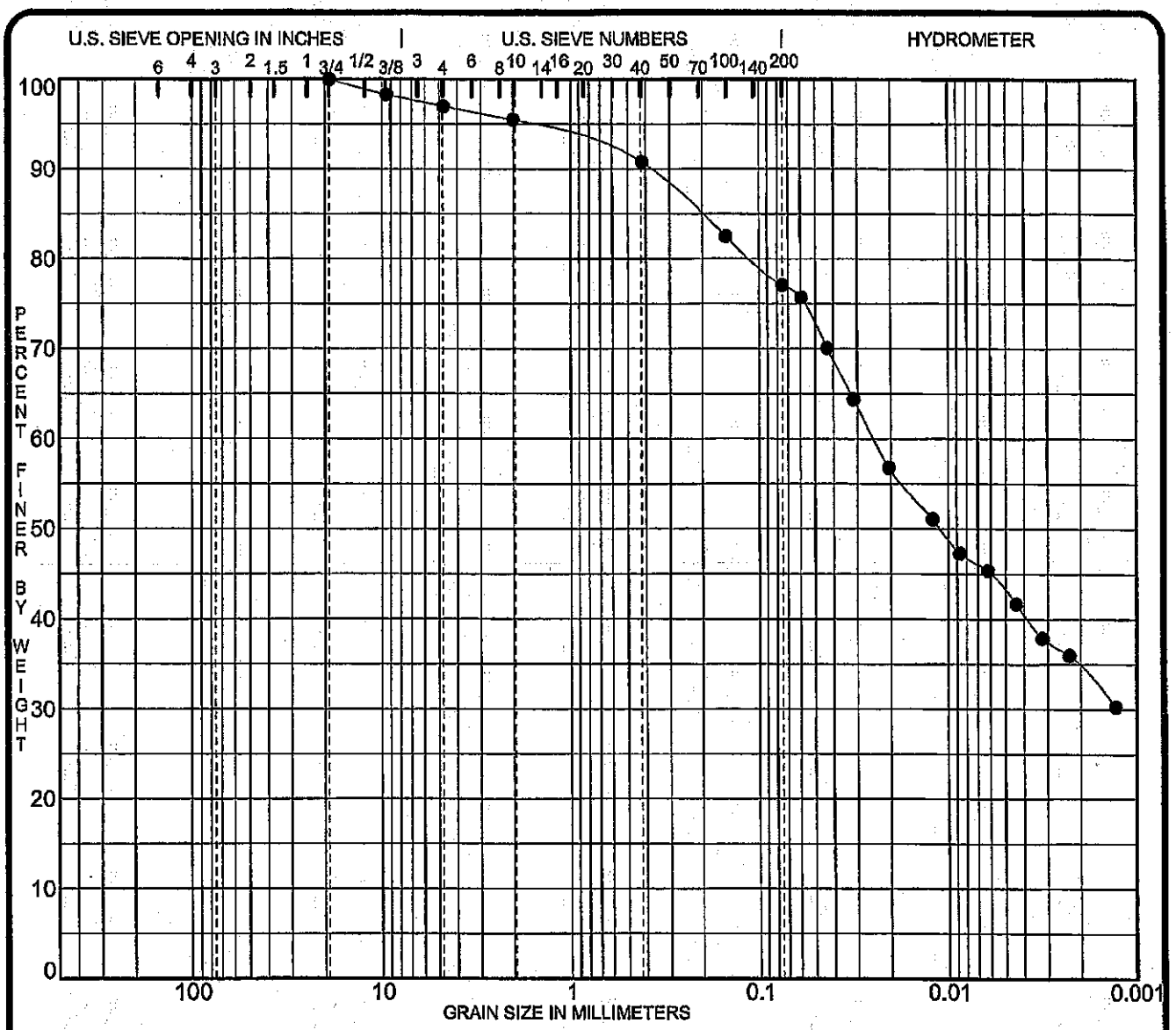
% of Original Sample Used
For Hydrometer Analysis: 94.2 %
Weight of Sample Dispersed: 50.18 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:47:30	0.5	41	18	4	37	73.7	0.01399	9.6	0.0613	69.5
9:48:00	1.0	38	18	4	34	67.8	0.01399	10.1	0.0445	63.8
9:49:00	2.0	34	18	4	30	59.8	0.01399	10.7	0.0324	56.3
9:52:00	5.0	29	18	4	25	49.8	0.01399	11.5	0.0212	46.9
10:02:00	15.0	25	18	4	21	41.8	0.01399	12.2	0.0126	39.4
10:17:00	30.0	23	18	4	19	37.9	0.01399	12.5	0.0090	35.7
10:47:00	60.0	21	18	4	17	33.9	0.01399	12.9	0.0065	31.9
11:47:00	120.0	19	18	4	15	29.9	0.01399	13.2	0.0046	28.2
13:47:00	240.0	18	18	4	14	27.9	0.01399	13.3	0.0033	26.3
17:44:00	477.0	16	18	4	12	23.9	0.01399	13.7	0.0024	22.5
9:47:00	1440.0	15	18	4	11	21.9	0.01399	13.8	0.0014	20.6

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: Wm D Red
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-10



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-10 0'-17'	(CL) LEAN CLAY, red-brown, with fine to coarse sand, trace fine gravel, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-10 0'-17'	19.00	0.02	0.011			3.0	19.9	34.0	43.1

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, red-brn, with fine to coarse ** **Boring No.** TP-10

Shape: **Hardness:** **Sample No.** Composite

Remarks: **sand, trace fine gravel, medium plastic **Depth:** 0' - 17'

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	13.90	1.7	98.3
4M	4.76	10.42	1.3	97.0
10M	2.00	12.16	1.5	95.5
40M	0.42	2.35	4.7	95.3 /* 90.8
100M	0.149	4.49	8.9	86.4 /* 82.5
200M	0.074	2.87	5.7	80.7 /* 77.1
Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 36.48 gm = 4.5% %

Material passing No. 10 mesh: weight = 782.7 gm = 95.5% %

Weight of Total Sample = 819.18 gm

Tested By: Graham Donahue **Date:** 2/4/2011

Submitted By: [signature] **Date:** 2/4/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-10
Sample No:
Depth: Composite
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 10:17:00

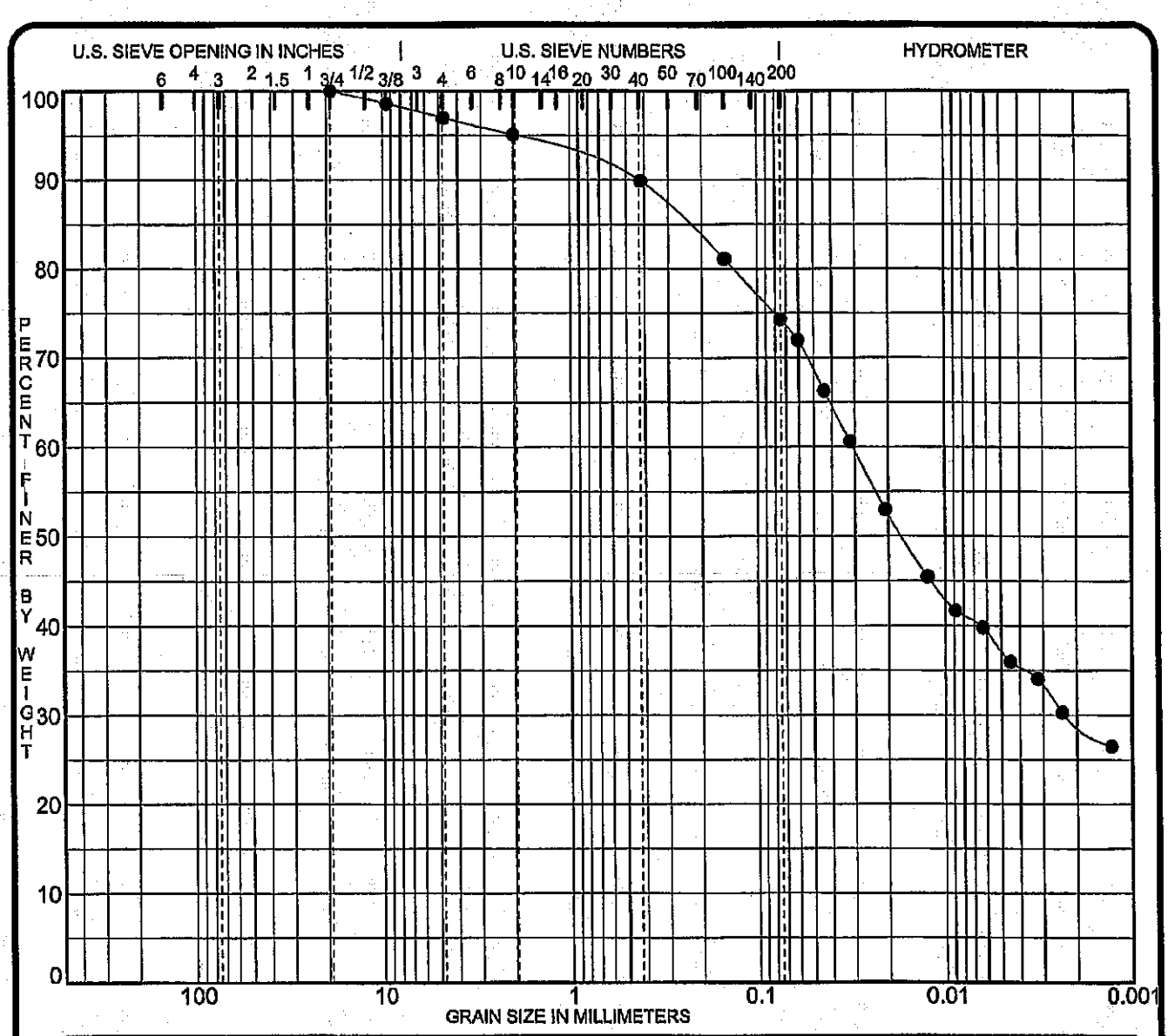
% of Original Sample Used
For Hydrometer Analysis: 95.5 %
Weight of Sample Dispersed: 50.43 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
10:17:30	0.5	44	18	4	40	79.3	0.01399	9.1	0.0597	75.7
10:18:00	1.0	41	18	4	37	73.4	0.01399	9.6	0.0433	70.1
10:19:00	2.0	38	18	4	34	67.4	0.01399	10.1	0.0314	64.4
10:22:00	5.0	34	18	4	30	59.5	0.01399	10.7	0.0205	56.8
10:32:00	15.0	31	18	4	27	53.5	0.01399	11.2	0.0121	51.1
10:47:00	30.0	29	18	4	25	49.6	0.01399	11.5	0.0087	47.3
11:17:00	60.0	28	18	4	24	47.6	0.01399	11.7	0.0062	45.4
12:17:00	120.0	26	18	4	22	43.6	0.01399	12.0	0.0044	41.7
14:17:00	240.0	24	18	4	20	39.7	0.01399	12.4	0.0032	37.9
17:50:00	453.0	23	18	4	19	37.7	0.01399	12.5	0.0023	36.0
10:17:00	1440.0	20	18	4	16	31.7	0.01399	13.0	0.0013	30.3

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: Wm D Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-11 0'-17'	(CL) LEAN CLAY, red-brown, with fine to coarse sand, trace gravel, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-11 0'-17'	19.00	0.03	0.017	0.002		3.0	22.7	37.1	37.2

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Soil Description: (CL) LEAN CLAY, red-brn, w/ fine to coarse sand* **Boring No.** TP-11
Shape: **Hardness:** **Sample No.** Composite
Remarks: *trace gravel, medium plastic **Depth:** 0' - 17'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	20.06	1.4	98.6
4M	4.76	22.45	1.6	97.0
10M	2.00	27.09	1.9	95.1
40M	0.42	2.77	5.5	94.5 /* 89.9
100M	0.149	4.60	9.2	85.3 /* 81.1
200M	0.074	3.64	7.2	78.1 /* 74.3
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:
Material retained on No. 10 mesh: weight = 69.6 gm = 4.9% %
Material passing No. 10 mesh: weight = 1360.02 gm = 95.1% %
Weight of Total Sample = 1429.62 gm

Tested By: Graham Donahue **Date:** 2/4/2011
Submitted By: [signature] **Date:** 2/4/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Remarks:
Boring No: TP-11
Sample No:
Depth: Composite
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 10:11:00

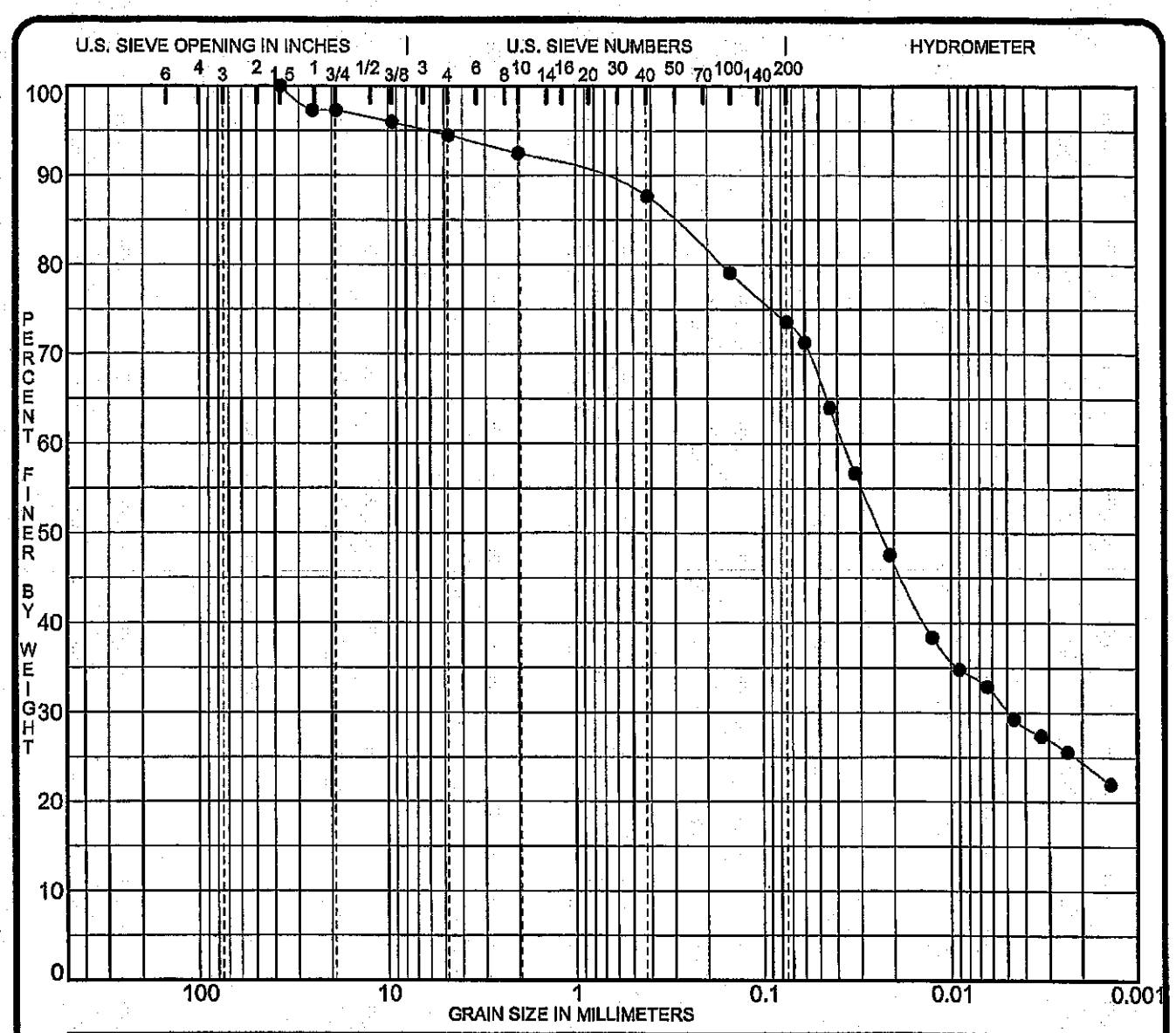
% of Original Sample Used For Hydrometer Analysis: 95.1 %
Weight of Sample Dispersed: 50.21 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
10:11:30	0.5	42	18	4	38	75.7	0.01399	9.4	0.0607	72.0
10:12:00	1.0	39	18	4	35	69.7	0.01399	9.9	0.0440	66.3
10:13:00	2.0	36	18	4	32	63.7	0.01399	10.4	0.0319	60.6
10:16:00	5.0	32	18	4	28	55.8	0.01399	11.1	0.0208	53.0
10:26:00	15.0	28	18	4	24	47.8	0.01399	11.7	0.0124	45.5
10:41:00	30.0	26	18	4	22	43.8	0.01399	12.0	0.0088	41.7
11:11:00	60.0	25	18	4	21	41.8	0.01399	12.2	0.0063	39.8
12:11:00	120.0	23	18	4	19	37.8	0.01399	12.5	0.0045	36.0
14:11:00	240.0	22	18	4	18	35.8	0.01399	12.7	0.0032	34.1
17:49:00	458.0	20	18	4	16	31.9	0.01399	13.0	0.0024	30.3
10:11:00	1440.0	18	18	4	14	27.9	0.01399	13.3	0.0013	26.5

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: Wm D Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-12



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-12 0'-17'	(CL) LEAN CLAY, red-brown, with fine to coarse sand, some gravel, moist, medium plastic, crumbly						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-12 0'-17'	37.50	0.04	0.024	0.005		5.5	20.9	43.4	30.2

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 2/28/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Soil Description: (CL) LEAN CLAY, red-brn, with fine to coarse sand* **Boring No.** TP-12
Shape: **Hardness:** **Sample No.** Composite
Remarks: *some gravel, moist, medium plastic, crumbly **Depth:** 0' - 17'

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	0.0	0.0	100.0
1	25.4	37.70	2.7	97.3
3/4	19.1	0.00	0.0	97.3
3/8	9.5	18.20	1.3	96.0
4M	4.76	21.21	1.5	94.5
10M	2.00	28.06	2.0	92.5
40M	0.42	2.58	5.1	94.9 /* 87.7
100M	0.149	4.71	9.3	85.6 /* 79.1
200M	0.074	3.02	6.0	79.6 /* 73.6
Pan				/*

***Percent Based on Total Sample**

Original Sample:
Material retained on No. 10 mesh: weight = 105.17 gm = 7.6% %
Material passing No. 10 mesh: weight = 1273.16 gm = 92.4% %
Weight of Total Sample = 1378.33 gm

Tested By: Graham Donahue **Date:** 2/4/2011
Submitted By: [signature] **Date:** 2/4/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: TP-12
Sample No:
Depth: Composite
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 1/27/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 10:05:00

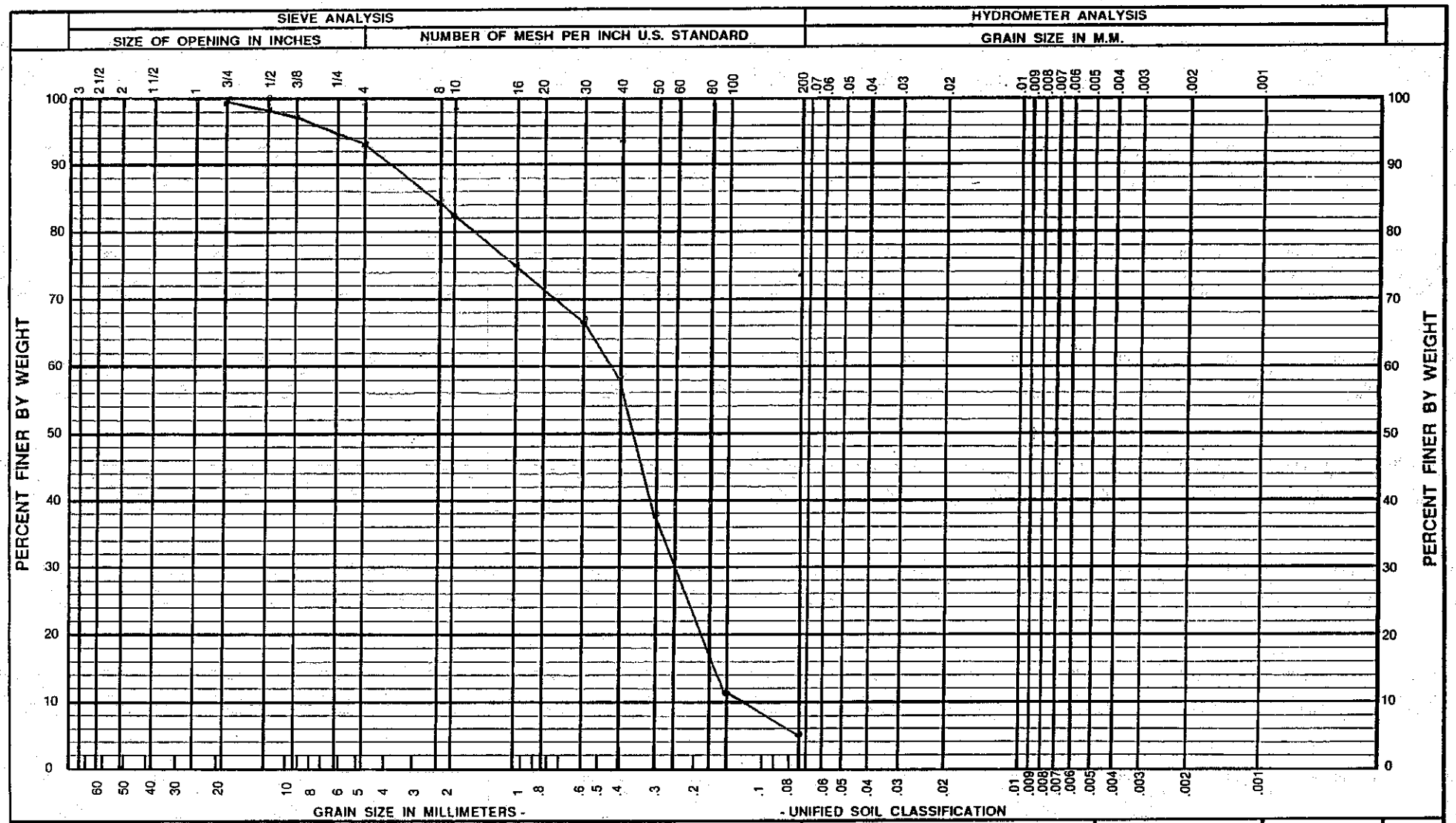
% of Original Sample Used
For Hydrometer Analysis: 92.4 %
Weight of Sample Dispersed: 50.51 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
10:05:30	0.5	43	18	4	39	77.2	0.01399	9.2	0.0600	71.3
10:06:00	1.0	39	18	4	35	69.3	0.01399	9.9	0.0440	64.0
10:07:00	2.0	35	18	4	31	61.4	0.01399	10.6	0.0322	56.7
10:10:00	5.0	30	18	4	26	51.5	0.01399	11.4	0.0211	47.6
10:20:00	15.0	25	18	4	21	41.6	0.01399	12.2	0.0126	38.4
10:35:00	30.0	23	18	4	19	37.6	0.01399	12.5	0.0090	34.8
11:05:00	60.0	22	18	4	18	35.6	0.01399	12.7	0.0064	32.9
12:05:00	120.0	20	18	4	16	31.7	0.01399	13.0	0.0046	29.3
14:05:00	240.0	19	18	4	15	29.7	0.01399	13.2	0.0033	27.4
17:48:00	463.0	18	18	4	14	27.7	0.01399	13.3	0.0024	25.6
10:05:00	1440.0	16	18	4	12	23.8	0.01399	13.7	0.0014	22.0

Tested By: Graham Donahue
Date: 2/4/2011
Submitted By: [signature]
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

TP-13



BORING NO.	GRAVEL	F. SAND	D_{60}	C_U
SAMPLE NO.	C. SAND	SILT	D	C_Z
DEPTH	M. SAND	CLAY	D_{10}	UNIFIED CLASS
ELEV.				

COLEMAN ENGINEERING CO.

⊙ MECHANICAL
△ HYDROMETER

PROJECT: Copperwood

REMARKS: TP # 13

DATE: 2-21-2011

JOB NO.: CL-11006

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

ASTM C136

Project: Copperwood **Job No.:** GL-11006

Client: Orvana Minerals **Lab No.:** 4

Address: **Date Received:** 2/15/2011

Date Sampled: 2/15/2011 **Sample No.:** **TP-13** **Sampled by:** GS

Soil Description: (SP) Sand, brown, fine to coarse, some fine gravel

Sieve Size No.	Weight Retained	Percent Retained	Percent Passing	Specification
6-Inch				
3-Inch				
2-Inch				
1-1/2-Inch				
1-Inch				
3/4-Inch	**0**	**0.0**	**100.0**	
1/2-Inch	**18.7**	**1.4**	**98.6**	
3/8-Inch	**30.6**	**2.3**	**97.7**	
No. 4	**90.0**	**6.9**	**93.1**	
No. 8	**203.4**	**15.5**	**84.5**	
No. 10	**231.4**	**17.7**	**82.3**	
No. 16	**316.1**	**24.2**	**75.8**	
No. 30	**434.6**	**33.2**	**66.8**	
No. 40	**544.9**	**41.6**	**58.4**	
No. 50	**811.1**	**62.0**	**38.0**	
No. 80				
No. 100	**1154.1**	**88.2**	**11.8**	
No. 200	**1241.2**	**94.8**	**5.2**	
LBW (C117)				
PAN	**7.0**			
Total				

Material Spec: Filter Material

DRY INITIAL WT: **1308.7** **gm**

	Actual	Specification
Crushed Count:		
Fineness Modulus:		
Other:		
Other:		
Other:		

☐ Sample Meets Gradation Specifications

☐ Sample Does Not Meet Gradation Specifications

Remarks: Test Pit #13

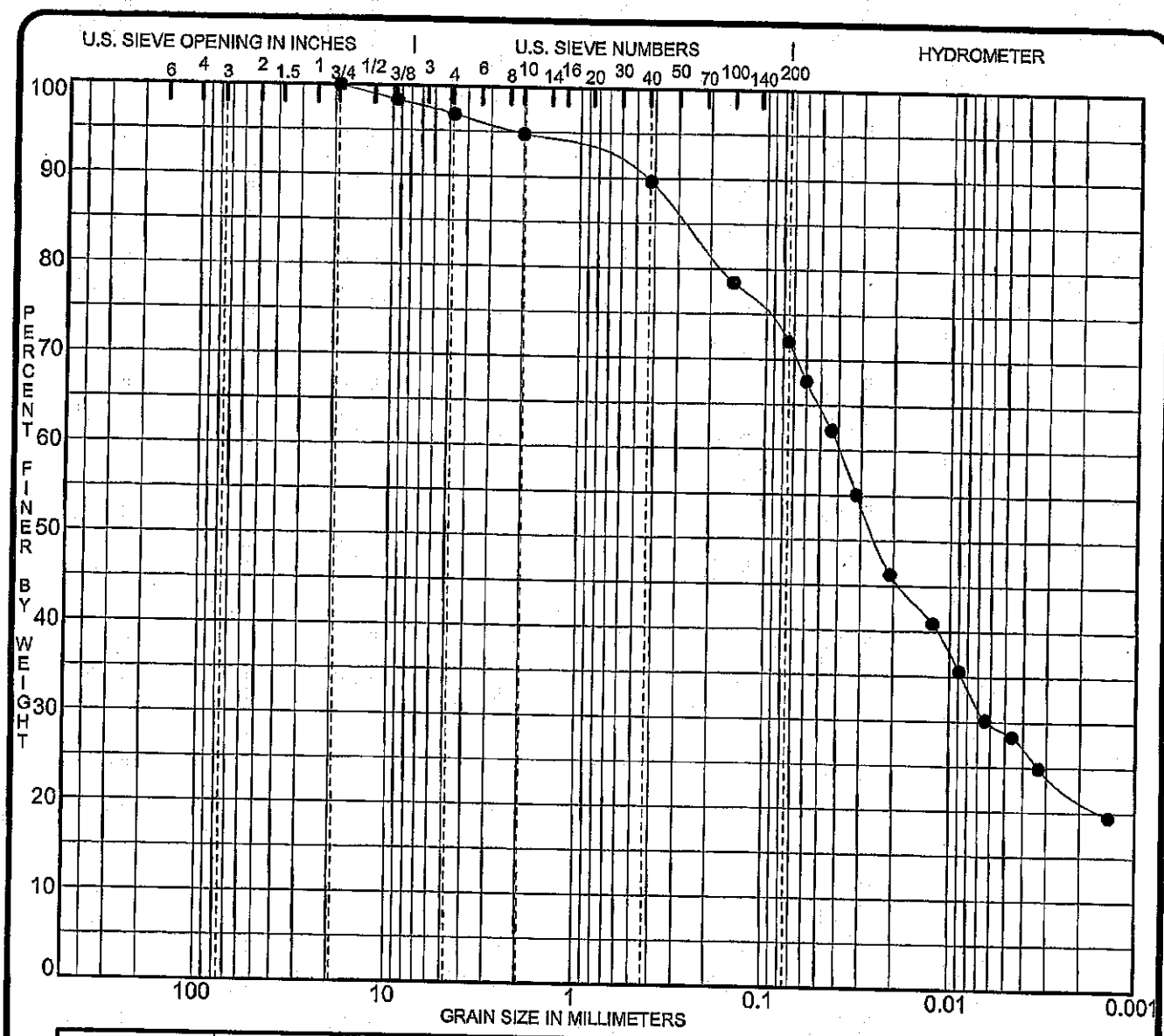
Pan No.: 6
Wet Initial Wt. 2879.1 gm.
DRY INITIAL WT: 2353.6 gm.
Washed Wt.: gm.
% Moisture: 22.3 %

Tested by: M.E. Douglas Date: 2/18/2011

Submitted By: M.E. Douglas Date: 2/21/11

Form C136 Revised: 04-07-05

TP-14



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-14 0'-15'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-14 0'-15'	19.00	0.04	0.025	0.006		3.1	24.9	43.1	28.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand trace fine gravel

Boring No. TP-14

Sample No. Comp

Depth: 0' - 15'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	7.11	1.6	98.4
4M	4.76	6.54	1.5	96.9
10M	2.00	9.51	2.1	94.8
40M	0.42	2.89	5.4	94.6 /* 89.7
100M	0.149	6.28	11.8	82.8 /* 78.5
200M	0.074	3.60	6.8	76.0 /* 72.0
Pan				

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 23.16 gm = 5.2% %

Material passing No. 10 mesh: weight = 424.49 gm = 94.8% %

Weight of Total Sample = 447.65 gm

Tested By: Graham Doanhue & Dan Absolon **Date:** 2/24/2011

Submitted By: [signature] **Date:** 2/24/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

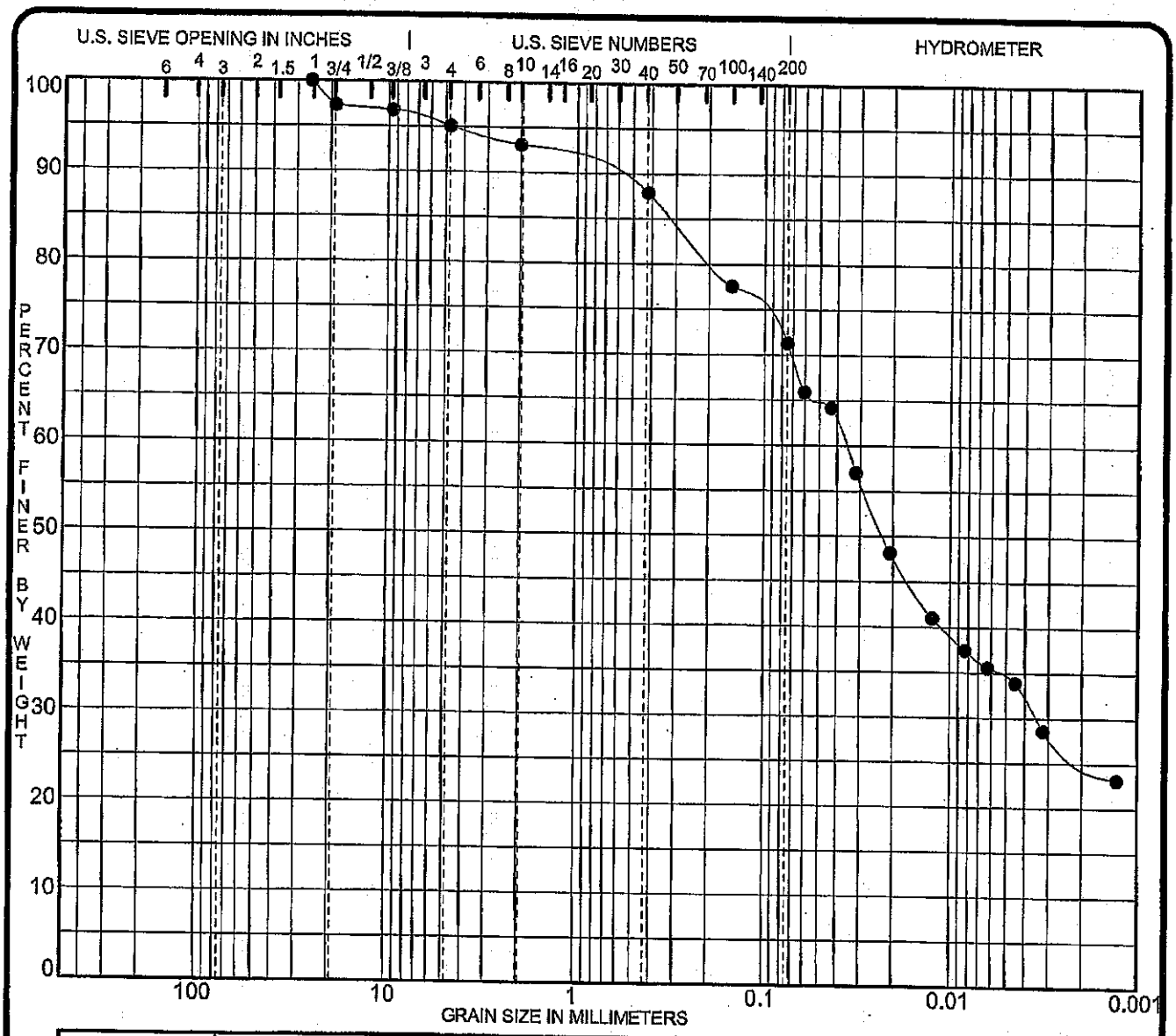
Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Remarks:
Boring No: TP-14
Sample No: Comp.
Depth: 0' - 15'
Date Received: 2/17/2011
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:12:00
% of Original Sample Used For Hydrometer Analysis: 94.8 %
Weight of Sample Dispersed: 53.32 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:12:30	0.5	43	18	5	38	71.3	0.01399	9.2	0.0600	67.6
8:13:00	1.0	40	18	5	35	65.6	0.01399	9.7	0.0436	62.2
8:14:00	2.0	36	18	5	31	58.1	0.01399	10.4	0.0319	55.1
8:17:00	5.0	31	18	5	26	48.8	0.01399	11.2	0.0209	46.2
8:27:00	15.0	28	18	5	23	43.1	0.01399	11.7	0.0124	40.9
8:42:00	30.0	25	18	5	20	37.5	0.01399	12.2	0.0089	35.6
9:12:00	60.0	22	18	5	17	31.9	0.01399	12.7	0.0064	30.2
10:12:00	120.0	21	18	5	16	30.0	0.01399	12.9	0.0046	28.4
12:12:00	240.0	19	18	5	14	26.3	0.01399	13.2	0.0033	24.9
4:12:00	480.0									
8:12:00	1440.0	16	18	5	11	20.6	0.01399	13.7	0.0014	19.6

Tested By: Graham Donahue
Date: 2/24/2011
Submitted By: [signature]
Date: 2/24/2011

Form #: 0422B Revision Date: 1/17/05

TP-15



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-15 2'-15'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-15 2'-15'	25.40	0.04	0.023	0.004		4.9	23.8	36.9	34.4

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown medium plastic with fine to coarse sand, trace fine gravel

Boring No. TP-15

Sample No. Comp

Depth: 2' - 15'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4	0.00	0.0	100.00
3/4	19.1	11.24	2.7	97.3
3/8	9.5	2.25	0.5	96.8
4M	4.76	7.06	1.7	95.1
10M	2.00	8.24	2.0	93.1
40M	0.42	2.85	5.5	94.5 /* 87.9
100M	0.149	5.77	11.1	83.4 /* 77.6
200M	0.074	3.50	6.7	76.7 /* 71.3
Pan				

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 28.79 gm = 7.0% %

Material passing No. 10 mesh: weight = 380.39 gm = 93.0% %

Weight of Total Sample = 409.18 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 2/24/2011

Submitted By: [illegible] **Date:** 2/24/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-15
Sample No: Comp
Depth: 2' - 15'
Date Received: 2/17/2011

Dispersing Agent Used: 4% sodium hexametaphosphate solution

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:00:00

% of Original Sample Used For Hydrometer Analysis: 93.0 %
Weight of Sample Dispersed: 52.17 g.

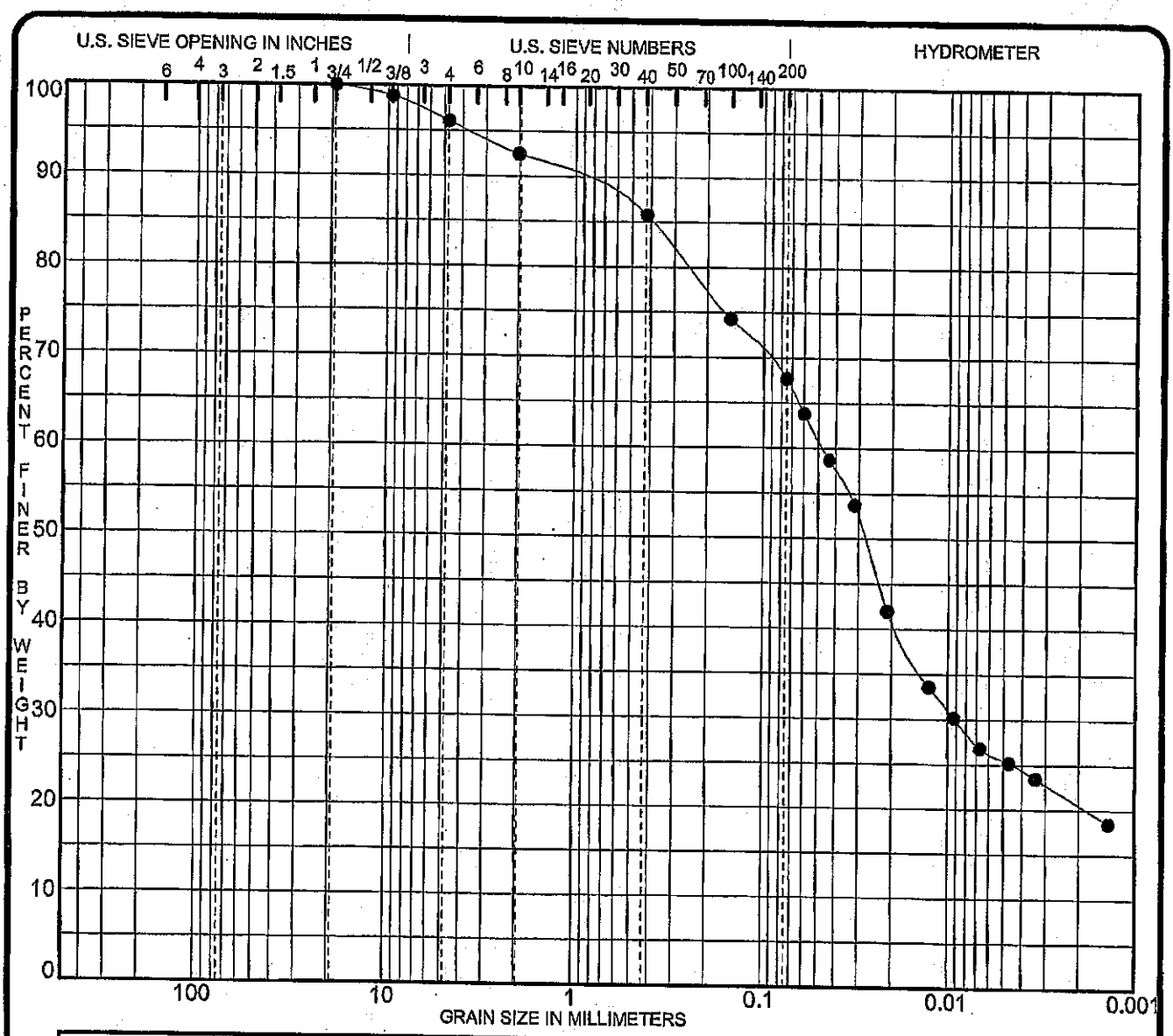
Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:00:30	0.5	42	18	5	37	70.9	0.01399	9.4	0.0607	66.0
8:01:00	1.0	41	18	5	36	69.0	0.01399	9.6	0.0433	64.2
8:02:00	2.0	37	18	5	32	61.3	0.01399	10.2	0.0316	57.0
8:05:00	5.0	32	18	5	27	51.8	0.01399	11.1	0.0208	48.1
8:15:00	15.0	28	18	5	23	44.1	0.01399	11.7	0.0124	41.0
8:34:00	34.0	26	18	5	21	40.3	0.01399	12.0	0.0083	37.4
9:00:00	60.0	25	18	5	20	38.3	0.01399	12.2	0.0063	35.7
10:00:00	120.0	24	18	5	19	36.4	0.01399	12.4	0.0045	33.9
12:00:00	240.0	21	18	5	16	30.7	0.01399	12.9	0.0032	28.5
16:00:00	480.0									
8:00:00	1440.0	18	18	5	13	24.9	0.01399	13.3	0.0013	23.2

Tested By: Graham Donahue & Dan Absolon Date: 2/24/2011

Submitted By: [signature] Date: 2/24/2011

Form #: 0422B Revision Date: 1/17/05

TP-16



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-16 0'-15'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-16 0'-15'	19.00	0.05	0.028	0.009		3.9	28.4	42.2	25.5

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. TP-16

Sample No. Comp

Depth: 0' - 15'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	5.02	1.2	98.8
4M	4.76	11.19	2.7	96.1
10M	2.00	14.70	3.6	92.5
40M	0.42	3.97	7.2	92.8 /* 85.8
100M	0.149	6.89	12.5	80.3 /* 74.3
200M	0.074	3.89	7.1	73.2 /* 67.7
Pan				

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 30.91 gm = 7.5% %

Material passing No. 10 mesh: weight = 382.46 gm = 92.5% %

Weight of Total Sample = 413.37 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 2/24/2011

Submitted By: [signature] **Date:** 2/24/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-16
Sample No: Comp
Depth: 0' - 15'
Date Received: 2/17/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:24:00

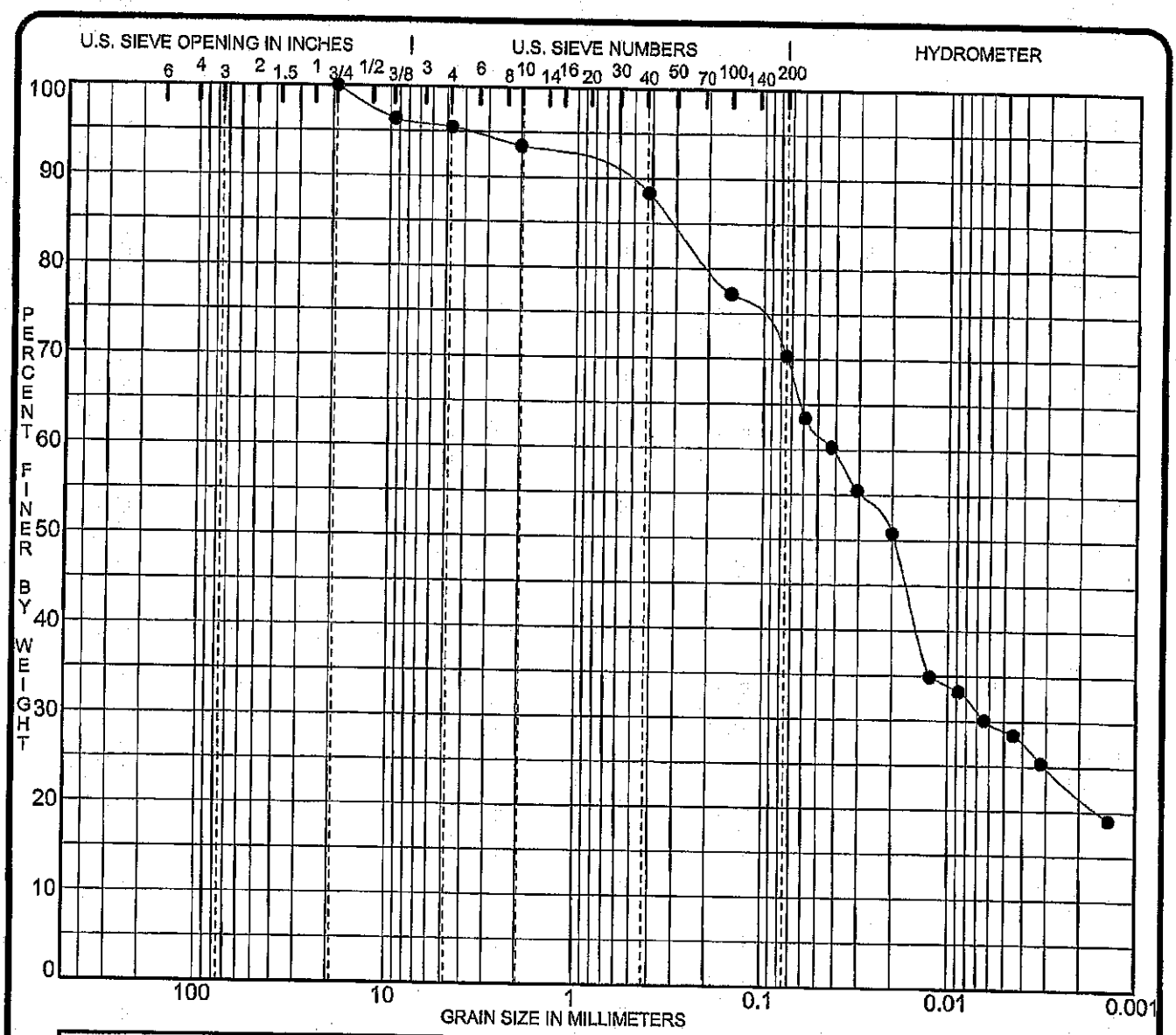
% of Original Sample Used
For Hydrometer Analysis: 92.5 %
Weight of Sample Dispersed: 55.11 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:24:30	0.5	43	18	5	38	69.0	0.01399	9.2	0.0600	63.8
8:25:00	1.0	40	18	5	35	63.5	0.01399	9.7	0.0436	58.7
8:26:00	2.0	37	18	5	32	58.1	0.01399	10.2	0.0316	53.7
8:29:00	5.0	30	18	5	25	45.4	0.01399	11.4	0.0211	42.0
8:39:00	15.0	25	18	5	20	36.3	0.01399	12.2	0.0126	33.6
8:54:00	30.0	23	18	5	18	32.7	0.01399	13.3	0.0093	30.2
9:24:00	60.0	21	18	5	16	29.0	0.01399	13.7	0.0067	26.9
10:24:00	120.0	20	18	5	15	27.2	0.01399	13.8	0.0074	25.2
12:24:00	240.0	19	18	5	14	25.4	0.01399	14.0	0.0034	23.5
4:24:00	480.0									
8:24:00	1440.0	16	18	5	11	20.0	0.01399	14.5	0.0014	18.5

Tested By: Graham Donahue & Dan Absolon
Date: 2/24/2011
Submitted By: [signature]
Date: 2/24/2011

Form #: 0422B Revision Date: 1/17/05

TP-17



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-17 3'-15'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-17 3'-15'	19.00	0.04	0.020	0.006		4.5	25.1	41.4	29.0

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7778

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. TP-17
Sample No. Comp
Depth: 3' - 15'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	15.19	3.6	96.4
4M	4.76	3.75	0.9	95.5
10M	2.00	8.69	2.0	93.5
40M	0.42	3.22	5.5	94.5 /* 88.4
100M	0.149	7.04	11.9	82.6 /* 77.2
200M	0.074	4.29	7.3	75.3 /* 70.4
Pan				

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 27.63 gm = 6.5% %

Material passing No. 10 mesh: weight = 399.47 gm = 93.5% %

Weight of Total Sample = 427.1 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 2/24/2011

Submitted By: [signature] **Date:** 2/24/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

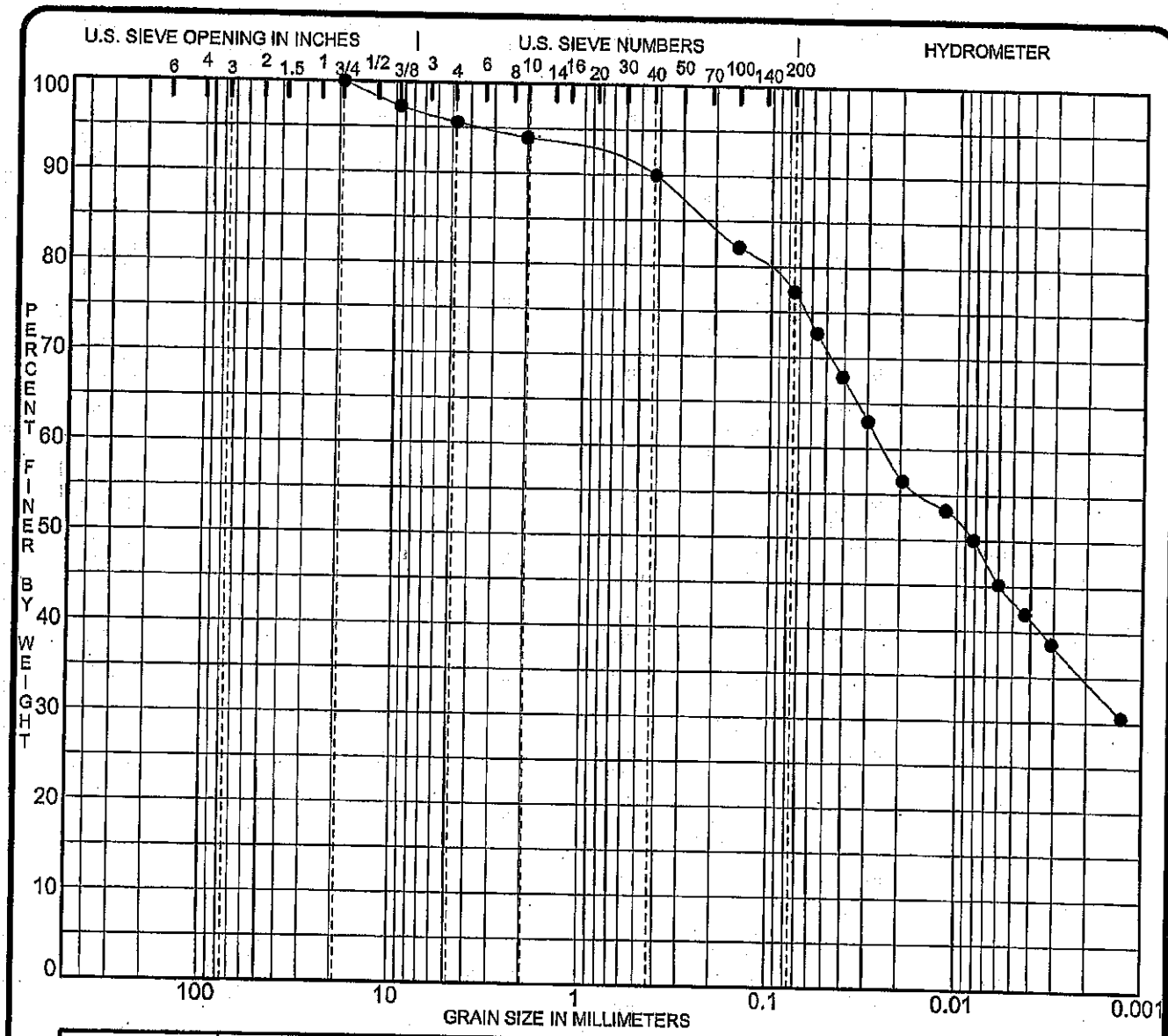
Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Remarks:
Boring No: TP-17
Sample No: Comp
Depth: 3' - 15'
Date Received: 2/17/2011
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:30:00
% of Original Sample Used For Hydrometer Analysis: 93.5 %
Weight of Sample Dispersed: 58.93 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:30:30	0.5	45	18	5	40	67.9	0.01399	8.9	0.0590	63.5
8:31:00	1.0	43	18	5	38	64.5	0.01399	9.2	0.0424	60.3
8:32:00	2.0	40	18	5	35	59.4	0.01399	9.7	0.0308	55.5
8:35:00	5.0	37	18	5	32	54.3	0.01399	10.2	0.0200	50.8
8:45:00	15.0	27	18	5	22	37.3	0.01399	11.9	0.0125	34.9
9:00:00	30.0	26	18	5	21	35.6	0.01399	12.0	0.0088	33.3
9:30:00	60.0	24	18	5	19	32.2	0.01399	12.4	0.0064	30.1
10:30:00	120.0	23	18	5	18	30.5	0.01399	12.5	0.0045	28.6
12:30:00	240.0	21	18	5	16	27.2	0.01399	12.9	0.0032	25.4
16:30:00	480.0									
8:30:00	1440.0	17	18	5	12	20.4	0.01399	13.5	0.0014	19.0

Tested By: Graham Donahue & Dan Absolon
Date: 2/24/2011
Submitted By:
Date: 2/24/2011

Form #: 0422B Revision Date: 1/17/05

TP-18



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-18 0'-15'	(CL) LEAN CLAY, brown, highly plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-18 0'-15'	19.00	0.02	0.008			4.4	18.3	33.9	43.4

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, highly plastic, with fine to coarse sand **Boring No.** TP-18

Sample No. Comp

Remarks: **Depth:** 0' - 15'

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	10.69	2.7	97.3
	4M	4.76	6.99	1.7	95.6
	10M	2.00	6.53	1.6	94.0
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.51	4.3	95.7 /* 90.0
	100M	0.149	4.89	8.4	87.3 /* 82.1
	200M	0.074	2.95	5.1	82.2 /* 77.3
	Pan				

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 24.21 gm = 6.0% %

Material passing No. 10 mesh: weight = 377.09 gm = 94.0% %

Weight of Total Sample = 401.30 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 2/24/2011

Submitted By: [signature] **Date:** 2/24/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

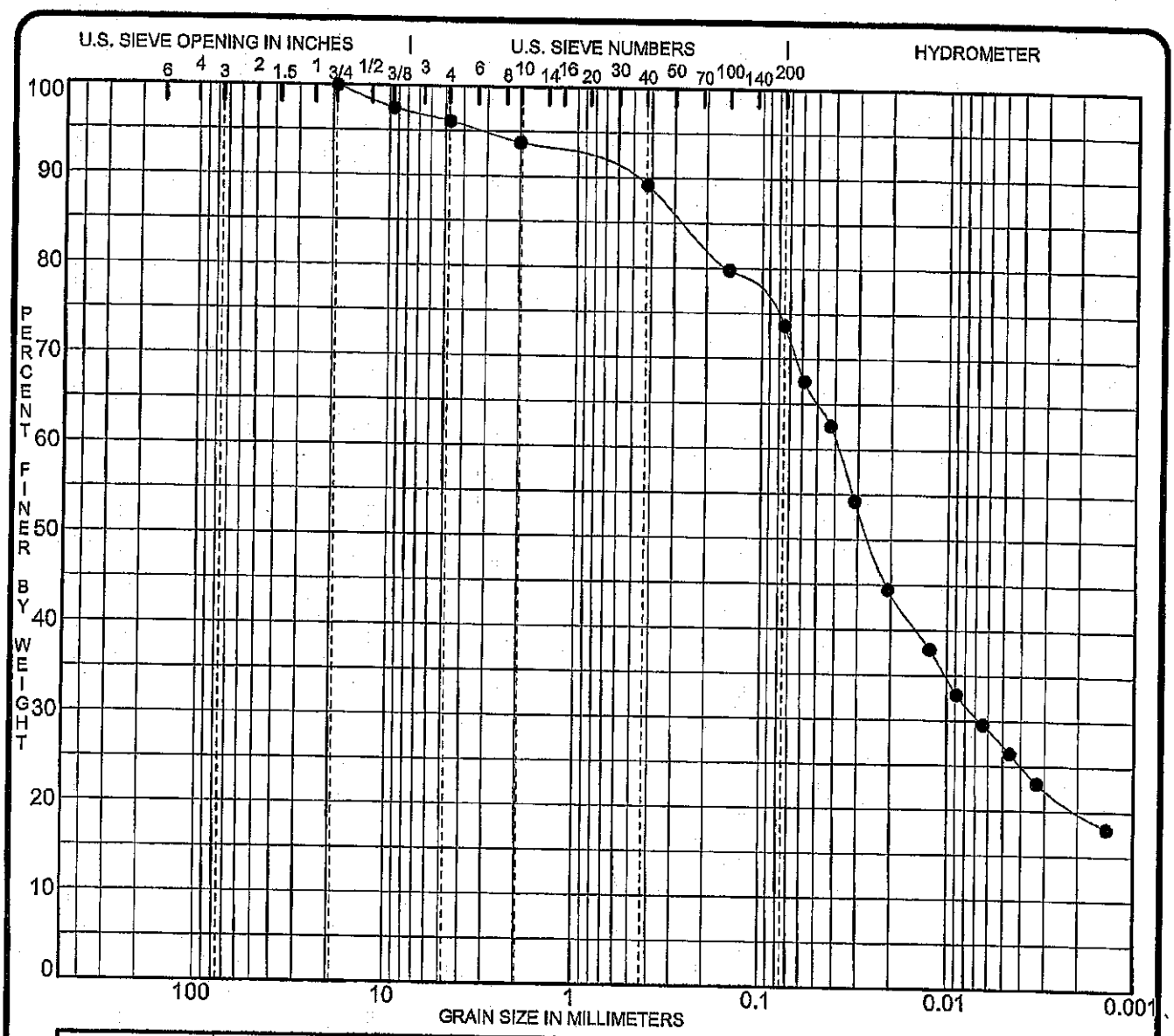
Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Remarks:
Boring No: TP-18
Sample No: Comp
Depth: 0' - 15'
Date Received: 2/17/2011
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:06:00
% of Original Sample Used For Hydrometer Analysis: 94.0 %
Weight of Sample Dispersed: 58.21 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:06:30	0.5	50	18	5	45	77.3	0.01399	8.1	0.0563	72.7
8:07:00	1.0	47	18	5	42	72.2	0.01399	8.6	0.0410	67.8
8:08:00	2.0	44	18	5	39	67.0	0.01399	9.1	0.0298	63.0
8:11:00	5.0	40	18	5	35	60.1	0.01399	9.7	0.0195	56.5
8:21:00	15.0	38	18	5	33	56.7	0.01399	10.1	0.0115	53.3
8:36:00	30.0	36	18	5	31	53.3	0.01399	10.4	0.0082	50.1
9:06:00	60.0	33	18	5	28	48.1	0.01399	10.9	0.0060	45.2
10:06:00	120.0	31	18	5	26	44.7	0.01399	11.2	0.0043	42.0
12:06:00	240.0	29	18	5	24	41.2	0.01399	11.5	0.0031	38.8
16:06:00	480.0									
8:06:00	1440.0	24	18	5	19	32.6	0.01399	12.4	0.0013	30.7

Tested By: Graham Donahue & Dan Absolon
Date: 2/24/2011
Submitted By: Wm D Pace
Date: 2/24/2011

Form #: 0422B Revision Date: 1/17/05

TP-19



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-19 0'-16'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-19 0'-16'	19.00	0.04	0.026	0.007		3.9	22.4	46.5	27.2

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic with fine to coarse sand, trace gravel

Boring No. TP-19
Sample No. Comp
Depth: 0' - 16'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	10.28	2.5	97.5
4M	4.76	5.65	1.4	96.1
10M	2.00	9.60	2.3	93.8
40M	0.42	2.82	4.9	95.1 /* 89.2
100M	0.149	5.68	10.0	85.1 /* 79.8
200M	0.074	3.68	6.5	78.6 /* 73.7
Pan				

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 25.53 gm = 6.2% %

Material passing No. 10 mesh: weight = 386.33 gm = 93.8% %

Weight of Total Sample = 411.86 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 2/24/2011

Submitted By: [signature] **Date:** 2/24/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility

C.E.C Job #: GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-19
Sample No: Comp
Depth: 0' - 16'
Date Received: 2/24/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:18:00

% of Original Sample Used
For Hydrometer Analysis: 93.8 %
Weight of Sample Dispersed: 56.98 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:18:30	0.5	46	18	5	41	72.0	0.01399	8.8	0.0587	67.5
8:19:00	1.0	43	18	5	38	66.7	0.01399	9.2	0.0424	62.6
8:20:00	2.0	38	18	5	33	57.9	0.01399	10.1	0.0314	54.3
8:23:00	5.0	32	18	5	27	47.4	0.01399	11.1	0.0208	44.4
8:33:00	15.0	28	18	5	23	40.4	0.01399	11.7	0.0124	37.9
8:48:00	30.0	25	18	5	20	35.1	0.01399	12.2	0.0089	32.9
9:18:00	60.0	23	18	5	18	31.6	0.01399	12.5	0.0064	29.6
10:18:00	120.0	21	18	5	16	28.1	0.01399	12.9	0.0046	26.3
12:18:00	240.0	19	18	5	14	24.6	0.01399	13.2	0.0033	23.0
16:18:00	480.0									
8:18:00	1440.0	16	18	5	11	19.3	0.01399	13.7	0.0014	18.1

Tested By: Graham Donahue & Dan Absolon

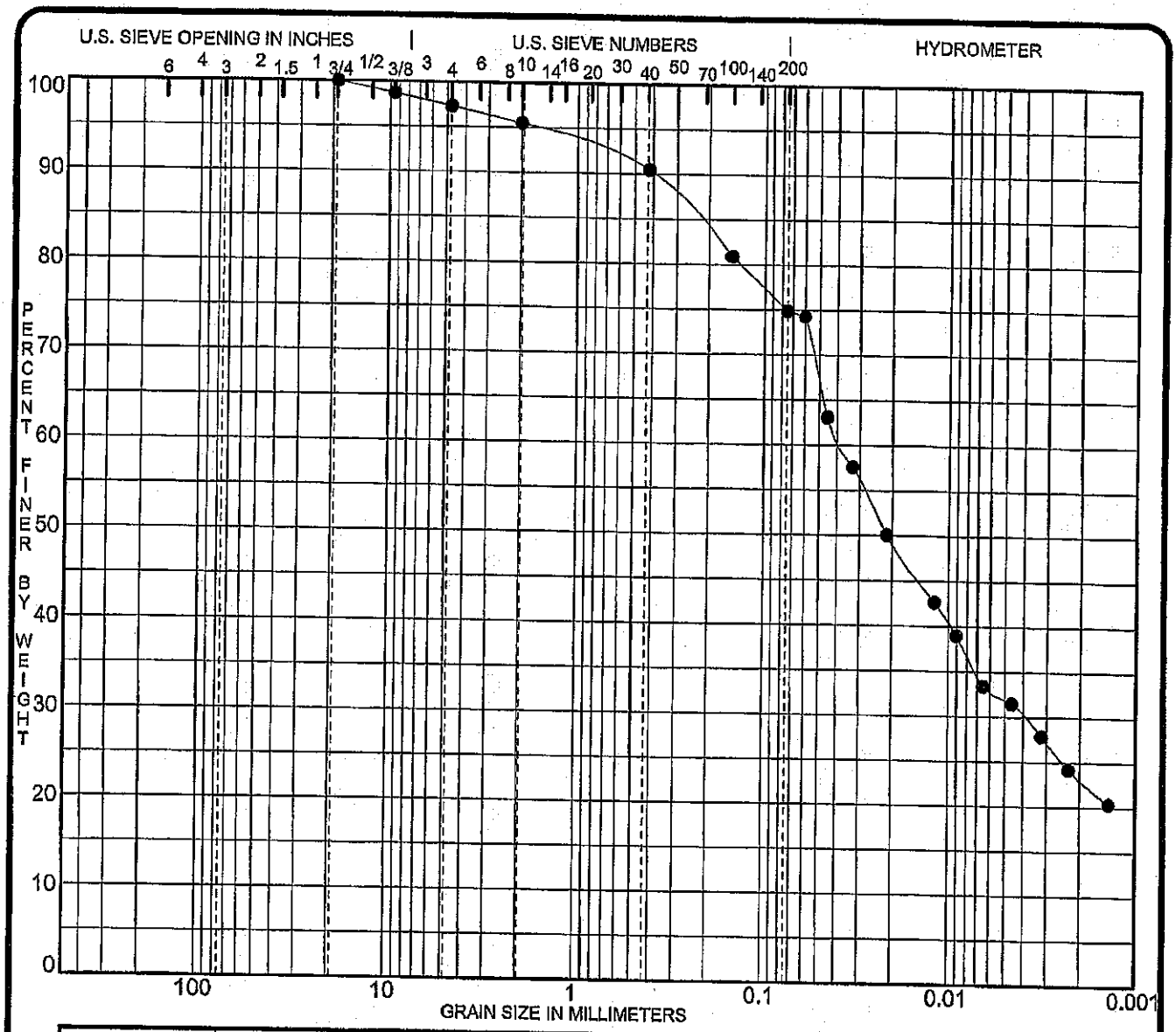
Date: 2/24/2011

Submitted By: Wm D Rud

Date: 2/24/2011

Form #: 0422B Revision Date: 1/17/05

TP-20



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-20 0'-16'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-20 0'-16'	19.00	0.04	0.021	0.004		2.7	22.4	42.9	32.0

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel **Boring No.** TP-20

Sample No. Comp

Remarks: **Depth:** 0 ' - 16 '

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	5.56	1.3	98.7
	4M	4.76	5.86	1.4	97.3
	10M	2.00	7.80	1.8	95.5
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.66	5.2	94.8 /* 90.5
	100M	0.149	5.22	10.1	84.7 /* 80.9
	200M	0.074	3.26	6.3	78.4 /* 74.9
	Pan				

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 19.22 gm = 4.5% %

Material passing No. 10 mesh: weight = 405.4 gm = 95.5% %

Weight of Total Sample = 424.62 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 3/1/2011

Submitted By: Wm D Ree **Date:** 3/1/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-20
Sample No: Comp
Depth: 0' - 16'
Date Received: 2/18/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:12:00

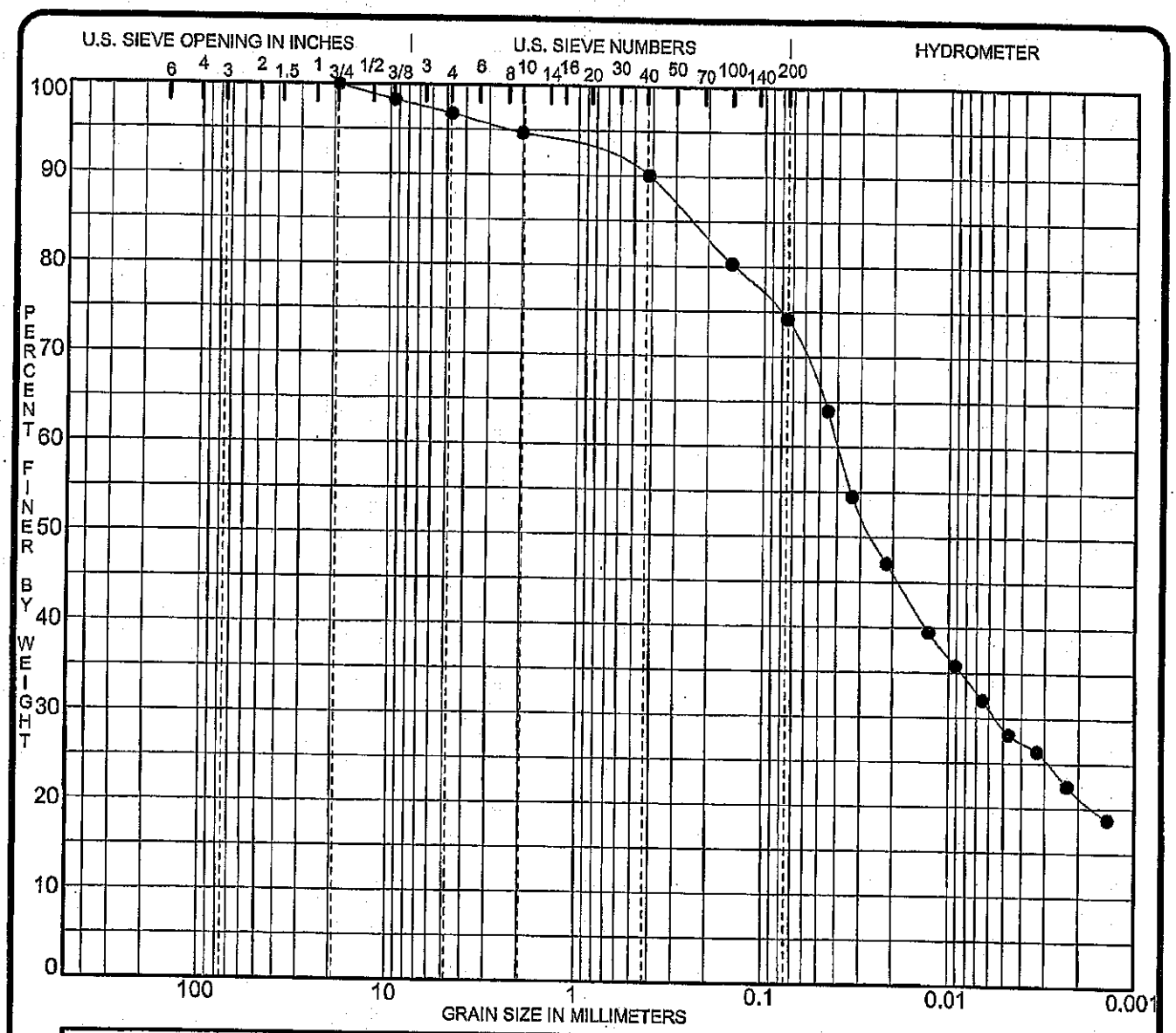
% of Original Sample Used For Hydrometer Analysis: 95.5 %
Weight of Sample Dispersed: 51.44 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:12:30	0.5	45	16	5	40	77.8	0.01435	8.9	0.0605	74.3
9:13:00	1.0	39	16	5	34	66.1	0.01435	9.9	0.0452	63.1
9:14:00	2.0	36	16	5	31	60.3	0.01435	10.4	0.0327	57.6
9:17:00	5.0	32	16	5	27	52.5	0.01435	11.1	0.0214	50.1
9:29:00	17.0	28	16	5	23	44.7	0.01435	11.7	0.0119	42.7
9:42:00	30.0	26	16	5	21	40.8	0.01435	12.0	0.0091	39.0
10:12:00	60.0	23	16.5	5	18	35.0	0.01426	12.5	0.0065	33.4
11:12:00	120.0	22	17	5	17	33.0	0.01417	12.7	0.0046	31.6
13:14:00	242.0	20	18	5	15	29.2	0.01399	13.0	0.0032	27.8
17:12:00	480.0	18	18.5	5	13	25.3	0.0139	13.3	0.0023	24.1
9:12:00	1440.0	16	18.5	5	11	21.4	0.0139	13.7	0.0014	20.4

Tested By: Graham Donahue & Dan Absolon
Date: 3/1/2011
Submitted By: Wm D Kee
Date: 3/1/2011

Form #: 0422B Revision Date: 1/17/05

TP-21



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-21 0'-21'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-21 0'-21'	19.00	0.04	0.026	0.005		3.2	22.6	45.3	28.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. TP-21

Sample No. Comp

Depth: 0' - 21'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	7.37	1.7	98.3
4M	4.76	6.82	1.5	96.8
10M	2.00	9.38	2.1	94.7
40M	0.42	2.46	4.9	95.1 /* 90.1
100M	0.149	5.17	10.3	84.8 /* 80.3
200M	0.074	3.24	6.4	78.4 /* 74.2
Pan				

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 23.57 gm = 5.3% %

Material passing No. 10 mesh: weight = 419.92 gm = 94.7% %

Weight of Total Sample = 443.49 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 3/1/2011

Submitted By: Wm D Ries **Date:** 3/1/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-21
Sample No: Comp
Depth: 0' - 21'
Date Received: 2/18/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:01:00

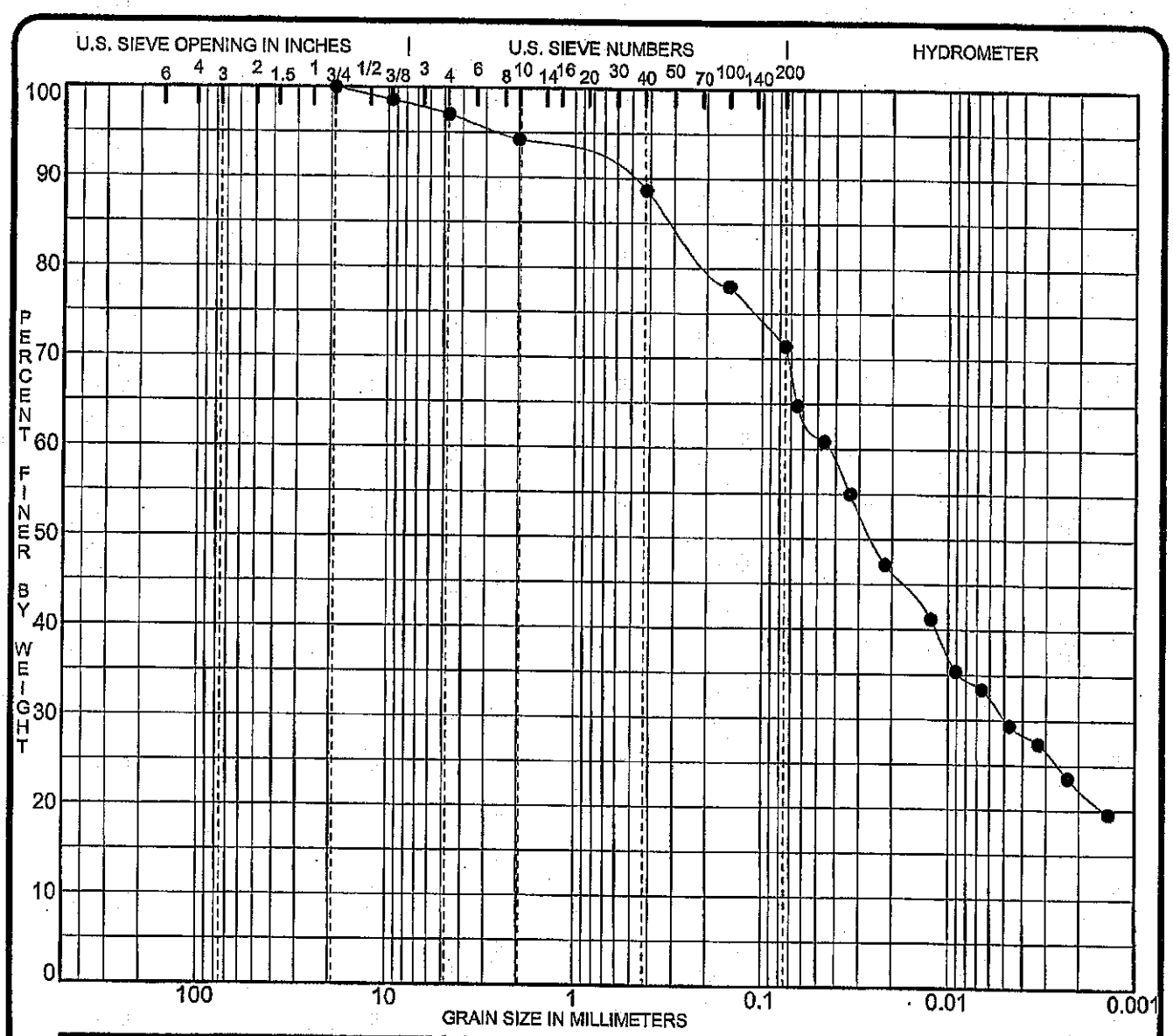
% of Original Sample Used
For Hydrometer Analysis: 94.7 %
Weight of Sample Dispersed: 50.32 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:01:30	0.5	45	16	5	40	79.5	0.01435	8.9	0.0605	75.3
9:02:00	1.0	39	16	5	34	67.6	0.01435	9.9	0.0452	64.0
9:03:00	2.0	34	16	5	29	57.6	0.01435	10.7	0.0332	54.6
9:06:00	5.0	30	16	5	25	49.7	0.01435	11.4	0.0217	47.0
9:16:00	15.0	26	16	5	21	41.7	0.01435	12.0	0.0128	39.5
9:31:00	30.0	24	16	5	19	37.8	0.01435	12.4	0.0092	35.8
10:03:00	62.0	22	16.5	5	17	33.8	0.01426	12.7	0.0065	32.0
11:01:00	120.0	20	17	5	15	29.8	0.01417	13.0	0.0047	28.2
13:01:00	240.0	19	18	5	14	27.8	0.01399	13.2	0.0033	26.3
17:05:00	484.0	17	18.5	5	12	23.8	0.0139	13.5	0.0023	22.6
9:01:00	1440.0	15	17.5	5	10	19.9	0.01408	13.8	0.0014	18.8

Tested By: Dan Absolon
Date: 3/1/2011
Submitted By: Wm D Rice
Date: 3/1/2011

Form #: 0422B Revision Date: 1/17/05

TP-22



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-22 4'-15'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-22 4'-15'	19.00	0.04	0.025	0.005		3.0	25.6	41.3	30.1

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. TP-22

Sample No. Comp

Depth: 4' - 15'

Remarks:

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	5.69	1.4	98.6
4M	4.76	6.20	1.6	97.0
10M	2.00	10.64	2.7	94.3
40M	0.42	2.82	5.9	94.1 /* 88.7
100M	0.149	5.48	11.4	82.7 /* 78.0
200M	0.074	3.34	7.0	75.7 /* 71.4
Pan				

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 22.53 gm = 5.7% %

Material passing No. 10 mesh: weight = 370.79 gm = 94.3% %

Weight of Total Sample = 393.32 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 3/1/2011

Submitted By: Wm D Rice **Date:** 3/1/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

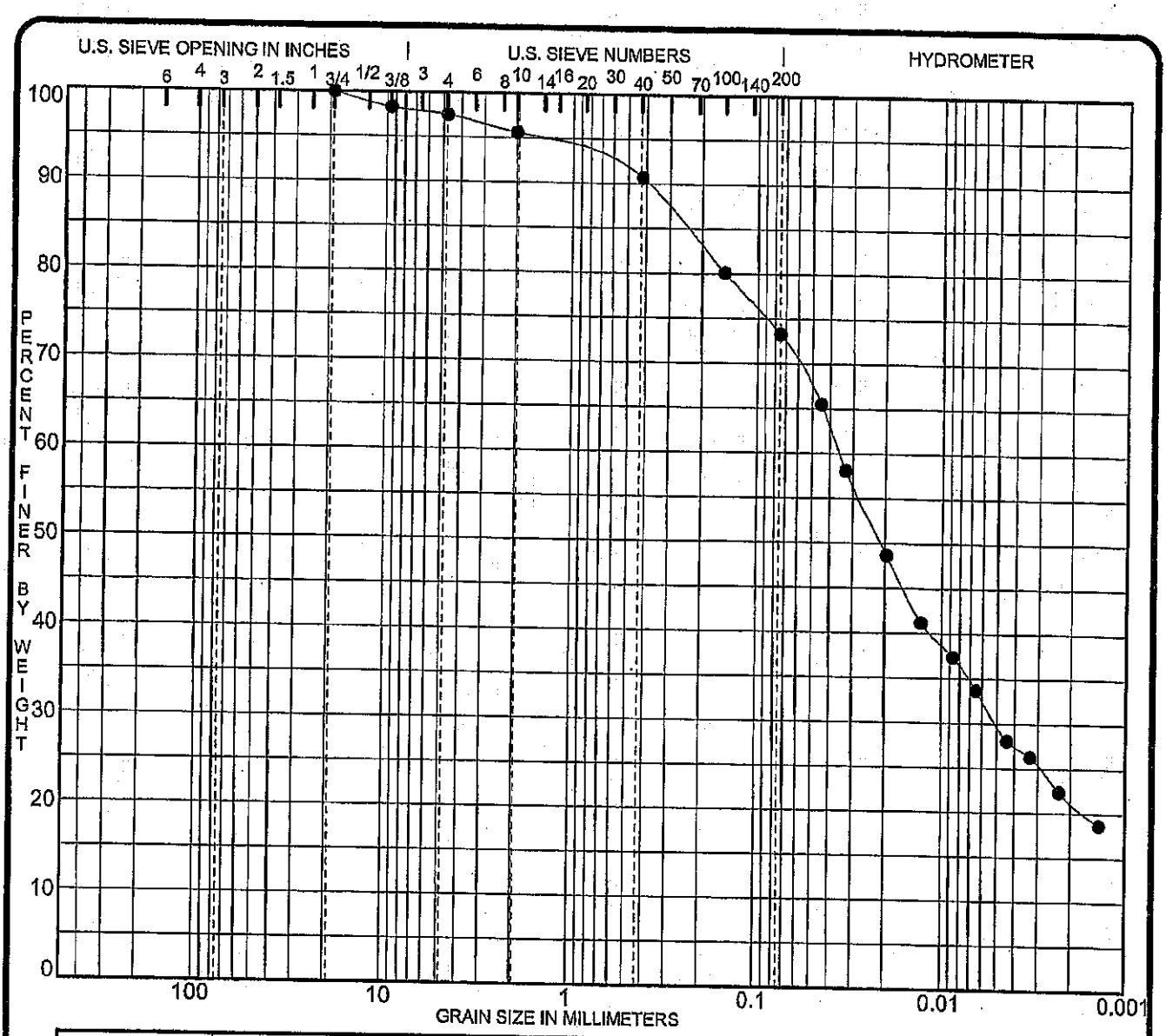
Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Remarks:
Boring No: TP-22
Sample No: Comp
Depth: 4' -15'
Date Received: 2/18/2011
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:04:00
% of Original Sample Used For Hydrometer Analysis: 94.3 %
Weight of Sample Dispersed: 48.04 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:04:30	0.5	38	16	5	33	68.7	0.01435	10.1	0.0645	64.8
9:05:00	1.0	36	16	5	31	64.5	0.01435	10.4	0.0463	60.9
9:06:00	2.0	33	16	5	28	58.3	0.01435	10.9	0.0335	55.0
9:09:00	5.0	29	16	5	24	50.0	0.01435	11.5	0.0218	47.1
9:20:00	16.0	26	16	5	21	43.7	0.01435	12.0	0.0124	41.2
9:35:00	31.0	23	16	5	18	37.5	0.01435	12.5	0.0091	35.3
10:04:00	60.0	22	16	5	17	35.4	0.01435	12.7	0.0066	33.4
11:04:00	120.0	20	16	5	15	31.2	0.01435	13.0	0.0047	29.4
13:04:00	240.0	19	16	5	14	29.1	0.01435	13.2	0.0034	27.5
17:04:00	480.0	17	16	5	12	25.0	0.01435	13.5	0.0024	23.6
9:04:00	1440.0	15	16	5	10	20.8	0.01435	13.8	0.0014	19.6

Tested By: Graham Donahue
Date: 3/1/2011
Submitted By: Wm D Rice
Date: 3/1/2011

Form #: 0422B Revision Date: 1/17/05

TP-23



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-23 2'-15'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-23 2'-15'	19.00	0.04	0.021	0.005		2.5	24.2	43.4	29.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. TP-23
Sample No. Comp
Depth: 2' - 15'

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	7.23	1.7	98.3
4M	4.76	3.44	0.8	97.5
10M	2.00	8.15	1.9	95.6
40M	0.42	2.53	5.0	95.0 /* 90.7
100M	0.149	5.67	11.1	83.9 /* 80.1
200M	0.074	3.64	7.1	76.8 /* 73.3
Pan				

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 18.82 gm = 4.5% %

Material passing No. 10 mesh: weight = 403.84 gm = 95.5% %

Weight of Total Sample = 422.66 gm

Tested By: Graham Donahue & Dan Absplon **Date:** 3/1/2011

Submitted By: [illegible] **Date:** 3/1/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility

C.E.C Job #: GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-23
Sample No: Comp
Depth: 2' - 15'
Date Received: 2/18/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:22:00

% of Original Sample Used
For Hydrometer Analysis: 95.5 %
Weight of Sample Dispersed: 51.00 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:22:30	0.5	45	16	5	40	78.4	0.01435	8.9	0.0605	74.9
9:23:00	1.0	40	16	5	35	68.6	0.01435	9.7	0.0447	65.5
9:24:00	2.0	36	16	5	31	60.8	0.01435	10.4	0.0327	58.0
9:28:00	6.0	31	16	5	26	51.0	0.01435	11.2	0.0196	48.7
9:37:00	15.0	27	16	5	22	43.1	0.01435	11.9	0.0128	41.2
9:55:00	33.0	25	16	5	20	39.2	0.01435	12.2	0.0087	37.5
10:22:00	60.0	23	16	5	18	35.3	0.01435	12.5	0.0065	33.7
11:35:00	133.0	20	16	5	15	29.4	0.01435	13.0	0.0044	28.1
13:22:00	240.0	19	16	5	14	27.5	0.01435	13.2	0.0033	26.2
17:25:00	483.0	17	16	5	12	23.5	0.01435	13.5	0.0023	22.5
9:22:00	1440.0	15	16	5	10	19.6	0.01435	13.8	0.0014	18.7

Tested By: Graham Donahue & Dan Absolon

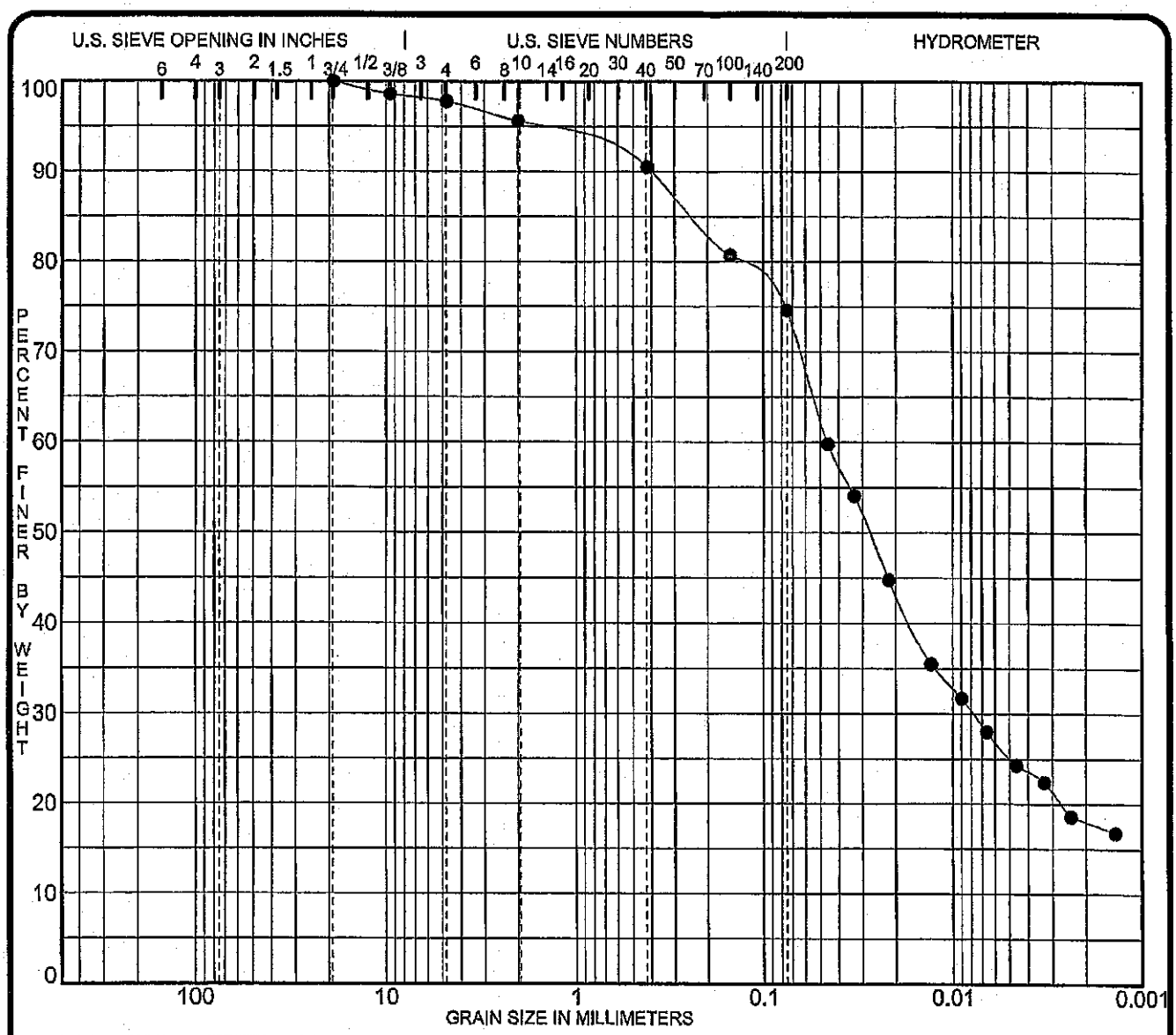
Date: 3/1/2011

Submitted By: [signature]

Date: 3/1/2011

Form #: 0422B Revision Date: 1/17/05

TP-24



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-24 2'-16'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-24 2'-16'	19.00	0.05	0.028	0.008		2.2	23.2	49.4	25.2

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. TP-24
Sample No. Comp
Depth: 2'-16'

Remarks:

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	6.10	1.4	98.6
	4M	4.76	3.48	0.8	97.8
	10M	2.00	9.44	2.2	95.6
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.73	5.3	94.7 /* 90.5
	100M	0.149	5.26	10.3	84.4 /* 80.7
	200M	0.074	3.30	6.4	78.0 /* 74.6
	Pan				

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 19.02 gm = 4.4% %

Material passing No. 10 mesh: weight = 417.49 gm = 95.6% %

Weight of Total Sample = 436.51 gm

Tested By: Graham Donahu & Dan Absolon **Date:** 3/1/2011

Submitted By: [signature] **Date:** 3/1/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility C.E.C Job #: GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-24
Sample No: Comp
Depth: 2' - 16'
Date Received: 2/18/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:31:00

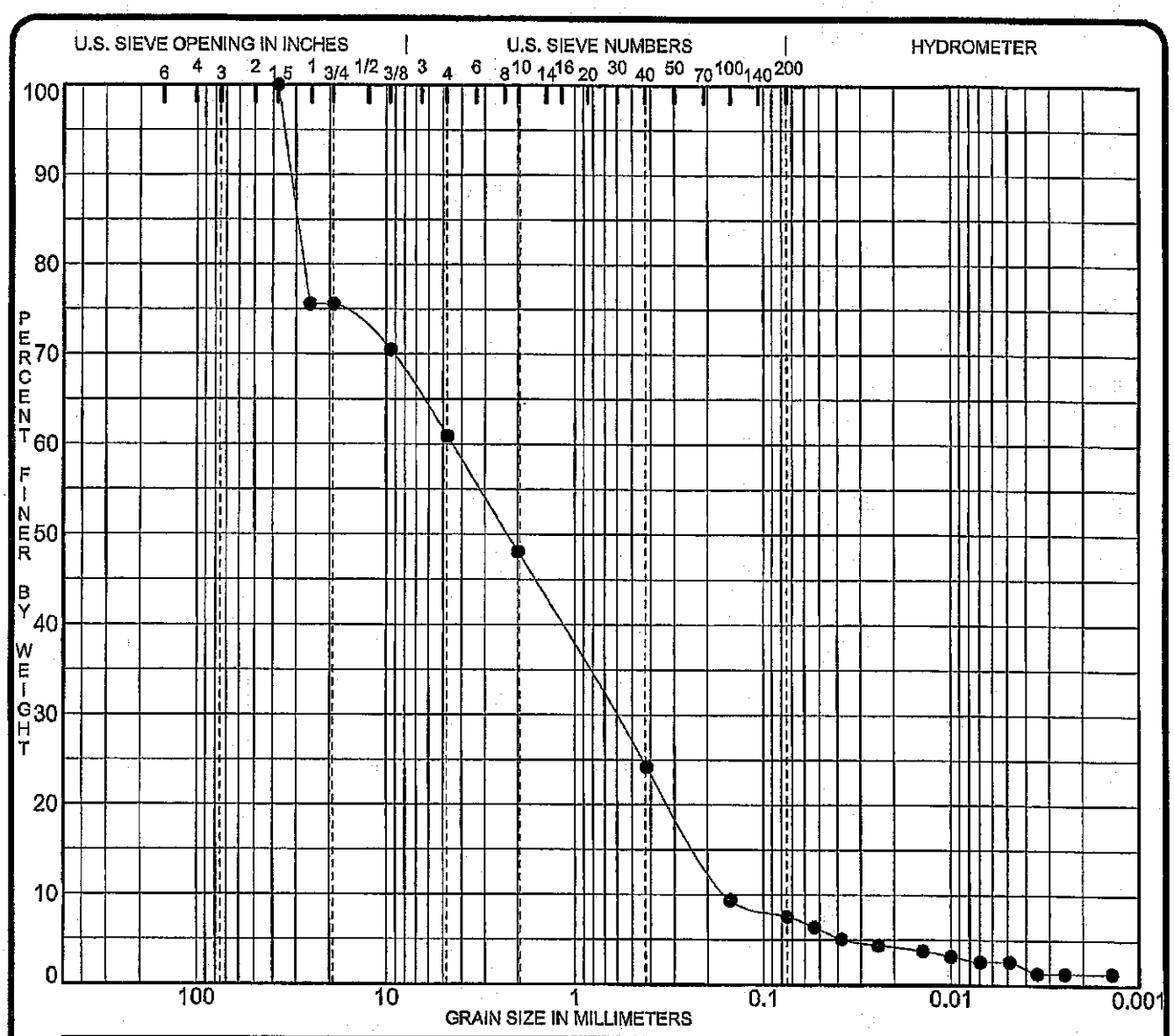
% of Original Sample Used For Hydrometer Analysis: 95.6 %
Weight of Sample Dispersed: 51.22 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:31:30	0.5	45	16	5	40	78.1	0.01435	8.9	0.0605	74.7
9:32:00	1.0	37	16	5	32	62.5	0.01435	10.2	0.0458	59.7
9:33:00	2.0	34	16	5	29	56.6	0.01435	10.7	0.0332	54.1
9:36:00	5.0	29	16	5	24	46.9	0.01435	11.5	0.0218	44.8
9:46:00	15.0	24	16	5	19	37.1	0.01435	12.4	0.0130	35.5
10:03:00	32.0	22	16	5	17	33.2	0.01435	12.7	0.0090	31.7
10:31:00	60.0	20	16	5	15	29.3	0.01435	13.0	0.0066	28.0
11:34:00	123.0	18	16	5	13	25.4	0.01435	13.3	0.0046	24.3
13:31:00	240.0	17	16	5	12	23.4	0.01435	13.5	0.0033	22.4
17:26:00	475.0	15	16	5	10	19.5	0.01435	13.8	0.0024	18.7
9:31:00	1440.0	14	16	5	9	17.6	0.01435	14.0	0.0014	16.8

Tested By: Graham Donahue & Dan Absolon Date: 3/1/2011

Submitted By: Date: 3/1/2011

TP-26



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● TP-26 2'-3'	(SP-SM) SAND, brown, fine to coarse, with fine to coarse gravel, some silt, non-plastic					0.54	28.6

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● TP-26 2'-3'	37.50	4.47	2.274	0.613	0.1564	39.1	53.3	5.0	2.6

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/4/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (SP-SM) Sand, brown, fine to coarse, with gravel, some silt, nonplastic **Boring No.** TP-26

Sample No. A

Remarks: **Depth:** 2' - 3'

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5	0	0	100.0
	1	25.4	80.18	24.4	75.6
	3/4	19.1	0.00	0.0	75.6
	3/8	9.5	16.62	5.1	70.5
	4M	4.76	31.40	9.6	60.9
	10M	2.00	42.08	12.8	48.1
MECHANICAL ANALYSIS	40M	0.42	37.77	49.8	50.2 /* 24.2
PORTION OF HYDROMETER ANALYSIS	100M	0.149	23.39	30.8	19.4 /* 9.4
	200M	0.074	2.79	3.7	15.7 /* 7.6
	Pan				

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 170.28 gm = 51.8% %

Material passing No. 10 mesh: weight = 158.48 gm = 48.2% %

Weight of Total Sample = 328.76 gm

Tested By: Graham Donahue & Dan Absolon **Date:** 3/1/2011

Submitted By: [illegible] **Date:** 3/1/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Remarks:

Boring No: TP-26
Sample No: A
Depth: 2' - 3'
Date Received: 2/18/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:40:00

% of Original Sample Used For Hydrometer Analysis: 48.2 %
Weight of Sample Dispersed: 75.82 g.

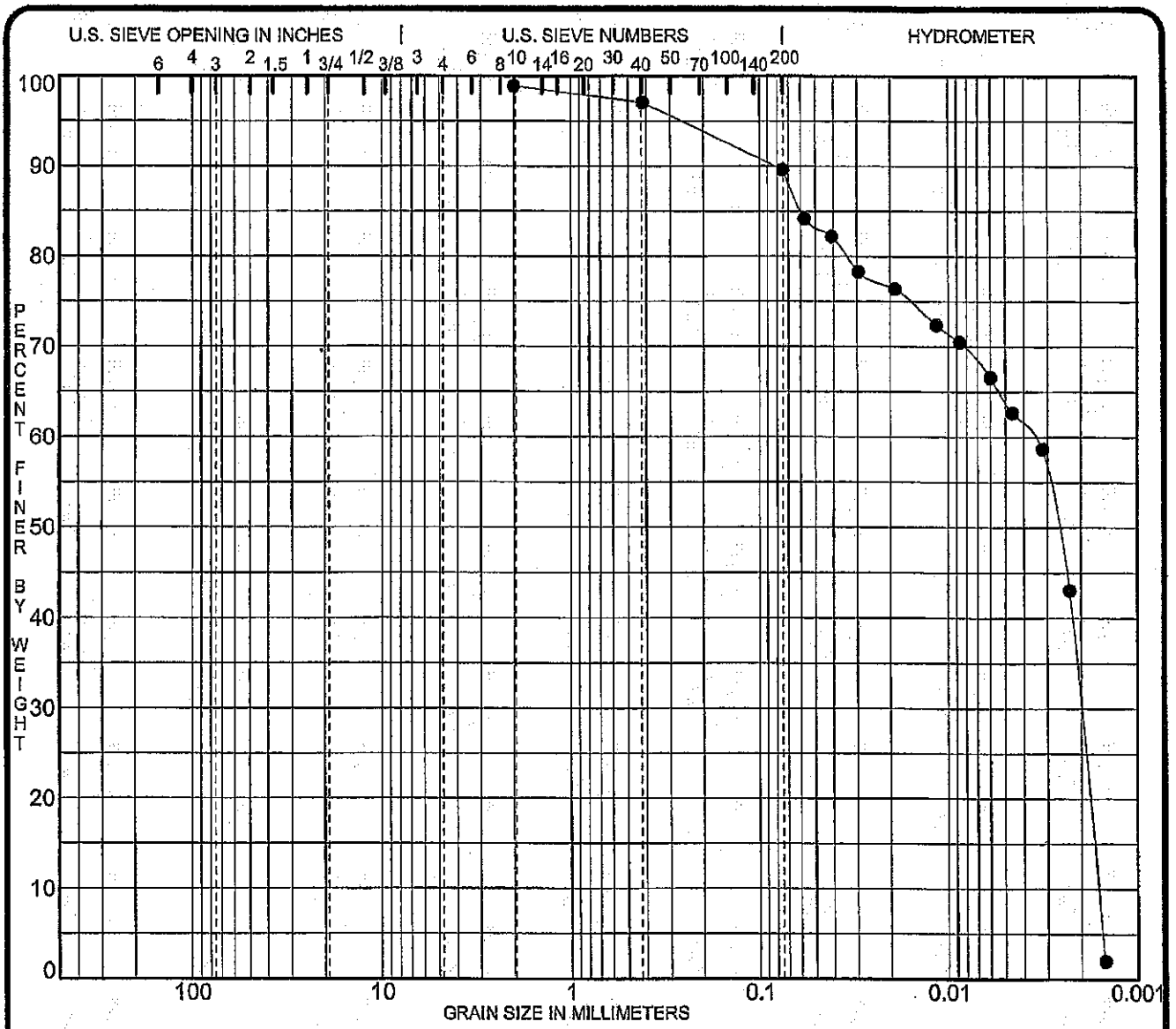
Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:40:30	0.5	20	16	5	15	19.8	0.01435	13.0	0.0732	9.5
9:41:00	1.0	15	16	5	10	13.2	0.01435	13.8	0.0533	6.4
9:42:00	2.0	13	16	5	8	10.6	0.01435	14.2	0.0382	5.1
9:45:00	5.0	12	16	5	7	9.2	0.01435	14.3	0.0243	4.4
9:55:00	15.0	11	16	5	6	7.9	0.01435	14.7	0.0142	3.8
10:10:00	30.0	10	16.5	5	5	6.6	0.01426	14.7	0.0100	3.2
10:42:00	62.0	9	16.5	5	4	5.3	0.01426	14.8	0.0070	2.6
11:40:00	120.0	9	17.5	5	4	5.3	0.01408	14.8	0.0049	2.6
13:45:00	245.0	7	18	2	5	2.6	0.01399	15.2	0.0035	1.3
17:27:00	467.0	7	18.5	5	2	2.6	0.0139	15.2	0.0025	1.3
9:40:00	1440.0	7	18.5	5	2	2.6	0.0139	15.2	0.0014	1.3

Tested By: Dan Absolon
Date: 3/1/2011

Submitted By: [signature]
Date: 3/1/2011

Form #: 0422B Revision Date: 1/17/05

BH-1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-1 20.3'-21.8'	(CH) FAT CLAY, red-brown, some fine to coarse sand, trace fine gravel, highly plastic					0.69	2.2

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-1 20.3'-21.8'	2.00	0.00	0.003	0.002	0.0016	0.0	9.3	25.7	63.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/1/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CH) FAT CLAY, red-brown, some fine to** **Boring No.** BH-01

Shape: - **Hardness:** - **Sample No.** 6 / 6A

Remarks: ** coarse sand, trace fine gravel, highly plastic **Depth:** 20.3 -21.8

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	0.00	0.0	100.0
4M	4.76	1.56	0.6	99.4
10M	2.00	1.26	0.5	98.9
40M	0.42	0.90	1.8	98.2 /* 97.1
100M	0.149	2.07	4.1	94.1 /* 93.1
200M	0.074	1.75	3.5	90.6 /* 89.6
Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 2.82 gm = 1.1% %

Material passing No. 10 mesh: weight = 258.89 gm = 98.9% %

Weight of Total Sample = 261.71 gm

Tested By: Graham Donahue **Date:** 2/15/2011

Submitted By: [signature] **Date:** 2/15/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH-01
Sample No: 6/6A
Depth: 20.3-21.8
Date Received: 2/4/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:52:00

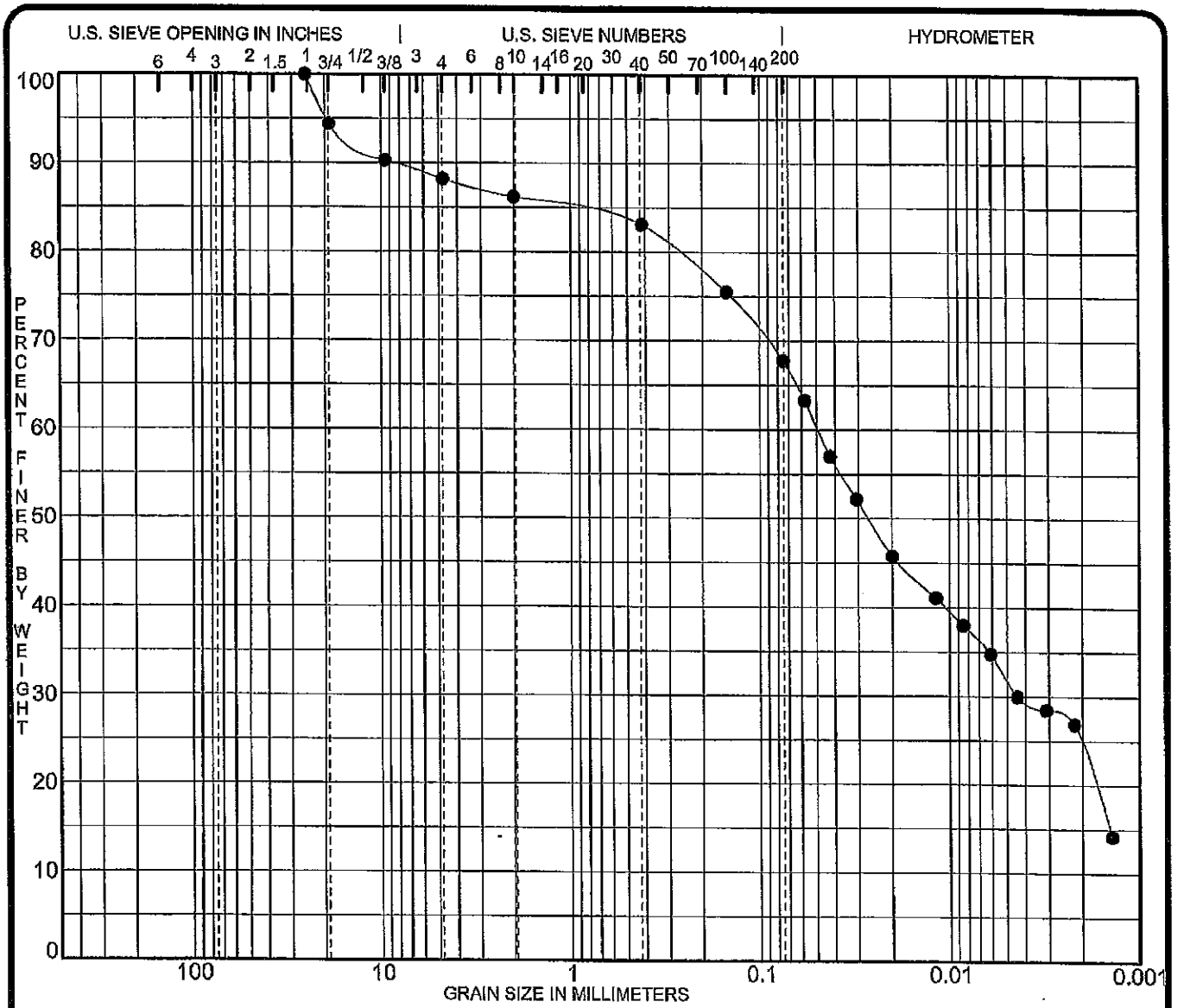
% of Original Sample Used For Hydrometer Analysis: 98.9 %
Weight of Sample Dispersed: 50.51 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:52:30	0.5	48	18	5	43	85.1	0.01399	8.4	0.0573	84.2
9:53:00	1.0	47	18	5	42	83.2	0.01399	8.6	0.0410	82.2
9:54:00	2.0	45	18	5	40	79.2	0.01399	8.9	0.0295	78.3
9:57:00	5.0	44	18	5	39	77.2	0.01399	9.1	0.0189	76.4
10:06:00	14	42	18	5	37	73.3	0.01399	9.4	0.0115	72.4
10:17:00	25	41	18	5	36	71.3	0.01399	9.6	0.0087	70.5
10:46:00	54	39	18	5	34	67.3	0.01399	9.9	0.0060	66.6
11:26:00	94	37	18	5	32	63.4	0.01399	10.2	0.0046	62.7
13:15:00	203	35	18	5	30	59.4	0.01399	10.6	0.0032	58.7
17:27:00	455	27	18	5	22	43.6	0.01399	11.9	0.0023	43.1
8:56:00	1386	6	18	5	1	2.0	0.01399	15.3	0.0015	2.0

Tested By: Bill Rice
Date: 2/10/2011
Submitted By: Wm D Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

BH-2



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-2	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand,						
25.2'-27.2'	some fine to coarse gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-2	25.40	0.05	0.026	0.004		11.8	20.4	35.9	31.9
25.2'-27.2'									

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/12/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, some fine to coarse gravel

Boring No. BH-02

Sample No. 7

Depth: 25.2 - 27.2

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4	0.00	0.0	100.00
3/4	19.1	19.21	5.6	94.4
3/8	9.5	14.01	4.1	90.3
4M	4.76	7.15	2.1	88.2
10M	2.00	6.81	2.0	86.2
40M	0.42	2.04	3.7	96.3 /* 83.1
100M	0.149	4.81	8.8	87.5 /* 75.5
200M	0.074	4.86	8.9	78.6 /* 67.8
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 47.18 gm = 13.7% %

Material passing No. 10 mesh: weight = 297.06 gm = 86.3% %

Weight of Total Sample = 344.24 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/11/2011

Submitted By: [signature] **Date:** 4-11-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH - 02
Sample No: 7
Depth: 25.2 - 27.2
Date Received: 3/31/2011

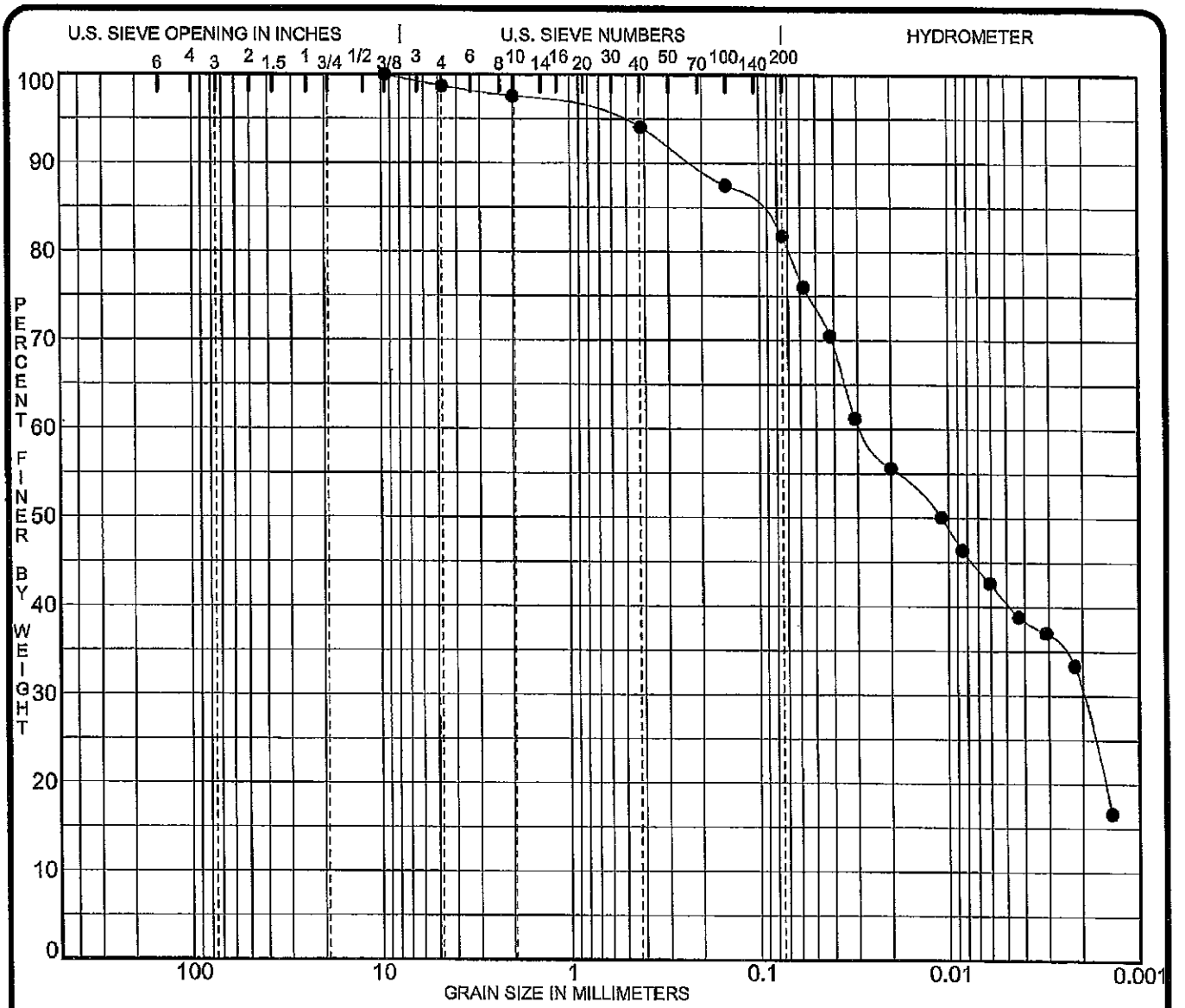
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:49:00

% of Original Sample Used For Hydrometer Analysis: 86.3 %
Weight of Sample Dispersed: 54.57 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:49:30	0.5	45	20	5	40	73.3	0.01365	8.9	0.0576	63.3
8:50:00	1.0	41	20	5	36	66.0	0.01365	9.6	0.0423	56.9
8:51:00	2.0	38	20	5	33	60.5	0.01365	10.1	0.0307	52.2
8:54:00	5.0	34	20	5	29	53.1	0.01365	10.7	0.0200	45.9
9:04:00	15.0	31	20	5	26	47.6	0.01365	11.2	0.0118	41.1
9:19:00	30.0	29	20	5	24	44.0	0.01365	11.5	0.0085	38.0
9:49:00	60.0	27	20	5	22	40.3	0.01365	11.9	0.0061	34.8
10:49:00	120.0	24	20	5	19	34.8	0.01365	12.4	0.0044	30.0
12:49:00	240.0	23	20	5	18	33.0	0.01365	12.5	0.0031	28.5
16:49:00	480.0	22	20	5	17	31.2	0.01365	12.7	0.0022	26.9
8:43:00	1434.0	14	17	5	9	16.5	0.01417	14.0	0.0014	14.2

Tested By: G. Donahue
Date: 4/11/2011
Submitted By:
Date:

BH-4



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-4 9.5	(CL) CLAY, red-brown, highly plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-4 9.5	9.50	0.03	0.011	0.002		1.3	16.9	41.3	40.5

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WMR 4-7-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) CLAY, red brown, highly plastic, with fine to coarse sand, trace fine gravel **Boring No.** BH-04

Sample No. ST

Remarks: **Depth:** 9.5' - 11.7'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1			
3/8	9.5	0.00	0.0	100.0
4M	4.76	0.77	1.3	98.7
10M	2.00	0.66	1.1	97.6
40M	0.42	1.87	3.6	96.4 /* 94.1
100M	0.149	3.52	6.7	89.7 /* 87.5
200M	0.074	3.11	5.9	83.8 /* 81.8
Pan				

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 1.43 gm = 2.4% %

Material passing No. 10 mesh: weight = 59.16 gm = 97.6% %

Weight of Total Sample = 60.59 gm

Tested By: Dan Absolon **Date:** 3/7/2011

Submitted By: [signature] **Date:** 3/7/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

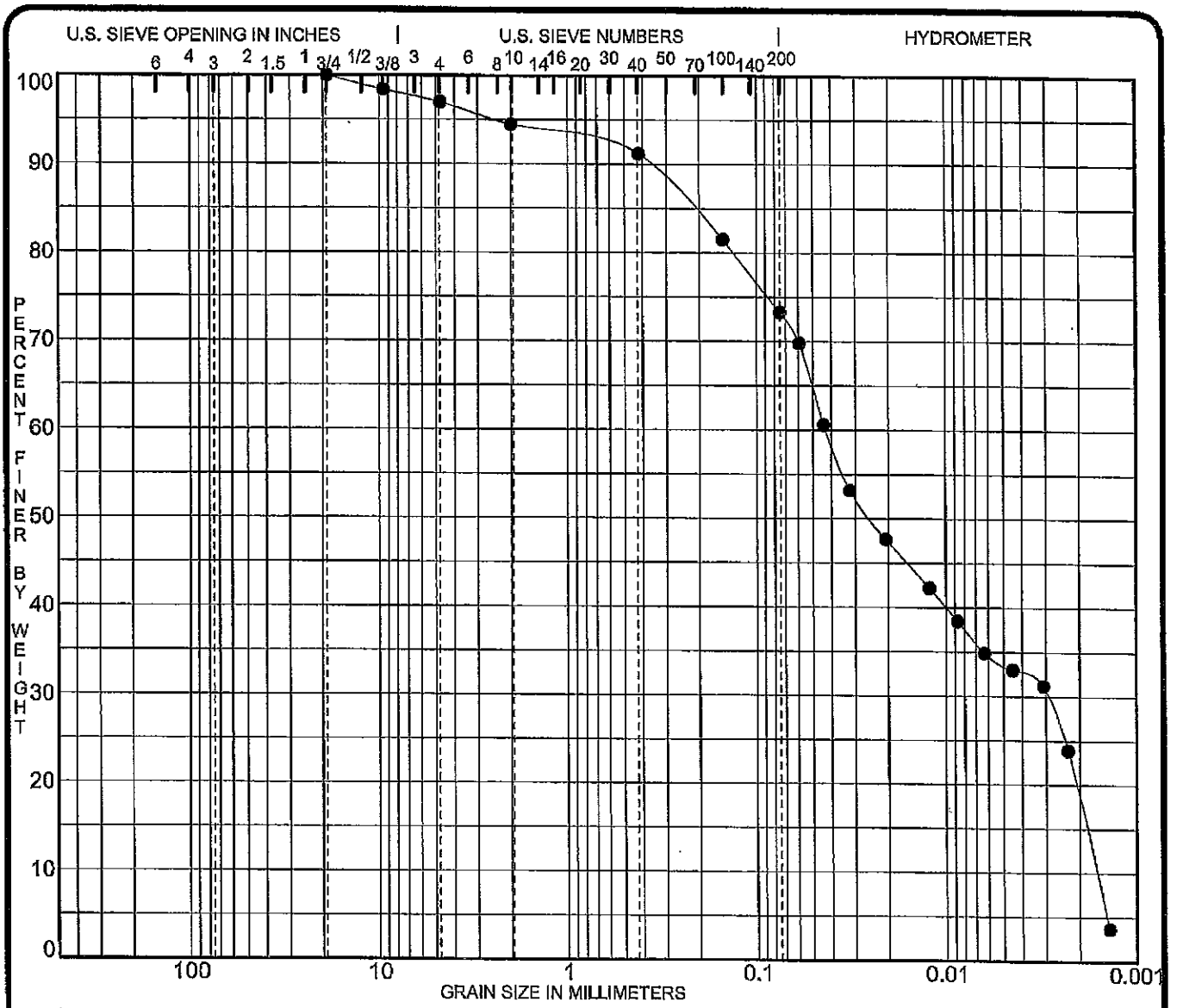
Remarks:
Boring No: BH-04
Sample No: ST
Depth: 9.5' - 11.7'
Date Received: 2/4/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:10:00

% of Original Sample Used For Hydrometer Analysis: 97.6 %
Weight of Sample Dispersed: 52.63 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:10:30	0.5	46	19	5	41	77.9	0.01382	8.8	0.0580	76.0
8:11:00	1.0	43	19	5	38	72.2	0.01382	9.2	0.0419	70.5
8:12:00	2.0	38	19	5	33	62.7	0.01382	10.1	0.0311	61.2
8:15:00	5.0	35	19	5	30	57.0	0.01382	10.6	0.0201	55.6
8:25:00	18.0	32	19	5	27	51.3	0.01382	11.1	0.0109	50.1
8:40:00	30.0	30	19	5	25	47.5	0.01382	11.4	0.0085	46.4
9:10:00	60.0	28	19	5	23	43.7	0.01382	11.7	0.0061	42.7
10:13:00	123.0	26	19	5	21	39.9	0.01382	12.0	0.0043	38.9
12:10:00	240.0	25	20	5	20	38.0	0.01365	12.2	0.0031	37.1
16:13:00	483.0	23	20	5	18	34.2	0.01365	12.5	0.0022	33.4
8:10:00	1440.0	14	19	5	9	17.1	0.01382	14.0	0.0014	16.7

Tested By: Dan Absolon
Date: 3/3/2011
Submitted By:
Date: 3/3/2011



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-04 20.0	(CL) CLAY, red-brown, highly plastic, with fine to coarse sand, trace fine gravel					0.12	26.2

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-04 20.0	19.00	0.04	0.025	0.003	0.0016	3.0	23.7	39.7	33.6

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WDR 4-7-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 ,Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) CLAY red brown, highly plastic, with fine to coarse sand, trace fine gravel

Boring No. BH-04

Sample No. ST

Remarks:

Depth: 20.0' - 22.5'

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	1.52	1.6	98.4
4M	4.76	1.34	1.4	97.0
10M	2.00	2.39	2.5	94.5
40M	0.42	1.79	3.5	96.5 /* 91.2
100M	0.149	5.30	10.3	86.2 /* 81.5
200M	0.074	4.41	8.6	77.6 /* 73.3
Pan				

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 5.25 gm = 5.5% %

Material passing No. 10 mesh: weight = 89.4 gm = 94.5% %

Weight of Total Sample = 94.65 gm

Tested By: Dan Absolon **Date:** 3/7/2011

Submitted By: [signature] **Date:** 3/7/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH-04
Sample No: ST
Depth: 20.0' - 22.5'
Date Received: 2/11/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

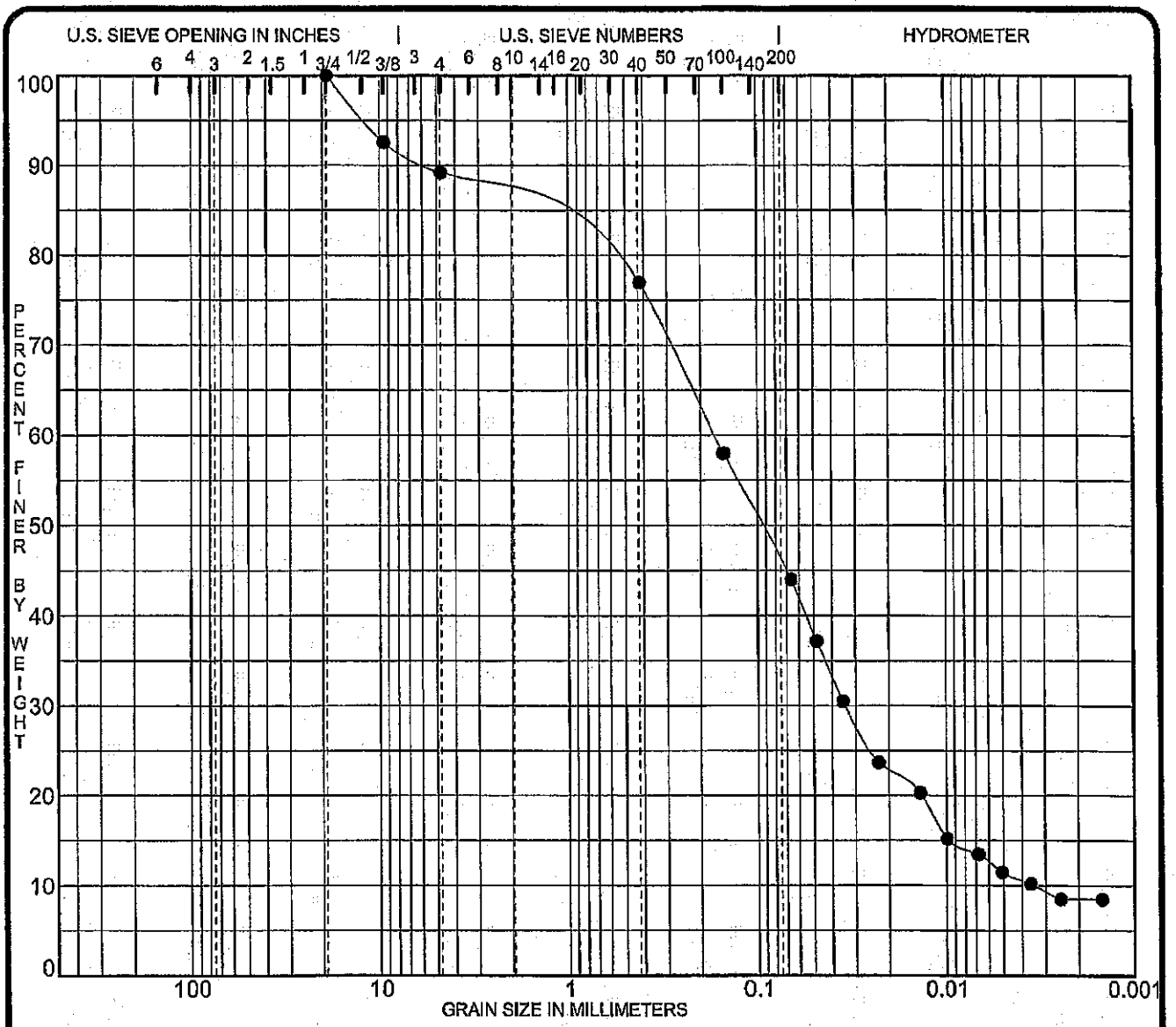
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:01:00

% of Original Sample Used For Hydrometer Analysis: 94.5 %
Weight of Sample Dispersed: 51.48 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:01:30	0.5	43	19	5	38	73.8	0.01382	9.2	0.0593	69.8
8:02:00	1.0	38	19	5	33	64.1	0.01382	10.1	0.0439	60.6
8:03:00	2.0	34	19	5	29	56.3	0.01382	10.7	0.0320	53.2
8:06:00	5.0	31	19	5	26	50.5	0.01382	11.2	0.0207	47.7
8:16:00	15.0	28	19	5	23	44.7	0.01382	11.7	0.0122	42.2
8:31:00	30.0	26	19	5	21	40.8	0.01382	12.0	0.0087	38.5
9:01:00	60.0	24	19	5	19	36.9	0.01382	12.4	0.0063	34.9
10:01:00	120.0	23	19	5	18	35.0	0.01382	12.5	0.0045	33.0
12:01:00	240.0	22	20	5	17	33.0	0.01365	12.7	0.0031	31.2
4:01:00	480.0	18	20	5	13	25.3	0.01365	13.3	0.0023	23.9
8:01:00	1440.0	7	19	5	2	3.9	0.01382	15.2	0.0014	3.7

Tested By: Dan Absolon
Date: 3/3/2011

Submitted By:
Date: 3/3/2011



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-4 25'-26.5'	(SM) SILTY SAND, brown, fine to coarse, some fine gravel, slightly plastic					1.99	48.5

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-4 25'-26.5'	19.00	0.17	0.094	0.034	0.0034	10.8			11.4

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/1/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938
Soil Description: (SM) SILTY SAND, brown, fine to coarse, *** **Boring No.** BH-04
Shape: - **Hardness:** - **Sample No.** 6 / 6A
Remarks: ***some fine gravel, slight plasticity **Depth:** 25 - 26.5

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2	-	-	-
2"	50.8	-	-	-
1 1/2"	37.5	-	-	-
1	25.4	-	-	-
3/4	19.1	0.00	0.0	100.0
3/8	9.5	26.75	7.4	92.6
4M	4.76	12.26	3.4	89.2
10M	2.00	14.97	4.1	85.1
40M	0.42	4.76	9.5	90.5 /* 77.0
100M	0.149	11.25	22.4	68.1 /* 58.0
200M	0.074	6.24	12.4	55.7 /* 47.4
Pan				/*

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:
Material retained on No. 10 mesh: weight = 53.98 gm = 14.9% %
Material passing No. 10 mesh: weight = 308.7 gm = 85.1% %
Weight of Total Sample = 362.64 gm

Tested By: Graham Donahue **Date:** 2/15/2011
Submitted By: [signature] **Date:** 2/15/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH-04
Sample No: 6/6A
Depth: 25-26.5
Date Received: 2/4/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:34:00

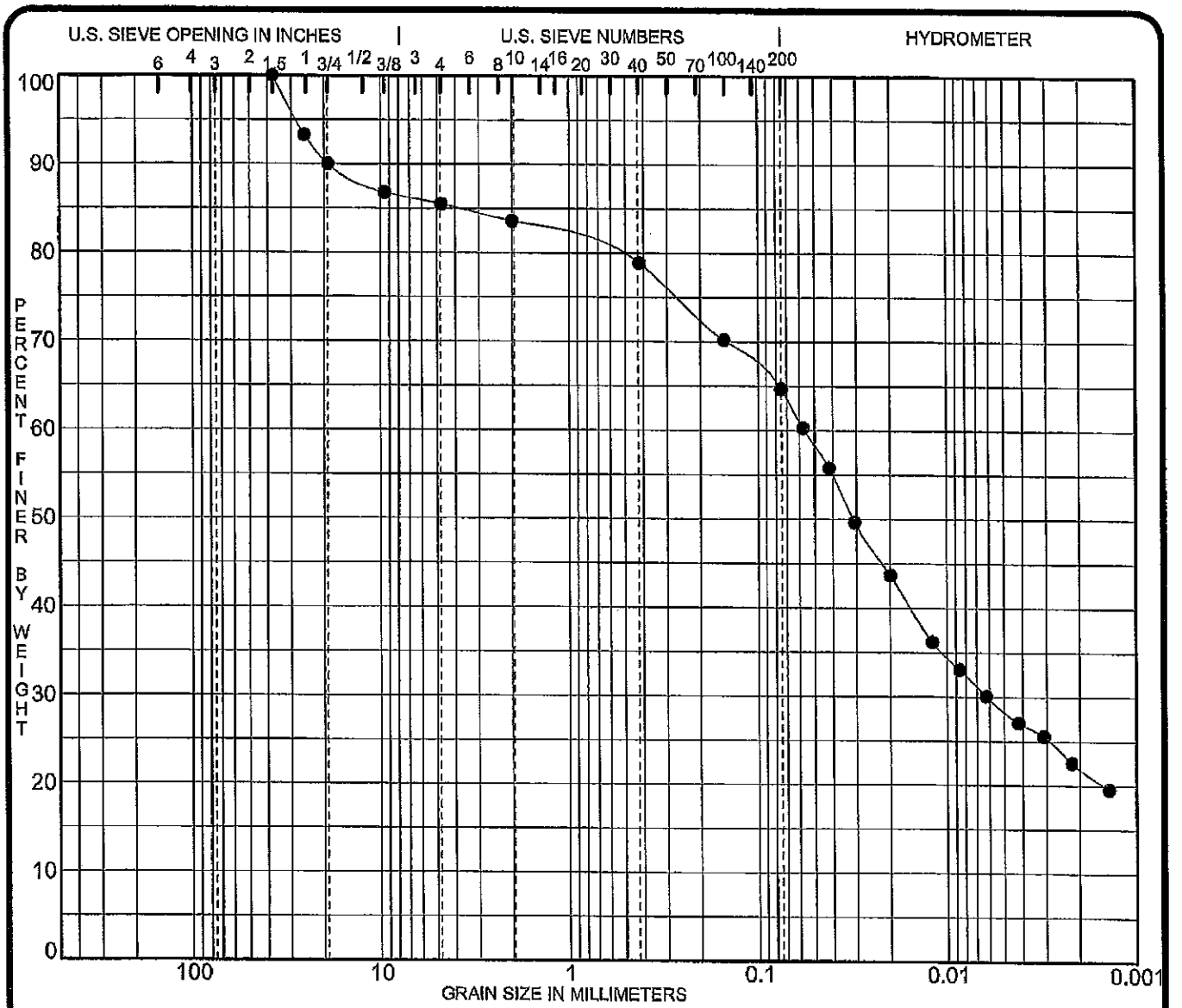
% of Original Sample Used For Hydrometer Analysis: 85.1 %
Weight of Sample Dispersed: 50.3 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:34:30	0.5	31	18	5	26	51.7	0.01399	11.2	0.0662	44.0
9:35:00	1.0	27	18	5	22	43.7	0.01399	11.9	0.0483	37.2
9:36:00	2.0	23	18	5	18	35.8	0.01399	12.5	0.0350	30.5
9:39:00	5.0	19	18	5	14	27.8	0.01399	13.2	0.0227	23.7
9:48:00	14.0	17	18	5	12	23.9	0.01399	13.5	0.0137	20.3
10:02:00	28.0	14	18	5	9	17.9	0.01399	14.0	0.0099	15.2
10:34:00	60.0	13	18	5	8	15.9	0.01399	14.2	0.0068	13.5
11:22:00	108.0	12	18	5	7	13.9	0.01399	14.3	0.0051	11.8
13:34:00	217.0	11	18	5	6	11.9	0.01399	14.7	0.0036	10.2
17:34:00	470.0	10	18	5	5	9.9	0.01399	14.7	0.0025	8.5
8:52:00	1348.0	10	18	5	5	9.9	0.01399	14.7	0.0015	8.5

Tested By: Bill Rice
Date: 2/10/2011
Submitted By: William D Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05

BH-7



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-07 15.0'-17.0'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, with fine to coarse gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-07 15.0'-17.0'	37.50	0.06	0.031	0.006		14.5	20.8	36.3	28.4

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/12/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, with fine to coarse gravel

Boring No. BH - 07

Sample No. 6

Remarks:

Depth: 15.0 - 17.0

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5	0	0	100
	1	25.4	31.42	6.7	93.3
	3/4	19.1	15.56	3.3	90.0
	3/8	9.5	15.28	3.2	86.8
	4M	4.76	6.29	1.3	85.5
	10M	2.00	8.89	1.9	83.6
MECHANICAL ANALYSIS	40M	0.42	3.03	5.5	94.5 /* 78.9
PORTION OF HYDROMETER	100M	0.149	5.77	10.4	84.1 /* 70.2
ANALYSIS	200M	0.074	3.65	6.6	77.5 /* 64.7
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 77.44 gm = 16.5% %

Material passing No. 10 mesh: weight = 393.31 gm = 83.5% %

Weight of Total Sample = 470.75 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/11/2011

Submitted By: Wm D Rice **Date:** 4-11-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH - 07
Sample No: 6
Depth: 15 - 17
Date Received: 3/31/2011

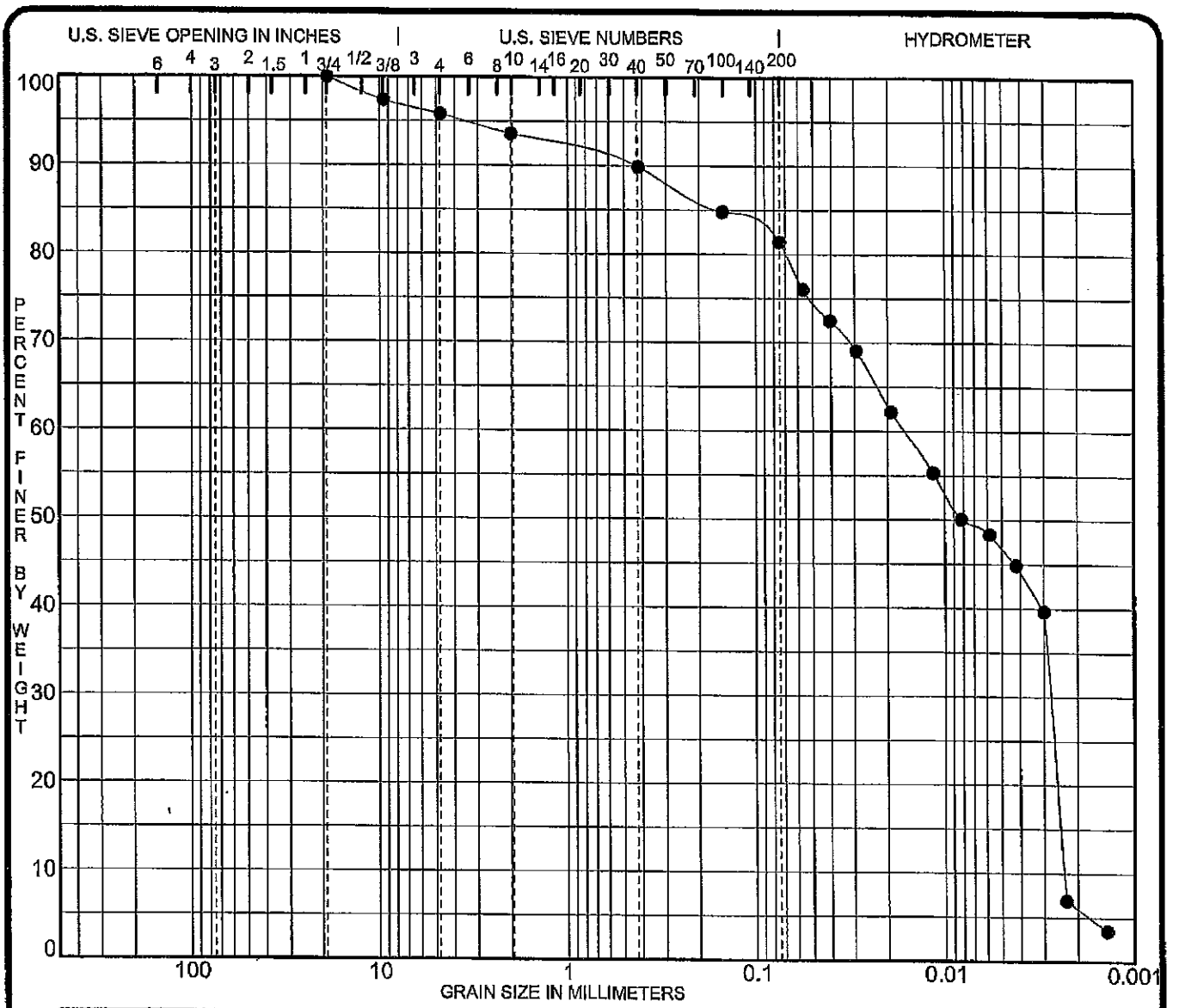
Dispersing Agent Used: 4% Sodium Hexametaphosphate

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:39:00

% of Original Sample Used
For Hydrometer Analysis: 83.5 %
Weight of Sample Dispersed: 55.43 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:39:30	0.5	45	20	5	40	72.2	0.01365	8.9	0.0576	60.3
8:40:00	1.0	42	20	5	37	66.8	0.01365	9.4	0.0419	55.7
8:41:00	2.0	38	20	5	33	59.5	0.01365	10.1	0.0307	49.7
8:44:00	5.0	34	20	5	29	52.3	0.01365	10.7	0.0200	43.7
8:54:00	15.0	29	20	5	24	43.3	0.01365	11.5	0.0120	36.2
9:09:00	30.0	27	20	5	22	39.7	0.01365	11.9	0.0086	33.1
9:39:00	60.0	25	20	5	20	36.1	0.01365	12.2	0.0062	30.1
10:50:00	131.0	23	20	5	18	32.5	0.01365	12.5	0.0042	27.1
12:39:00	240.0	22	20	5	17	30.7	0.01365	12.7	0.0031	25.6
16:50:00	491.0	20	20	5	15	27.1	0.01365	13.0	0.0022	22.6
8:39:00	1440.0	18	17	5	13	23.5	0.01417	13.3	0.0014	19.6

Tested By: G. Donahue
Date: 4/11/2011
Submitted By:
Date:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-07 34.0	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel					0.20	6.9

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-07 34.0	19.00	0.02	0.008	0.003	0.0024	4.2	14.4	34.6	46.8

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WDR 4-7-11

COLEMAN ENGINEERING COMPANY
636 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel **Boring No.** BH-07

Sample No. 11

Remarks: **Depth:** 34.0 - 36.0

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	8.12	2.6	97.4
	4M	4.76	5.10	1.6	95.8
	10M	2.00	6.86	2.2	93.6
MECHANICAL ANALYSIS	40M	0.42	2.20	4.1	95.9 /* 89.9
PORTION OF HYDROMETER	100M	0.149	2.92	5.4	90.5 /* 84.8
ANALYSIS	200M	0.074	1.97	3.6	86.9 /* 81.4
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 20.08 gm = 6.3% %

Material passing No. 10 mesh: weight = 298.16 gm = 93.7% %

Weight of Total Sample = 318.24 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/4/2011

Submitted By: [signature] **Date:** 4/5/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

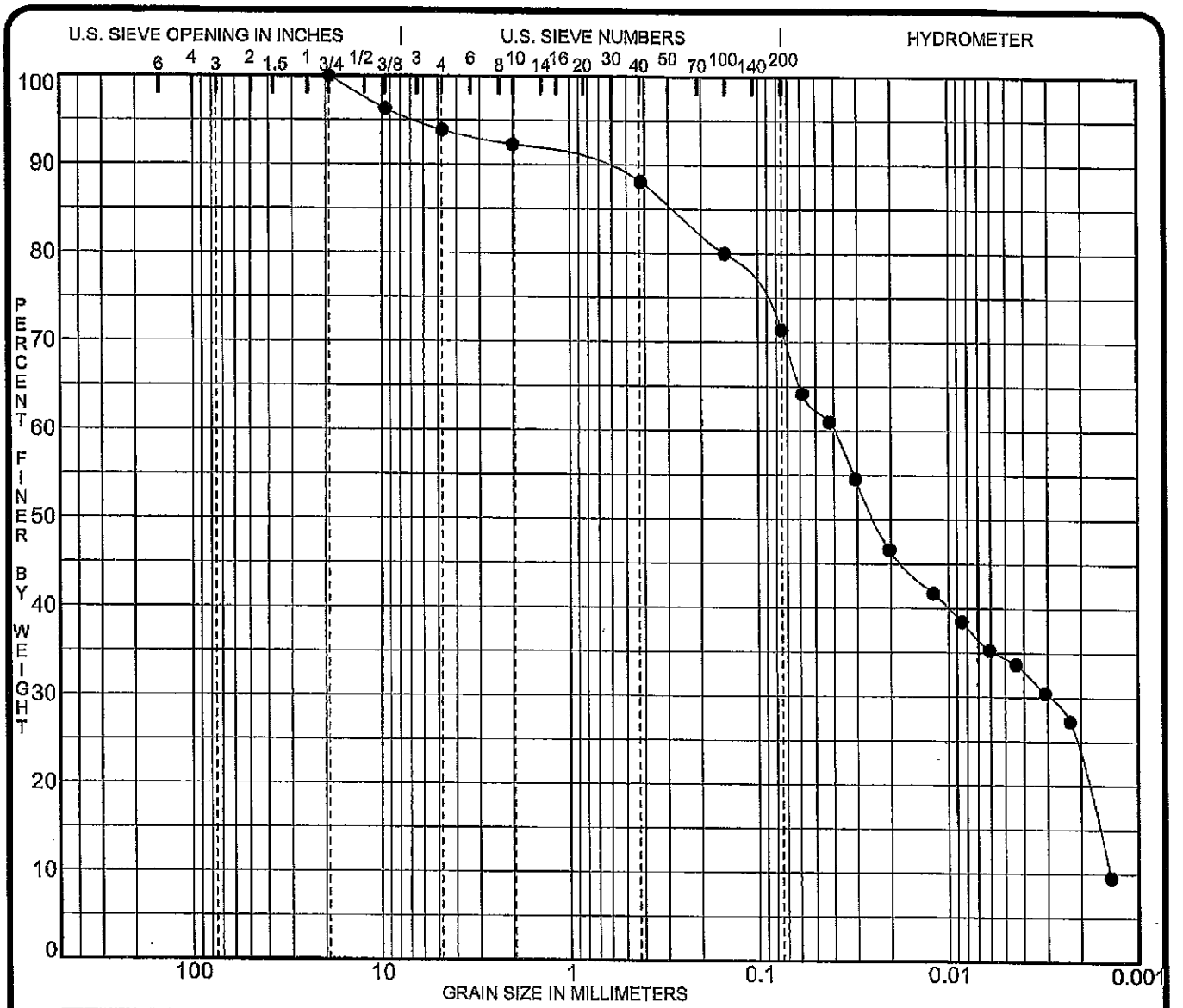
Remarks:
Boring No: BH-07
Sample No: 11
Depth: 34.0 - 36.0
Date Received: 3/24/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:29:00

% of Original Sample Used For Hydrometer Analysis: 93.7 %
Weight of Sample Dispersed: 54.26 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:29:30	0.5	50	18	6	44	81.1	0.01399	8.1	0.0563	76.0
9:30:00	1.0	48	18	6	42	77.4	0.01399	8.4	0.0405	72.5
9:31:00	2.0	46	18	6	40	73.7	0.01399	8.8	0.0293	69.1
9:34:00	5.0	42	18	6	36	66.3	0.01399	9.4	0.0192	62.2
9:44:00	15.0	38	18	6	32	59.0	0.01399	10.1	0.0115	55.3
9:59:00	30.0	35	19	6	29	53.4	0.01382	10.6	0.0082	50.1
10:29:00	60.0	34	19	6	28	51.6	0.01382	10.7	0.0058	48.4
11:29:00	120.0	32	20	6	26	47.9	0.01365	11.1	0.0042	44.9
13:29:00	240.0	29	20	6	23	42.4	0.01365	11.5	0.0030	39.7
17:59:00	510.0	10	20	6	4	7.4	0.01365	14.7	0.0023	6.9
9:11:00	1422.0	8	20	6	2	3.7	0.01365	15.0	0.0014	3.5

Tested By: D. Absolon and G. Donahue
Date: 4/4/2011
Submitted By:
Date:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-07 45.0	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, some fine gravel					0.15	28.4

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-07 45.0	19.00	0.04	0.024	0.003	0.0014	6.1	22.5	37.1	34.3

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WDR 4-7-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, some fine gravel **Boring No.** BH - 07

Sample No. 13

Remarks: **Depth:** 45.0 - 47.0

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	12.29	3.7	96.3
	4M	4.76	8.02	2.4	93.9
	10M	2.00	5.25	1.6	92.3
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.66	4.6	95.4 /* 88.1
	100M	0.149	5.08	8.8	86.6 /* 80.0
	200M	0.074	5.36	9.3	77.3 /* 71.4
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 25.56 gm = 7.6% %

Material passing No. 10 mesh: weight = 310.23 gm = 92.4% %

Weight of Total Sample = 335.79 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/4/2011

Submitted By: William J Reid **Date:** 4-7-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

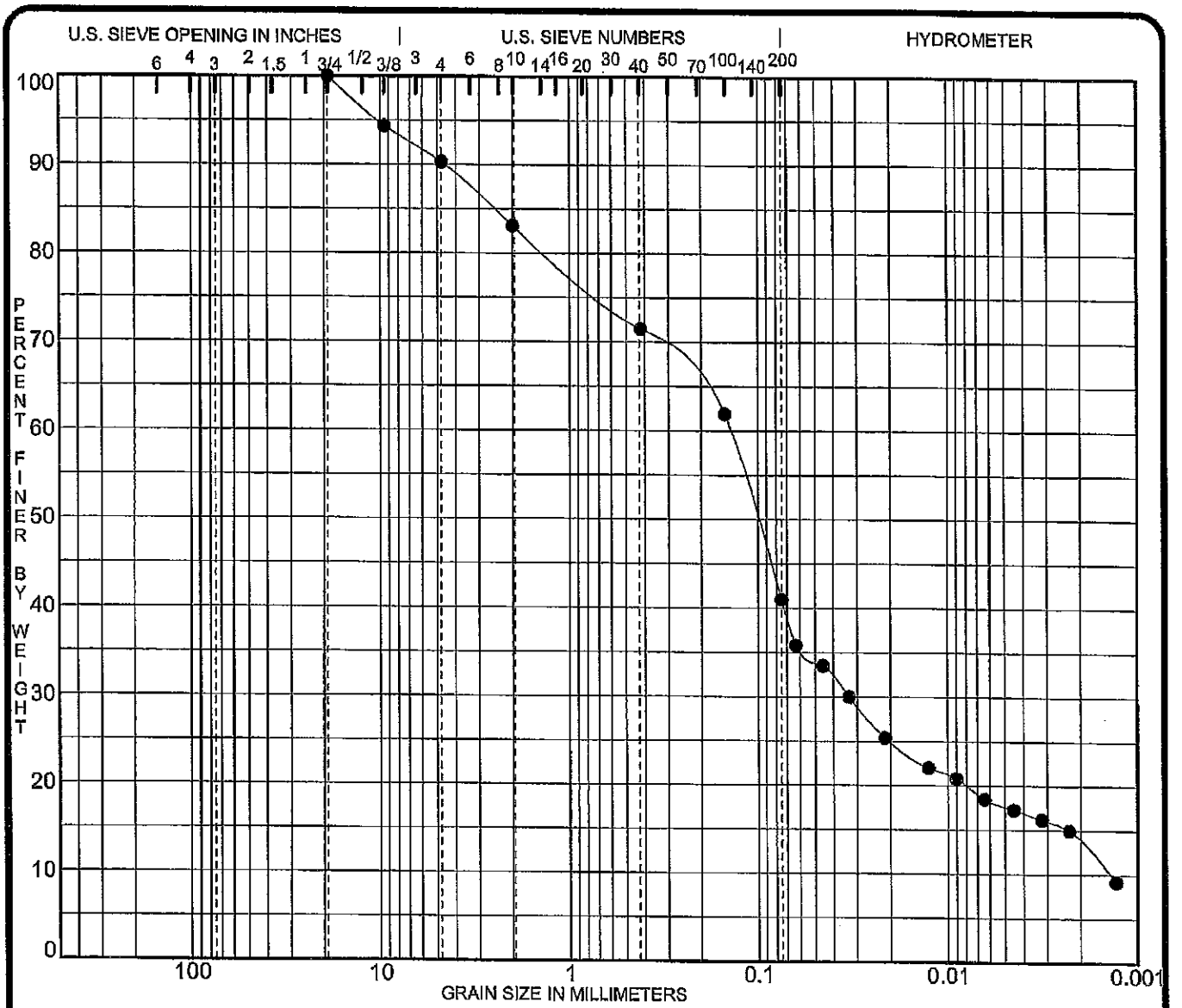
Remarks:
Boring No: BH - 07
Sample No: 13
Depth: 45.0 - 47.0
Date Received: 3/24/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:23:00

% of Original Sample Used For Hydrometer Analysis: 92.4 %
Weight of Sample Dispersed: 57.56 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:23:30	0.5	46	18	6	40	69.5	0.01399	8.8	0.0587	64.2
9:24:00	1.0	44	18	6	38	66.0	0.01399	9.1	0.0422	61.0
9:25:00	2.0	40	18	6	34	59.1	0.01399	9.7	0.0308	54.6
9:28:00	5.0	35	18	6	29	50.4	0.01399	10.6	0.0204	46.6
9:38:00	15.0	32	18	6	26	45.2	0.01399	11.1	0.0120	41.7
9:53:00	30.0	30	19	6	24	41.7	0.01382	11.4	0.0085	38.5
10:23:00	60.0	28	19	6	22	38.2	0.01382	11.7	0.0061	35.3
11:23:00	120.0	27	19	6	21	36.5	0.01382	11.9	0.0044	33.7
13:23:00	240.0	25	20	6	19	33.0	0.01365	12.2	0.0031	30.5
17:00:00	457.0	23	20	6	17	29.5	0.01365	12.5	0.0023	27.3
9:10:00	1427.0	12	20	6	6	10.4	0.01365	14.3	0.0014	9.6

Tested By: G. Donahue and D. Absolon
Date: 4/4/2011
Submitted By:
Date:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-07 80.0	(SM) SILTY SAND, brown, fine to coarse, some fine gravel					5.50	100.1

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-07 80.0	19.00	0.14	0.101	0.033	0.0014	9.7	49.3	23.3	17.7

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

CVDR 4-7-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (SM) SILTY SAND, brown, fine to coarse, some fine gravel **Boring No.** BH - 07

Sample No. 17

Remarks: **Depth:** 80.0 - 82.0

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	6.02	5.6	94.4
	4M	4.76	4.36	4.1	90.3
	10M	2.00	7.69	7.2	83.1
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	10.03	13.9	86.1 /* 71.5
	100M	0.149	8.34	11.6	74.5 /* 61.9
	200M	0.074	18.09	25.2	49.3 /* 41.0
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 18.07 gm = 16.9% %

Material passing No. 10 mesh: weight = 88.8 gm = 83.1% %

Weight of Total Sample = 106.87 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/4/2011

Submitted By: [signature] **Date:** 4-7-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH - 07
Sample No: 17
Depth: 80.0 - 82.0
Date Received: 3/24/2011

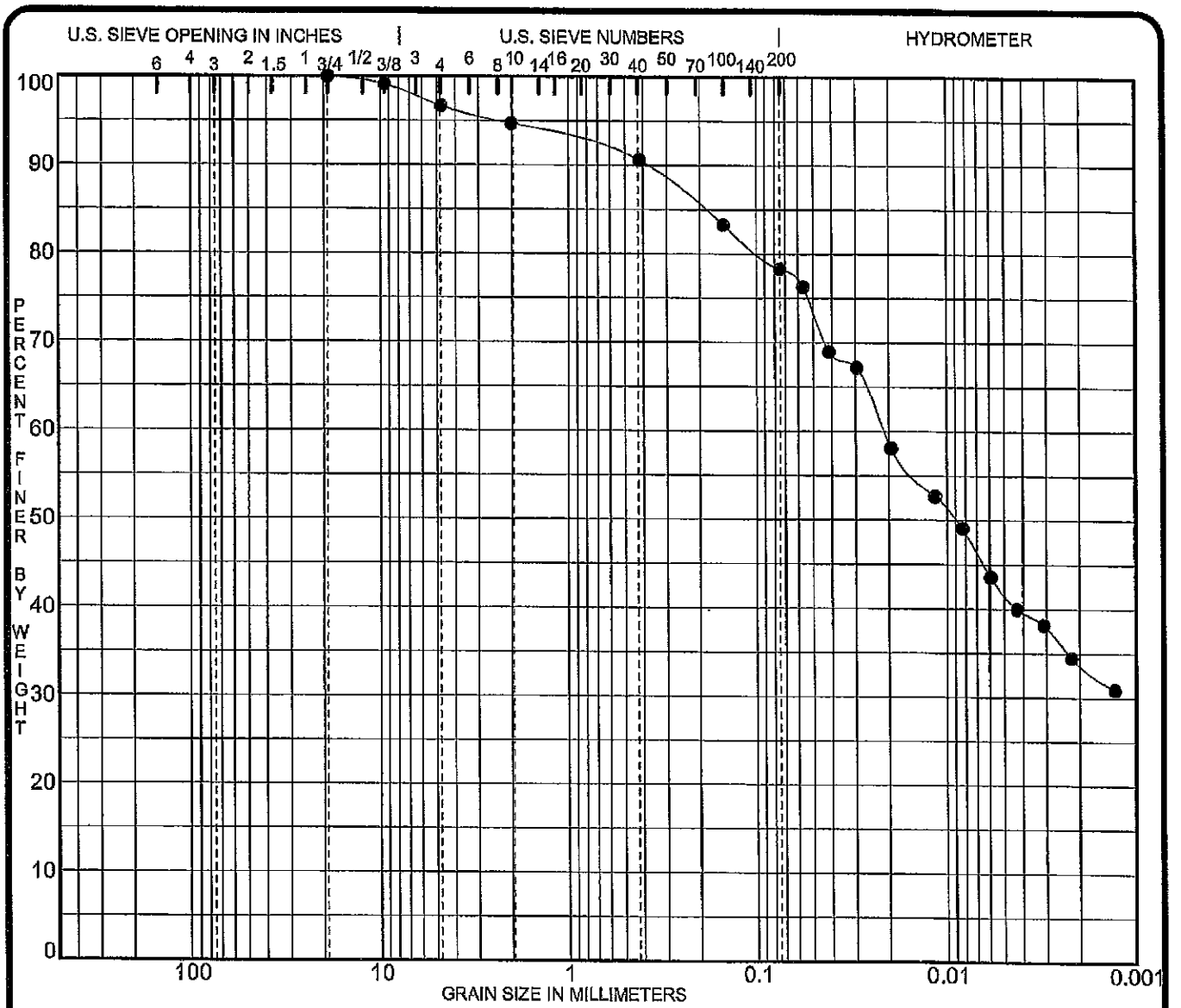
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:17:00

% of Original Sample Used For Hydrometer Analysis: 83.1 %
Weight of Sample Dispersed: 71.92 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:17:30	0.5	37	18	6	31	43.1	0.01399	10.2	0.0632	35.8
9:18:00	1.0	35	18	6	29	40.3	0.01399	10.6	0.0455	33.5
9:19:00	2.0	32	18	6	26	36.2	0.01399	11.1	0.0330	30.0
9:22:00	5.0	28	18	6	22	30.6	0.01399	11.7	0.0214	25.4
9:32:00	15.0	25	18	6	19	26.4	0.01399	12.2	0.0126	22.0
9:47:00	30.0	24	18	6	18	25.0	0.01399	12.4	0.0090	20.8
10:17:00	60.0	22	19	6	16	22.2	0.01382	12.7	0.0064	18.5
11:17:00	120.0	21	19	6	15	20.9	0.01382	12.9	0.0045	17.3
13:17:00	240.0	20	20	6	14	19.5	0.01365	13.0	0.0032	16.2
4:58:00	461.0	19	20	6	13	18.1	0.01365	13.2	0.0023	15.0
9:09:00	1432.0	14	20	6	8	11.1	0.01365	14.0	0.0013	9.2

Tested By: G. Donahue and D. Absolon
Date: 4/4/2011
Submitted By:
Date:

BH-8



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-8 10.0'-12.0'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-8 10.0'-12.0'	19.00	0.02	0.009			3.3	18.4	36.6	41.7

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/12/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel

Boring No. BH - 08
Sample No. 3
Depth: 10.0 - 12.0

Remarks:

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	2.30	0.9	99.1
4M	4.76	6.13	2.4	96.7
10M	2.00	5.09	2.0	94.7
40M	0.42	2.29	4.4	95.6 /* 90.6
100M	0.149	4.03	7.7	87.9 /* 83.3
200M	0.074	2.76	5.3	82.6 /* 78.3
Pan				/*

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 13.52 gm = 5.2% %

Material passing No. 10 mesh: weight = 244.85 gm = 94.8% %

Weight of Total Sample = 258.37 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/11/2011

Submitted By: [signature] **Date:** 4-11-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

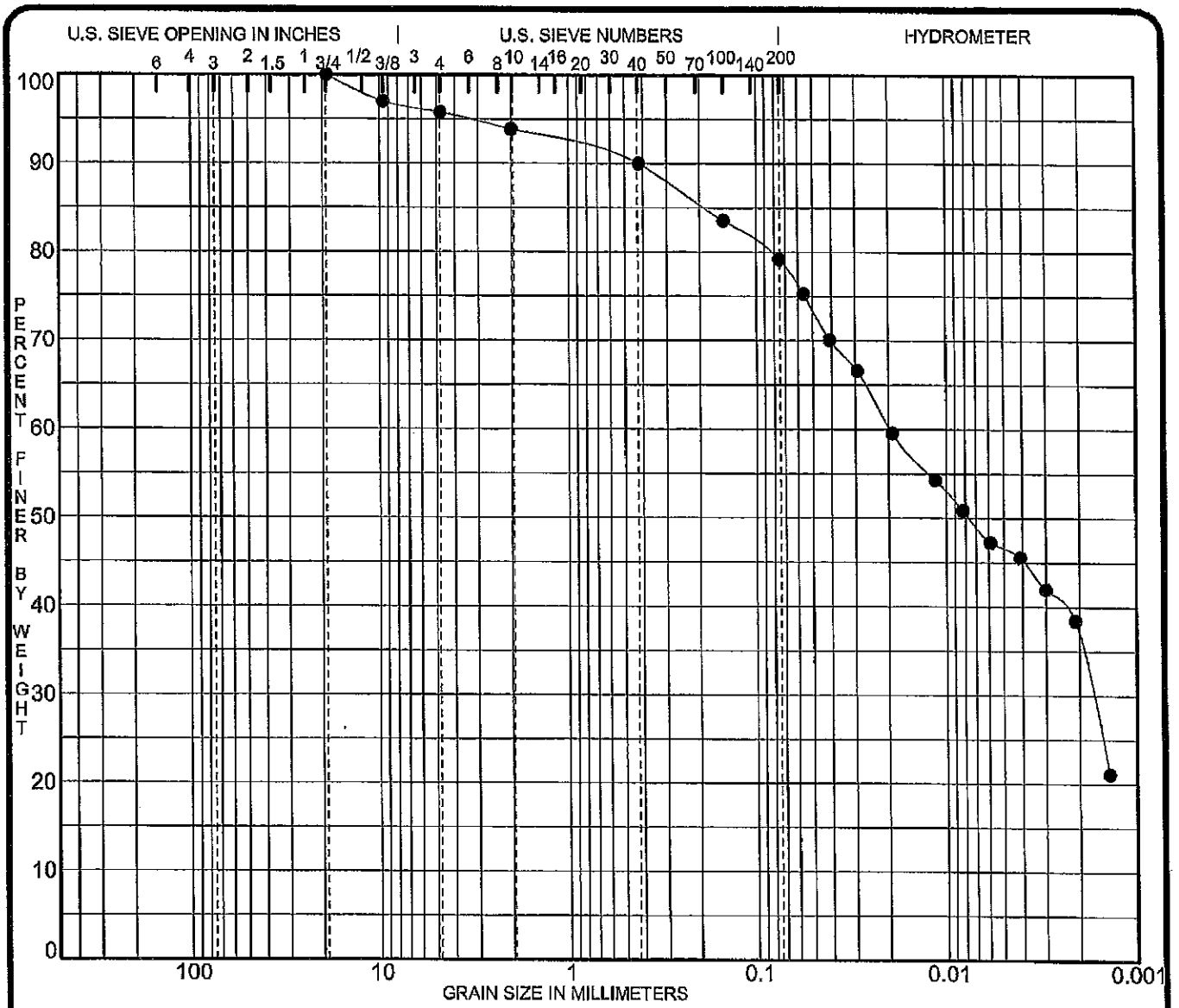
Remarks:
Boring No: BH - 08
Sample No: 3
Depth: 10 - 12
Date Received: 3/31/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:59:00

% of Original Sample Used For Hydrometer Analysis: 94.8 %
Weight of Sample Dispersed: 52.17 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:59:30	0.5	47	20	5	42	80.5	0.01365	8.6	0.0566	76.3
9:00:00	1.0	43	20	5	38	72.8	0.01365	9.2	0.0414	69.1
9:01:00	2.0	42	20	5	37	70.9	0.01365	9.4	0.0296	67.2
9:04:00	5.0	37	20	5	32	61.3	0.01365	10.2	0.0195	58.1
9:14:00	15.0	34	20	5	29	55.6	0.01365	10.7	0.0115	52.7
9:29:00	30.0	32	20	5	27	51.8	0.01365	11.1	0.0083	49.1
10:00:00	61.0	29	20	5	24	46.0	0.01365	11.5	0.0059	43.6
10:59:00	120.0	27	20	5	22	42.2	0.01365	11.9	0.0043	40.0
12:59:00	240.0	26	20	5	21	40.3	0.01365	12.0	0.0031	38.2
16:53:00	474.0	24	20	5	19	36.4	0.01365	12.4	0.0022	34.5
8:47:00	1428.0	22	17	5	17	32.6	0.01417	12.7	0.0013	30.9

Tested By: G. Donahue
Date: 4/11/2011
Submitted By:
Date:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-8	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand,						
19.6'-21.8'	trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-8	19.00	0.02	0.008	0.002		4.2	16.6	32.7	46.5
19.6'-21.8'									

PROJECT **Copperwood Project - Wakefield Township, MI**

JOB NO. **11006**

DATE **4/12/11**

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic,with fine to coarse sand, trace fine gravel **Boring No.** BH - 08 **Sample No.** 6

Remarks: **Depth:** 19.6 - 21.8

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	7.84	3.0	97.0
	4M	4.76	3.07	1.2	95.8
	10M	2.00	4.98	1.9	93.9
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.32	4.3	95.7 /* 90.0
	100M	0.149	3.66	6.8	88.9 /* 83.6
	200M	0.074	2.49	4.6	84.3 /* 79.2
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 15.89 gm = 6.0% %

Material passing No. 10 mesh: weight = 247.17 gm = 94.0% %

Weight of Total Sample = 263.06 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/11/2011

Submitted By: Glenn D Rice **Date:** 4-11-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH - 08
Sample No: 6
Depth: 19.6 - 21.8
Date Received: 3/31/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate

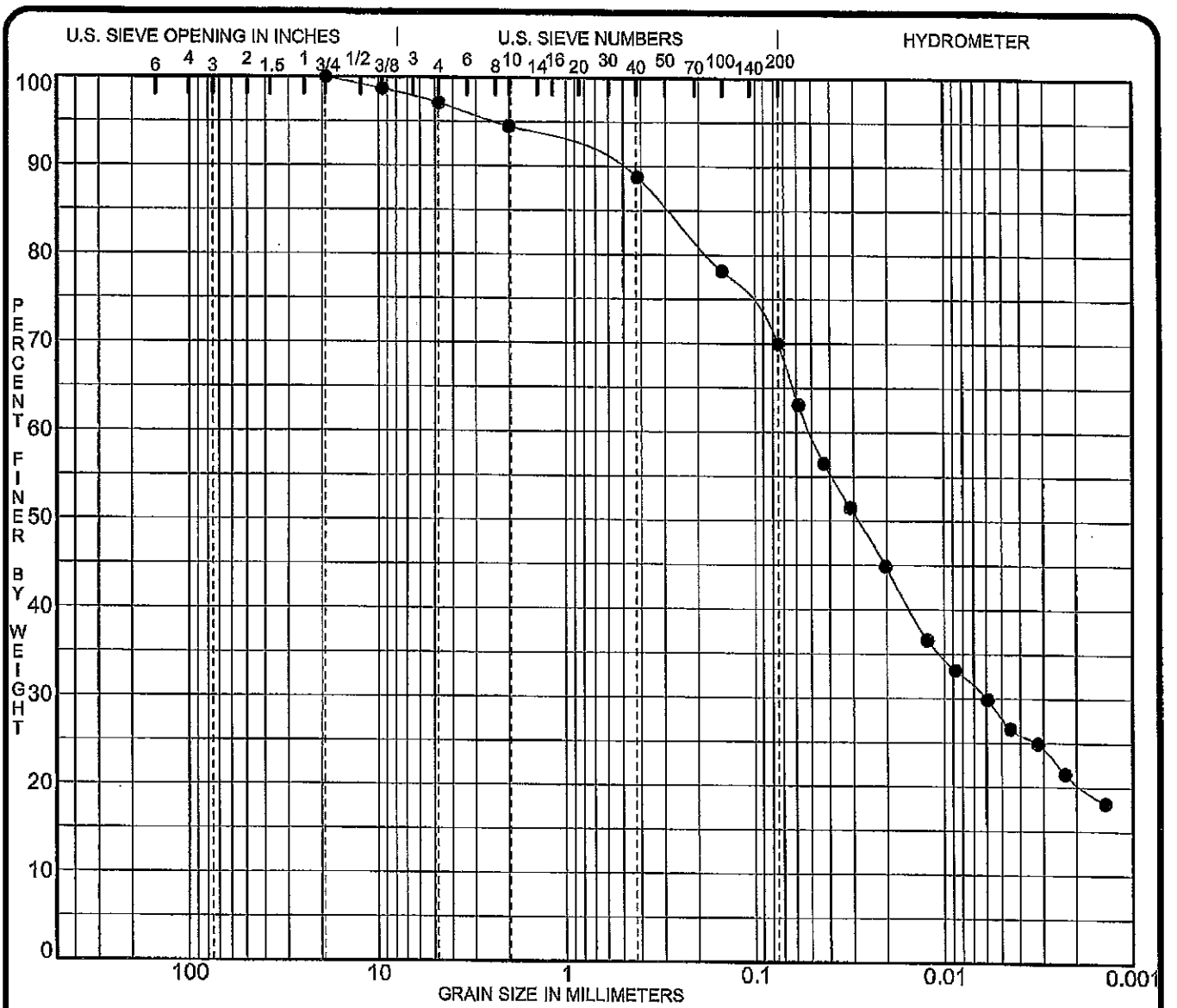
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:45:00

% of Original Sample Used For Hydrometer Analysis: 94 %
Weight of Sample Dispersed: 53.65 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:45:30	0.5	48	20	5	43	80.1	0.01365	8.4	0.0559	75.3
8:46:00	1.0	45	20	5	40	74.6	0.01365	8.9	0.0407	70.1
8:47:00	2.0	43	20	5	38	70.8	0.01365	9.2	0.0293	66.6
8:50:00	5.0	39	20	5	34	63.4	0.01365	9.9	0.0192	59.6
9:00:00	15.0	36	20	5	31	57.8	0.01365	10.4	0.0114	54.3
9:15:00	30.0	34	20	5	29	54.1	0.01365	10.7	0.0082	50.8
9:45:00	60.0	32	20	5	27	50.3	0.01365	11.1	0.0059	47.3
10:49:00	124.0	31	20	5	26	48.5	0.01365	11.2	0.0041	45.6
12:45:00	240.0	29	20	5	24	44.7	0.01365	11.5	0.0030	42.1
16:49:00	484.0	27	20	5	22	41.0	0.01365	11.9	0.0021	38.5
8:41:00	1436.0	17	17	5	12	22.4	0.01417	13.5	0.0014	21.0

Tested By: G. Donahue
Date: 4/11/2011

Submitted By:
Date:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-8 29.6'-31.8'	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-8 29.6'-31.8'	19.00	0.05	0.028	0.006		2.9	27.1	42.1	27.9

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/12/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel **Boring No.** BH - 08

Sample No. 8

Remarks: **Depth:** 29.6 - 31.8

Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
3"	76.2			
2"	50.8			
1 1/2"	37.5			
1	25.4			
3/4	19.1	0.00	0.0	100.0
3/8	9.5	4.67	1.3	98.7
4M	4.76	5.57	1.6	97.1
10M	2.00	9.25	2.6	94.5
40M	0.42	3.39	6.0	94.0 /* 88.8
100M	0.149	6.42	11.3	82.7 /* 78.2
200M	0.074	4.92	8.6	74.1 /* 70.0
Pan				/*

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 19.49 gm = 5.5% %

Material passing No. 10 mesh: weight = 337.39 gm = 94.5% %

Weight of Total Sample = 356.88 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/11/2011

Submitted By: [signature] **Date:** 4-11-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH - 08
Sample No: 8
Depth: 29.6 - 31.8
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received:

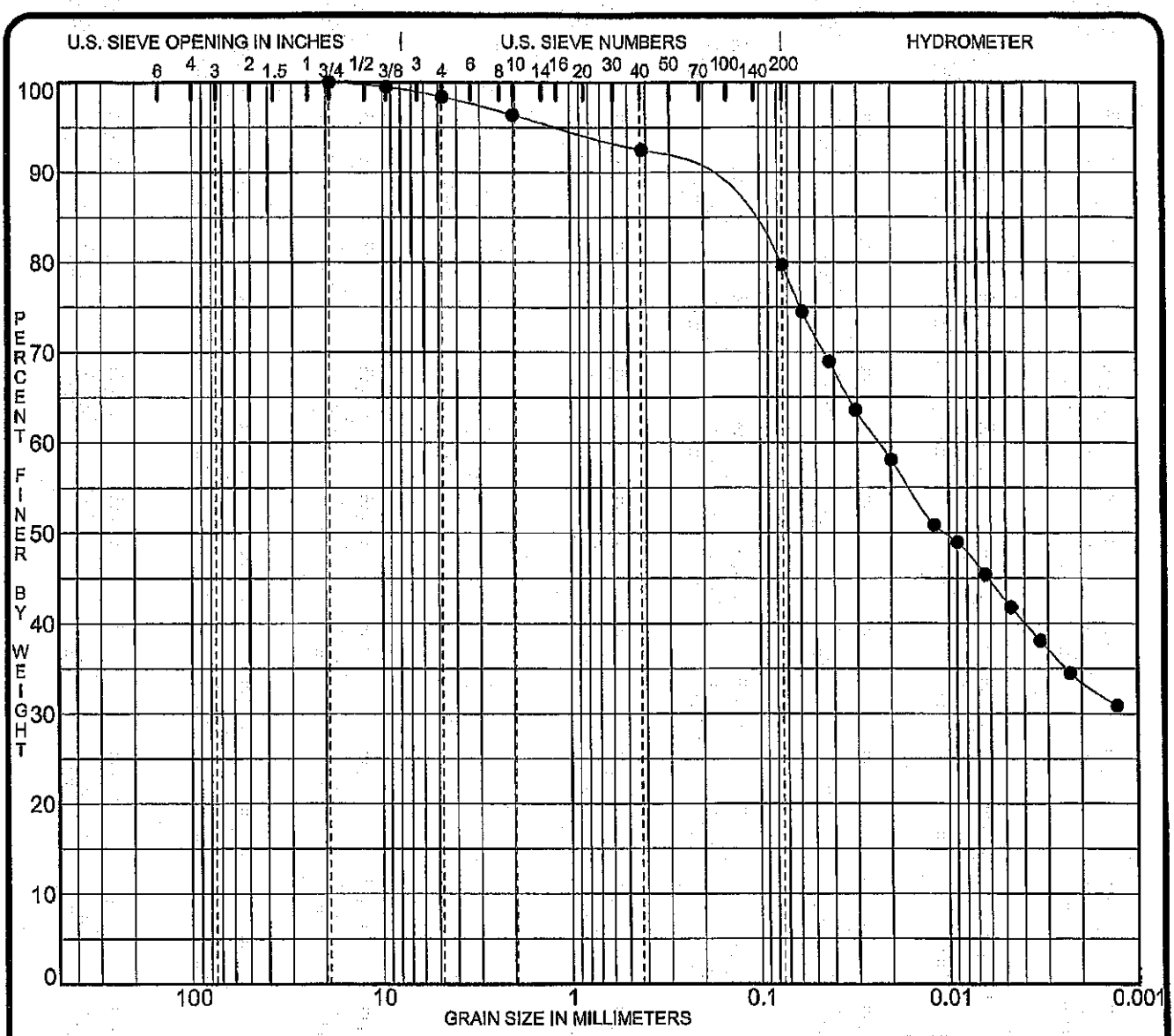
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:53:00

% of Original Sample Used For Hydrometer Analysis: 94.5 %
Weight of Sample Dispersed: 56.9 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:53:30	0.5	43	20	5	38	66.8	0.01365	9.2	0.0586	63.1
8:54:00	1.0	39	20	5	34	59.8	0.01365	9.9	0.0429	56.5
8:55:00	2.0	36	20	5	31	54.5	0.01365	10.4	0.0311	51.5
8:58:00	5.0	32	20	5	27	47.5	0.01365	11.1	0.0203	44.8
9:08:00	15.0	27	20	5	22	38.7	0.01365	11.9	0.0122	36.5
9:23:00	30.0	25	20	5	20	35.1	0.01365	12.2	0.0087	33.2
10:01:00	68.0	23	20	5	18	31.6	0.01365	12.5	0.0059	29.9
10:53:00	120.0	21	20	5	16	28.1	0.01365	12.9	0.0045	26.6
12:54:00	241.0	20	20	5	15	26.4	0.01365	13.0	0.0032	24.9
16:53:00	480.0	18	20	5	13	22.8	0.01365	13.3	0.0023	21.6
8:45:00	1432.0	16	17	5	11	19.3	0.01417	13.7	0.0014	18.3

Tested By: G. Donahue
Date: 4/11/2011
Submitted By:
Date:

BH-10



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-10 9.5'-11.0'	(CL) LEAN CLAY, reddish-brown, trace of fine gravel, with fine to coarse sand, medium plastic						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-10 9.5'-11.0'	19.00	0.02	0.010			1.6	18.7	37.2	42.5

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 3/1/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, red-brn, trace fine gravel,** **Boring No.** BH-10

Shape: **Hardness:** **Sample No.** 3 / 3A

Remarks: **with fine to coarse sand, medium plastic **Depth:** 9.5' - 11'

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2	-	-	-
	2"	50.8	-	-	-
	1 1/2"	37.5	-	-	-
	1	25.4	-	-	-
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	1.88	0.5	99.5
	4M	4.76	4.09	1.1	98.4
	10M	2.00	7.12	2.0	96.4
MECHANICAL ANALYSIS	40M	0.42	2.14	4.0	96.0 /* 92.5
PORTION OF HYDROMETER	100M	0.149	4.23	8.0	88.0 /* 84.8
ANALYSIS	200M	0.074	2.81	5.3	82.7 /* 79.7
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 13.09 gm = 3.6% %

Material passing No. 10 mesh: weight = 346.5 gm = 96.4% %

Weight of Total Sample = 359.6 gm

Tested By: Graham Donahue **Date:** 2/15/2011

Submitted By: [signature] **Date:** 2/15/2011

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH-10
Sample No: 3/3A
Depth: 9.5-11.0
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 2/4/2011

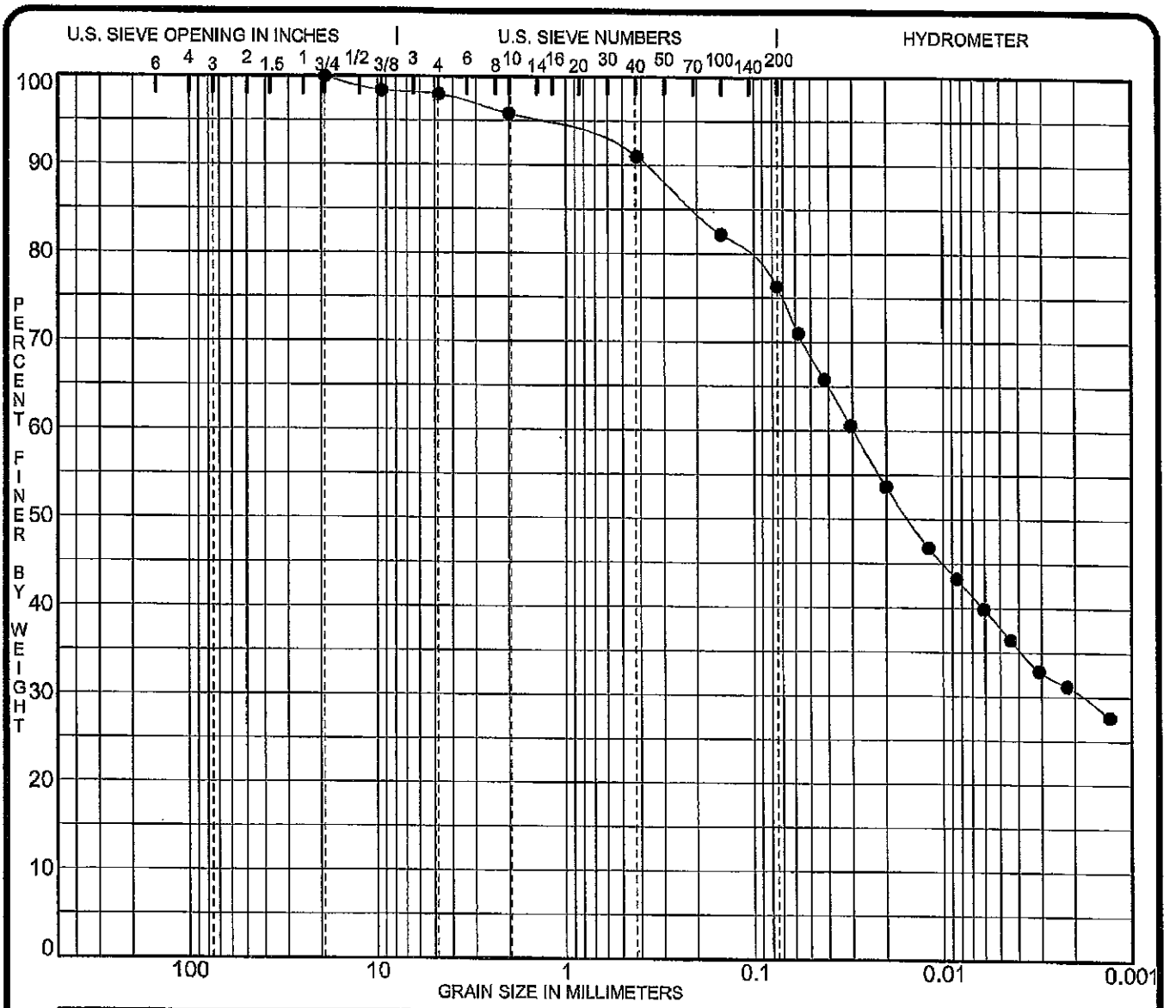
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:41:00

% of Original Sample Used
For Hydrometer Analysis: 96.4 %
Weight of Sample Dispersed: 53.08 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:41:30	0.5	46	18	5	41	77.2	0.01399	8.8	0.0587	74.5
9:42:00	1.0	43	18	5	38	71.6	0.01399	9.2	0.0424	69.0
9:43:00	2.0	40	18	5	35	65.9	0.01399	9.7	0.0308	63.6
9:46:00	5.0	37	18	5	32	60.3	0.01399	10.2	0.0200	58.1
9:56:00	15.0	33	18	5	28	52.8	0.01399	10.9	0.0119	50.9
10:08:00	27.0	32	18	5	27	50.9	0.01399	11.1	0.0090	49.0
10:35:00	54.0	30	18	5	25	47.1	0.01399	11.4	0.0064	45.4
11:24:00	103.0	28	18	5	23	43.3	0.01399	11.7	0.0047	41.8
1:13:00	212.0	26	18	5	21	39.6	0.01399	12.0	0.0033	38.1
5:26:00	465.0	24	18	5	19	35.8	0.01399	12.4	0.0023	34.5
8:54:00	1393.0	22	18	5	17	32.0	0.01399	12.7	0.0013	30.9

Tested By: Bill Rice
Date: 2/10/2011
Submitted By: Bill Rice
Date: 2/4/2011

Form #: 0422B Revision Date: 1/17/05



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-10 15.0	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-10 15.0	19.00	0.03	0.015	0.002		2.0	21.7	38.5	37.8

PROJECT **Copperwood Project - Wakefield Township, MI**

JOB NO. **11006**
DATE **4/7/11**

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WDR 4-7-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel **Boring No.** BH - 10

Sample No. 4

Remarks: **Depth:** 15.0 - 17.0

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	2.43	1.6	98.4
	4M	4.76	0.63	0.4	98.0
	10M	2.00	3.35	2.2	95.8
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.70	4.9	95.1 /* 91.0
	100M	0.149	5.09	9.2	85.9 /* 82.2
	200M	0.074	3.42	6.2	79.7 /* 76.3
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 6.41 gm = 4.3% %

Material passing No. 10 mesh: weight = 142.97 gm = 95.7% %

Weight of Total Sample = 149.38 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/4/2011

Submitted By: [signature] **Date:** 4-7-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

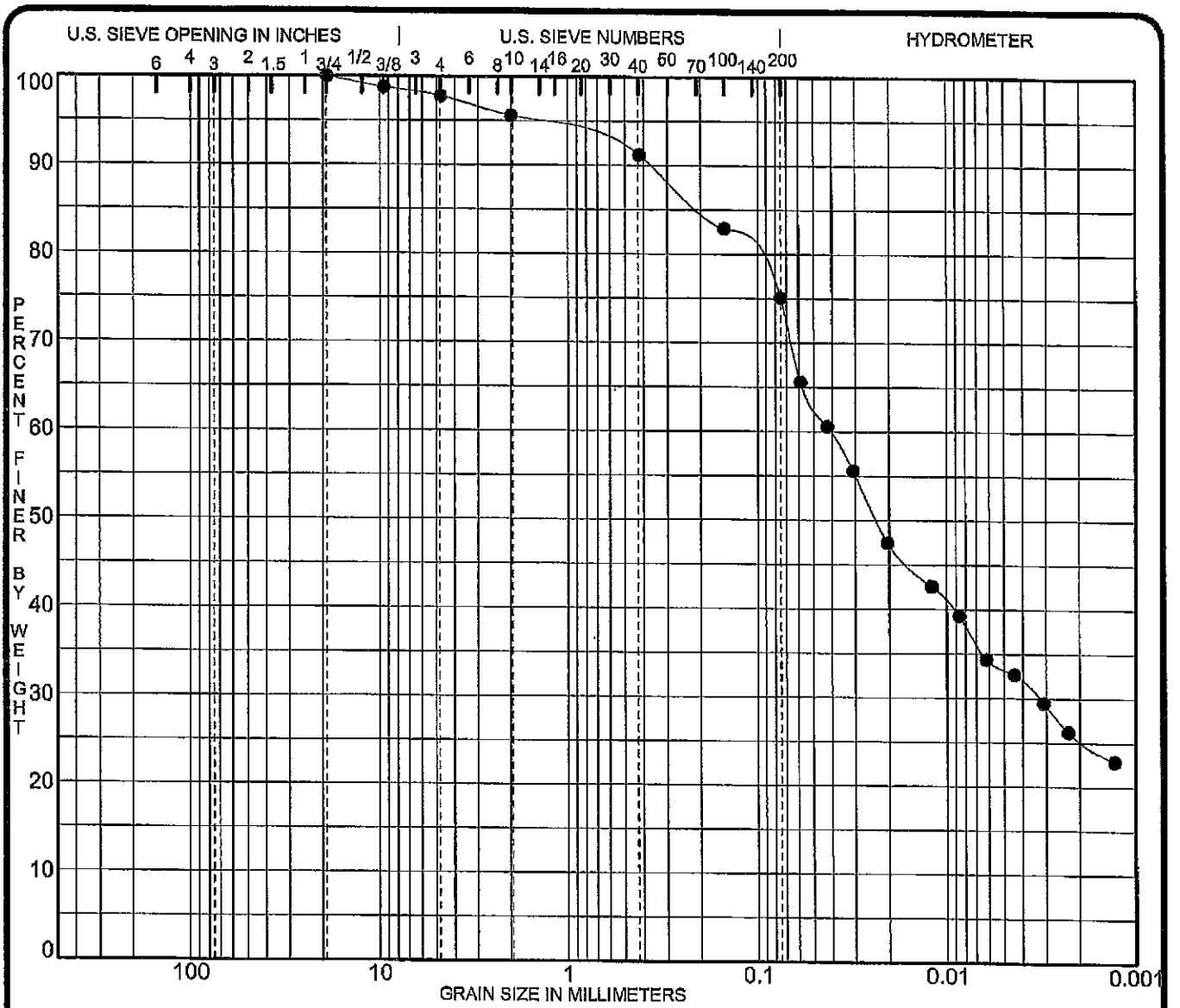
Remarks:
Boring No: BH - 10
Sample No: 4
Depth: 15.0 - 17.0
Date Received: 3/24/2011

Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:05:00

% of Original Sample Used For Hydrometer Analysis: 95.7 %
Weight of Sample Dispersed: 55.23 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:05:30	0.5	47	18	6	41	74.2	0.01399	8.6	0.0580	71.0
9:06:00	1.0	44	18	6	38	68.8	0.01399	9.1	0.0422	65.8
9:07:00	2.0	41	18	6	35	63.4	0.01399	9.6	0.0307	60.6
9:10:00	5.0	37	18	6	31	56.1	0.01399	10.2	0.0200	53.7
9:20:00	15.0	33	18	6	27	48.9	0.01399	10.9	0.0119	46.8
9:35:00	30.0	31	18	6	25	45.3	0.01399	11.2	0.0085	43.3
10:05:00	60.0	29	19	6	23	41.6	0.01382	11.5	0.0061	39.9
11:05:00	120.0	27	19	6	21	38.0	0.01382	11.9	0.0044	36.4
13:05:00	240.0	25	20	6	19	34.4	0.01365	12.2	0.0031	32.9
16:55:00	470.0	24	20	6	18	32.6	0.01365	12.4	0.0022	31.2
9:07:00	1442.0	22	20	6	16	29.0	0.01365	12.7	0.0013	27.7

Tested By: D. Absolon and G. Donahue
Date: 4/4/2011
Submitted By:
Date:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● BH-10 25.5	(CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BH-10 25.5	19.00	0.04	0.023	0.003		2.2	22.7	41.8	33.3

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WMR 4-7-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, brown, medium plastic, with fine to coarse sand, trace fine gravel **Boring No.** BH - 10 **Sample No.** 6

Remarks: **Depth:** 25.5 - 27.5

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	4.73	1.2	98.8
	4M	4.76	3.77	1.0	97.8
	10M	2.00	8.34	2.2	95.6
MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS	40M	0.42	2.68	4.6	95.4 /* 91.2
	100M	0.149	5.09	8.7	86.7 /* 82.9
	200M	0.074	4.76	8.1	78.6 /* 75.1
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 16.84 gm = 4.4% %

Material passing No. 10 mesh: weight = 366.82 gm = 95.6% %

Weight of Total Sample = 383.66 gm

Tested By: Dan Absolon and Graham Donahue **Date:** 4/4/2011

Submitted By: Wm D Riel **Date:** 4-7-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: BH - 10
Sample No: 6
Depth: 25.5 - 27.5
Date Received: 3/24/2011

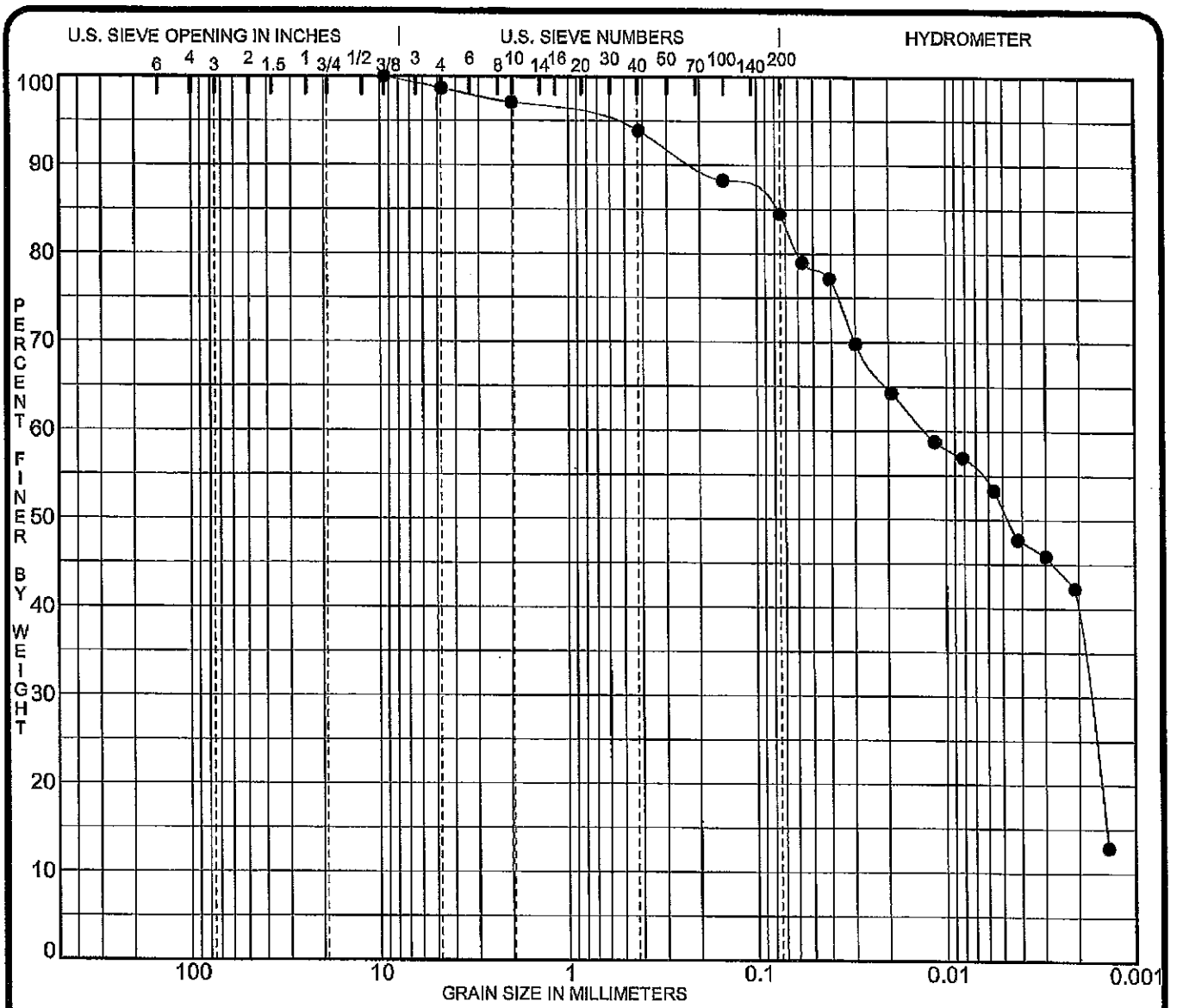
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 9:11:00

% of Original Sample Used For Hydrometer Analysis: 95.6 %
Weight of Sample Dispersed: 58.41 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:11:30	0.5	46	18	6	40	68.5	0.01399	8.8	0.0587	65.5
9:12:00	1.0	43	18	6	37	63.3	0.01399	9.2	0.0424	60.6
9:13:00	2.0	40	18	6	34	58.2	0.01399	9.7	0.0308	55.6
9:16:00	5.0	35	18	6	29	49.6	0.01399	10.6	0.0204	47.5
9:26:00	15.0	32	18	6	26	44.5	0.01399	11.1	0.0120	42.6
9:41:00	30.0	30	18	6	24	41.1	0.01399	11.4	0.0086	39.3
10:11:00	60.0	27	19	6	21	36.0	0.01382	11.9	0.0062	34.4
11:11:00	120.0	26	19	6	20	34.2	0.01382	12.0	0.0044	32.7
13:11:00	240.0	24	20	6	18	30.8	0.01365	12.4	0.0031	29.5
16:57:00	466.0	22	20	6	16	27.4	0.01365	12.7	0.0023	26.2
9:08:00	1437.0	20	20	6	14	24.0	0.01365	13.0	0.0013	22.9

Tested By: G. Donahue and D. Absolon
Date: 4/4/2011
Submitted By:
Date:

MW-7



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen I.D.	Classification	MC%	LL	PL	PI	Cc	Cu
● MW-7 23.3	(CL) LEAN CLAY, with fine to coarse sand, trace fine gravel						

Specimen I.D.	D100	D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
● MW-7 23.3	9.50	0.01	0.005	0.002		1.3	14.2	33.4	51.1

PROJECT Copperwood Project - Wakefield Township, MI

JOB NO. 11006
DATE 4/7/11

GRADATION CURVES

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

WDR 4-7-11

COLEMAN ENGINEERING COMPANY
636 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood Tailings Facility **C.E.C. Job #:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Soil Description: (CL) LEAN CLAY, with fine to coarse sand, trace fine gravel **Boring No.** MW-7

Sample No. 2

Remarks: **Depth:** 23.3 - 25.3

	Sieve Size	Grain Diameter (mm)	Weight Retained	Percent Retained	Percent Finer
	3"	76.2			
	2"	50.8			
	1 1/2"	37.5			
	1	25.4			
	3/4	19.1	0.00	0.0	100.0
	3/8	9.5	0.00	0.0	100.0
	4M	4.76	3.65	1.3	98.7
	10M	2.00	4.75	1.6	97.1
MECHANICAL ANALYSIS	40M	0.42	1.73	3.3	96.7 /* 93.9
PORTION OF HYDROMETER	100M	0.149	3.06	5.8	90.9 /* 88.3
ANALYSIS	200M	0.074	2.07	3.9	87.0 /* 84.5
	Pan				/*

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 8.4 gm = 2.9% %

Material passing No. 10 mesh: weight = 282.81 gm = 97.1% %

Weight of Total Sample = 291.21 gm

Tested By: D. Absolon/Graham Donahue **Date:** 4/1/2011

Submitted By: [illegible] **Date:** 4-7-11

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood Tailings Facility
C.E.C Job #: GL-11006
Client: Orvana Resources US Corp.
Address: N10199 Lake Road Ironwood MI 49938

Remarks:
Boring No: MW-07
Sample No: 2
Depth: 23.3'-25.3'
Dispersing Agent Used: 4% Sodium Hexametaphosphate
Date Received: 3/24/2011

Amount: 125ml
Hydrometer Number: 152H
Specific Gravity (G): 2.65
Starting Time: 8:30:00

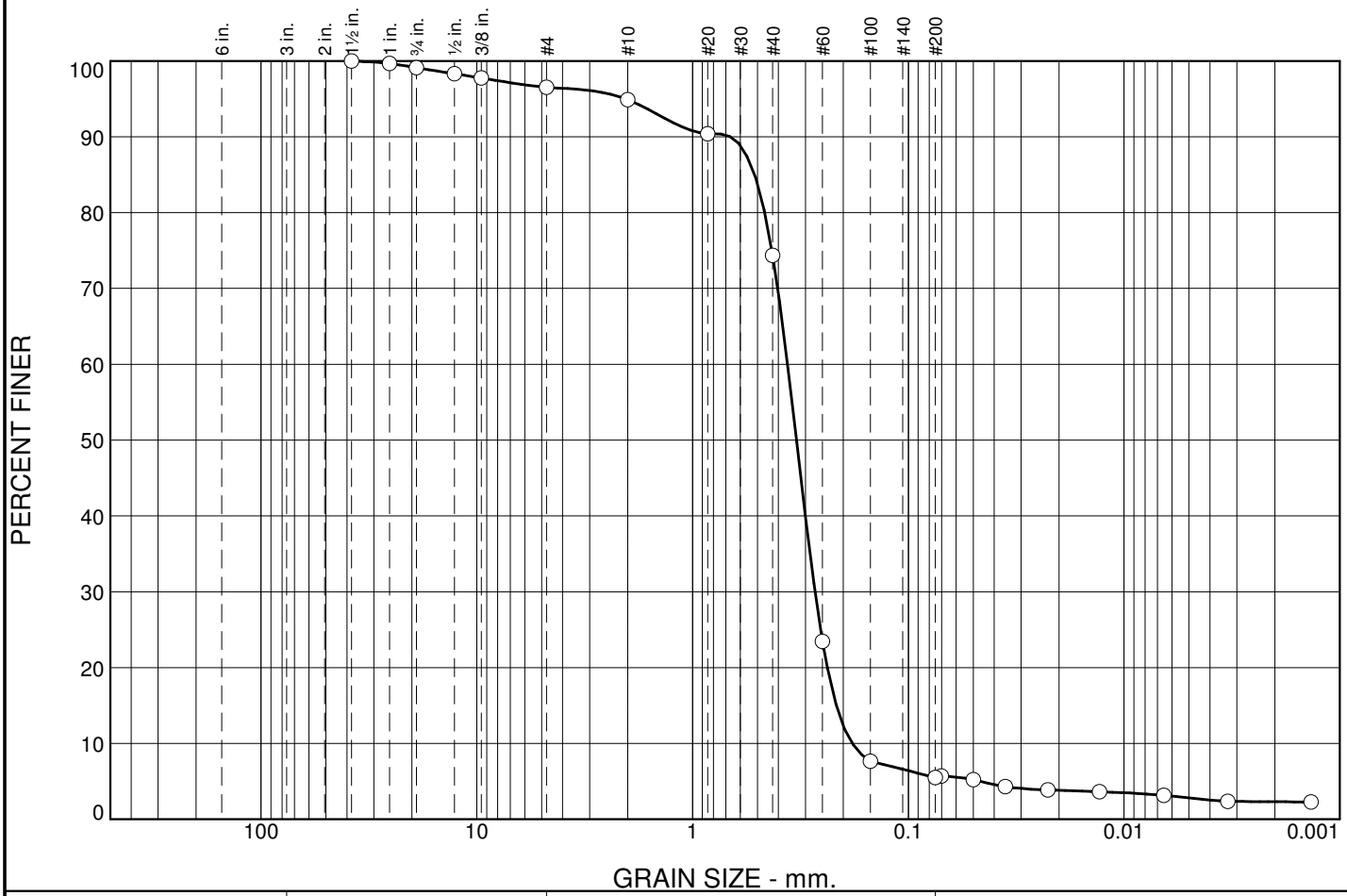
% of Original Sample Used For Hydrometer Analysis: 97.1 %
Weight of Sample Dispersed: 52.84 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:30:30	0.5	49	18	6	43	81.4	0.01399	8.3	0.0570	79.0
8:31:00	1.0	47	18	5	42	79.5	0.01399	8.6	0.0410	77.2
8:32:00	2.0	44	18	6	38	71.9	0.01399	9.1	0.0298	69.8
8:35:00	5.0	41	18	6	35	66.2	0.01399	9.6	0.0194	64.3
8:45:00	15.0	38	18	6	32	60.6	0.01399	10.1	0.0115	58.8
9:00:00	30.0	37	18	6	31	58.7	0.01399	10.2	0.0082	57.0
9:35:00	65.0	35	19	6	29	54.9	0.01382	10.6	0.0056	53.3
10:30:00	120.0	32	19	6	26	49.2	0.01382	11.1	0.0042	47.8
12:17:00	227	31	20	6	25	47.3	0.01365	11.2	0.0030	45.9
4:01:00	480.0	29	20	6	23	43.5	0.01365	11.5	0.0021	42.3
8:30:00	1440.0	13	20	6	7	13.2	0.01365	14.2	0.0014	12.9

Tested By: Dan Absolon
Date: 3/3/2011
Submitted By:
Date: 4/4/2011

Sand Pits

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.9	2.6	1.6	20.6	68.8	3.2	2.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	99.7		
.75	99.1		
.5	98.3		
0.375	97.7		
#4	96.5		
#10	94.9		
#20	90.4		
#40	74.3		
#60	23.5		
#100	7.7		
#200	5.5		
0.0704 mm.	5.7		
0.0499 mm.	5.2		
0.0355 mm.	4.3		
0.0225 mm.	3.9		
0.0130 mm.	3.6		
0.0065 mm.	3.2		
0.0033 mm.	2.4		
0.0014 mm.	2.3		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.5162 D_{60}= 0.3627 D_{50}= 0.3297
D_{30}= 0.2706 D_{15}= 0.2155 D_{10}= 0.1818
C_u= 2.00 C_c= 1.11

Classification

USCS= AASHTO=

Remarks

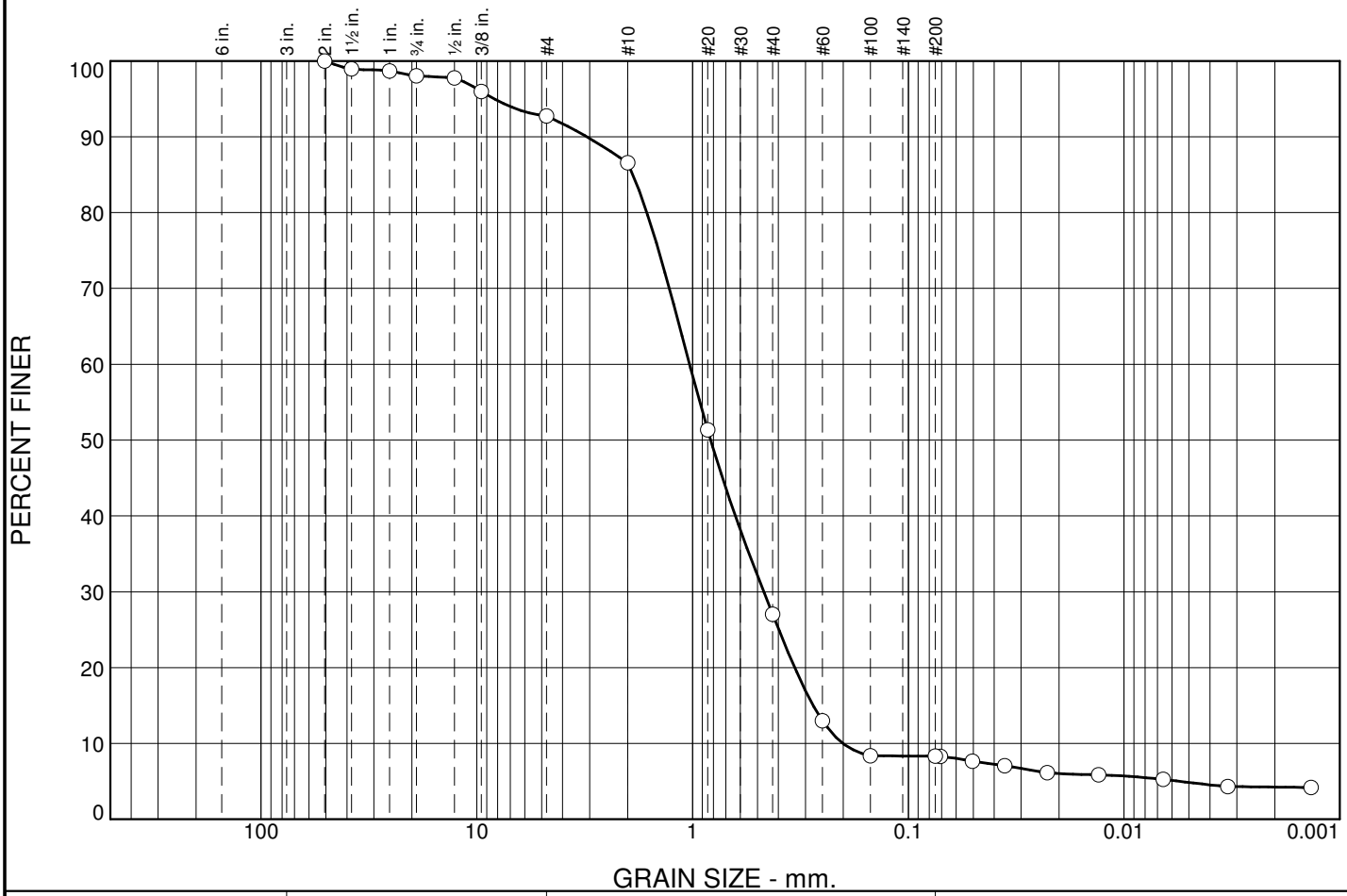
Sample No.: CP **Source of Sample:** **Date:** 2/23/11
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client: Orvana Resources
Project: Copperwood

Project No: DV101-429.02 **Fig.**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.0	5.2	6.2	59.6	18.7	4.0	4.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	99.0		
1	98.7		
.75	98.0		
.5	97.8		
0.375	95.9		
#4	92.8		
#10	86.6		
#20	51.3		
#40	27.0		
#60	13.0		
#100	8.4		
#200	8.3		
0.0710 mm.	8.3		
0.0504 mm.	7.7		
0.0357 mm.	7.1		
0.0227 mm.	6.2		
0.0131 mm.	5.9		
0.0066 mm.	5.3		
0.0033 mm.	4.3		
0.0014 mm.	4.2		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.8893 D_{60}= 1.0319 D_{50}= 0.8234
D_{30}= 0.4674 D_{15}= 0.2759 D_{10}= 0.2004
C_u= 5.15 C_c= 1.06

Classification

USCS= AASHTO=

Remarks

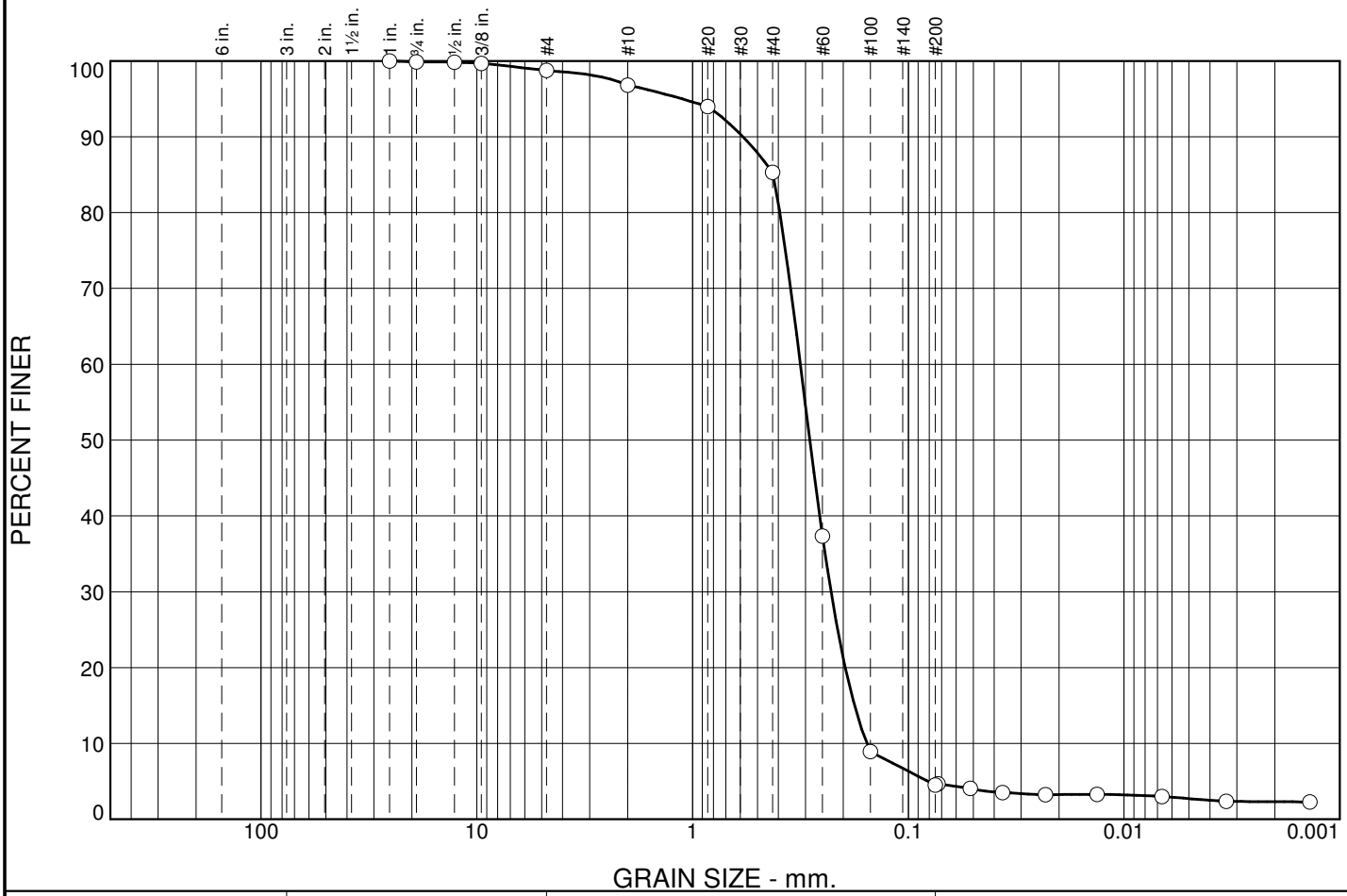
Sample No.: LP **Source of Sample:** **Date:** 2/23/11
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client: Orvana Resources
Project: Copperwood

Project No: DV101-429.02 **Fig.**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.1	1.2	1.9	11.5	80.8	2.2	2.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	99.9		
.5	99.8		
0.375	99.7		
#4	98.7		
#10	96.8		
#20	94.0		
#40	85.3		
#60	37.3		
#100	8.9		
#200	4.5		
0.0728 mm.	4.7		
0.0516 mm.	4.1		
0.0365 mm.	3.5		
0.0231 mm.	3.3		
0.0133 mm.	3.3		
0.0067 mm.	3.0		
0.0034 mm.	2.4		
0.0014 mm.	2.3		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.4230 D_{60}= 0.3163 D_{50}= 0.2861
D_{30}= 0.2283 D_{15}= 0.1773 D_{10}= 0.1556
C_u= 2.03 C_c= 1.06

Classification

USCS= SP AASHTO=

Remarks

Sample No.: #2 **Source of Sample:** **Date:** 2/23/11
Location: Connor Pit **Elev./Depth:**

Knight Piésold CONSULTING

Client: Orvana Resources
Project: Copperwood
Project No: DV101-429.02 **Fig.**

Knight Piésold CONSULTING

Appendix F-2

Laboratory Test Data – Atterberg Limits Data (Test Pits and Boreholes)

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

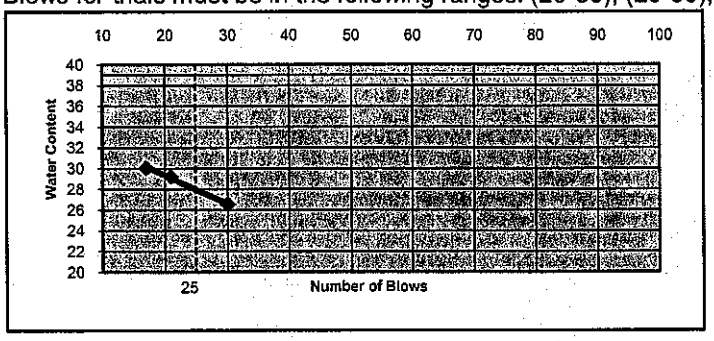
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 13' - 16' **Boring No.:** TP - 1 **Sample No.:** B

Liquid Limit Determination

Can No.	41	43	33			
Wt. of wet soil +can (g)	22.41	25.11	22.82			
Wt. of dry soil + can (g)	21.05	23.09	21.24			
Wt. of can (g)	15.91	16.17	15.97			
Wt of dry soil (g)	5.14	6.92	5.27			
Wt of moisture (g)	1.36	2.02	1.58			
* No of blows, N (g)	**30**	**21**	**17**			
Water content, *w* %	**26.5**	**29.2**	**30.0**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 28
Plastic limit = 14
Plasticity index I_p = 14

Plastic Limit Determination

Can no.	26	39				
Wt. of wet soil + can (g)	25.31	25.86				
Wt. of dry soil + can (g)	24.19	24.68				
Wt. of can (g)	16.08	16.00				
Wt. of dry soil (g)	8.11	8.68				
Wt. of moisture (g)	1.12	1.18				
Water content, $w\% = w_p$	13.8	13.6			Average	13.7

Tested by: D. Absolon / W. Rice **Date:** 2/10/2011
Submitted By: William J. Rice **Date:** 2/10/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

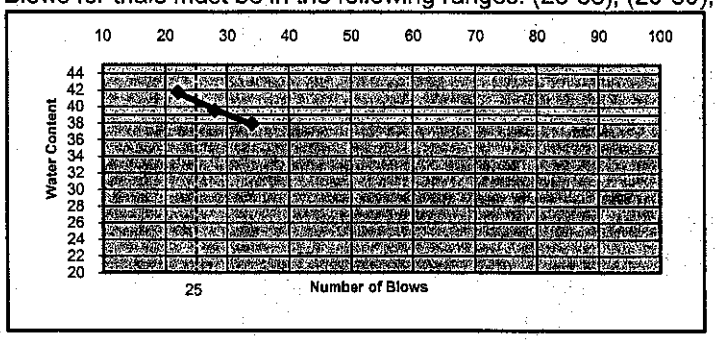
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, trace sand, trace gravel, highly plastic
Depth of Sample: 4' **Boring No.:** TP - 2 **Sample No.:** A

Liquid Limit Determination

Can No.	33	44	40			
Wt. of wet soil +can (g)	22.84	22.64	23.09			
Wt. of dry soil + can (g)	20.95	20.73	20.94			
Wt. of can (g)	15.96	15.90	15.79			
Wt of dry soil (g)	4.99	4.83	5.15			
Wt of moisture (g)	1.89	1.91	2.15			
* No of blows, N (g)	**34**	**28**	**22**			
Water content, *w* %	**37.9**	**39.5**	**41.7**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 41
Plastic limit = 16
Plasticity index I_p = 25

Plastic Limit Determination

Can no.	39	23				
Wt. of wet soil + can (g)	25.88	25.67				
Wt. of dry soil + can (g)	24.56	24.34				
Wt. of can (g)	16.00	16.00				
Wt. of dry soil (g)	8.56	8.34				
Wt. of moisture (g)	1.32	1.33				
Water content, $w\% = w_p$	15.4	15.9			Average	15.6

Tested by: D. Absolon **Date:** 2/9/2011
Submitted By: [signature] **Date:** 2/9/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

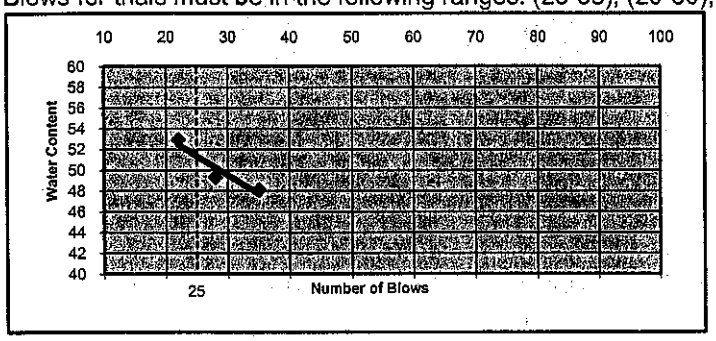
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CH) FAT CLAY, brown, some fine to coarse sand, trace gravel, highly plastic
Depth of Sample: 10' - 12' **Boring No.:** TP - 2 **Sample No.:** B

Liquid Limit Determination

Can No.	39	43	41			
Wt. of wet soil +can (g)	23.35	21.71	20.95			
Wt. of dry soil + can (g)	20.96	19.88	19.21			
Wt. of can (g)	15.99	16.17	15.92			
Wt of dry soil (g)	4.97	3.71	3.29			
Wt of moisture (g)	2.39	1.83	1.74			
* No of blows, N (g)	**35**	**28**	**22**			
Water content, *w* %	**48.1**	**49.3**	**52.9**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 52
Plastic limit = 18
Plasticity index I_p = 34

Plastic Limit Determination

Can no.	27	44				
Wt. of wet soil + can (g)	23.95	23.37				
Wt. of dry soil + can (g)	22.70	22.24				
Wt. of can (g)	15.85	15.89				
Wt. of dry soil (g)	6.85	6.35				
Wt. of moisture (g)	1.25	1.13				
Water content, $w\% = w_p$	18.2	17.8			Average	18.0

Tested by: D. Absolon **Date:** 2/14/2011
Submitted By: Wm O Reid **Date:** 2/14/2011

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

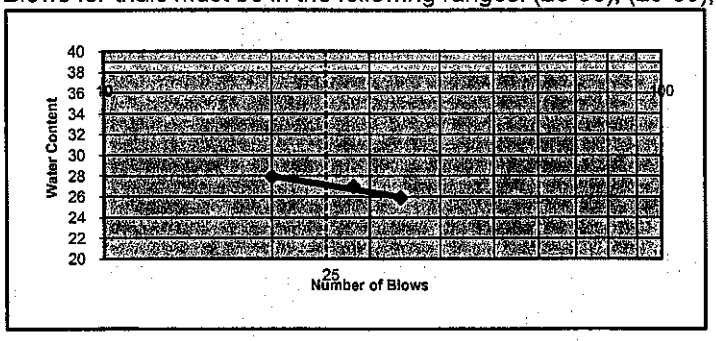
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, trace fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 0' - 17' **Boring No.:** TP - 3 **Sample No.:** Composite

Liquid Limit Determination

Can No.	46	27	41			
Wt. of wet soil +can (g)	24.65	21.73	22.69			
Wt. of dry soil + can (g)	22.88	20.48	21.21			
Wt. of can (g)	16.05	15.85	15.91			
Wt of dry soil (g)	6.83	4.63	5.30			
Wt of moisture (g)	1.77	1.25	1.48			
* No of blows, N (g)	**34**	**28**	**20**			
Water content, *w* %	**25.9**	**27**	**27.9**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 27
Plastic limit = 14
Plasticity index I_p = 13

Plastic Limit Determination

Can no.	30	43				
Wt. of wet soil + can (g)	26.60	25.32				
Wt. of dry soil + can (g)	25.30	24.20				
Wt. of can (g)	16.16	16.18				
Wt. of dry soil (g)	9.14	8.02				
Wt. of moisture (g)	1.30	1.12				
Water content, $w\% = w_p$	14.2	14.0			Average	14.1

Tested by: D. Absolon **Date:** 2/8/2011
Submitted By: [illegible] **Date:** 2/24/11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

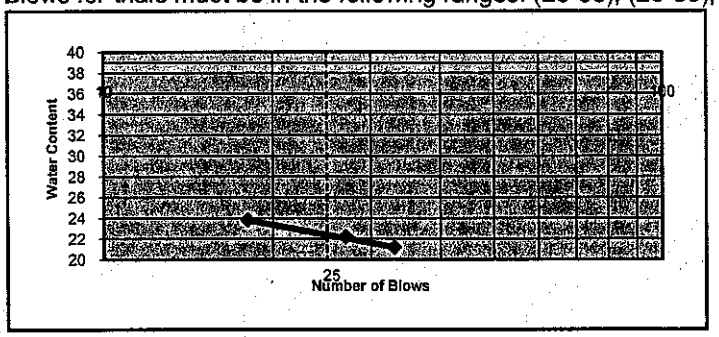
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, some fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 7' - 10' **Boring No.:** TP - 4 **Sample No.:** B

Liquid Limit Determination

Can No.	31	24	45			
Wt. of wet soil +can (g)	21.84	20.79	21.97			
Wt. of dry soil + can (g)	2088	19.91	20.81			
Wt. of can (g)	16.35	15.95	15.94			
Wt of dry soil (g)	4.53	3.96	4.87			
Wt of moisture (g)	0.96	0.88	1.16			
* No of blows, N (g)	**33**	**27**	**18**			
Water content, *w* %	**21.2**	**22.2**	**23.8**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 22
Plastic limit = 13
Plasticity index I_p = 9

Plastic Limit Determination

Can no.	27	44				
Wt. of wet soil + can (g)	25.92	26.72				
Wt. of dry soil + can (g)	24.73	25.44				
Wt. of can (g)	15.85	15.89				
Wt. of dry soil (g)	8.88	9.55				
Wt. of moisture (g)	1.19	1.28				
Water content, $w\% = w_p$	13.4	13.4			Average	13.4

Tested by: D. Absolon / W. Rice **Date:** 2/10/2011
Submitted By: [signature] **Date:** 2/10/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

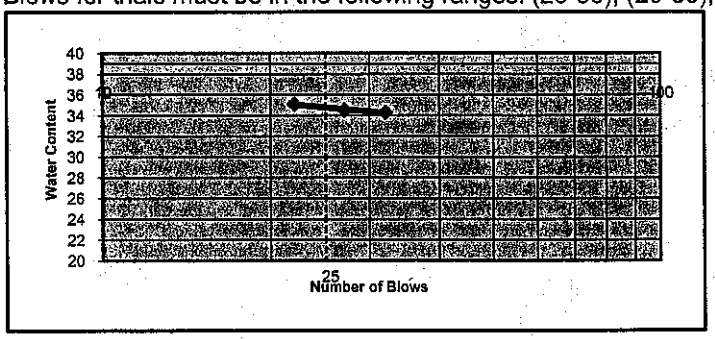
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, tr fine gravel, medium plastic
Depth of Sample: 0' - 17' **Boring No.:** TP - 5 **Sample No.:** Composite

Liquid Limit Determination

Can No.	32	43	31			
Wt. of wet soil +can (g)	22.63	24.66	25.39			
Wt. of dry soil + can (g)	20.90	22.48	23.04			
Wt. of can (g)	15.86	16.16	16.35			
Wt of dry soil (g)	5.04	6.32	6.69			
Wt of moisture (g)	1.73	2.18	2.35			
* No of blows, N (g)	**32**	**27**	**22**			
Water content, *w* %	**34.3**	**34.5**	**35.1**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 35
Plastic limit = 15
Plasticity index I_p = 20

Plastic Limit Determination

Can no.	23	38				
Wt. of wet soil + can (g)	27.62	26.37				
Wt. of dry soil + can (g)	26.12	25.07				
Wt. of can (g)	16.00	16.01				
Wt. of dry soil (g)	10.12	9.06				
Wt. of moisture (g)	1.50	1.30				
Water content, $w\% = w_p$	14.8	14.3			Average	14.6

Tested by: D. Absolon **Date:** 2/7/2011
Submitted By: [signature] **Date:** 2/24/11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

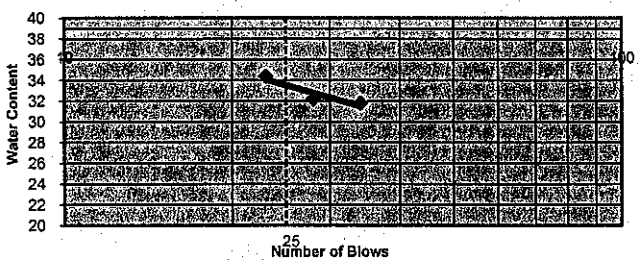
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel,medium plastic
Depth of Sample: 5' - 10' **Boring No.:** TP - 6 **Sample No.:** B

Liquid Limit Determination

Can No.	27	44	30			
Wt. of wet soil +can (g)	27.67	25.08	27.05			
Wt. of dry soil + can (g)	24.82	22.84	24.26			
Wt. of can (g)	15.85	15.88	16.14			
Wt of dry soil (g)	8.97	6.96	8.12			
Wt of moisture (g)	2.85	2.24	2.79			
* No of blows, N (g)	**34**	**28**	**23**			
Water content, *w* %	**31.8**	**32.2**	**34.4**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 33
Plastic limit = 14
Plasticity index I_p = 19

Plastic Limit Determination

Can no.	41	36				
Wt. of wet soil + can (g)	27.95	26.50				
Wt. of dry soil + can (g)	26.42	25.18				
Wt. of can (g)	15.92	15.85				
Wt. of dry soil (g)	10.50	9.33				
Wt. of moisture (g)	1.53	1.32				
Water content, $w\% = w_p$	14.6	14.1				

Tested by: D. Absolon **Date:** 2/7/2011
Submitted By: Wm D Fick **Date:** 2/24/11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

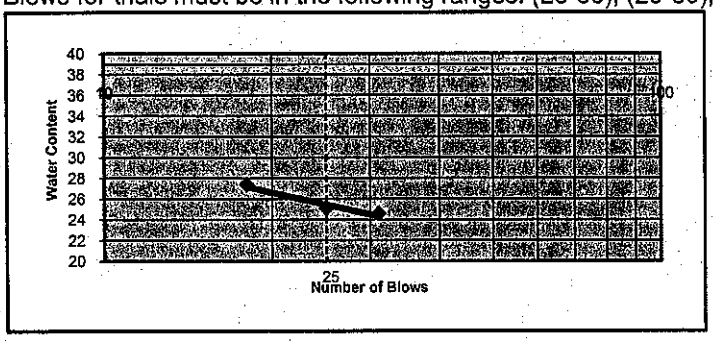
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 10' - 15' **Boring No.:** TP - 7 **Sample No.:** C

Liquid Limit Determination

Can No.	33	21	42			
Wt. of wet soil +can (g)	22.46	22.83	24.55			
Wt. of dry soil + can (g)	21.18	21.44	22.71			
Wt. of can (g)	15.97	15.90	16.00			
Wt of dry soil (g)	5.21	5.54	6.71			
Wt of moisture (g)	1.28	1.39	1.84			
* No of blows, N (g)	**31**	**25**	**18**			
Water content, *w* %	**24.6**	**25.1**	**27.4**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 26
Plastic limit = 13
Plasticity index I_p = 13

Plastic Limit Determination

Can no.	5	44				
Wt. of wet soil + can (g)	24.80	25.42				
Wt. of dry soil + can (g)	23.75	24.31				
Wt. of can (g)	15.81	15.88				
Wt. of dry soil (g)	7.94	8.43				
Wt. of moisture (g)	1.05	1.11				
Water content, $w\% = w_p$	13.2	13.2			Average	13.2

Tested by: D. Absolon **Date:** 2/8/2011
Submitted By: [signature] **Date:** 2/24/11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

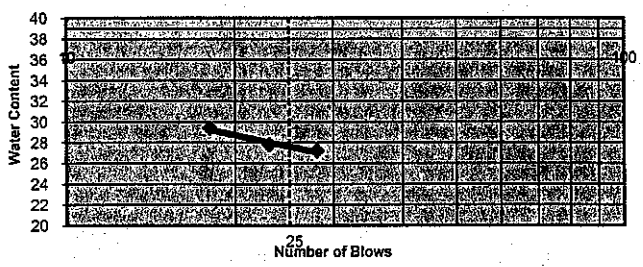
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown,with fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 0' - 5' **Boring No.:** TP - 8 **Sample No.:** A

Liquid Limit Determination

Can No.	40	26	37			
Wt. of wet soil +can (g)	23.32	23.45	22.46			
Wt. of dry soil + can (g)	21.71	21.85	20.99			
Wt. of can (g)	15.79	16.09	15.99			
Wt of dry soil (g)	5.92	5.76	5.00			
Wt of moisture (g)	1.61	1.60	1.47			
* No of blows, N (g)	**28**	**23**	**18**			
Water content, *w* %	**27.2**	**27.8**	**29.4**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 28
Plastic limit = 14
Plasticity index I_p = 14

Plastic Limit Determination

Can no.	32	12				
Wt. of wet soil + can (g)	25.08	25.84				
Wt. of dry soil + can (g)	23.95	24.61				
Wt. of can (g)	15.86	15.91				
Wt. of dry soil (g)	8.09	8.70				
Wt. of moisture (g)	1.13	1.23				
Water content, $w\% = w_p$	14.0	14.1			Average	14.0

Tested by: D. Absolon **Date:** 2/8/2011
Submitted By: Wm D Rice **Date:** 2/24/11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

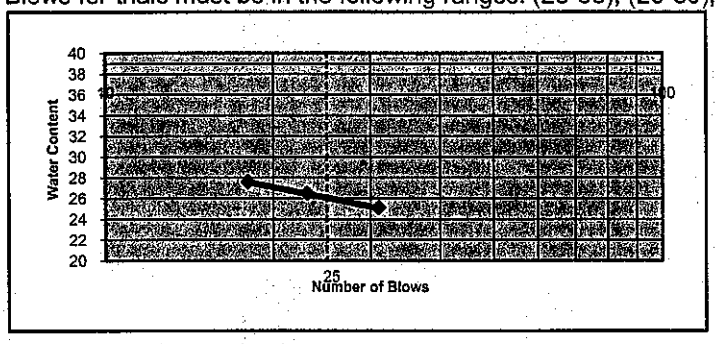
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 5' - 10' **Boring No.:** TP - 9 **Sample No.:** B

Liquid Limit Determination

Can No.	36	38	31			
Wt. of wet soil +can (g)	23.96	23.19	26.42			
Wt. of dry soil + can (g)	22.33	21.68	24.24			
Wt. of can (g)	15.84	15.99	16.34			
Wt of dry soil (g)	6.49	5.69	7.90			
Wt of moisture (g)	1.63	1.51	2.18			
* No of blows, N (g)	**31**	**23**	**18**			
Water content, *w* %	**25.1**	**26.5**	**27.6**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 26
Plastic limit = 14
Plasticity index I_p = 12

Plastic Limit Determination

Can no.	24	23				
Wt. of wet soil + can (g)	26.31	25.26				
Wt. of dry soil + can (g)	25.00	24.10				
Wt. of can (g)	15.94	15.98				
Wt. of dry soil (g)	9.06	8.12				
Wt. of moisture (g)	1.31	1.16				
Water content, $w\% = w_p$	14.5	14.3			Average	14.4

Tested by: D. Absolon **Date:** 2/8/2011
Submitted By: [signature] **Date:** 2/24/11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

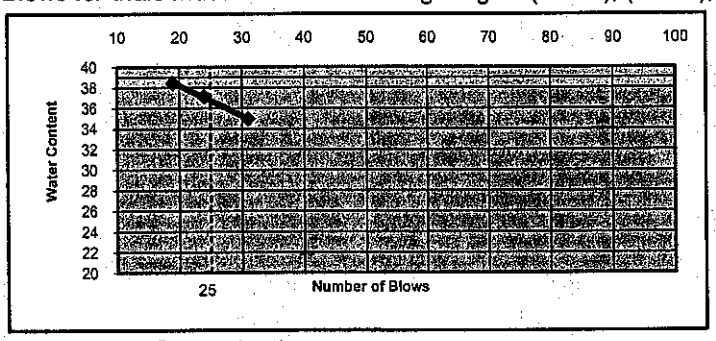
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, tr. Gravel, medium plastic
Depth of Sample: 0' - 17' **Boring No.:** TP - 10 **Sample No.:** Composite

Liquid Limit Determination

Can No.	30	27	41			
Wt. of wet soil +can (g)	23.45	24.06	21.91			
Wt. of dry soil + can (g)	21.56	21.84	20.25			
Wt. of can (g)	16.14	15.85	15.93			
Wt of dry soil (g)	5.42	5.99	4.32			
Wt of moisture (g)	1.89	2.22	1.66			
* No of blows, N (g)	**31**	**24**	**19**			
Water content, *w* %	**34.9**	**37.1**	**38.4**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 37
Plastic limit = 15
Plasticity index I_p = 22

Plastic Limit Determination

Can no.	43	45				
Wt. of wet soil + can (g)	25.17	24.59				
Wt. of dry soil + can (g)	23.97	23.46				
Wt. of can (g)	16.18	15.94				
Wt. of dry soil (g)	7.79	7.52				
Wt. of moisture (g)	1.20	1.13				
Water content, $w\% = w_p$	15.4	15.0			Average	15.2

Tested by: D. Absolon **Date:** 2/9/2011
Submitted By: [signature] **Date:** 2/9/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

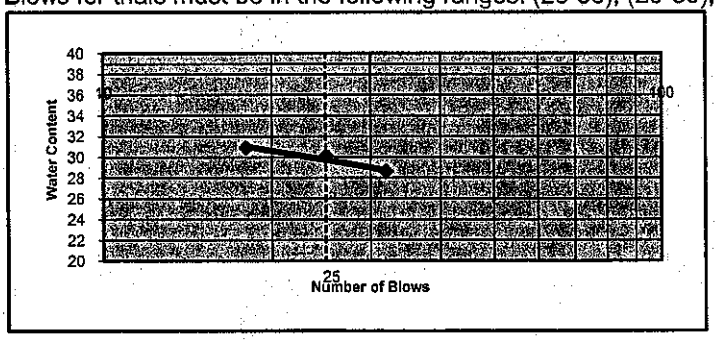
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, tr. gravel, medium plastic
Depth of Sample: 0' - 17' **Boring No.:** TP - 11 **Sample No.:** Composite

Liquid Limit Determination

Can No.	12	26	31			
Wt. of wet soil +can (g)	25.5	24.98	24.69			
Wt. of dry soil + can (g)	23.36	22.92	22.72			
Wt. of can (g)	15.87	16.08	16.35			
Wt of dry soil (g)	7.49	6.84	6.37			
Wt of moisture (g)	2.14	2.06	1.97			
* No of blows, N (g)	**32**	**25**	**18**			
Water content, *w* %	**28.6**	**30.1**	**30.9**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 30
Plastic limit = 14
Plasticity index I_p = 16

Plastic Limit Determination

Can no.	32	24				
Wt. of wet soil + can (g)	26.06	26.87				
Wt. of dry soil + can (g)	24.78	25.52				
Wt. of can (g)	15.85	15.95				
Wt. of dry soil (g)	8.93	9.57				
Wt. of moisture (g)	1.28	1.35				
Water content, $w\% = w_p$	14.3	14.1			Average	14.2

Tested by: D. Absolon **Date:** 2/9/2011
Submitted By: [signature] **Date:** 2/9/2011

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

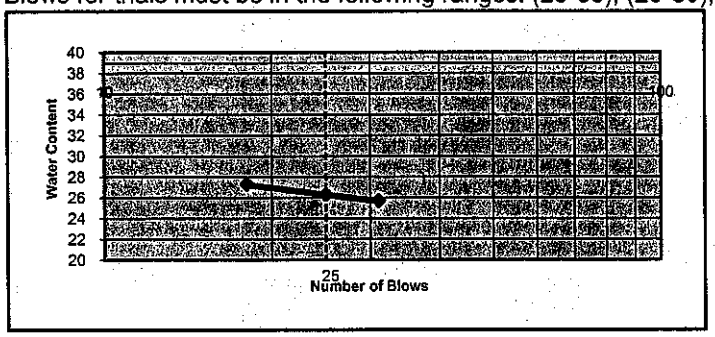
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 1/27/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, some f-c gravel, medium plastic
Depth of Sample: 0' - 17' **Boring No.:** TP - 12 **Sample No.:** Composite

Liquid Limit Determination

Can No.	20	25	39			
Wt. of wet soil +can (g)	28.42	26.43	23.00			
Wt. of dry soil + can (g)	27.18	25.10	21.50			
Wt. of can (g)	22.35	20.05	16.01			
Wt of dry soil (g)	4.83	5.05	5.49			
Wt of moisture (g)	1.24	1.33	1.50			
* No of blows, N (g)	**31**	**25**	**18**			
Water content, *w* %	**25.7**	**26.3**	**27.3**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 26
Plastic limit = 15
Plasticity index I_p = 11

Plastic Limit Determination

Can no.	45	9				
Wt. of wet soil + can (g)	26.59	26.92				
Wt. of dry soil + can (g)	25.24	25.51				
Wt. of can (g)	15.95	15.88				
Wt. of dry soil (g)	9.29	9.63				
Wt. of moisture (g)	1.35	1.41				
Water content, $w\% = w_p$	14.5	14.6			Average	14.6

Tested by: D. Absolon **Date:** 2/8/2011
Submitted By: Wm D Rice **Date:** 2/24/11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

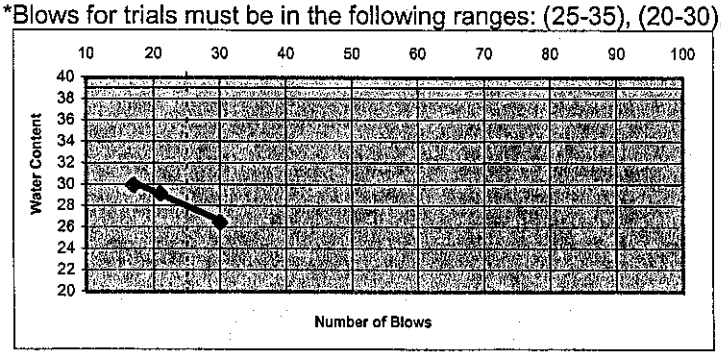
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 0 - 15' **Boring No.:** TP - 14 **Sample No.:** Composite

Liquid Limit Determination

Can No.	24	21	31			
Wt. of wet soil +can (g)	24.32	22.72	22.60			
Wt. of dry soil + can (g)	22.73	21.38	21.33			
Wt. of can (g)	15.95	15.90	16.35			
Wt of dry soil (g)	6.78	5.48	4.98			
Wt of moisture (g)	1.59	1.34	1.27			
* No of blows, N (g)	**34**	**26**	**18**			
Water content, *w* %	**23.5**	**24.5**	**25.5**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 25
Plastic limit = 14
Plasticity index I_p = 11

Plastic Limit Determination

Can no.	39	26				
Wt. of wet soil + can (g)	25.55	25.19				
Wt. of dry soil + can (g)	24.38	24.07				
Wt. of can (g)	16.00	16.08				
Wt. of dry soil (g)	8.38	7.99				
Wt. of moisture (g)	1.17	1.12				
Water content, $w\% = w_p$	14.0	14.0			Average	14.0

Tested by: D. Absolon **Date:** 2/23/2011
Submitted By: [signature] **Date:** 3-4-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

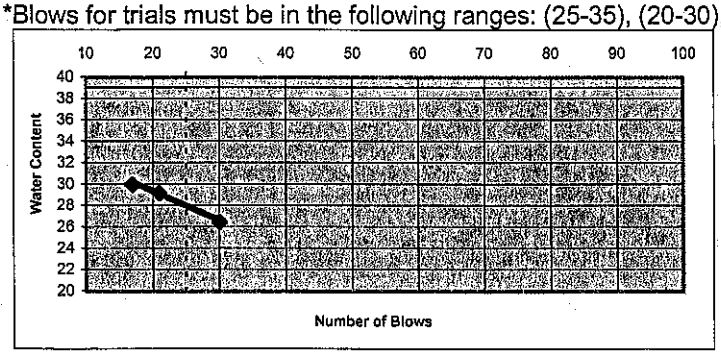
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 2' - 15' **Boring No.:** TP - 15 **Sample No.:** Composite

Liquid Limit Determination

Can No.	42	38	43			
Wt. of wet soil +can (g)	21.98	22.88	22.91			
Wt. of dry soil + can (g)	20.71	21.36	21.35			
Wt. of can (g)	16.00	16.01	16.17			
Wt of dry soil (g)	4.71	5.35	5.18			
Wt of moisture (g)	1.27	1.52	1.56			
* No of blows, N (g)	**30**	**24**	**18**			
Water content, *w* %	**27.0**	**28.4**	**30.1**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 28
Plastic limit = 14
Plasticity index I_p = 14

Plastic Limit Determination

Can no.	24	33				
Wt. of wet soil + can (g)	24.02	24.75				
Wt. of dry soil + can (g)	23.02	23.65				
Wt. of can (g)	15.97	15.95				
Wt. of dry soil (g)	7.05	7.70				
Wt. of moisture (g)	1.00	1.10				
Water content, $w\% = w_p$	14.2	14.3			Average	14.2

Tested by: D. Absolon **Date:** 2/24/2011
Submitted By: [signature] **Date:** 3-4-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

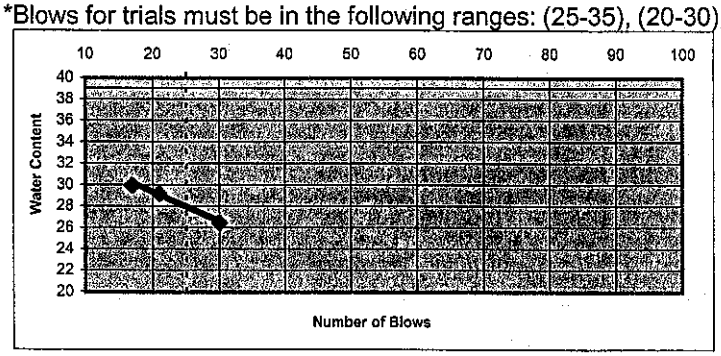
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 0' - 15' **Boring No.:** TP - 16 **Sample No.:** Composite

Liquid Limit Determination

Can No.	44	32	36			
Wt. of wet soil +can (g)	22.83	22.68	23.17			
Wt. of dry soil + can (g)	21.55	21.36	21.69			
Wt. of can (g)	15.89	15.85	15.85			
Wt of dry soil (g)	5.66	5.51	5.84			
Wt of moisture (g)	1.28	1.32	1.48			
* No of blows, N (g)	**34**	**25**	**18**			
Water content, *w* %	**22.6**	**24.0**	**25.3**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 24
Plastic limit = 14
Plasticity index I_p = 10

Plastic Limit Determination

Can no.	43	27				
Wt. of wet soil + can (g)	26.54	24.67				
Wt. of dry soil + can (g)	25.26	23.60				
Wt. of can (g)	16.17	15.85				
Wt. of dry soil (g)	9.09	7.75				
Wt. of moisture (g)	1.28	1.07				
Water content, $w\% = w_p$	14.1	13.8			Average	14.0

Tested by: D. Absolon **Date:** 2/23/2011
Submitted By: [signature] **Date:** 3-4-11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

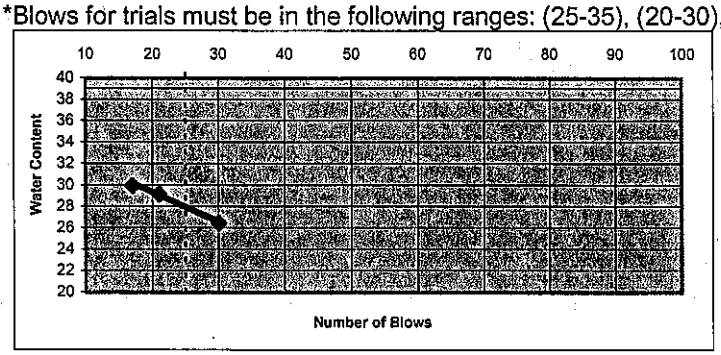
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 3' - 15' **Boring No.:** TP - 17 **Sample No.:** Composite

Liquid Limit Determination

Can No.	42	46	38			
Wt. of wet soil +can (g)	22.2	22.48	22.67			
Wt. of dry soil + can (g)	21.08	21.28	21.35			
Wt. of can (g)	16.01	16.05	16.01			
Wt of dry soil (g)	5.07	5.23	5.34			
Wt of moisture (g)	1.12	1.20	1.32			
* No of blows, N (g)	**34**	**28**	**20**			
Water content, *w* %	**22.1**	**22.9**	**24.7**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 24
Plastic limit = 14
Plasticity index I_p = 10

Plastic Limit Determination

Can no.	33	9				
Wt. of wet soil + can (g)	25.95	26.43				
Wt. of dry soil + can (g)	24.71	25.19				
Wt. of can (g)	15.96	15.88				
Wt. of dry soil (g)	8.75	9.31				
Wt. of moisture (g)	1.24	1.24				
Water content, $w\% = w_p$	14.2	13.3			Average	13.8

Tested by: D. Absolon **Date:** 2/23/2011
Submitted By: [signature] **Date:** 3-4-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

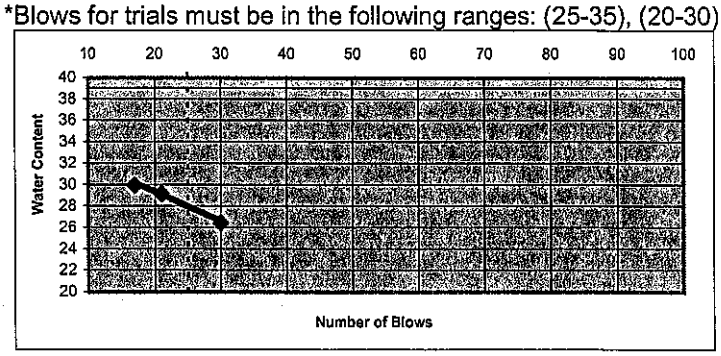
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, highly plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 0' - 15' **Boring No.:** TP - 18 **Sample No.:** Composite

Liquid Limit Determination

Can No.	23	41	12			
Wt. of wet soil +can (g)	21.57	22.00	22.33			
Wt. of dry soil + can (g)	20.11	20.36	20.50			
Wt. of can (g)	15.99	15.91	15.87			
Wt of dry soil (g)	4.12	4.45	4.63			
Wt of moisture (g)	1.46	1.64	1.83			
* No of blows, N (g)	**34**	**24**	**18**			
Water content, *w* %	**35.4**	**36.9**	**39.5**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 37
Plastic limit = 15
Plasticity index I_p = 25

Plastic Limit Determination

Can no.	37	1				
Wt. of wet soil + can (g)	25.03	31.14				
Wt. of dry soil + can (g)	23.86	29.99				
Wt. of can (g)	15.98	22.19				
Wt. of dry soil (g)	7.88	7.80				
Wt. of moisture (g)	1.17	1.15				
Water content, $w\% = w_p$	14.8	14.7			Average	14.8

Tested by: D. Absolon **Date:** 2/23/2011
Submitted By: [signature] **Date:** 3-4-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

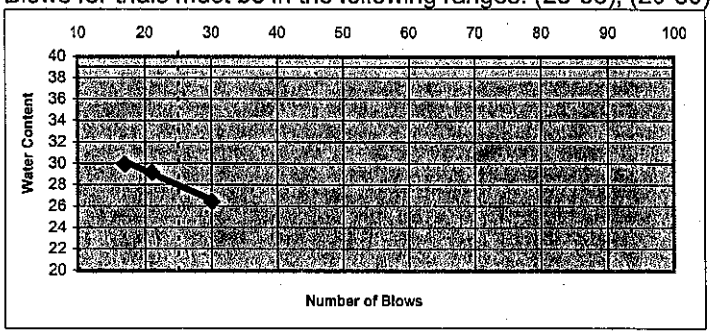
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 0' - 16' **Boring No.:** TP - 19 **Sample No.:** Composite

Liquid Limit Determination

Can No.	42	40	23			
Wt. of wet soil +can (g)	23.00	22.58	22.94			
Wt. of dry soil + can (g)	21.68	21.26	21.56			
Wt. of can (g)	16.02	15.79	16.00			
Wt of dry soil (g)	5.66	5.47	5.56			
Wt of moisture (g)	1.32	1.32	1.38			
* No of blows, N (g)	**34**	**26**	**19**			
Water content, *w* %	**23.3**	**24.1**	**24.8**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 24
Plastic limit = 15
Plasticity index I_p = 9

Plastic Limit Determination

Can no.	30	36				
Wt. of wet soil + can (g)	26.53	25.58				
Wt. of dry soil + can (g)	25.18	24.32				
Wt. of can (g)	16.15	15.85				
Wt. of dry soil (g)	9.03	8.47				
Wt. of moisture (g)	1.35	1.26				
Water content, $w\% = w_p$	15.0	14.9			Average	15.0

Tested by: D. Absolon **Date:** 3/1/2011
Submitted By: [illegible] **Date:** 3-4-11

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635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

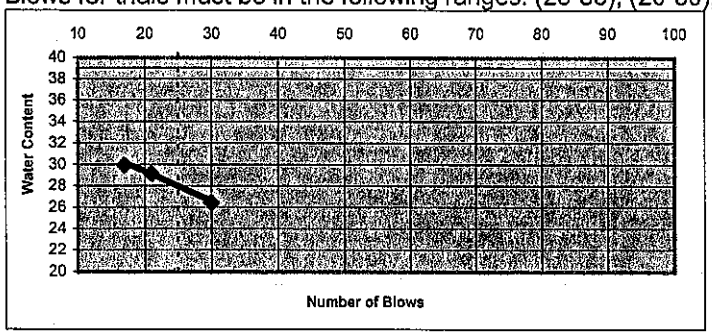
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 0' - 16' **Boring No.:** TP - 20 **Sample No.:** Composite

Liquid Limit Determination

Can No.	32	46	44			
Wt. of wet soil +can (g)	21.04	22.57	22.84			
Wt. of dry soil + can (g)	20.02	21.22	21.32			
Wt. of can (g)	15.85	16.06	15.89			
Wt of dry soil (g)	4.17	5.16	5.43			
Wt of moisture (g)	1.02	1.35	1.52			
* No of blows, N (g)	**35**	**29**	**18**			
Water content, *w* %	**24.5**	**26.2**	**28.0**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 26
Plastic limit = 14
Plasticity index I_p = 12

Plastic Limit Determination

Can no.	12	31				
Wt. of wet soil + can (g)	25.22	25.38				
Wt. of dry soil + can (g)	24.07	24.27				
Wt. of can (g)	15.88	16.35				
Wt. of dry soil (g)	8.19	7.92				
Wt. of moisture (g)	1.15	1.11				
Water content, $w\% = w_p$	14.0	14.0			Average	14.0

Tested by: D. Absolon **Date:** 2/24/2011
Submitted By: [signature] **Date:** 3-4-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

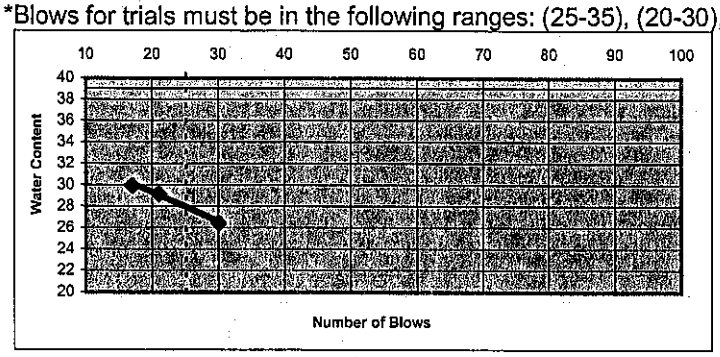
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 0' - 21' **Boring No.:** TP - 21 **Sample No.:** Composite

Liquid Limit Determination

Can No.	20	25	40			
Wt. of wet soil +can (g)	29.28	26.41	24.16			
Wt. of dry soil + can (g)	27.85	25.05	22.33			
Wt. of can (g)	22.34	20.03	15.78			
Wt of dry soil (g)	5.51	5.02	6.55			
Wt of moisture (g)	1.43	1.36	1.83			
* No of blows, N (g)	**31**	**24**	**17**			
Water content, *w* %	**26.0**	**27.1**	**27.9**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 27
Plastic limit = 14
Plasticity index I_p = 13

Plastic Limit Determination

Can no.	30	5				
Wt. of wet soil + can (g)	25.21	24.93				
Wt. of dry soil + can (g)	24.12	23.80				
Wt. of can (g)	16.15	15.80				
Wt. of dry soil (g)	7.97	8.00				
Wt. of moisture (g)	1.09	1.13				
Water content, $w\% = w_p$	13.7	14.1			Average	13.9

Tested by: D. Absolon **Date:** 2/24/2011
Submitted By: [signature] **Date:** 3-4-11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

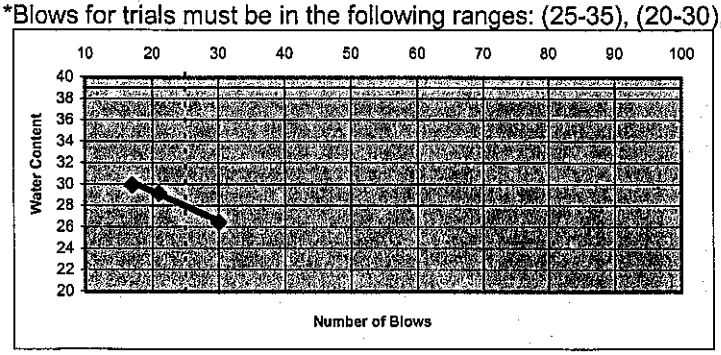
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 4' - 15' **Boring No.:** TP - 22 **Sample No.:** Composite

Liquid Limit Determination

Can No.	45	26	37			
Wt. of wet soil +can (g)	22.55	22.98	22.64			
Wt. of dry soil + can (g)	21.18	21.49	21.15			
Wt. of can (g)	15.92	16.08	15.98			
Wt of dry soil (g)	5.26	5.41	5.17			
Wt of moisture (g)	1.37	1.49	1.49			
* No of blows, N (g)	**31**	**24**	**17**			
Water content, *w* %	**26.0**	**27.5**	**28.8**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 27
Plastic limit = 14
Plasticity index I_p = 13

Plastic Limit Determination

Can no.	21	23				
Wt. of wet soil + can (g)	24.49	25.33				
Wt. of dry soil + can (g)	23.41	24.17				
Wt. of can (g)	15.9	16.00				
Wt. of dry soil (g)	7.51	8.17				
Wt. of moisture (g)	1.08	1.16				
Water content, $w\% = w_p$	14.4	14.2			Average	14.3

Tested by: D. Absolon **Date:** 2/24/2011
Submitted By: [signature] **Date:** 3-4-11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

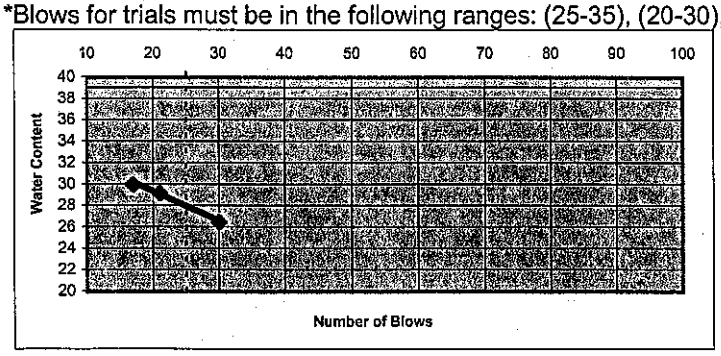
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 2' - 15' **Boring No.:** TP - 23 **Sample No.:** Composite

Liquid Limit Determination

Can No.	33	43	31			
Wt. of wet soil +can (g)	22.56	23.31	22.58			
Wt. of dry soil + can (g)	21.37	22.00	21.38			
Wt. of can (g)	15.97	16.17	16.34			
Wt of dry soil (g)	5.40	5.83	5.04			
Wt of moisture (g)	1.19	1.31	1.2			
* No of blows, N (g)	**30**	**25**	**19**			
Water content, *w* %	**22.0**	**22.5**	**23.8**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 23
Plastic limit = 14
Plasticity index I_p = 9

Plastic Limit Determination

Can no.	12	5				
Wt. of wet soil + can (g)	25.57	25.46				
Wt. of dry soil + can (g)	24.34	24.25				
Wt. of can (g)	15.87	15.80				
Wt. of dry soil (g)	8.47	8.45				
Wt. of moisture (g)	1.23	1.21				
Water content, $w\% = w_p$	14.5	14.3			Average	14.4

Tested by: D. Absolon **Date:** 3/1/2011
Submitted By: [signature] **Date:** 3-4-11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

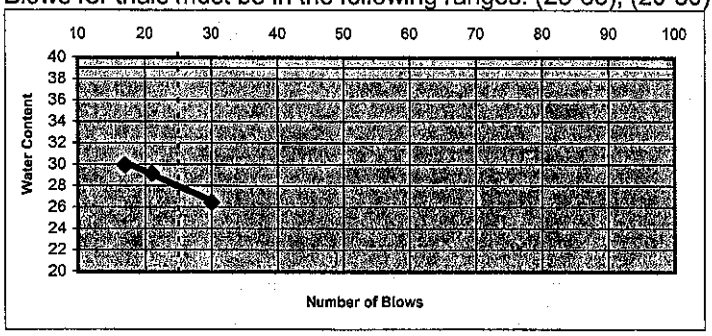
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, red-brown, medium plastic, with fine to coarse sand, trace fine gravel
Depth of Sample: 2' - 16' **Boring No.:** TP - 24 **Sample No.:** Composite

Liquid Limit Determination

Can No.	41	9	27			
Wt. of wet soil +can (g)	22.46	22.70	21.98			
Wt. of dry soil + can (g)	21.31	21.45	20.80			
Wt. of can (g)	15.92	15.88	15.85			
Wt of dry soil (g)	5.39	5.57	4.95			
Wt of moisture (g)	1.15	1.25	1.18			
* No of blows, N (g)	**29**	**23**	**18**			
Water content, *w* %	**21.3**	**22.4**	**23.8**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 22
Plastic limit = 14
Plasticity index I_p = 8

Plastic Limit Determination

Can no.	36	39				
Wt. of wet soil + can (g)	25.14	25.98				
Wt. of dry soil + can (g)	23.97	24.72				
Wt. of can (g)	15.85	16.00				
Wt. of dry soil (g)	8.12	8.72				
Wt. of moisture (g)	1.17	1.26				
Water content, $w\% = w_p$	14.4	14.4			Average	14.4

Tested by: D. Absolon **Date:** 2/24/2011
Submitted By: [signature] **Date:** 3-4-11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

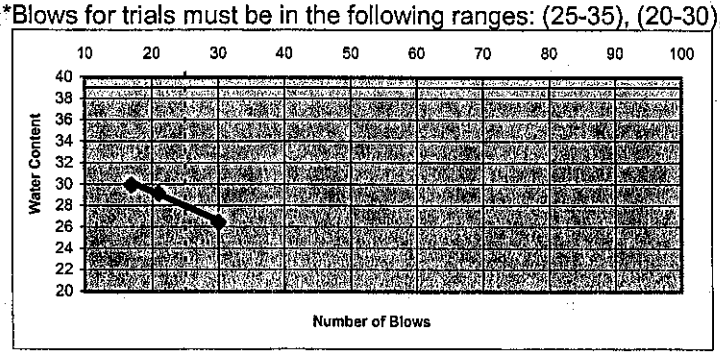
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/17/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (SP-SM) SAND, brown, fine to coarse, with fine to coarse gravel, some silt, non-plastic
Depth of Sample: 2' - 3' **Boring No.:** TP - 26 **Sample No.:** A

Liquid Limit Determination

Can No.						
Wt. of wet soil +can (g)						
Wt. of dry soil + can (g)						
Wt. of can (g)						
Wt of dry soil (g)						
Wt of moisture (g)						
* No of blows, N (g)						
Water content, *w* %	**Non Plastic**					
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = Non Plastic
Plastic limit =
Plasticity index I_p =

Plastic Limit Determination

Can no.						
Wt. of wet soil + can (g)						
Wt. of dry soil + can (g)						
Wt. of can (g)						
Wt. of dry soil (g)						
Wt. of moisture (g)	Non Plastic					
Water content, $w\% = w_p$					Average	

Tested by: D. Absolon **Date:** 2/22/2011
Submitted By: [signature] **Date:** 3-4-11

Form D4318 Revised: 03-22-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

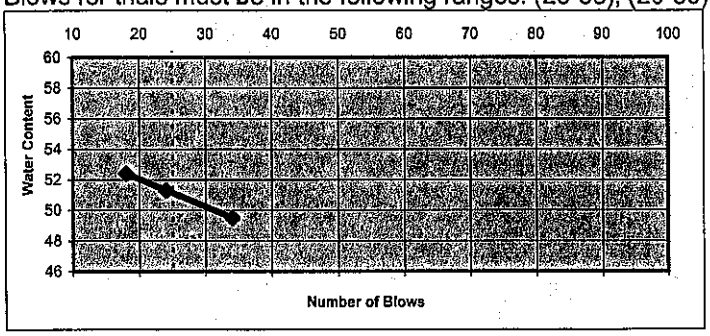
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/4/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CH) FAT CLAY, brown, some fine to coarse sand, tr. fine gravel, highly plastic
Depth of Sample: 20.3' - 21.8' **Boring No.:** BH-01 **Sample No.:** 6 / 6A

Liquid Limit Determination

Can No.	24	33	43			
Wt. of wet soil +can (g)	22.77	22.86	21.77			
Wt. of dry soil + can (g)	20.51	20.52	19.84			
Wt. of can (g)	15.94	15.96	16.16			
Wt of dry soil (g)	4.57	4.56	3.68			
Wt of moisture (g)	2.26	2.34	1.93			
* No of blows, N (g)	**34**	**24**	**18**			
Water content, *w* %	**49.5**	**51.3**	**52.4**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 51
Plastic limit = 18
Plasticity index I_p = 33

Plastic Limit Determination

Can no.	31	45				
Wt. of wet soil + can (g)	24.63	24.1				
Wt. of dry soil + can (g)	23.34	22.86				
Wt. of can (g)	16.34	15.93				
Wt. of dry soil (g)	7.00	6.93				
Wt. of moisture (g)	1.29	1.24				
Water content, $w\% = w_p$	18.4	17.9			Average	18.2

Tested by: D. Absolon **Date:** 2/15/2011
Submitted By: [signature] **Date:** 2/15/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

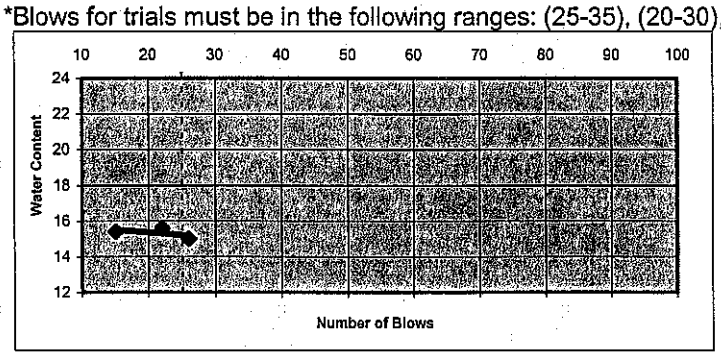
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/4/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (SM) SILTY SAND, brown, fine to coarse sand, some fine gravel, slightly plastic
Depth of Sample: 25.0' - 26.5' **Boring No.:** BH-04 **Sample No.:** 6 / 6A

Liquid Limit Determination

Can No.	27	44	39			
Wt. of wet soil +can (g)	24.37	22.10	22.67			
Wt. of dry soil + can (g)	23.26	24.26	21.78			
Wt. of can (g)	15.85	15.89	16.00			
Wt of dry soil (g)	7.41	5.37	5.78			
Wt of moisture (g)	1.11	0.84	0.89			
* No of blows, N (g)	**26**	**22**	**15**			
Water content, *w* %	**15.0**	**15.6**	**15.4**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 15
Plastic limit = 12
Plasticity index I_p = 3

Plastic Limit Determination

Can no.	41	26				
Wt. of wet soil + can (g)	25.74	26.13				
Wt. of dry soil + can (g)	24.65	25.03				
Wt. of can (g)	15.92	16.08				
Wt. of dry soil (g)	8.73	8.95				
Wt. of moisture (g)	1.09	1.10				
Water content, $w\% = w_p$	12.5	12.3			Average	12.4

Tested by: D. Absolon **Date:** 2/15/2011
Submitted By: [signature] **Date:** 2/15/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

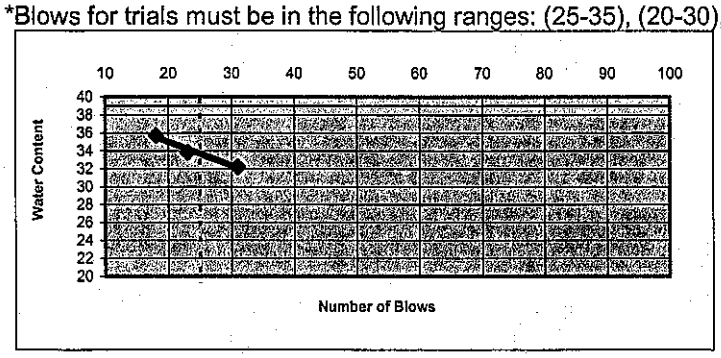
ASTM D-4318

Project: Copperwood Tailings Facility **Job No.:** GL-11006
Client: Orvana Resources US Corp. **Date Received:** 2/4/2011
Address: N10199 Lake Road Ironwood MI 49938
Description of Soil: (CL) LEAN CLAY, brown, with fine to coarse sand, trace gravel, medium plastic
Depth of Sample: 9.5' - 11.0' **Boring No.:** BH-10 **Sample No.:** 3 / 3A

Liquid Limit Determination

Can No.	24	33	31			
Wt. of wet soil +can (g)	22.43	21.63	23.96			
Wt. of dry soil + can (g)	20.85	20.20	21.96			
Wt. of can (g)	15.95	15.97	16.35			
Wt of dry soil (g)	4.9	4.23	5.61			
Wt of moisture (g)	1.58	1.43	2.00			
* No of blows, N (g)	**31**	**23**	**18**			
Water content, *w* %	**32.2**	**33.8**	**35.7**			
K Values and Corrected Average					**Corrected Average**	

*Blows for trials must be in the following ranges: (25-35), (20-30), (15-25)



Liquid limit = 34
Plastic limit = 14
Plasticity index I_p = 20

Plastic Limit Determination

Can no.	26	45				
Wt. of wet soil + can (g)	25.68	24.94				
Wt. of dry soil + can (g)	24.44	23.82				
Wt. of can (g)	16.08	15.94				
Wt. of dry soil (g)	8.36	7.88				
Wt. of moisture (g)	1.24	1.12				
Water content, *w* % = w_p	14.8	14.2			Average	14.5

Tested by: D. Absolon **Date:** 2/14/2011
Submitted By: [signature] **Date:** 2/14/2011

Knight Piésold CONSULTING

Appendix F-3

Laboratory Test Data – Natural Moisture Content Data (Test Pits and Boreholes)

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: 11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, MI Date: 1/31/2011

Boring No.	TP - 1	TP - 1	TP - 2	TP - 2	TP - 2
Sample No.	A	B	A	B	C
Depth (ft.)	0' - 3'	13' - 16'	4'	10' - 12'	15'
Pan No.	75	51	62	66	68
Weight-Wet Sample & Tare (g)	245.28	572.34	596.00	527.22	521.76
Weight-Dry Sample & Tare (g)	231.45	541.45	564.15	496.47	487.98
Weight of Moisture (g)	13.83	30.89	31.85	30.75	33.78
Weight of Tare (g)	103.47	343.00	342.09	343.93	341.92
Weight of Dry Soil (g)	127.98	198.45	222.06	152.54	146.06
Moisture Content (%)	10.8	15.6	14.3	20.2	23.1

Boring No.	TP - 3	TP - 3	TP - 3	TP - 4	TP - 4
Sample No.	A	B	C	A	B
Depth (ft.)	0' - 3'	9' - 12'	13' - 17'	0' - 7'	7' - 10'
Pan No.	76	2	64	58	60
Weight-Wet Sample & Tare (g)	294.95	353.95	604.16	549.26	601.72
Weight-Dry Sample & Tare (g)	265.72	317.95	571.93	527.12	569.77
Weight of Moisture (g)	29.23	36.00	32.23	22.14	31.95
Weight of Tare (g)	103.25	109.38	343.89	342.28	341.14
Weight of Dry Soil (g)	162.47	208.57	228.04	184.84	228.63
Moisture Content (g)	18.0	17.3	14.1	12.0	14.0

Remarks:

Tested By: D. Absolon Date: 2/1/2011

Submitted By: [signature] Date: 2/14/11

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: 11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, MI Date: 1/31/2011

Boring No.	TP - 5	TP - 5	TP - 6	TP - 6	TP - 6
Sample No.	A	B	A	B	C
Depth (ft.)	4'	12'	0' - 5'	5' - 10'	10' - 15'
Pan No.	61	26	54	83	79
Weight-Wet Sample & Tare (g)	632.99	354.2	574.95	719.20	471.07
Weight-Dry Sample & Tare (g)	599.78	327.26	547.26	668.94	419.01
Weight of Moisture (g)	33.21	26.94	27.69	50.26	52.06
Weight of Tare (g)	341.37	116.26	344.10	342.36	105.20
Weight of Dry Soil (g)	258.41	211.0	203.16	326.58	313.81
Moisture Content (%)	12.9	12.8	13.6	15.4	16.6

Boring No.	TP - 7	TP - 7	TP - 7	TP - 8	TP - 8
Sample No.	A	B	C	A	B
Depth (ft.)	0' - 5'	5' - 10'	10' - 15'	0' - 5'	5' - 10'
Pan No.	56	67	77	55	63
Weight-Wet Sample & Tare (g)	725.21	618.90	507.98	737.34	674.49
Weight-Dry Sample & Tare (g)	692.60	583.97	470.64	692.67	634.53
Weight of Moisture (g)	32.61	34.93	37.34	44.67	39.96
Weight of Tare (g)	341.86	342.52	104.15	342.16	343.24
Weight of Dry Soil (g)	350.74	241.45	366.49	350.51	291.29
Moisture Content (g)	9.3	14.5	10.2	12.7	13.7

Remarks:

Tested By: D. Absolon Date: 2/1/2011

Submitted By: Chr Nassen Date: 2/14/11

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: 11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, MI Date: 1/31/2011

Boring No.	TP - 8	TP - 9	TP - 9	TP - 9	
Sample No.	C	A	B	C	
Depth (ft.)	10' - 15'	0' - 5'	5' - 10'	10' - 15'	
Pan No.	50	65	59	16	
Weight-Wet Sample & Tare (g)	653.27	851.33	854.54	528.49	
Weight-Dry Sample & Tare (g)	599.93	798.67	799.82	483.80	
Weight of Moisture (g)	53.34	52.66	54.72	44.69	
Weight of Tare (g)	341.80	342.79	343.18	116.59	
Weight of Dry Soil (g)	258.13	455.88	456.64	367.21	
Moisture Content (%)	20.7	11.6	12.0	12.2	

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: D. Absolon Date: 2/1/2011

Submitted By: [signature] Date: 2/14/11

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: 11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, MI Date: 1/31/2011

Boring No.	TP - 10	TP - 10	TP - 10	TP - 11	TP - 11
Sample No.	A	B	C	A	B
Depth (ft.)	5'	10'	15'	5'	10'
Pan No.	68	63	83	54	60
Weight-Wet Sample & Tare (g)	637.74	656.86	672.67	835.17	904.95
Weight-Dry Sample & Tare (g)	602.43	616.98	617.27	778.21	846.79
Weight of Moisture (g)	35.31	39.88	55.40	56.96	58.16
Weight of Tare (g)	341.91	343.18	342.32	344.09	341.13
Weight of Dry Soil (g)	260.52	273.80	274.95	434.12	505.66
Moisture Content (%)	13.6	14.6	20.1	13.1	11.5

Boring No.	TP - 11	TP - 12	TP - 12	TP - 12	
Sample No.	C	A	B	C	
Depth (ft.)	15'	0' - 5'	5' - 10'	10' - 15'	
Pan No.	58	64	2	50	
Weight-Wet Sample & Tare (g)	882.26	855.05	571.60	870.83	
Weight-Dry Sample & Tare (g)	820.46	811.11	531.07	821.66	
Weight of Moisture (g)	61.80	43.94	40.53	49.17	
Weight of Tare (g)	342.30	343.83	109.38	341.80	
Weight of Dry Soil (g)	478.16	467.28	421.69	479.86	
Moisture Content (g)	12.9	9.4	9.6	10.2	

Remarks:

Tested By: D. Absolon Date: 2/2/2011

Submitted By: [signature] Date: 2/14/11

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/17/2011

Boring No.	BH-01	BH-01	BH-01	BH-01	BH-01
Sample No.	1	2	4	6	8B
Depth (ft.)	0-1.5	4.5-6.0	10.0-11.5	20.3-21.8	20.3-31.8
Pan No.	27	31	45	44	39
Weight-Wet Sample & Tare (g)	38.81	44.89	54.71	33.85	38.63
Weight-Dry Sample & Tare (g)	34.60	43.01	51.12	30.15	33.79
Weight of Moisture (g)	4.21	1.88	3.59	3.70	4.84
Weight of Tare (g)	15.85	16.34	15.94	15.89	16.00
Weight of Dry Soil (g)	18.75	26.67	35.18	14.26	17.79
Moisture Content (%)	22.5	7.0	10.2	25.9	27.2

Boring No.	BH-01	BH-01	BH-01	BH-01	BH-01
Sample No.	10A	11B	12B	14B	19B
Depth (ft.)	40.3-41.8	45.3-46.8	50.3-51.8	60.3-61.8	85.3-86.8
Pan No.	30	33	26	24	36
Weight-Wet Sample & Tare (g)	43.86	36.37	53.10	46.42	45.50
Weight-Dry Sample & Tare (g)	40.93	33.82	48.61	41.89	43.81
Weight of Moisture (g)	2.93	2.55	4.49	4.53	1.69
Weight of Tare (g)	16.15	15.96	16.08	15.94	15.85
Weight of Dry Soil (g)	24.78	17.86	32.53	25.95	27.96
Moisture Content (g)	11.8	14.3	13.8	17.5	6.0

Remarks:

Tested By: Graham Donahue Date: 2/17/2011

Submitted By: Ch Dam Date: 2/17/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/17/2011

Boring No.	BH-01	BH-01	BH-01	BH-01	
Sample No.	18B	17B	16B	20B	
Depth (ft.)	80.3-81.8	75.4-76.9	70.3-71.8	90.3-91.8	
Pan No.	46	21	37	13	
Weight-Wet Sample & Tare (g)	43.89	35.37	38.55	56.41	
Weight-Dry Sample & Tare (g)	41.52	33.37	36.41	53.52	
Weight of Moisture (g)	2.37	2.00	2.14	2.89	
Weight of Tare (g)	16.05	15.90	15.99	22.13	
Weight of Dry Soil (g)	25.47	17.47	20.42	31.39	
Moisture Content (%)	9.3	11.4	10.5	9.2	

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: Graham Donahue Date: 2/17/2011

Submitted By: Date: 2/17/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	BH-04	BH-04	BH-04	BH-04	BH-04
Sample No.	1	2A	4	6A	7A
Depth (ft.)	0-1.5	5-6.5	15-16.5	25-26.5	30-31.5
Pan No.	36	24	9	30	33
Weight-Wet Sample & Tare (g)	31.64	60.03	29.81	28.69	49.03
Weight-Dry Sample & Tare (g)	28.2	55.31	27.73	27.37	47.01
Weight of Moisture (g)	3.44	4.72	2.08	1.32	2.02
Weight of Tare (g)	15.85	15.99	15.88	16.15	15.97
Weight of Dry Soil (g)	12.35	39.32	11.85	11.22	31.04
Moisture Content (%)	27.9	12.0	17.6	11.8	6.5

Boring No.	BH-04	BH-04			
Sample No.	8A	12			
Depth (ft.)	35-36.5	45-45.2			
Pan No.	26	44			
Weight-Wet Sample & Tare (g)	39.28	33.63			
Weight-Dry Sample & Tare (g)	37.38	32.37			
Weight of Moisture (g)	1.90	1.26			
Weight of Tare (g)	16.10	15.90			
Weight of Dry Soil (g)	21.28	16.47			
Moisture Content (g)	8.9	7.7			

Remarks:

Tested By: Graham Donahue Date: 2/18/2011

Submitted By: Date: 2/18/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/24/2011

Boring No.	**BH-04**	**BH-04**			
Sample No.	**ST**	**ST**			
Depth (ft.)	**9.5' - 11.7'**	**20' - 22.5'**			
Pan No.	**56**	**62**			
Weight-Wet Sample & Tare (g)	**456.71**	**450.97**			
Weight-Dry Sample & Tare (g)	**442.88**	**436.74**			
Weight of Moisture (g)	**13.83**	**14.23**			
Weight of Tare (g)	**341.92**	**342.09**			
Weight of Dry Soil (g)	**100.96**	**94.65**			
Moisture Content (%)	**13.7**	**15.0**			

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: Graham Donahue & Dan Absolon Date: 2/24/2011

Submitted By: Date: 2/24/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	BH-05	BH-05	BH-05	BH-05	BH-05
Sample No.	2B	3B	5A	7B	9B
Depth (ft.)	5.0-6.5	10.0-11.5	22.0-23.5	32.0-33.5	42.0-43.5
Pan No.	23	21	26	41	36
Weight-Wet Sample & Tare (g)	45.99	39.18	41.53	33.84	36.20
Weight-Dry Sample & Tare (g)	41.93	35.43	37.45	31.98	34.06
Weight of Moisture (g)	4.06	3.75	4.08	1.86	2.14
Weight of Tare (g)	15.99	15.94	16.10	15.93	15.86
Weight of Dry Soil (g)	25.94	19.49	21.35	16.05	18.20
Moisture Content (%)	15.7	19.2	19.1	11.6	11.8

Boring No.	BH-05	BH-05	BH-05		
Sample No.	10B	11B	12B		
Depth (ft.)	47.5-48.5	52.0-53.5	57.0-58.5		
Pan No.	27	31	43		
Weight-Wet Sample & Tare (g)	38.05	21.95	45.89		
Weight-Dry Sample & Tare (g)	34.65	21.46	43.71		
Weight of Moisture (g)	3.40	0.49	2.18		
Weight of Tare (g)	15.84	16.37	16.18		
Weight of Dry Soil (g)	18.81	5.09	27.53		
Moisture Content (g)	18.1	9.6	7.9		

Remarks:

Tested By: Graham Donahue Date: 2/21/2011

Submitted By: Date: 2/21/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/17/2011

Boring No.	BH-06	BH-06	BH-06	BH-06	BH-06
Sample No.	1	2A	4B	6B	8B
Depth (ft.)	0-1.5	5.0-6.5	15.0-16.5	26.2-27.5	37.2-38.7
Pan No.	9	5	40	23	38
Weight-Wet Sample & Tare (g)	32.20	43.01	41.98	48.60	51.60
Weight-Dry Sample & Tare (g)	30.28	39.66	37.46	43.38	43.24
Weight of Moisture (g)	1.92	3.35	4.52	5.22	8.36
Weight of Tare (g)	15.87	15.83	15.79	16.00	16.00
Weight of Dry Soil (g)	14.41	23.83	21.67	27.38	27.24
Moisture Content (%)	13.3	14.1	20.9	19.1	30.7

Boring No.	BH-06	BH-06	BH-06	BH-06	BH-06
Sample No.	15B	16B	10B	12B	14B
Depth (ft.)	70.9-71.4	80.9-82.4	47.2-48.7	57.2-58.7	64.4-65.4
Pan No.	41	32	12	42	43
Weight-Wet Sample & Tare (g)	47.96	39.75	36.01	37.66	47.95
Weight-Dry Sample & Tare (g)	44.78	37.96	32.86	35.12	45.00
Weight of Moisture (g)	3.18	1.79	3.15	2.54	2.95
Weight of Tare (g)	15.91	15.84	15.95	16.01	16.17
Weight of Dry Soil (g)	28.87	22.12	16.91	19.11	28.83
Moisture Content (g)	11.0	8.1	18.6	13.3	10.2

Remarks:

Tested By: Graham Donahue Date: 2/17/2011

Submitted By: Date: 2/17/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	BH-09	BH-09	BH-09	BH-09	BH-09
Sample No.	1B	2B	4B	7B	8B
Depth (ft.)	0.0-1.5	4.0-5.5	16.5-18.0	31.5-33.0	36.5-38.0
Pan No.	32	27	43	45	23
Weight-Wet Sample & Tare (g)	46.13	57.96	42.79	52.88	36.30
Weight-Dry Sample & Tare (g)	41.04	53.51	38.99	47.95	34.04
Weight of Moisture (g)	5.09	4.45	3.80	4.93	2.26
Weight of Tare (g)	15.84	15.85	16.18	15.95	16.00
Weight of Dry Soil (g)	25.20	37.66	22.81	32.00	18.04
Moisture Content (%)	20.2	11.8	16.7	15.4	12.5

Boring No.	BH-09	BH-09	BH-09		
Sample No.	9B	10B	11A		
Depth (ft.)	41.5-43.0	46.5-48.0	51.5-53.0		
Pan No.	12	41	31		
Weight-Wet Sample & Tare (g)	55.09	65.60	47.90		
Weight-Dry Sample & Tare (g)	51.83	60.70	44.55		
Weight of Moisture (g)	3.26	4.90	3.35		
Weight of Tare (g)	15.87	15.93	16.35		
Weight of Dry Soil (g)	35.96	44.77	28.20		
Moisture Content (g)	10.7	10.9	11.9		

Remarks:

Tested By: Graham Donahue Date: 2/18/2011

Submitted By: Date: 2/18/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	BH-10	BH-10	BH-10	BH-10	BH-10
Sample No.	1A	2A	3	5	7A
Depth (ft.)	0-1.5	4.5-6.0	9.5-11.0	19.5-20.5	30-31.5
Pan No.	40	5	39	44	33
Weight-Wet Sample & Tare (g)	48.43	44.78	46.60	43.83	33.04
Weight-Dry Sample & Tare (g)	43.42	41.95	43.04	40.42	30.66
Weight of Moisture (g)	5.01	2.83	3.56	3.41	2.38
Weight of Tare (g)	16.19	16.23	16.04	15.89	15.98
Weight of Dry Soil (g)	27.23	25.72	27.00	24.53	14.68
Moisture Content (%)	18.4	11.0	13.2	13.9	16.2

Boring No.	BH-10	BH-10	BH-10		
Sample No.	9A	10	11		
Depth (ft.)	40-41.5	45-46.5	50-51		
Pan No.	9	30	38		
Weight-Wet Sample & Tare (g)	31.36	36.47	42.99		
Weight-Dry Sample & Tare (g)	29.24	34.60	40.32		
Weight of Moisture (g)	2.12	1.87	2.67		
Weight of Tare (g)	15.89	16.16	16.02		
Weight of Dry Soil (g)	13.35	18.44	24.3		
Moisture Content (g)	15.9	10.1	11.0		

Remarks:

Tested By: Graham Donahue Date: 2/21/2011

Submitted By: Date: 2/21/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	**BH-10**	**BH-10**			
Sample No.	**15**	**18A**			
Depth (ft.)	**70-71.5**	**100-101.5**			
Pan No.	**42**	**21**			
Weight-Wet Sample & Tare (g)	**51.51**	**39.47**			
Weight-Dry Sample & Tare (g)	**48.30**	**37.30**			
Weight of Moisture (g)	**3.13**	**2.17**			
Weight of Tare (g)	**16.01**	**15.94**			
Weight of Dry Soil (g)	**32.29**	**21.36**			
Moisture Content (%)	**9.7**	**10.2**			

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: Graham Donahue Date: 2/18/2011

Submitted By: Date: 2/18/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	**BH-11**	**BH-11**	**BH-11**		
Sample No.	**1B**	**2B**	**3**		
Depth (ft.)	**0.0-1.5**	**5.0-6.5**	**10.0-11.5**		
Pan No.	**46**	**12**	**45**		
Weight-Wet Sample & Tare (g)	**46.22**	**38.69**	**37.30**		
Weight-Dry Sample & Tare (g)	**44.09**	**37.15**	**36.08**		
Weight of Moisture (g)	**2.13**	**1.54**	**1.22**		
Weight of Tare (g)	**16.05**	**15.89**	**15.95**		
Weight of Dry Soil (g)	**28.04**	**21.26**	**20.13**		
Moisture Content (%)	**7.6**	**7.2**	**6.1**		

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: Graham Donahue Date: 2/21/2011

Submitted By: Date: 2/21/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/11/2011

Boring No.	**BH-12**	**BH-12**	**BH-12**		
Sample No.	**1**	**2A**	**3**		
Depth (ft.)	**0-1.5**	**4-6.5**	**9.5-11**		
Pan No.	**42**	**24**	**32**		
Weight-Wet Sample & Tare (g)	**23.49**	**41.33**	**33.19**		
Weight-Dry Sample & Tare (g)	**21.98**	**38.86**	**32.59**		
Weight of Moisture (g)	**1.51**	**2.47**	**0.60**		
Weight of Tare (g)	**16.01**	**15.97**	**15.86**		
Weight of Dry Soil (g)	**5.97**	**22.89**	**16.73**		
Moisture Content (%)	**25.3**	**10.8**	**3.6**		

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: Graham Donahue Date: 2/21/2011

Submitted By: Date: 2/21/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/18/2011

Boring No.	TP-14	TP-14	TP-15	TP-15	TP-16
Sample No.	A	B	A	B	A
Depth (ft.)	5.0	11.0	13.0	5.0	5.0
Pan No.	60	64	67	83	62
Weight-Wet Sample & Tare (g)	979.79	840.53	798.73	736.56	866.35
Weight-Dry Sample & Tare (g)	919.91	786.48	746.91	693.32	818.58
Weight of Moisture (g)	59.88	54.05	51.82	43.24	47.77
Weight of Tare (g)	341.07	343.80	342.57	342.34	342.05
Weight of Dry Soil (g)	578.84	442.68	404.34	350.98	476.53
Moisture Content (%)	10.3	12.2	12.8	12.3	10.0

Boring No.	TP-16	TP-17	TP-17	TP-18	TP-18
Sample No.	B	A	B	A	B
Depth (ft.)	11.0	9.0	12.0	5.0	12.0
Pan No.	65	61	58	51	68
Weight-Wet Sample & Tare (g)	941.28	828.77	707.62	809.49	513.61
Weight-Dry Sample & Tare (g)	876.88	771.46	672.15	759.92	492.78
Weight of Moisture (g)	64.40	57.31	35.47	49.57	20.83
Weight of Tare (g)	342.80	341.34	342.27	343.08	341.88
Weight of Dry Soil (g)	534.08	430.12	329.88	416.84	150.90
Moisture Content (g)	12.1	13.3	10.8	11.9	13.8

Remarks:

Tested By: Graham Donahue/ Dan Absolon Date: 2/21/2011

Submitted By: Date: 2/21/2011

COLEMAN ENGINEERING COMPANY
635 Cirlce Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/18/2011

Boring No.	TP-19	TP-19	TP-20	TP-20	TP-21
Sample No.	A	B	A	B	A
Depth (ft.)	9.0	10.0	6.0	14.0	5.0
Pan No.	79	77	16	26	2
Weight-Wet Sample & Tare (g)	575.63	478.92	708.69	521.06	573.80
Weight-Dry Sample & Tare (g)	533.60	437.53	655.63	467.81	531.08
Weight of Moisture (g)	42.03	41.39	53.06	53.25	42.72
Weight of Tare (g)	105.13	104.10	116.19	116.22	109.35
Weight of Dry Soil (g)	428.47	333.43	539.44	351.59	421.73
Moisture Content (%)	9.8	12.4	9.8	15.1	10.1

Boring No.	TP-21	TP-22	TP-22	TP-23	TP-23
Sample No.	B	A	B	A	B
Depth (ft.)	12.0	6.0	12.0	5.0	14.0
Pan No.	6-B	5-B	4-B	3-B	7-B
Weight-Wet Sample & Tare (g)	1135.69	1052.74	1201.85	1095.08	1135.39
Weight-Dry Sample & Tare (g)	1088.55	1008.13	1129.89	1049.98	1084.36
Weight of Moisture (g)	47.14	44.61	71.96	45.10	51.03
Weight of Tare (g)	629.08	626.94	625.51	626.23	625.02
Weight of Dry Soil (g)	459.47	381.19	504.38	423.75	458.34
Moisture Content (g)	10.3	11.7	14.3	10.6	11.1

Remarks:

Tested By: Graham Donahue / Dan Absolon Date: 2/21/2011

Submitted By: Date: 2/21/2011

COLEMAN ENGINEERING COMPANY
635 Circe Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood Tailings Facility

Client: Orvana Resources US Corp. Job No: GL-11006

Address: N10199 Lake Road Ironwood MI 49938

Location of Project: Wakefield Township, Michigan Date: 2/18/2011

Boring No.	TP-24	TP-24	TP-26		
Sample No.	A	B	A		
Depth (ft.)	5.0	12.0	2.0 - 3.0		
Pan No.	56	50	66		
Weight-Wet Sample & Tare (g)	860.59	1038.52	696.26		
Weight-Dry Sample & Tare (g)	810.28	984.91	671.64		
Weight of Moisture (g)	50.31	53.61	24.62		
Weight of Tare (g)	341.89	341.74	343.81		
Weight of Dry Soil (g)	468.39	643.17	327.83		
Moisture Content (%)	10.7	8.3	7.5		

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (g)					

Remarks:

Tested By: Graham Donahue / Dan Absolon Date: 2/22/2011

Submitted By: Date: 2/22/2011

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Appendix F-4

Laboratory Test Data – Specific Gravity Data (Test Pits, Boreholes, and Sand Pits)

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

SPECIFIC GRAVITY OF SOIL

ASTM D854

Project: Copperwood Tailings Facility **Job No:** GL-11006

Client: Orvana - Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Location: Wakefield Township, MI **Received:** 1/27/2011

Sample Description: Composite description (CL) Clay, reddish brown, some sand, trace fine gravel, moist

Sample or Specimen No.			TP-3	TP-6	TP-9	TP-12
Pycnometer No.			1	2	3	5
Pan No.			27	28	29	30
Weight in grams	Dish + Dry Soil (g)		286.42	299.83	290.69	304.22
	Dish (g)		236.52	240.14	234.44	253.34
	Dry Soil (g)	W_s	49.9	59.69	56.25	50.88
	Pycnometer + Water @T (g)	W_{bw}	673.34	665.97	666.13	666.95
	Ws + W_{bw}		723.24	722.76	722.38	717.83
	Pycnometer + Water+dry Soil (g)	W_{bws}	704.31	699.95	701.26	698.77
	Displaced Water, $W_s+W_{bw}-W_{bws}$		18.93	22.81	21.12	19.06
	Temp ° C		20.0	20.0	20.0	20.0
Correction Factor		K	1.00	1.00	1.00	1.00
$(W_sK) / (W_s + W_{bw} - W_{bws})$		G_s	2.64	2.62	2.66	2.67
Depth			Composite	5' - 10'	5' - 10'	Composite

Tested by: Graham Donahue **Date:** 2/5/2011

Submitted by: Chi Rasmussen **Date:** 2/14/2011

Form D854 Revised: 03-23-05

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

SPECIFIC GRAVITY OF SOIL

ASTM D854

Project: Copperwood Tailings Facility **Job No:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Location: Wakefield Township, MI **Received:** 2/4/2011

Sample Description: Composite description

Sample or Specimen No.			BH-05/5B	BH-06/4A		
Pycnometer No.			1	2		
Pan No.			28	29		
Weight in grams	Dish + Dry Soil (g)		293.04	292.15		
	Dish (g)		240.15	234.44		
	Dry Soil (g)	W_s	52.89	57.71		
	Pycnometer + Water @T (g)	W_{bw}	674.07	666.77		
	Ws + W_{bw}		726.96	724.48		
	Pycnometer + Water+dry Soil (g)	W_{bws}	707.03	702.59		
	Displaced Water, $W_s+W_{bw}-W_{bws}$		19.93	21.89		
			20	20		
Correction Factor		K	1	1		
$(W_sK) + (W_s + W_{bw} - W_{bws})$		G_s	2.65	2.64		
			22'	16'		

Tested by: Graham Donahue **Date:** 2/10/2011

Submitted by: [signature] **Date:** 2/24/2011

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

SPECIFIC GRAVITY OF SOIL

ASTM D854

Project: Copperwood Tailings Facility **Job No:** GL-11006

Client: Orvana Resources US Corp.

Address: N10199 Lake Road Ironwood MI 49938

Location: **Received:** 2/4/2011

Sample Description:

Sample or Specimen No.			BH-04			
Pycnometer No.			2			
Pan No.			56			
Weight in grams	Dish + Dry Soil (g)		280.50			
	Dish (g)		240.13			
	Dry Soil (g)	W_s	40.37			
	Pycnometer + Water @T (g)	W_{bw}	66.93			
	Ws + W_{bw}		707.30			
	Pycnometer + Water+dry Soil (g)	W_{bws}	691.94			
	Displaced Water, $W_s+W_{bw}-W_{bws}$		15.36			
Correction Factor		K	1			
$(W_sK) / (W_s + W_{bw} - W_{bws})$		G_s	2.63			
Temp. °C			20.0			
Depth			9.5' - 11.7'			

Tested by: Graham Donahue **Date:** 2/28/2011

Submitted by: [signature] **Date:** 2/28/2011

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Specific Gravity - Soil
ASTM D 854

Project	Copperwood	Project No.	DV101-00429/2
Date Staged	2/24/2011	Act. Code	300
Date Completed	2/27/2011	Lab No.	L2010-138
Tested By	jk	Checked By	spb

Sample No.	LP		CP		Conner Pit #2		WPC-4 Composite			
Sample Prep. (Wet or Dry)	dry		dry		dry					
Flask No.	1	42	112	116	2		116	11A		
1) Wt. of Flask + Soil										
2) Wt. of Flask										
3) Wt. of Soil (1-2)	33.22	33.97	32.34	33.70	34.06		34.84	34.74		
4) Calibrated Wt. of Flask + Water	352.65	351.48	346.67	353.94	352.91		354.10	359.40		
5) #3 + #4	385.87	385.45	379.01	387.64	386.97		388.94	394.14		
6) Wt. of Flask + Water + Soil	373.60	372.84	367.18	375.30	374.28		376.47	381.67		
7) Volume of Soil (5 - 6)	12.27	12.61	11.83	12.34	12.69		12.47	12.47		
8) Test Temperature, deg. C	21.3	21.4	21.3	21.3	21.3		20.5	20.5		
9) Temperature Correction, k	0.999724	0.999701	0.999724	0.999724	0.999724		0.999890	0.999890		
10) Specific Gravity ((3 / 7) * k)	2.707	2.693	2.733	2.730	2.683		2.794	2.786		
Reported Average, G_s @ 20 deg.C	2.70		2.73		2.68		2.79			
Tare	f	17	100	48	39		P10	P07		
Dry Soil + tare, g	179.06	182.40	146.66	230.33	144.94		150.91	147.48		
Tare, g	145.84	148.43	114.32	196.63	110.88		116.07	112.74		

General Notes: Line 9, k, is determined by dividing the density of water at test temperature recorded by the density of water at 20 deg. C.

Wet prep samples soaked overnight prior to application of vacuum.

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Appendix F-5

Laboratory Test Data – Moisture Density Data (Test Pits)

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/31/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-2M **Sample No.** TP-2,4' **Lab No.** 3824

Test Method ASTM D 1557 Modified Proctor Method B **Specific Gravity 2.65**

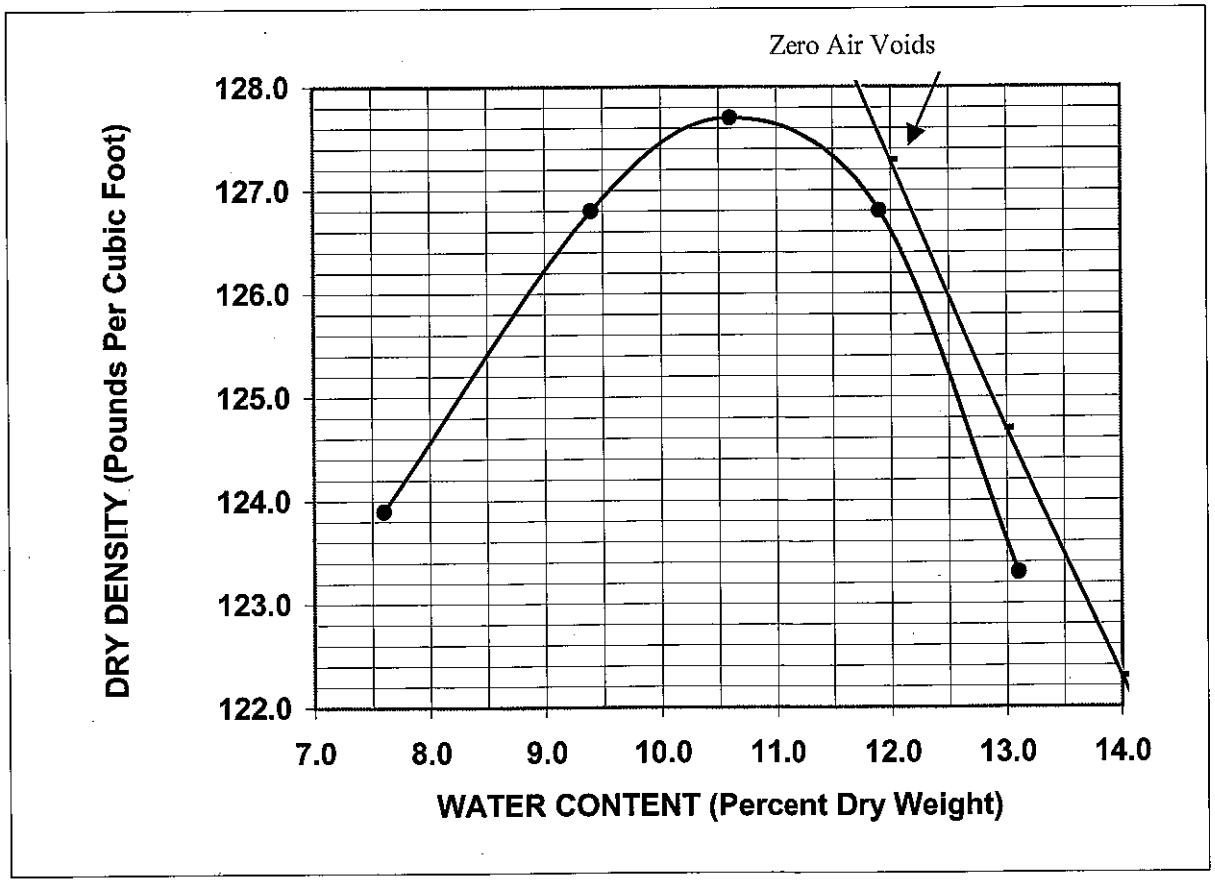
Description of Soil (CL) LEAN CLAY brown, trace sand, trace gravel, highly plastic

Source of Material Test Pit #2, 4

TEST RESULTS

Maximum Dry Density 127.7 PCF

Optimum Water Content 10.6 %



Tested By: Daniel Absolon **Date:** 2/3/2011

Submitted By: Wm D Rice **Date:** 2/3/2011

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-2S **Sample No.** TP-2,4' **Lab No.** 3824

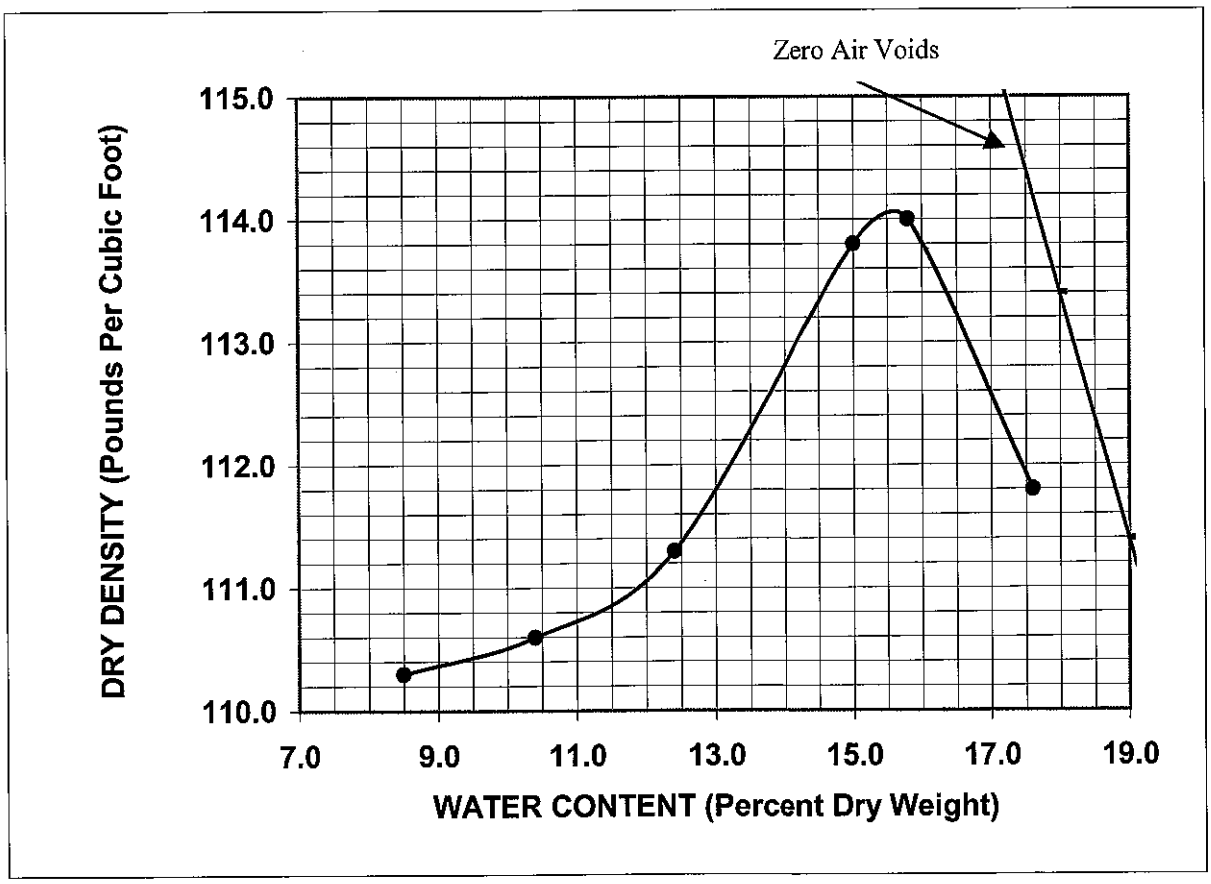
Test Method ASTM D 698 Standard Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, brown, trace sand, trace gravel, highly plastic

Source of Material Test Pit Sample #2, 4'

TEST RESULTS **Maximum Dry Density** 114.0 PCF

Optimum Water Content 15.8 %



Tested By: Daniel Absolon **Date:** 2/9/2011

Submitted By: [signature] **Date:** 2/9/2011

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-6M **Sample No.** TP-6, 5'-10' **Lab No.** 3835

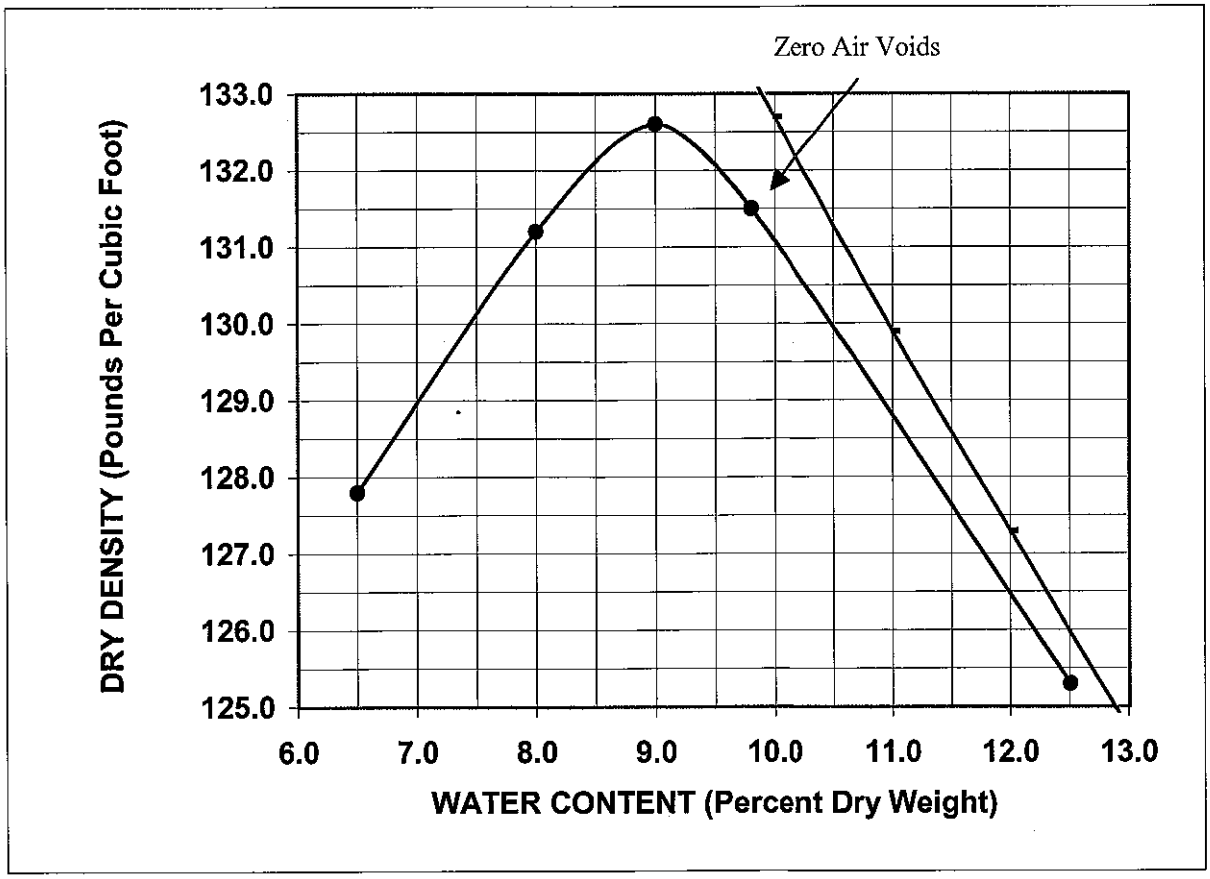
Test Method ASTM D 1557, Modified Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, red-brn, w/ f-c sand, tr. fine gvl, medium plastic

Source of Material Test Pit Sample #6 B

TEST RESULTS **Maximum Dry Density** 132.6 PCF

Optimum Water Content 9 %



Tested By: Dan Absolon **Date:** 2/18/2011

Submitted By: Wm D Rice **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-6S **Sample No.** TP-6, 5'-10' **Lab No.** 3835

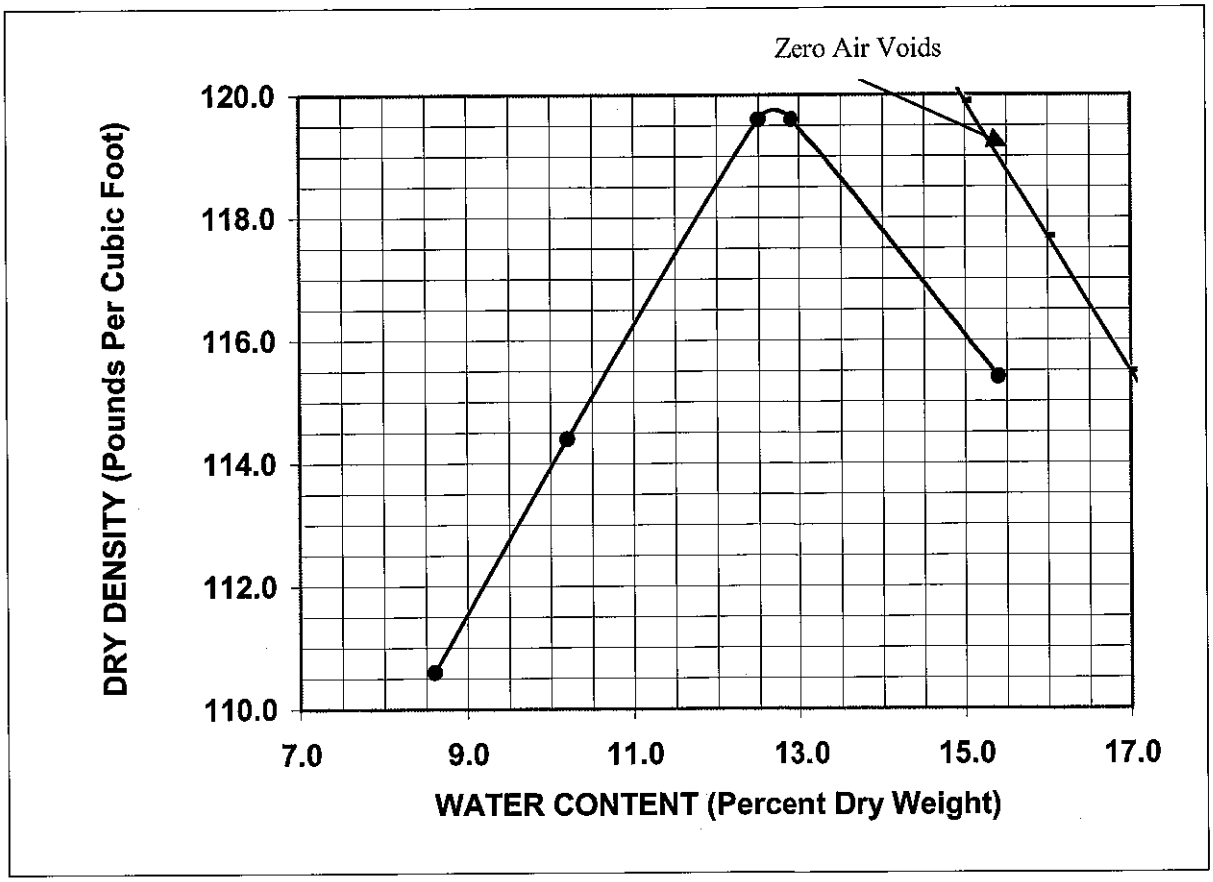
Test Method ASTM D 698 Standard Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, red-brn, w/ f-c sand, tr. fine gvl, medium plastic

Source of Material Test Pit Sample #6 B

TEST RESULTS **Maximum Dry Density** 119.6 PCF

Optimum Water Content 12.5 %



Tested By: Dan Absolon **Date:** 2/16/2011

Submitted By: Wm D Rice **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-7M **Sample No.** TP-7, 10' -15' **Lab No.** 3839

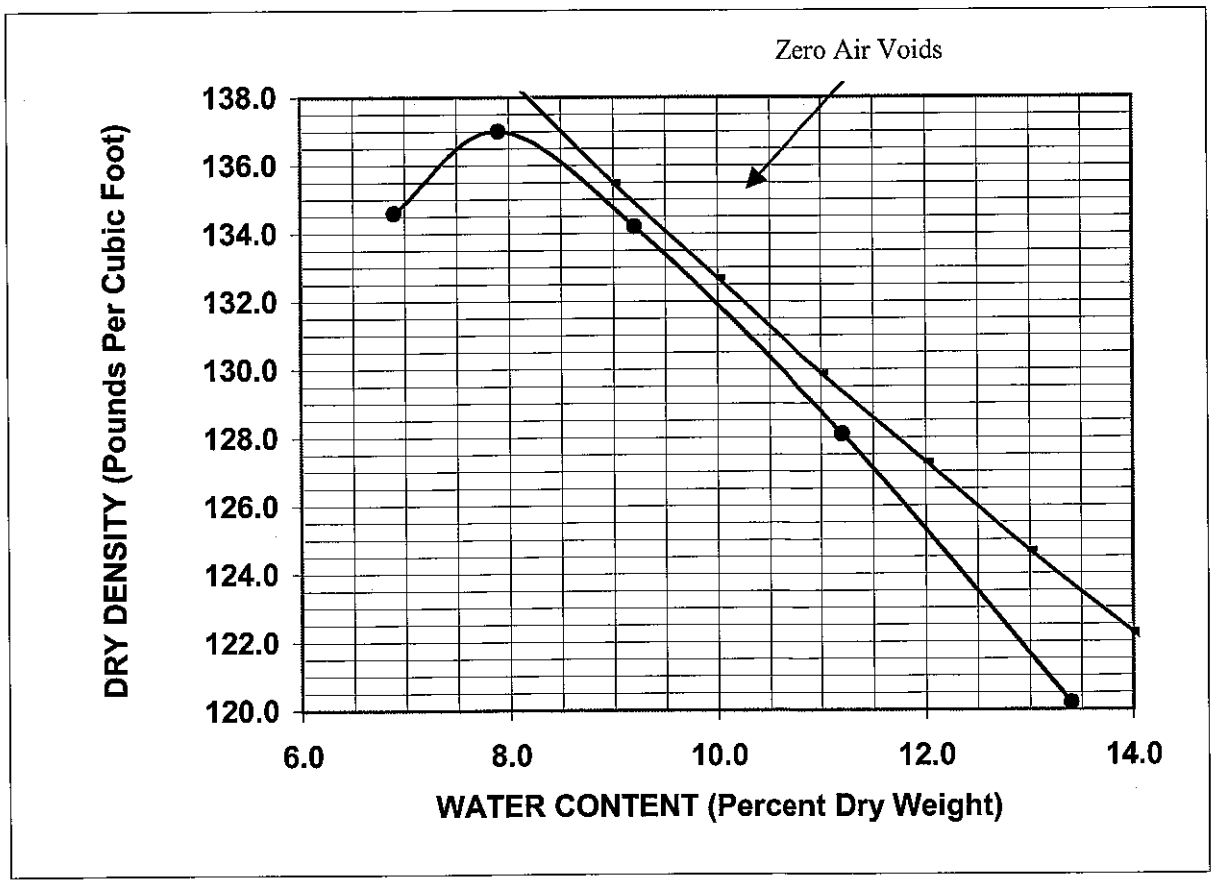
Test Method ASTM D 1557 Modified Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, red-brn, w/ f-c sand, tr. fine gvl, medium plastic

Source of Material Test Pit Sample #7 C

TEST RESULTS **Maximum Dry Density** 137.0 PCF

Optimum Water Content 7.9 %



Tested By: Dan Absolon **Date:** 2/16/2011

Submitted By: Wm D Rice **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-7S **Sample No.** TP-7, 10'-15' **Lab No.** 3839

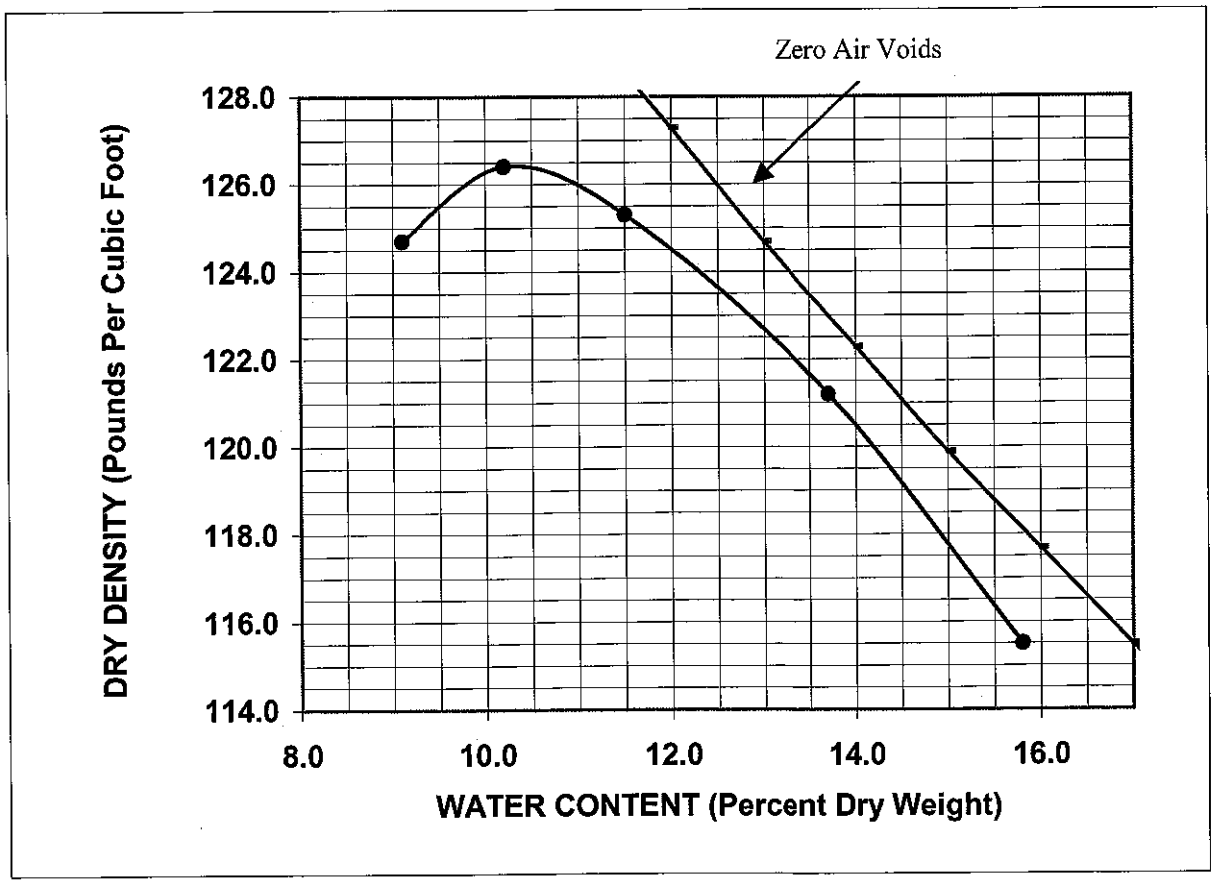
Test Method ASTM D 698 Standard Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, red-brn, w/ f-c sand, tr. fine gvl, medium plastic

Source of Material Test Pit Sample #7 C

TEST RESULTS **Maximum Dry Density** 126.4 PCF

Optimum Water Content 10.2 %



Tested By: Dan Absolon **Date:** 2/16/2011

Submitted By: Wm D Rice **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-8M **Sample No.** TP-8, 0'-5' **Lab No.** 3841

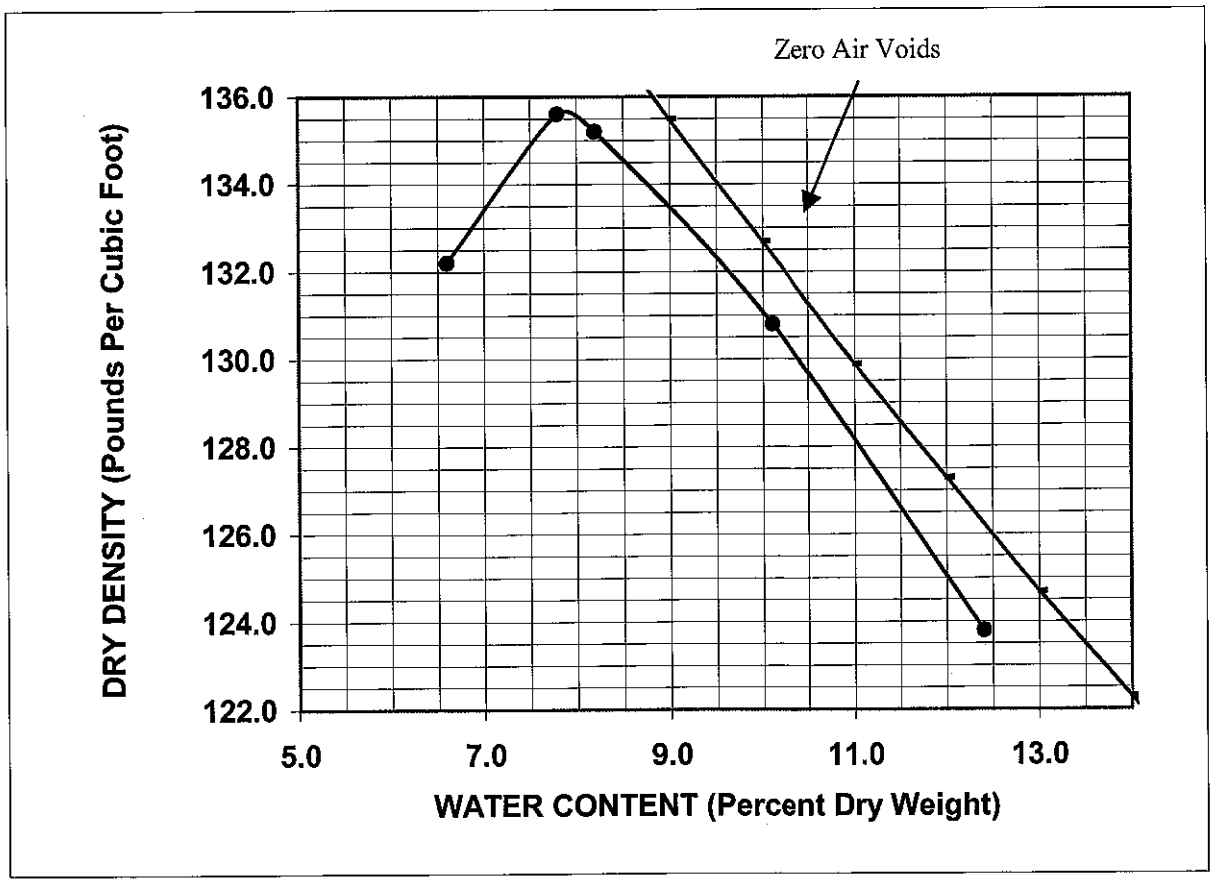
Test Method ASTM D 1557 Modified Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, brn, w/ f-c sand, tr. gravel, medium plastic

Source of Material Test Pit Sample #8 A

TEST RESULTS **Maximum Dry Density** 135.6 PCF

Optimum Water Content 7.8 %



Tested By: Dan Absolon **Date:** 2/18/2011

Submitted By: Wm D Rice **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

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635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-8S **Sample No.** TP-8, 0-5 **Lab No.** 3841

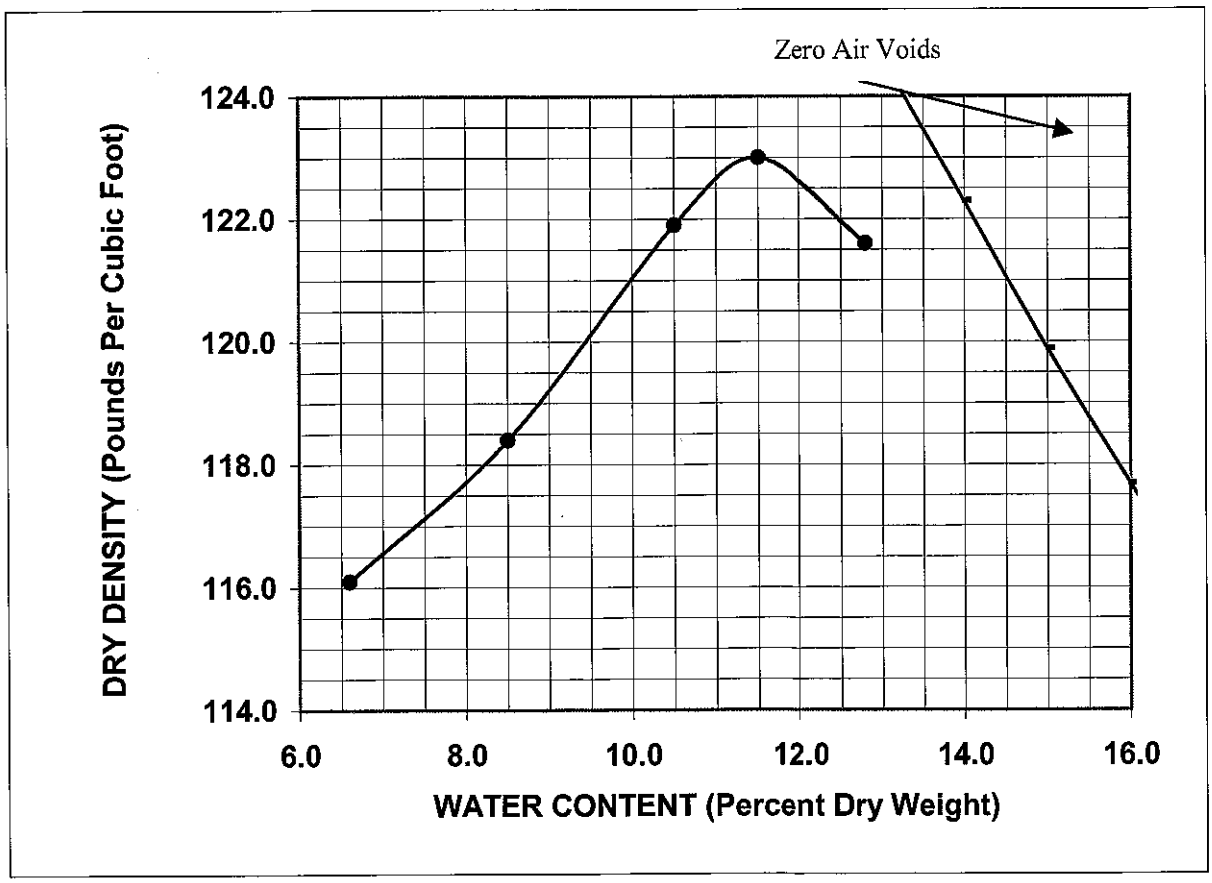
Test Method ASTM D 698, Standard Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, brn, w/ f-c sand, tr. gravel, medium plastic

Source of Material Test Pit Sample # 8 A

TEST RESULTS **Maximum Dry Density** 123.0 PCF

Optimum Water Content 11.5 %



Tested By: Dan Absolon **Date:** 2/18/2011

Submitted By: Wm D Rice **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-9M **Sample No.** TP-9, 5-10 **Lab No.** 3844

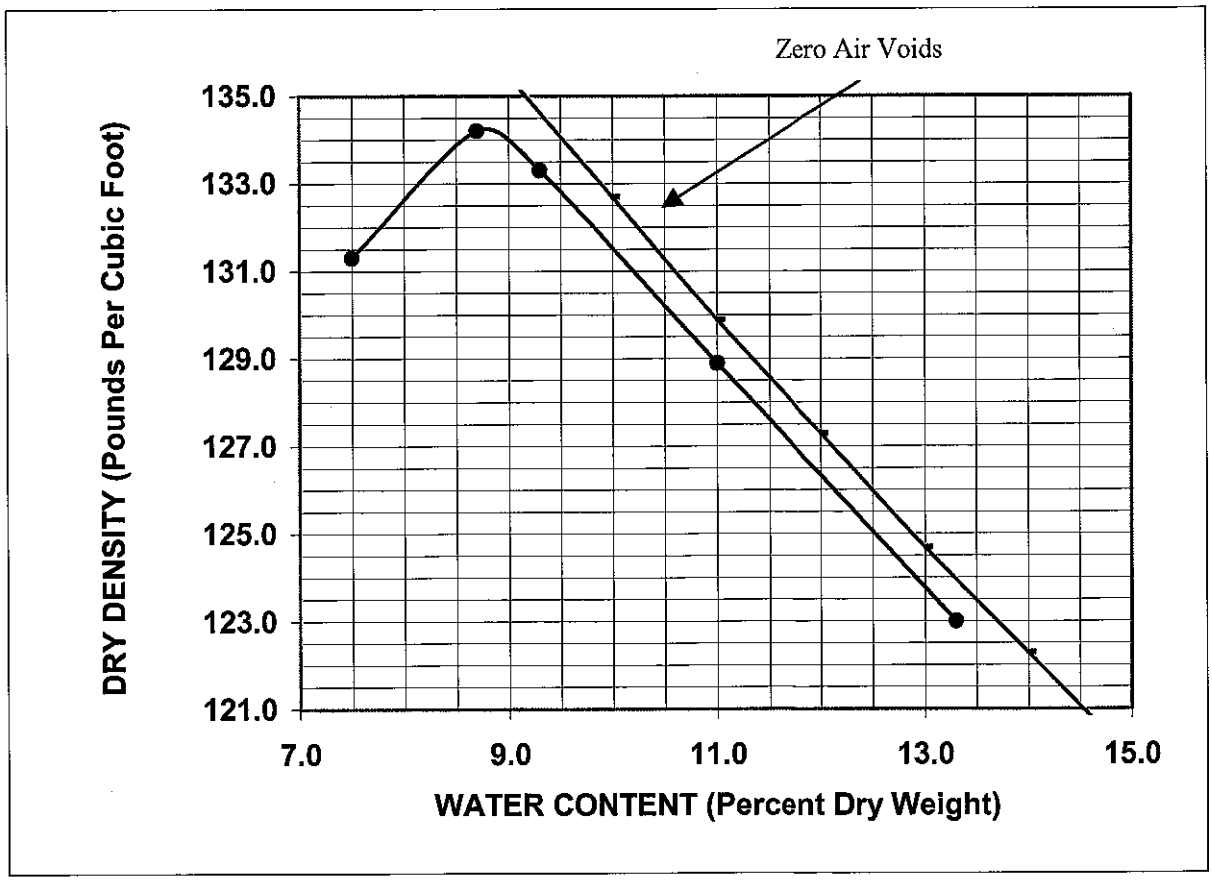
Test Method ASTM D 1557 Modified Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, brown, with fine to coarse sand, tr gravel, medium plastic

Source of Material Test Pit Sample #9 B

TEST RESULTS **Maximum Dry Density** 134.2 PCF

Optimum Water Content 8.7 %



Tested By: Dan Absolon **Date:** 2/21/2011

Submitted By: Wm D Rice **Date:** 2/21/2011

Form D698/1557 Revised: 06-16-08

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

MOISTURE-DENSITY RELATIONSHIP

Job Number 11006 **Date** 1/27/2011

Project Copperwood Tailings Facility

Client Orvana Resources US Corp

Address: N10199 Lake Road Ironwood, MI 49938

Proctor No. TP-9S **Sample No.** TP-9 5-10 **Lab No.** 3844

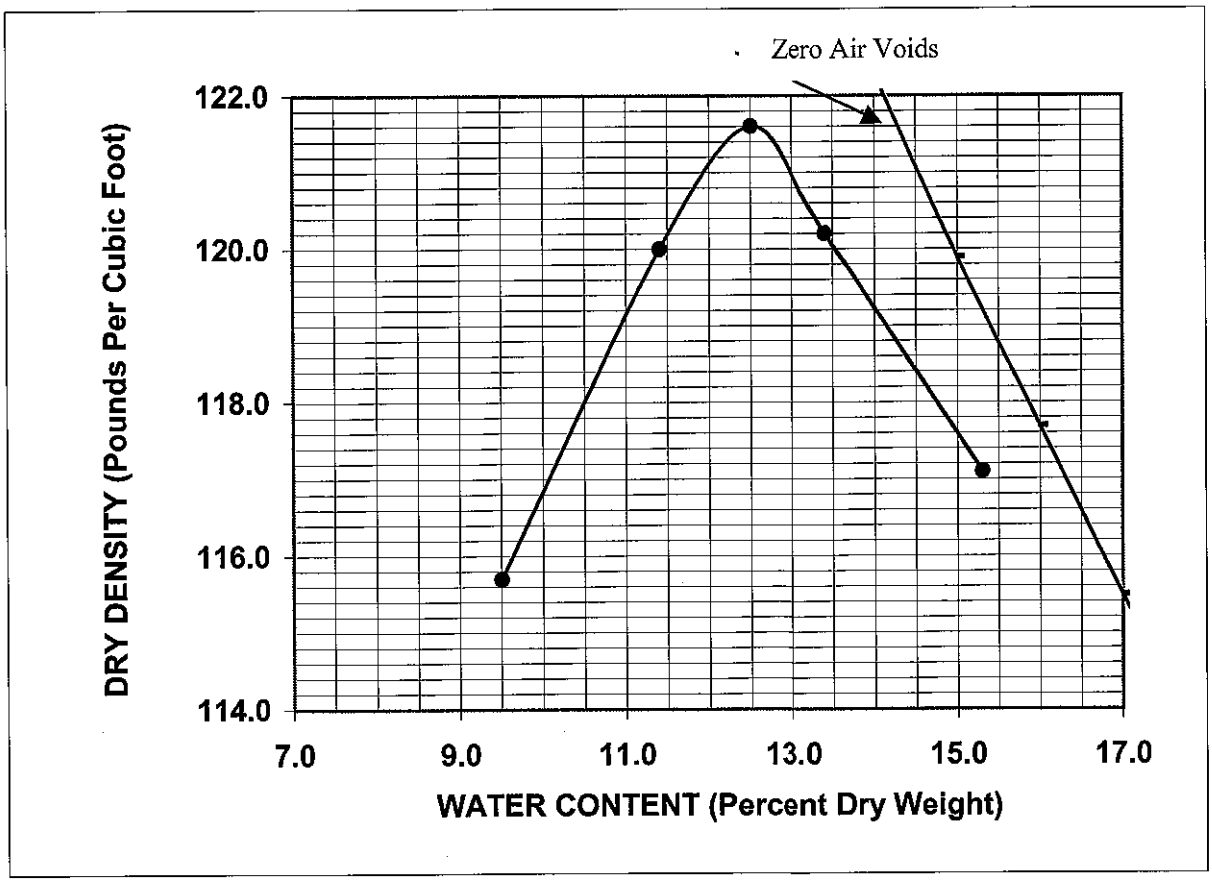
Test Method ASTM D 698 Standard Proctor Method B **Specific Gravity 2.65**

Description of Soil (CL) LEAN CLAY, red-brn, with fine to coarse sand, trace gravel, medium plastic

Source of Material Test Pit sample #9 B

TEST RESULTS **Maximum Dry Density** 121.6 PCF

Optimum Water Content 12.5 %



Tested By: _____ **Date:** _____

Submitted By: [signature] **Date:** 2-24-11

Form D698/1557 Revised: 06-16-08

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Appendix F-6

Laboratory Test Data – Permeability Data (Test Pits and Boreholes)

Constant Head Permeability Test

Project: Orvana Tailings Facility
Project #: GL-11006
Sample #: BH-04
Shelby Tube 9.5' - 11.7'

Date: 2/18/2011
Tech: MD
cell #1

INPUT VALUES

	Init.	Final
Sample Dia. (cm)	7.2	7.3
Sample Ht (cm)	7.3	7.3
Tare & Wet (g)	756.7	906.2
Tare & Dry (g)	682.8	809.7
Tare (g)	241.3	242.3
Sample Wt (g)	661.1	665.1
Moisture (%):	16.7	17.0
Wet Density (pcf):	139.3	141.3
Dry Density (pcf):	119.3	120.8
Saturation (%):	105.1	111.1

Permeant:	Water
Sample Specific Gravity:	2.75
Confining Pressure (psi):	55.0
Out Burette Dia. (cm):	0.996
In Burette Dia. (cm):	0.996
Chamber Burette Dia. (cm):	1.613

CALCULATED VALUES

Maximum Gradient:	47.0
Average Gradient:	
Maximum Effect. Stress (psi):	
Minimum Effect. Stress (psi):	
Average Effect. Stress (psi):	

Date	Time	Temperature	Pressure (psi) Out	Pressure (psi) In	Readings (cm) Cham.	Readings (cm) Out	Readings (cm) In	Flow Diff. %	K cm/sec	Ave. 0,1
2/18/2011	16:42	0	42.0	46.8	17.7	66.6	10.1			
2/19/2011	12:16	70	41.7	46.6	20.1	64.3	9.8		5.8E-09	1
2/21/2011	7:56	68	41.7	46.4	22.5	60.0	10.4		6.7E-09	1
2/21/2011	16:33	75	41.7	46.3	22.9	59.4	10.6		5.6E-09	1
2/22/2011	7:44	69	41.6	46.3	23.1	58.3	11.4		7.4E-09	1
2/22/2011	16:43	72	41.6	46.2	23.5	57.7	11.8		6.7E-09	1
2/23/2011	7:35	67	41.6	46.2	23.6	56.8	12.5		6.5E-09	1
2/23/2011	16:32	70	41.5	46.3	23.7	56.3	13.2		7.8E-09	1
2/24/2011	7:46	68	41.5	46.4	23.9	55.5	13.7		4.9E-09	1
2/24/2011	16:25	67	41.4	46.3	24.2	55.0	14.0		5.3E-09	1
2/25/2011	7:44	68	41.4	46.3	24.3	54.3	14.5		4.5E-09	1
2/26/2011	12:13	70	41.4	46.3	24.7	53.1	15.5		4.4E-09	1
3/1/2011	6:37	70	41.5	46.3	25.7	50.4	18.2		4.7E-09	1

Average Permeability for Reading with a 1 in the Average Column: k= 5.9E-09 cm/s

Constant Head Permeability Test

Project: Orvana Minerals Copperwood Project
Project #: GL-11006
Sample #: TP# 7
Block Sample

Date: 2/16/2011
Tech: MD
cell #2

INPUT VALUES

	Init.	Final
Sample Dia. (cm)	7.5	7.4
Sample Ht (cm)	6.9	6.9
Tare & Wet (g)	517.0	927.1
Tare & Dry (g)	505.3	859.0
Tare (g)	384.3	241.3
Sample Wt (g)	679.8	687.0
Moisture (%):	9.7	11.0
Wet Density (pcf):	140.9	141.7
Dry Density (pcf):	128.4	127.6
Saturation (%):	89.4	98.9

Permeant:	Water
Sample Specific Gravity:	2.65
Confining Pressure (psi):	55.0
Out Burette Dia. (cm):	0.996
In Burette Dia. (cm):	0.996
Chamber Burette Dia. (cm):	1.613

CALCULATED VALUES

Maximum Gradient:	51.2
Average Gradient:	
Maximum Effect. Stress (psi):	
Minimum Effect. Stress (psi):	
Average Effect. Stress (psi):	

Date	Time	Temperature	Pressure (psi) Out	Pressure (psi) In	Readings (cm) Cham.	Readings (cm) Out	Readings (cm) In	Flow Diff. %	K cm/sec	Ave. 0,1
2/17/2011	7:43	0	41.5	46.6	17.8	71.5	20.0			
2/17/2011	16:37	70	41.4	46.4	18.4	67.5	24.0		4.3E-08	1
2/18/2011	7:39	76	41.4	46.4	18.8	61.4	30.3		4.0E-08	1
2/18/2011	16:44	72	41.3	46.4	18.9	58.0	34.0		3.7E-08	1
2/19/2011	12:12	70	41.1	46.3	19.2	51.7	40.7		3.1E-08	1
2/21/2011	7:53	67	40.9	46.3	19.5	39.9	52.9		2.4E-08	1
2/21/2011	16:30	75	40.7	46.1	19.7	37.8	55.0		2.2E-08	1
2/22/2011	7:41	68	41.3	46.0	19.8	34.5	58.3		2.2E-08	1
2/22/2011	16:31	73	41.4	45.7	19.8	32.9	60.1		2.2E-08	1
2/23/2011	7:33	67	41.4	46.3	19.9	30.0	62.9		1.9E-08	1
2/23/2011	16:30	70	41.3	46.3	20.1	28.4	64.4		1.7E-08	1
2/24/2011	7:44	67	41.4	46.3	20.3	26.0	66.9		1.6E-08	1
2/24/2011	16:23	67	41.3	46.3	20.3	24.6	68.3		1.6E-08	1
2/25/2011	7:42	70	41.3	46.3	20.3	22.4	70.5		1.4E-08	1

Average Permeability for Reading with a 1 in the Average Column: k= 2.5E-08 cm/s

Constant Head Permeability Test

Project: Orvana Minerals - Copperwood Project
Project #: GL-11006
Sample #: TP #9
Block Sample

Date: 3/2/2011
Tech: MD
cell #2

INPUT VALUES

	Init.	Final
Sample Dia. (cm)	7.2	7.2
Sample Ht (cm)	7.3	7.2
Tare & Wet (g)	736.8	1036.5
Tare & Dry (g)	692.7	951.8
Tare (g)	377.6	377.4
Sample Wt (g)	654.4	659.9
Moisture (%):	14.0	14.7
Wet Density (pcf):	137.8	139.3
Dry Density (pcf):	120.9	121.4
Saturation (%):	97.9	104.6

Permeant:	Water
Sample Specific Gravity:	2.68
Confining Pressure (psi):	55.0
Out Burette Dia. (cm):	0.996
In Burette Dia. (cm):	0.996
Chamber Burette Dia. (cm):	1.613

CALCULATED VALUES

Maximum Gradient:	49.3
Average Gradient:	
Maximum Effect. Stress (psi):	
Minimum Effect. Stress (psi):	
Average Effect. Stress (psi):	

Date	Time	Temperature	Pressure (psi) Out	Pressure (psi) In	Readings (cm) Cham.	Readings (cm) Out	Readings (cm) In	Flow Diff. %	K cm/sec	Ave. 0,1
3/3/2011	7:25	0	41.7	46.5	23.9	69.5	3.3			
3/3/2011	16:57	76	41.4	46.5	24.4	67.9	4.6		1.6E-08	1
3/4/2011	6:23	67	41.5	46.4	25.0	66.1	6.4		1.5E-08	1
3/4/2011	16:39	72	41.3	46.4	25.1	65.0	7.6		1.2E-08	1
3/7/2011	7:40	72	41.3	46.3	26.0	59.4	13.5		1.0E-08	1
3/8/2011	7:23	70	41.3	46.3	26.2	57.9	15.1		7.2E-09	1
3/8/2011	16:49	71	41.2	46.3	26.2	57.2	15.7		7.4E-09	1
3/9/2011	7:48	69	41.3	46.3	26.4	56.4	16.8		7.0E-09	1
3/10/2011	7:31	68	41.3	46.3	26.6	54.8	18.4		7.4E-09	1

Average Permeability for Reading with a 1 in the Average Column: k= 1.0E-08 cm/s

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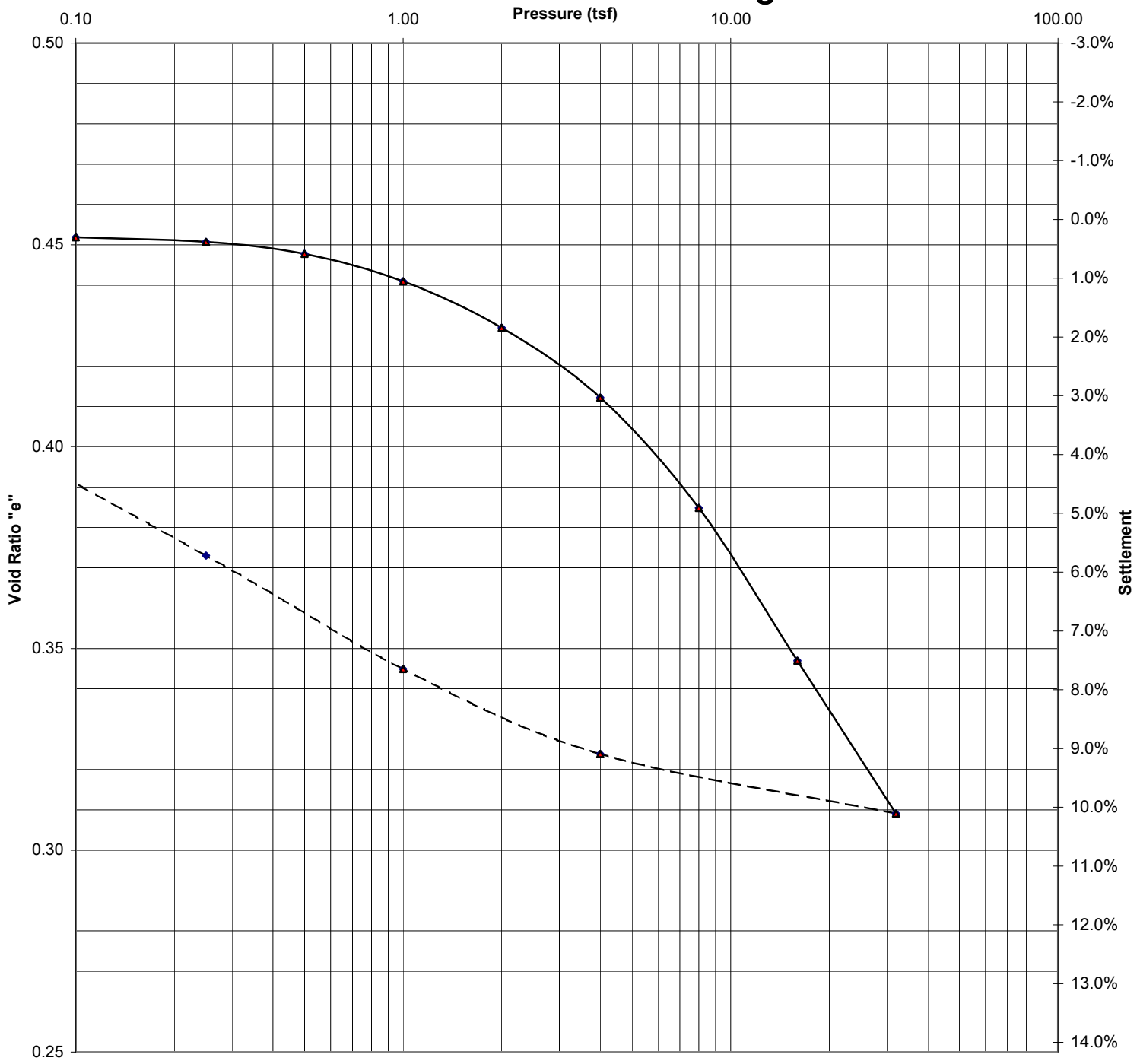
Appendix F-7

Laboratory Test Data – Oedometer Data (Boreholes)

Void Ratio and % Settlement vs. Log of Pressure



Project: Copperwood Mine			Date: 4/18/11
Sample #: BH-2	Boring #:	Depth ft: 25.2-27.2 (Bot)	Job #: 7835
Soil Type: Lean Clay, plastic, with fine to coarse sand, some fine to coarse gravel (CL)			
Initial W/C (%): 15.5	Dry Density (pcf): 118.3	LL: PL: PI:	Gs: 2.76 (Assumed)
Organic Content (%):	Initial Height (in.): 0.746	Diameter (in.): 2.506	e_o= 0.457
Preconsolidation Pressure (Pc): 3.8 tsf	Compression Index (Cc): 0.13	Recompression Index (Cr): ≅ 0.03	

Remarks:

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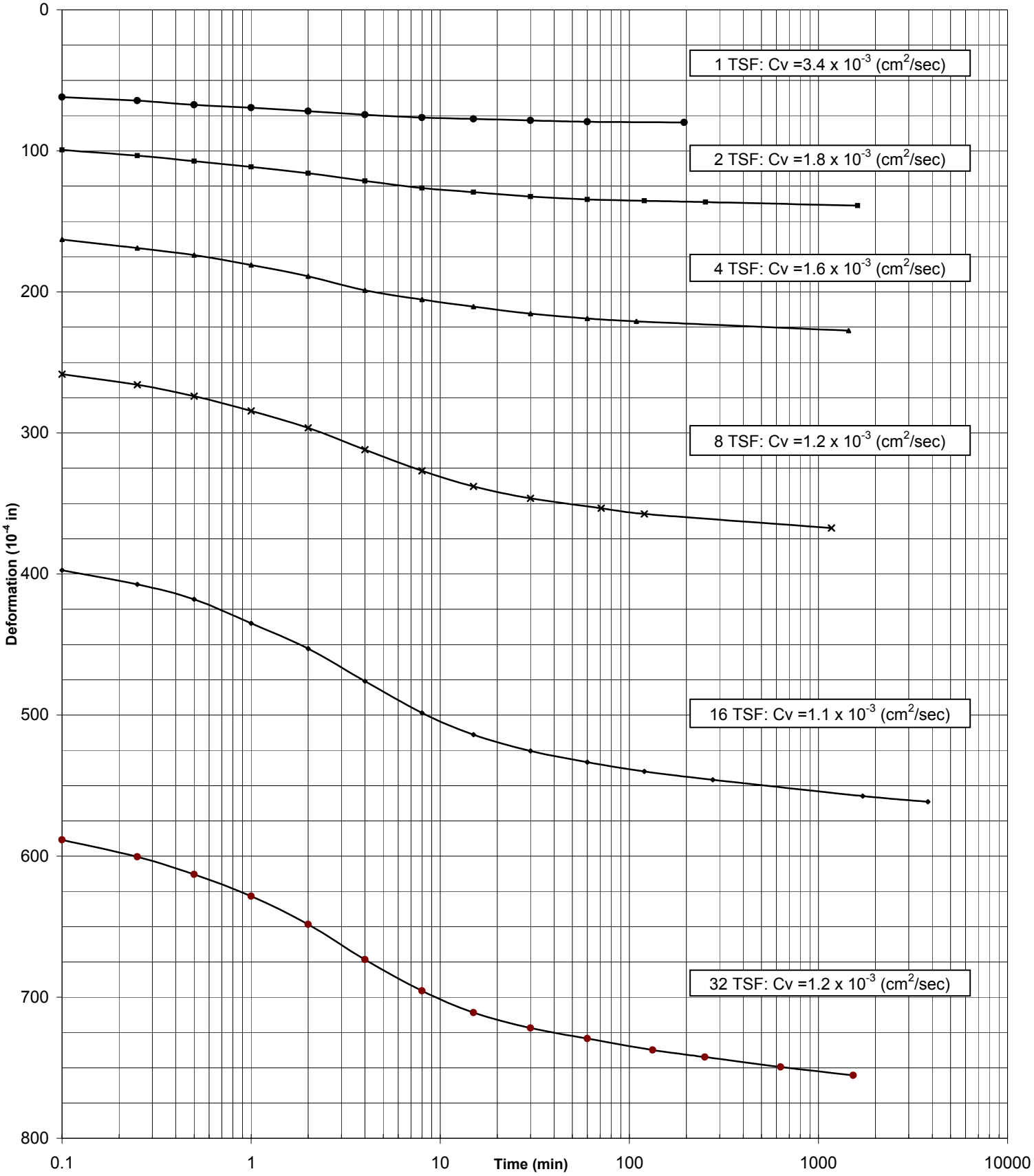
Consolidation Log of Time Curves



Project: Copperwood Mine			Date: 4/18/11
Sample #: BH-2	Boring #:	Depth ft: 25.2-27.2 (Bot)	Job #: 7835

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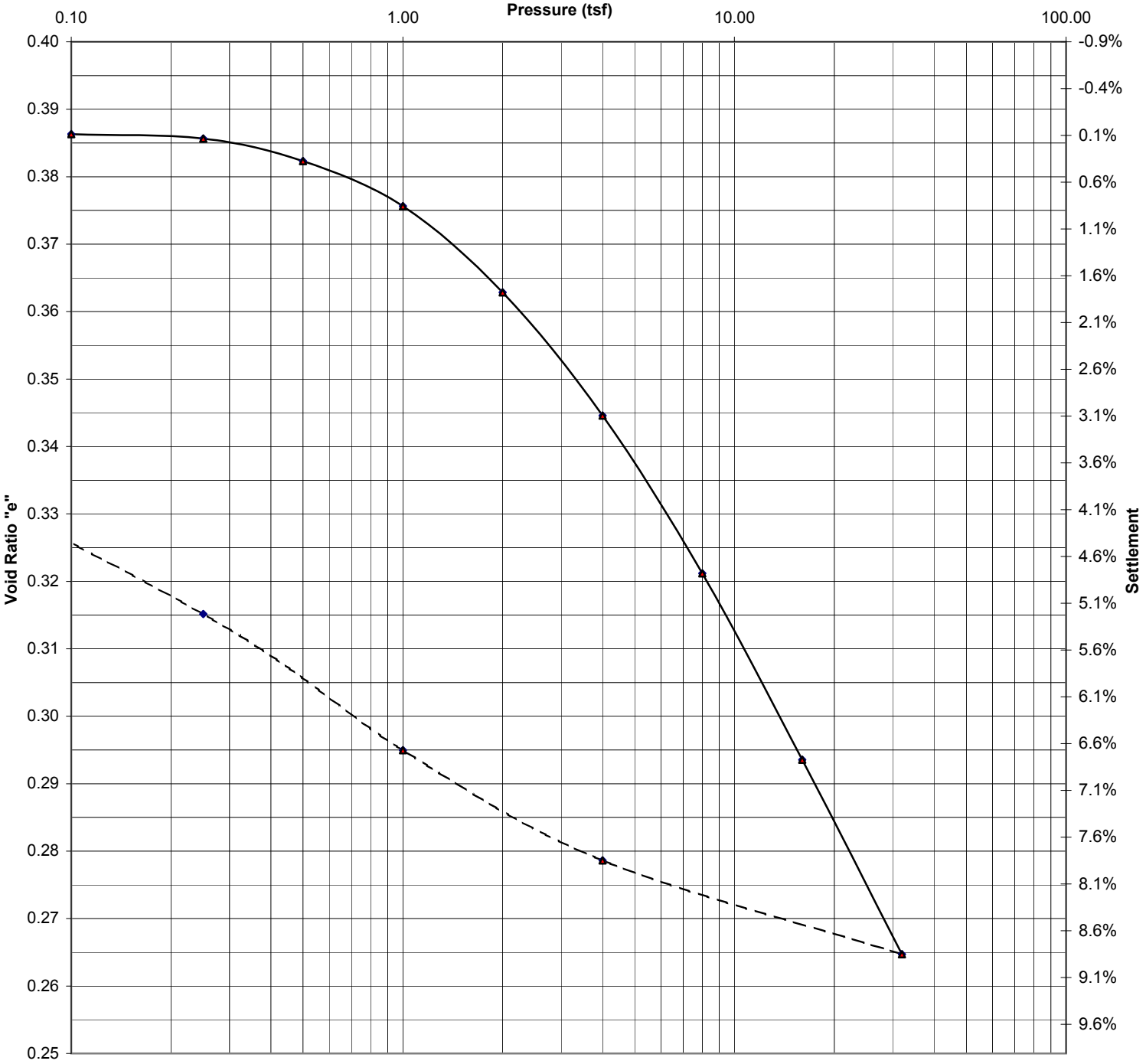
Job: 7835
Date: 4/18/11

Consolidation Test: Additional Coefficients

Sample: BH-2 Depth: 25.2-27.2 (Bot) Type: 3T
Soil Classification: Lean Clay, plastic, with fine to coarse sand, some fine to coarse gravel (CL)

Load Increment (TSF)	$\Delta\sigma'$ (TSF)	A_v: (Δe / tsf)	M_v (ft^2/ton)	Cv (cm^2/sec)	K (cm/sec)
0.1	0.1	0.046649	0.032027		
0.25	0.15	0.007807	0.005377		
0.5	0.25	0.011711	0.008073		
1	0.5	0.013663	0.009437	0.003406	3.3E-08
2	1	0.011516	0.007992	0.001787	1.5E-08
4	2	0.008637	0.006042	0.001649	1.0E-08
8	4	0.006831	0.004838	0.001235	6.1E-09
16	8	0.004733	0.003418	0.00113	4.0E-09
32	16	0.002368	0.001758	0.001229	2.2E-09

Void Ratio and % Settlement vs. Log of Pressure



Project: Copperwood Mine			Date: 4/13/11
Sample #: BH-4	Boring #:	Depth ft: 20-22.5	Job #: 7835
Soil Type: Lean Clay, highly plastic, with fine to coarse sand, trace of fine gravel (CL)			
Initial W/C (%): 13.0	Dry Density (pcf): 123.7	LL: PL: PI:	Gs: 2.75 (Assumed)
Organic Content (%):	Initial Height (in.): 0.748	Diameter (in.): 2.503	e_o= 0.387
Preconsolidation Pressure (Pc): 2.4 tsf	Compression Index (Cc): 0.10	Recompression Index (Cr): ≅ 0.02	
Remarks:			

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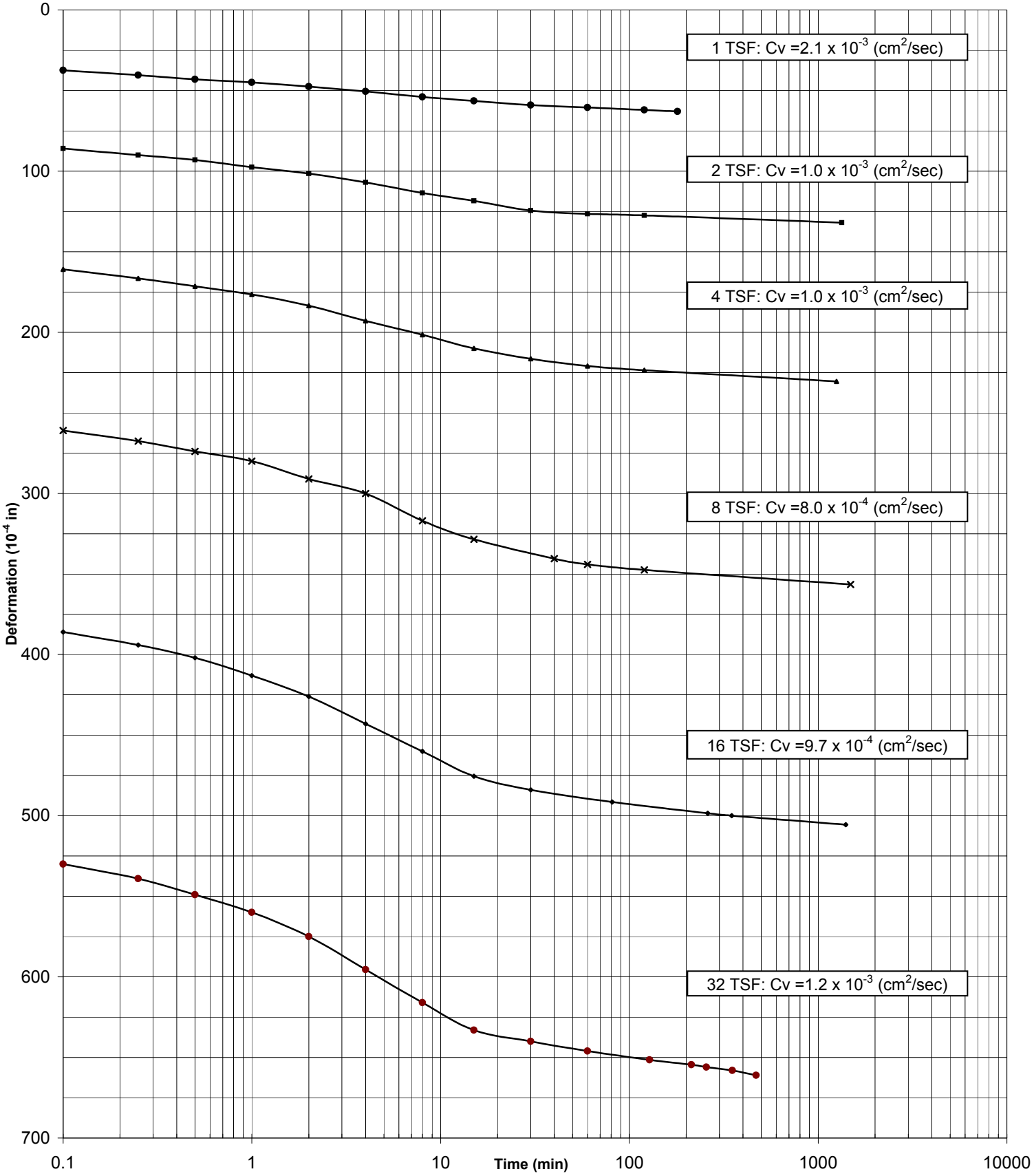
Consolidation Log of Time Curves



Project: Copperwood Mine			Date: 4/13/11
Sample #: BH-4	Boring #:	Depth ft: 20-22.5	Job #: 7835

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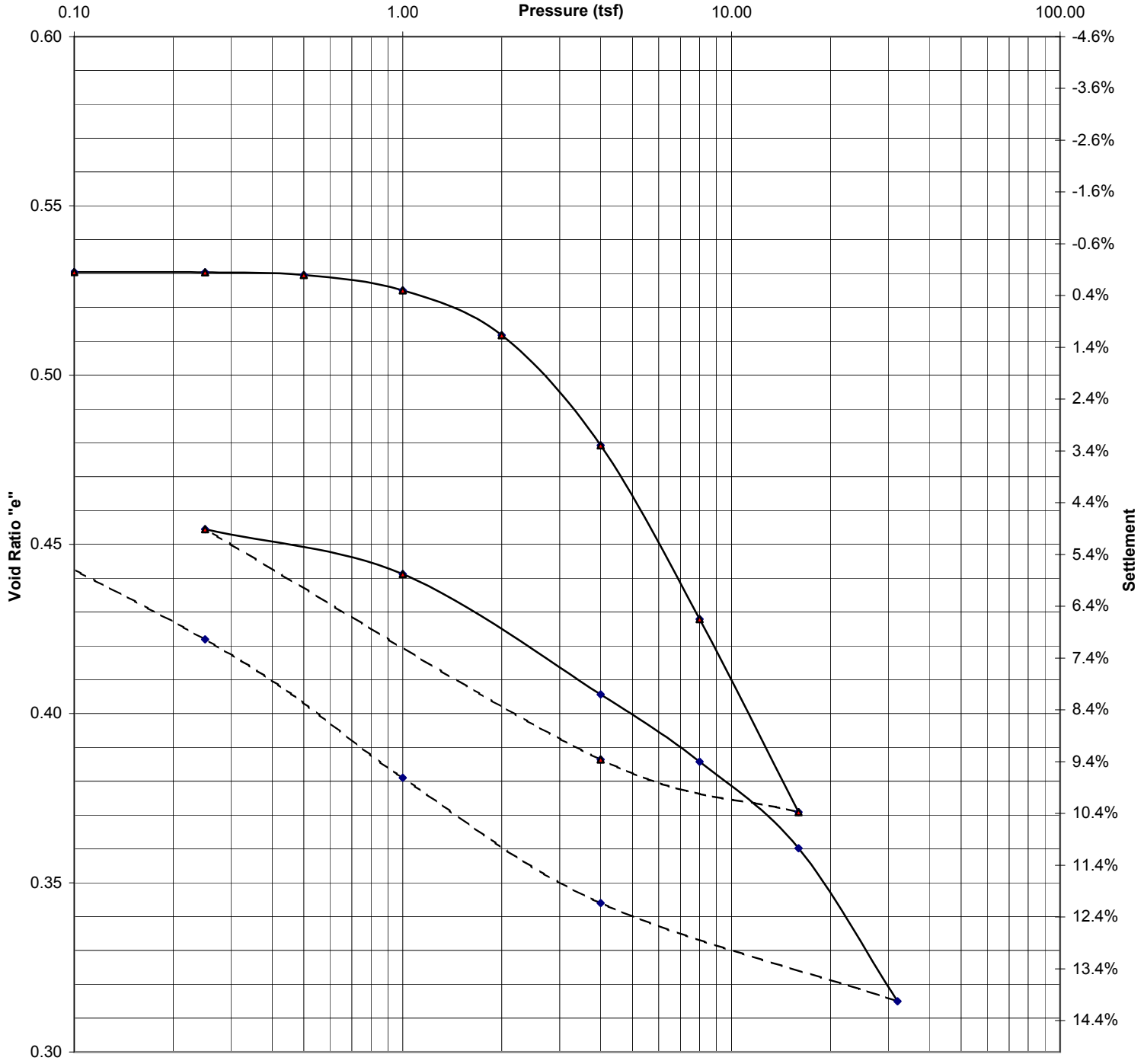
Job: 7835
Date: 4/18/11

Consolidation Test: Additional Coefficients

Sample: BH-4 Depth: 20-22.5 Type: 3T
Soil Classification: Lean Clay, highly plastic, with fine to coarse sand, trace of fine gravel (CL)

Load Increment (TSF)	$\Delta\sigma'$ (TSF)	A_v: (Δe / tsf)	M_v (ft^2/ton)	Cv (cm^2/sec)	K (cm/sec)
0.1	0.1	0.010201	0.007353		
0.25	0.15	0.004328	0.003122		
0.5	0.25	0.013354	0.009637		
1	0.5	0.013354	0.009661	0.00209	2.1E-08
2	1	0.012797	0.009303	0.001029	9.8E-09
4	2	0.009134	0.006703	0.001006	6.9E-09
8	4	0.005842	0.004345	0.000803	3.6E-09
16	8	0.003454	0.002615	0.000974	2.6E-09
32	16	0.001803	0.001393	0.001201	1.7E-09

Void Ratio and % Settlement vs. Log of Pressure



Project: Copperwood Mine				Date:	4/18/11
Sample #: BH-7	Boring #:	Depth ft: 23.3-25.3		Job #:	7835
Soil Type: Lean Clay, with fine - coarse sand, trace fine gravel (CL)					
Initial W/C (%): 19.3	Dry Density (pcf): 109.7	LL:	PL:	PI:	Gs: 2.69 (Assumed)
Organic Content (%):	Initial Height (in.): 0.748	Diameter (in.): 2.507	e_o= 0.530		
Preconsolidation Pressure (Pc): 3.0 tsf	Compression Index (Cc): 0.19	Recompression Index (Cr): 0.05			
Remarks:					

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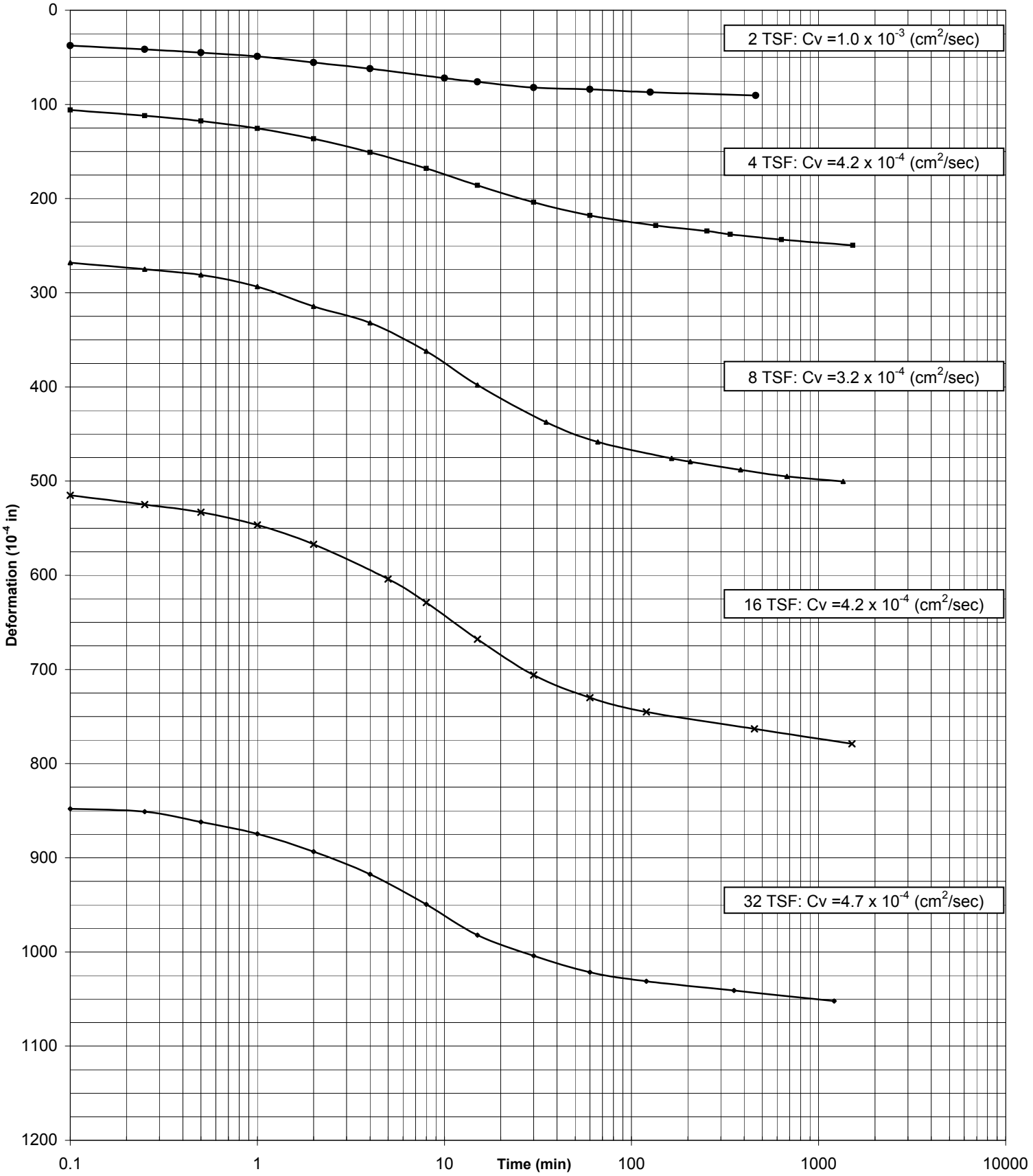
Consolidation Log of Time Curves



Project: Copperwood Mine			Date: 4/18/11
Sample #: BH-7	Boring #:	Depth ft: 23.3-25.3	Job #: 7835

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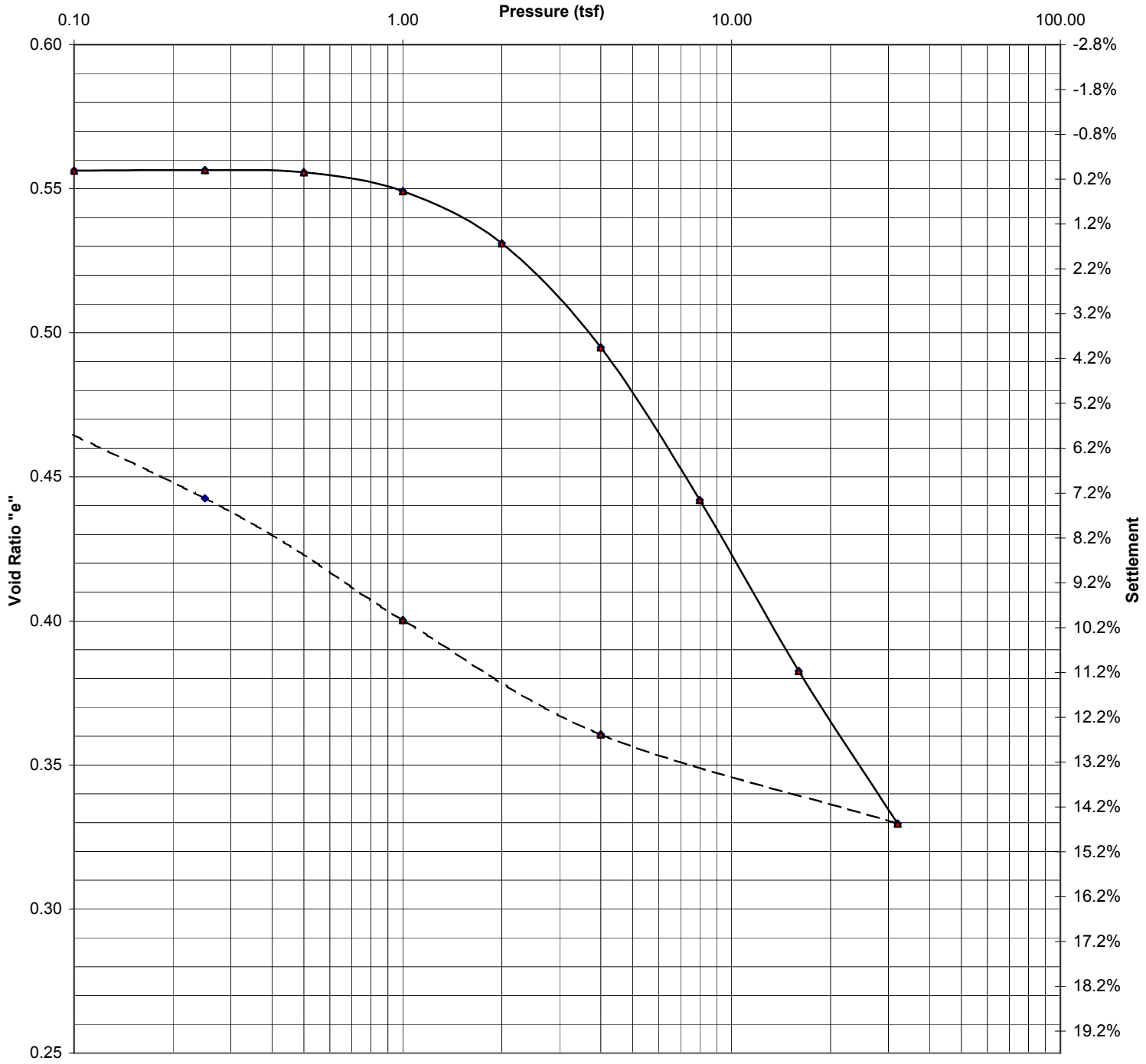
Job: 7835
Date: 4/18/11

Consolidation Test: Additional Coefficients

Sample: BH-7 Depth: 23.3-25.3 Type: 3T
Soil Classification: Lean Clay, with fine - coarse sand, trace fine gravel (CL)

Load Increment (TSF)	$\Delta\sigma'$ (TSF)	A_v: (Δe / tsf)	M_v (ft^2/ton)	Cv (cm^2/sec)	K (cm/sec)
0.1	0.1				
0.25	0.15	0.000341	0.000223		
0.5	0.25	0.003273	0.002138		
1	0.5	0.009	0.005884	0.001006	6.1E-09
2	1	0.013295	0.008718	0.001006	9.0E-09
4	2	0.016261	0.010756	0.000417	4.6E-09
8	4	0.012835	0.008677	0.000319	2.8E-09
16	8	0.007133	0.004996	0.000416	2.1E-09
32	16	0.002825	0.002061	0.000474	1.0E-09

Void Ratio and % Settlement vs. Log of Pressure



Project: Copperwood Mine			Date: 4/13/11
Sample #: BH-8	Boring #:	Depth ft: 19.6-21.8 (Top)	Job #: 7835
Soil Type: Lean Clay, plastic, with fine - coarse sand, trace fine gravel (CL)			
Initial W/C (%): 20.6	Dry Density (pcf): 108.3	LL: PL: PI:	Gs: 2.70 (Assumed)
Organic Content (%):	Initial Height (in.): 0.748	Diameter (in.): 2.503	e_o= 0.556
Preconsolidation Pressure (Pc): 2.5 tsf	Compression Index (Cc): 0.19	Recompression Index (Cr): ≅ 0.04	
Remarks:			

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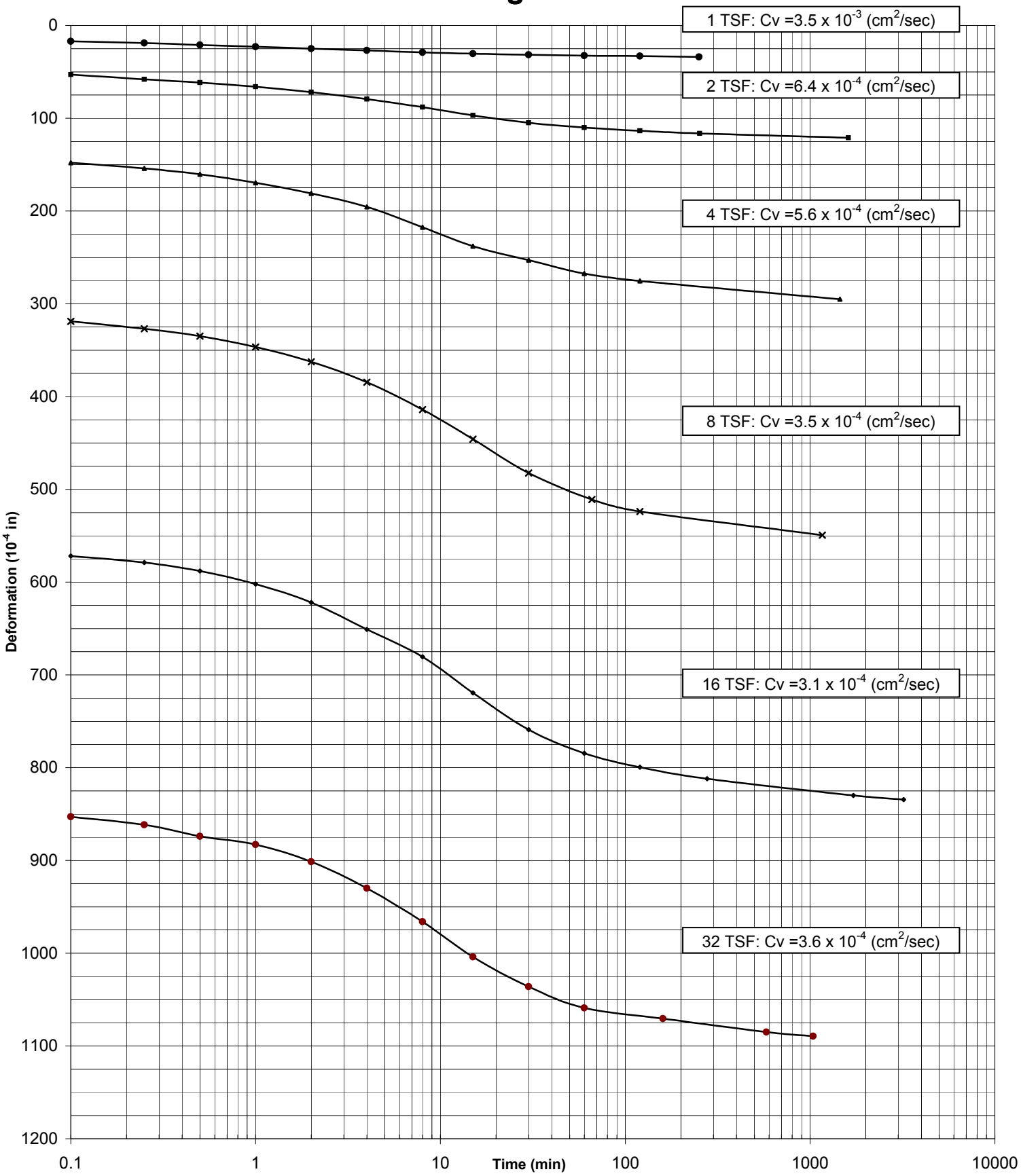
Consolidation Log of Time Curves



Project: Copperwood Mine			Date: 4/13/11
Sample #: BH-8	Boring #:	Depth ft: 19.6-21.8 (Top)	Job #: 7835

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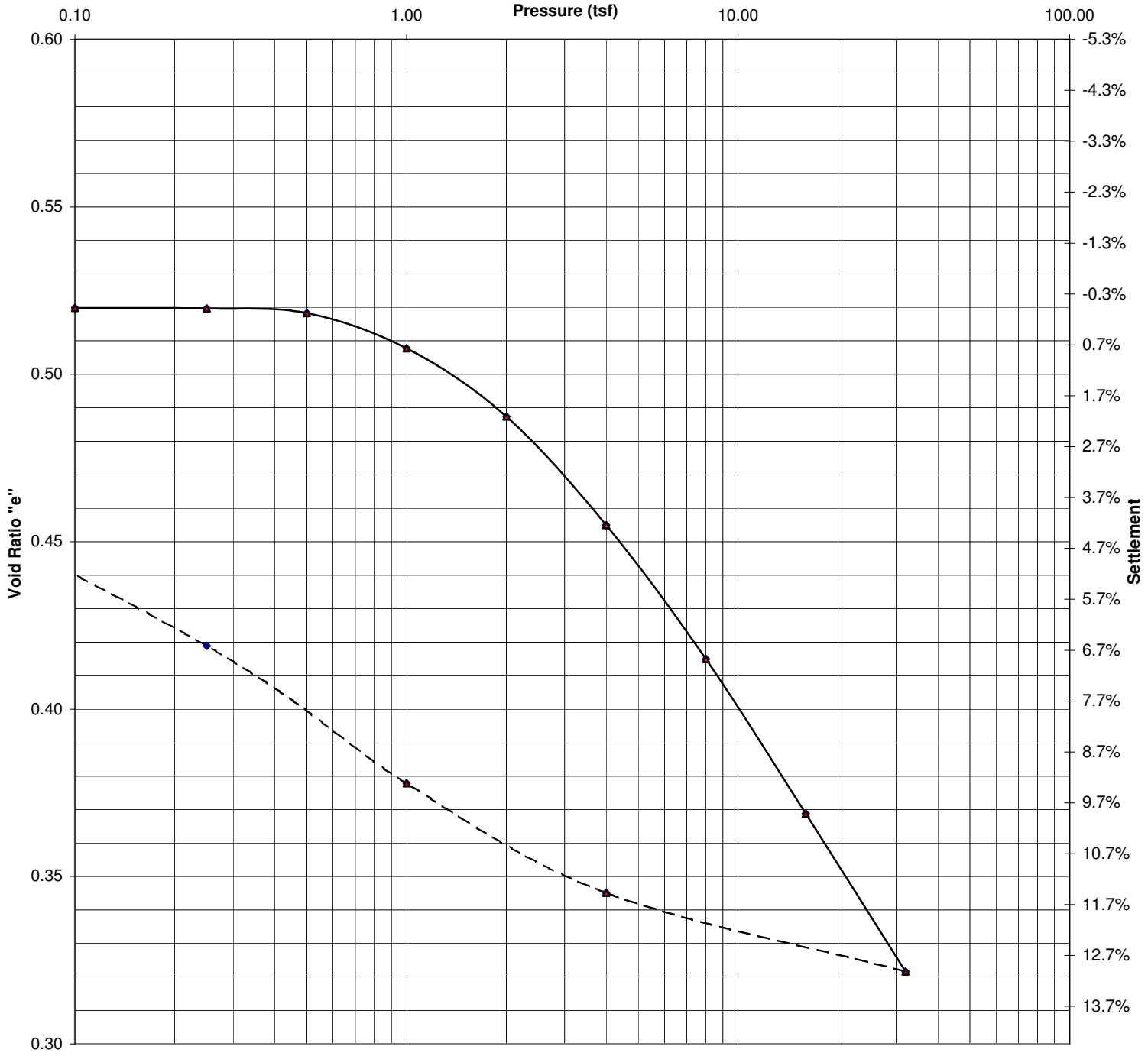
Job: 7835
Date: 4/18/11

Consolidation Test: Additional Coefficients

Sample: BH-8 Depth: 19.6-21.8 (Top) Type: 3T
Soil Classification: Lean Clay, plastic, with fine - coarse sand, trace fine gravel (CL)

Load Increment (TSF)	$\Delta\sigma'$ (TSF)	A_v: (Δe / tsf)	M_v (ft^2/ton)	Cv (cm^2/sec)	K (cm/sec)
0.1	0.1				
0.25	0.15				
0.5	0.25	0.002913	0.001871		
1	0.5	0.013108	0.008425	0.003549	3.1E-08
2	1	0.018101	0.011684	0.000644	7.7E-09
4	2	0.018101	0.011822	0.000561	6.8E-09
8	4	0.013238	0.008855	0.000348	3.2E-09
16	8	0.007412	0.00514	0.000306	1.6E-09
32	16	0.003309	0.002394	0.000364	8.9E-10

Void Ratio and % Settlement vs. Log of Pressure



Project: Copperwood Mine			Date: 4/18/11
Sample #: BH-10	Boring #:	Depth ft: 15-17	Job #: 7835
Soil Type: Lean Clay, plastic, some fine sand with fine to coarse gravel (CL)			
Initial W/C (%): 19.0	Dry Density (pcf): 111.7	LL: PL: PI:	Gs: 2.72 (Assumed)
Organic Content (%):	Initial Height (in.): 0.746	Diameter (in.): 2.506	e_o= 0.520
Preconsolidation Pressure (Pc): 2.7 tsf	Compression Index (Cc): 0.15	Recompression Index (Cr): ≅ 0.04	
Remarks:			

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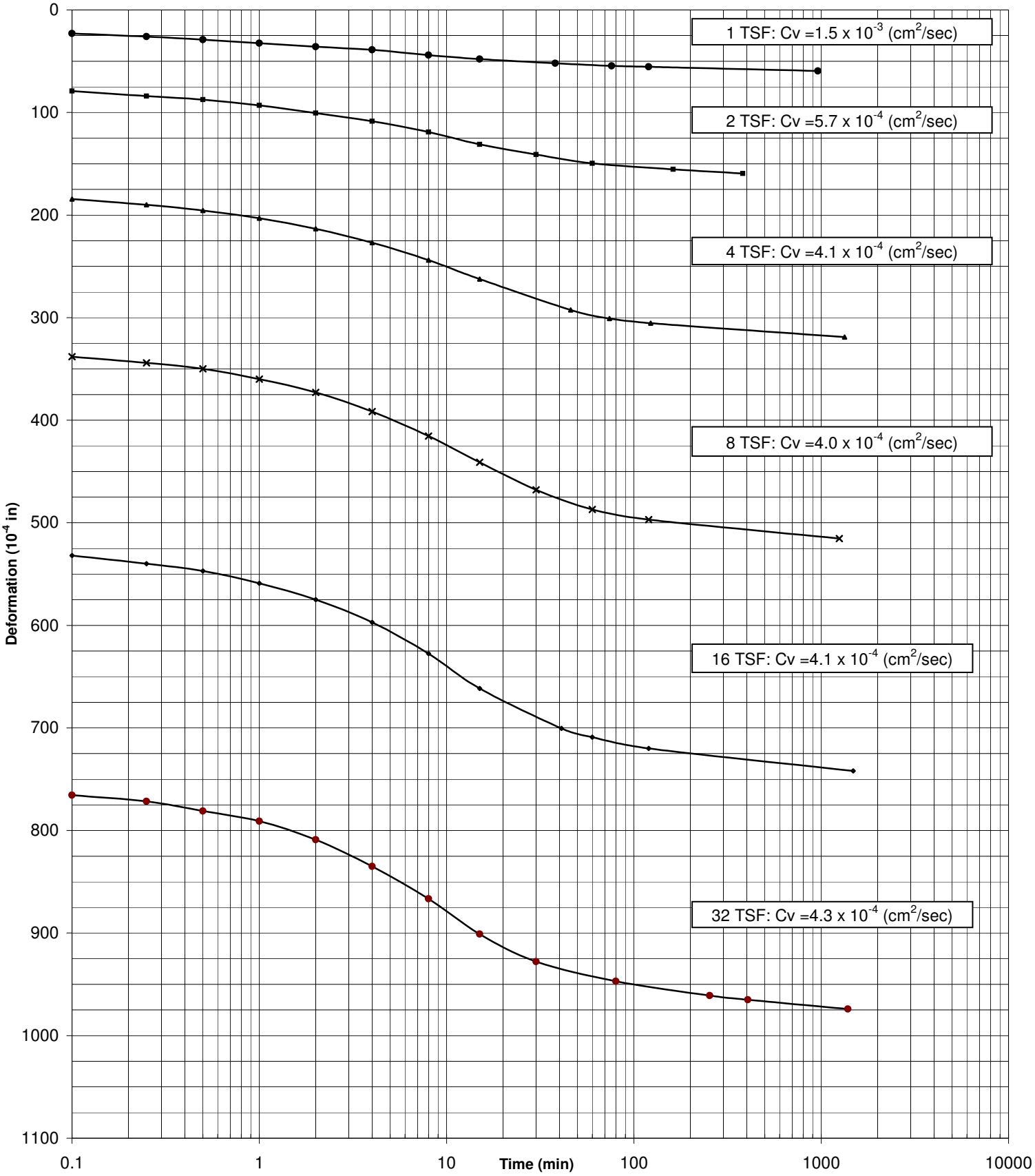
Consolidation Log of Time Curves



Project: Copperwood Mine			Date: 4/18/11
Sample #: BH-10	Boring #:	Depth ft: 15-17	Job #: 7835

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Job: 7835
Date: 4/18/11

Consolidation Test: Additional Coefficients

Sample: BH-10 Depth: 15-17 Type: 3T
Soil Classification: Lean Clay, plastic, some fine sand with fine to coarse gravel (CL)

Load Increment (TSF)	$\Delta\sigma'$ (TSF)	A_v: (Δe / tsf)	M_v (ft^2/ton)	Cv (cm^2/sec)	K (cm/sec)
0.1	0.1	0.001018	0.00067		
0.25	0.15	0.000679	0.000447		
0.5	0.25	0.005703	0.003753		
1	0.5	0.020978	0.013817	0.00146	2.1E-08
2	1	0.020367	0.013508	0.000572	7.9E-09
4	2	0.016243	0.01092	0.000406	4.5E-09
8	4	0.010005	0.006877	0.000399	2.8E-09
16	8	0.005766	0.004076	0.000414	1.7E-09
32	16	0.002947	0.002153	0.000429	9.5E-10

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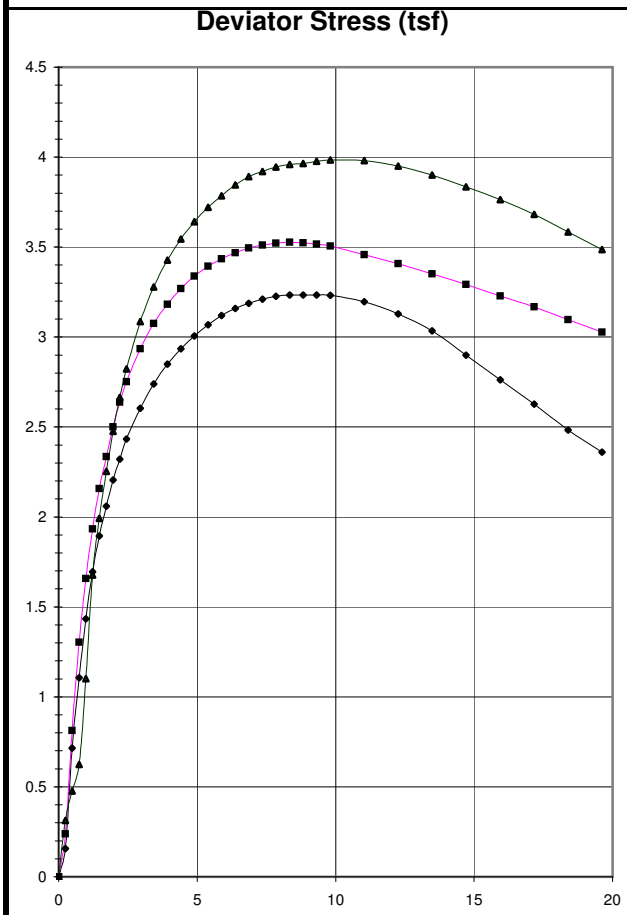
Appendix F-8

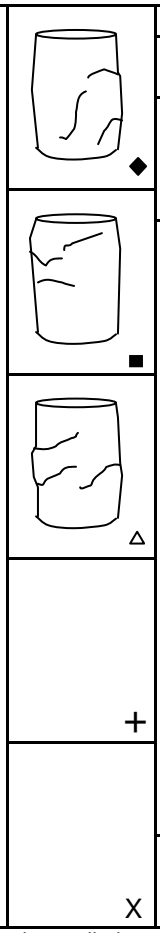
Laboratory Test Data – Shear Strength Data (Test Pits and Boreholes)

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **T-8** Type: **Block** Depth (ft):
Soil Type: **Lean Clay w/Sand & a Trace of Gravel (CL)**

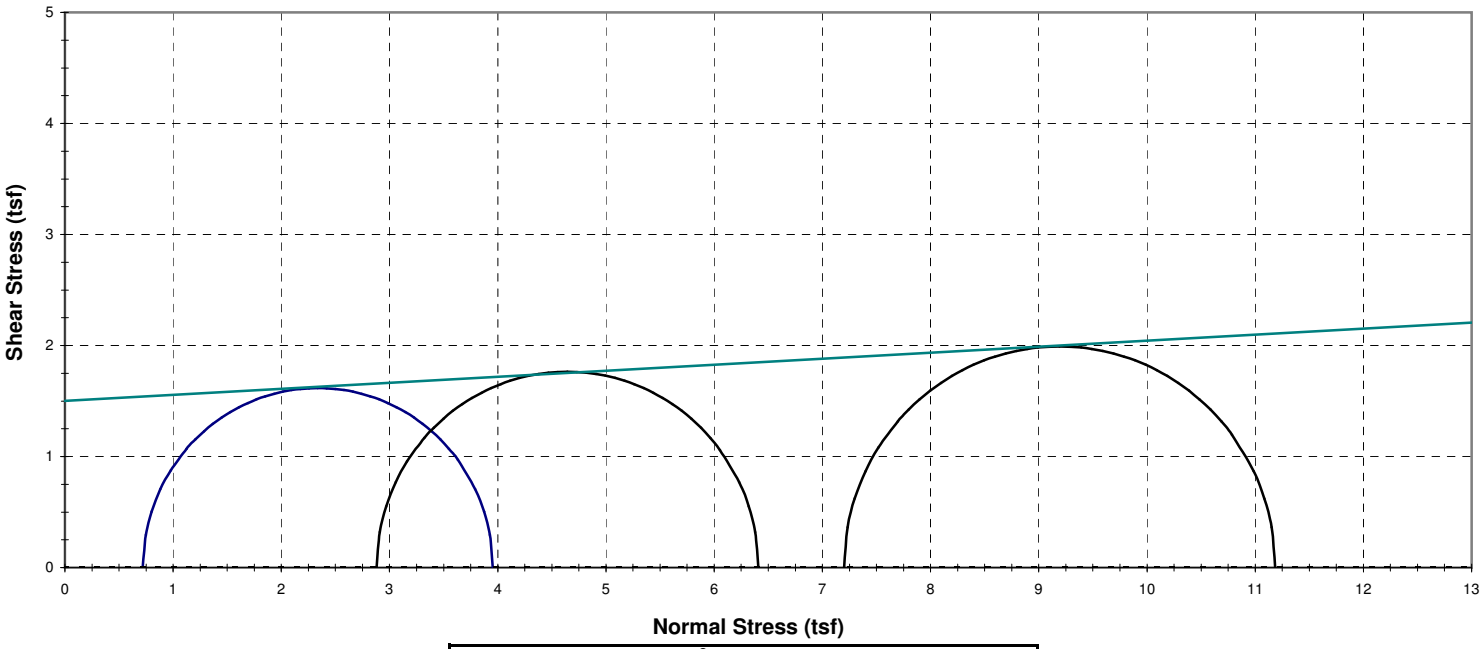




Failure Criterion:	**Max. Deviator Stress**				
Angle of internal friction, ϕ_u =	**3.1 °**				
Apparent Cohesion, c_u =	**1.50 (tsf)**				
Test Date: 4/12/11	Liquid Limit:				
Test Type: U-U	Plastic Limit:				
Strain Rate (in/min): 0.05	Plasticity Index:				
Strain Rate (%/min): 1.226	Spec. Gravity (Assumed):		2.69		
Before Consolidation	**A**	**B**	**C**	**D**	**E**
Diameter (in)	1.94	1.94	1.94		
Height (in)	4.08	4.08	4.08		
Water Content (%)	14.6	16.1	16.9		
Dry Density (pcf)	119.5	117.5	116.3		
Void Ratio	0.40	0.43	0.44		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	3.23	3.53	3.98		
Ultimate Deviator Stress (tsf)	2.36	3.03	3.49		
Deviator Stress at Failure (tsf)	3.23	3.53	3.98		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	9.3	8.3	9.8		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 3.1 ° c_u= 1.50 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

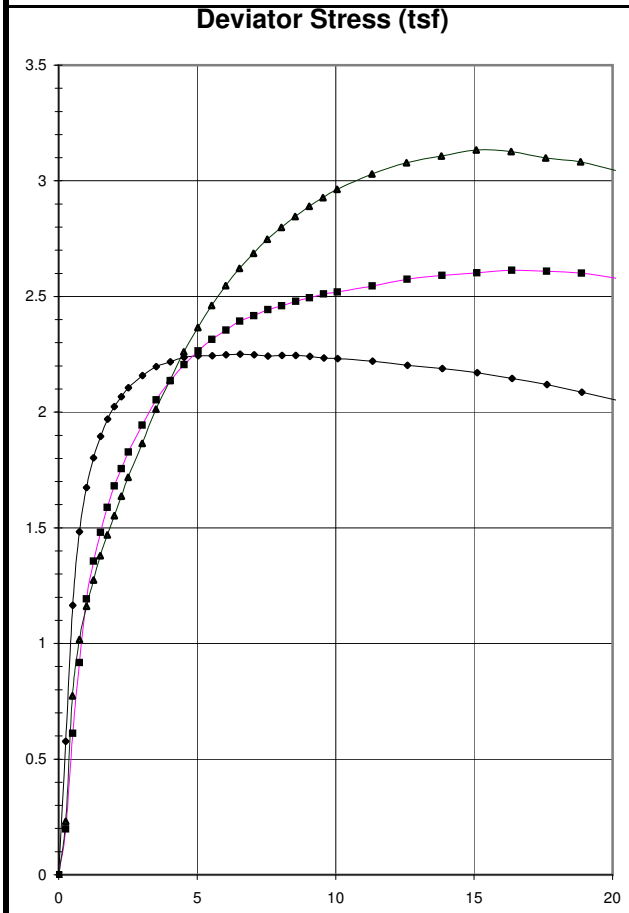
Sample No.: T-8, Sample Type: Block

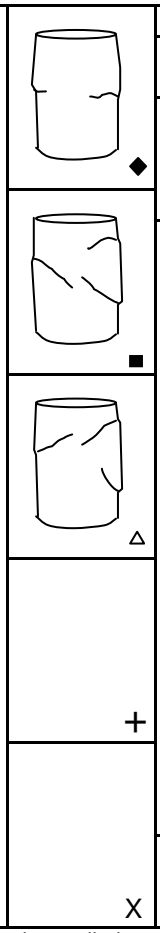
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.16	0.25	0.24	0.25	0.31
0.49	0.72	0.49	0.81	0.49	0.48
0.74	1.11	0.74	1.30	0.74	0.62
0.98	1.43	0.98	1.66	0.98	1.10
1.23	1.69	1.23	1.93	1.23	1.68
1.47	1.89	1.47	2.16	1.47	1.99
1.72	2.06	1.72	2.34	1.72	2.25
1.96	2.20	1.96	2.50	1.96	2.48
2.21	2.32	2.21	2.64	2.21	2.66
2.45	2.43	2.45	2.75	2.45	2.82
2.94	2.60	2.94	2.94	2.94	3.09
3.43	2.74	3.43	3.07	3.43	3.28
3.92	2.85	3.92	3.18	3.92	3.43
4.41	2.93	4.41	3.27	4.41	3.54
4.90	3.01	4.90	3.34	4.90	3.64
5.39	3.07	5.39	3.39	5.39	3.72
5.89	3.12	5.89	3.43	5.89	3.79
6.38	3.16	6.38	3.47	6.38	3.85
6.87	3.19	6.87	3.50	6.87	3.89
7.36	3.21	7.36	3.51	7.36	3.92
7.85	3.23	7.85	3.52	7.85	3.94
8.34	3.23	8.34	3.53	8.34	3.96
8.83	3.23	8.83	3.52	8.83	3.97
9.32	3.23	9.32	3.52	9.32	3.98
9.81	3.23	9.81	3.51	9.81	3.98
11.03	3.20	11.03	3.46	11.03	3.98
12.26	3.13	12.26	3.41	12.26	3.95
13.49	3.03	13.49	3.35	13.49	3.90
14.71	2.90	14.71	3.29	14.71	3.83
15.94	2.76	15.94	3.23	15.94	3.76
17.17	2.63	17.17	3.17	17.17	3.68
18.39	2.48	18.39	3.10	18.39	3.58
19.62	2.36	19.62	3.03	19.62	3.49

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-2** Type: **3T** Depth (ft): **14 - 16**
Soil Type: **Lean Clay w/Sand (CL)**



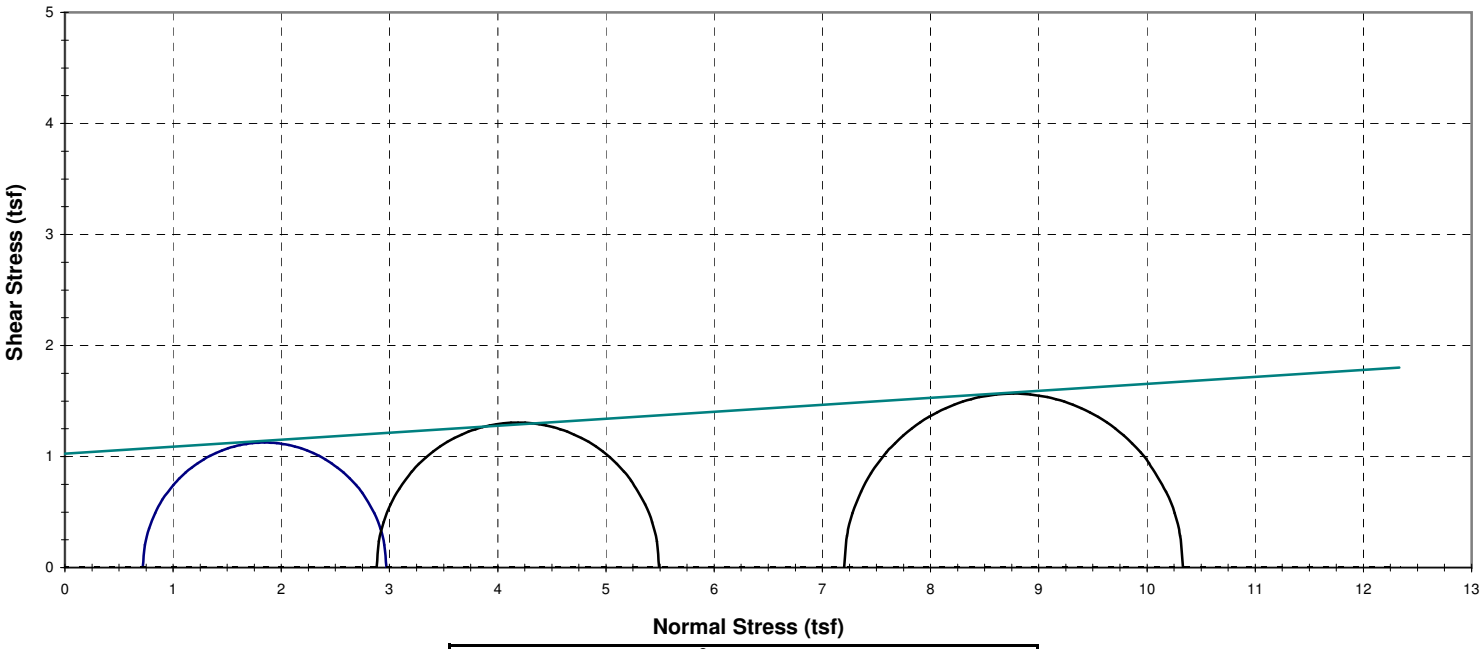


Failure Criterion:	**Max. Deviator Stress**		
Angle of internal friction, ϕ_u =	**3.6 °**		
Apparent Cohesion, c_u =	**1.03 (tsf)**		
Test Date: 4/4/11	Liquid Limit:		
Test Type: U-U	Plastic Limit:		
Strain Rate (in/min): 0.05	Plasticity Index:		
Strain Rate (%/min): 1.260	Spec. Gravity (Assumed):	2.69	

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.95	1.94		
Height (in)	3.97	3.97	3.98		
Water Content (%)	17.0	25.1	26.9		
Dry Density (pcf)	116.4	105.5	98.6		
Void Ratio	0.44	0.59	0.70		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	2.25	2.61	3.13		
Ultimate Deviator Stress (tsf)	2.05	2.58	3.05		
Deviator Stress at Failure (tsf)	2.25	2.61	3.13		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	6.5	16.4	15.1		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 3.6 ° c_u= 1.03 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

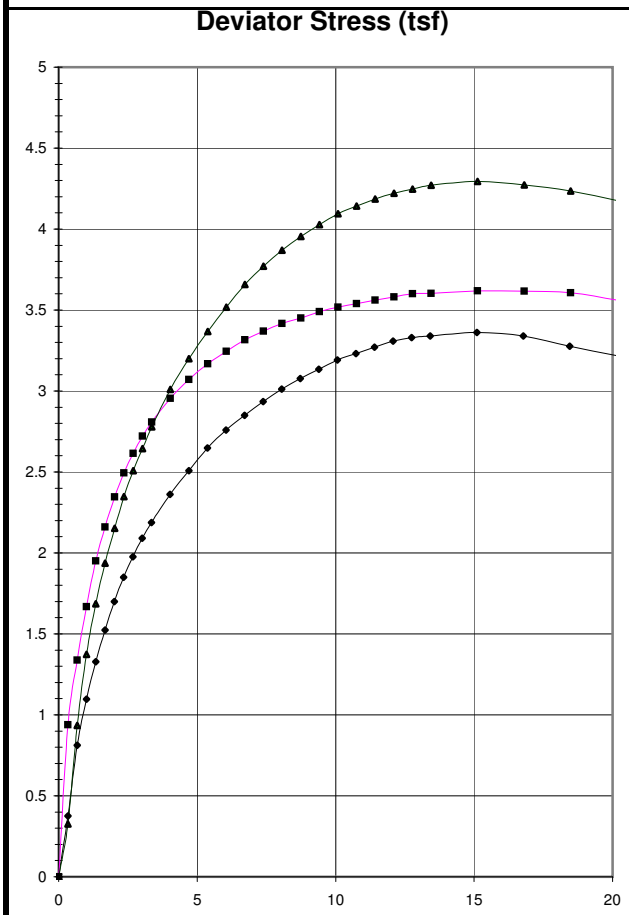
Sample No.: BH-2, Depth (ft.): 14 - 16

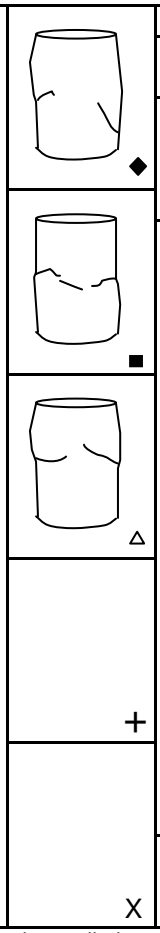
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.58	0.25	0.20	0.25	0.23
0.50	1.16	0.50	0.61	0.50	0.77
0.76	1.48	0.76	0.92	0.75	1.02
1.01	1.67	1.01	1.19	1.01	1.16
1.26	1.80	1.26	1.36	1.26	1.27
1.51	1.90	1.51	1.48	1.51	1.38
1.76	1.97	1.76	1.59	1.76	1.47
2.02	2.02	2.01	1.68	2.01	1.55
2.27	2.07	2.27	1.76	2.26	1.64
2.52	2.11	2.52	1.83	2.51	1.72
3.02	2.16	3.02	1.94	3.02	1.87
3.53	2.20	3.52	2.05	3.52	2.01
4.03	2.22	4.03	2.14	4.02	2.14
4.53	2.24	4.53	2.21	4.52	2.26
5.04	2.24	5.03	2.27	5.03	2.37
5.54	2.24	5.54	2.31	5.53	2.46
6.05	2.25	6.04	2.35	6.03	2.55
6.55	2.25	6.54	2.39	6.53	2.62
7.05	2.25	7.05	2.42	7.04	2.69
7.56	2.24	7.55	2.44	7.54	2.75
8.06	2.24	8.05	2.46	8.04	2.80
8.57	2.24	8.56	2.48	8.54	2.85
9.07	2.24	9.06	2.49	9.05	2.89
9.57	2.23	9.56	2.51	9.55	2.93
10.08	2.23	10.07	2.52	10.05	2.96
11.34	2.22	11.33	2.55	11.31	3.03
12.60	2.20	12.58	2.57	12.56	3.08
13.86	2.19	13.84	2.59	13.82	3.11
15.12	2.17	15.10	2.60	15.08	3.13
16.37	2.15	16.36	2.61	16.33	3.13
17.63	2.12	17.62	2.61	17.59	3.10
18.89	2.09	18.88	2.60	18.85	3.08
20.15	2.05	20.14	2.58	20.10	3.05

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-2** Type: **3T** Depth (ft): **45.2 - 47.2 (Bot)**
Soil Type: **Lean Clay w/Sand & a Trace of Gravel (CL)**





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, ϕ_u = **3.9 °**

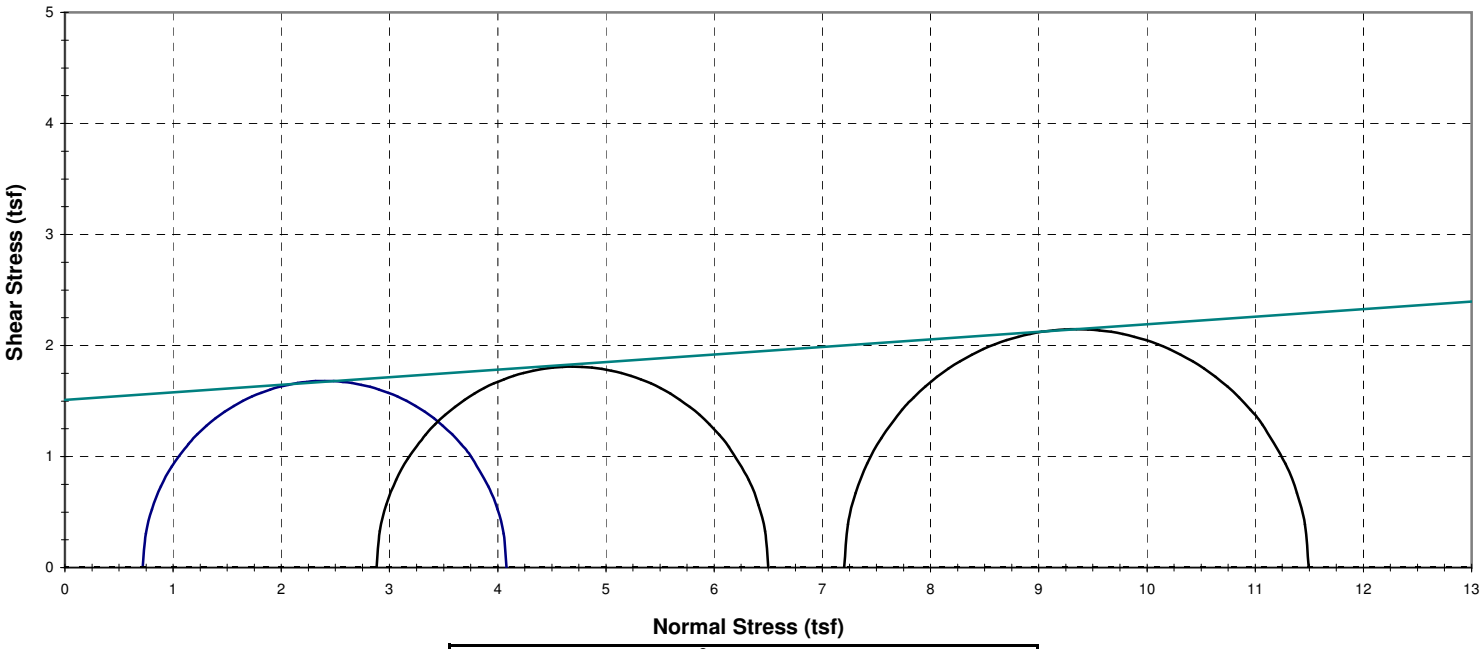
Apparent Cohesion, c_u = **1.51 (tsf)**

Test Date:	4/4/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	1.677	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.98	2.97	2.97		
Water Content (%)	19.1	12.9	12.4		
Dry Density (pcf)	118.2	123.5	123.6		
Void Ratio	0.42	0.36	0.36		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	3.36	3.62	4.29		
Ultimate Deviator Stress (tsf)	3.22	3.56	4.18		
Deviator Stress at Failure (tsf)	3.36	3.62	4.29		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	15.1	15.1	15.1		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 3.9 ° c_u= 1.51 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

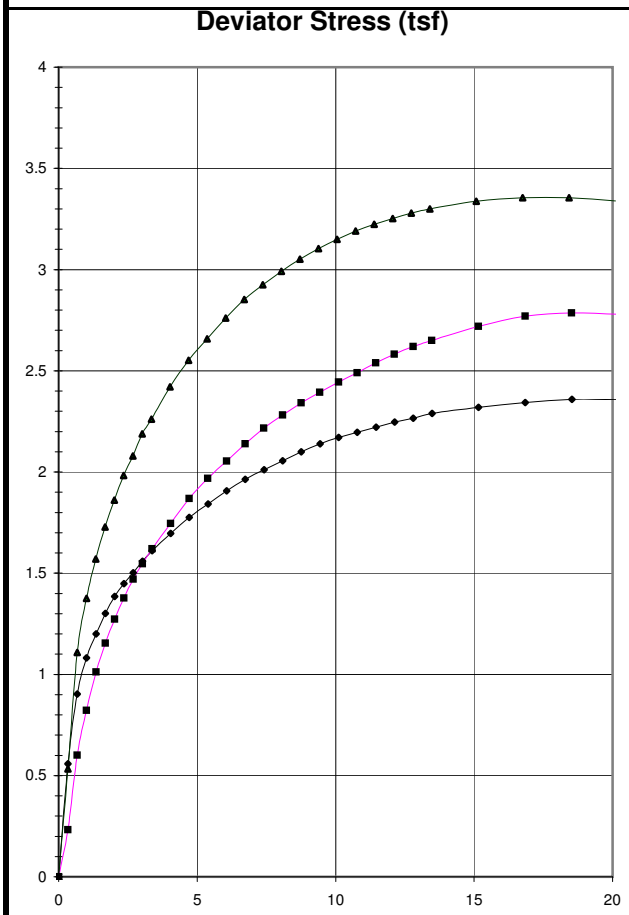
Sample No.: BH-2, Depth (ft.): 45.2 - 47.2 (Bot)

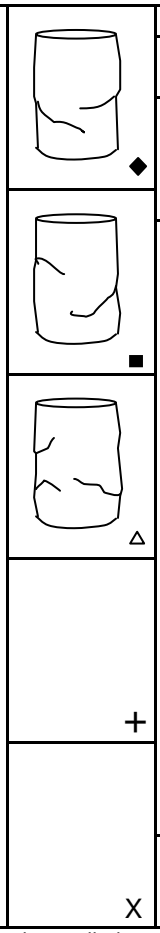
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.34	0.38	0.34	0.94	0.34	0.33
0.67	0.81	0.67	1.34	0.67	0.93
1.01	1.10	1.01	1.67	1.01	1.37
1.34	1.33	1.34	1.95	1.34	1.69
1.68	1.52	1.68	2.16	1.68	1.94
2.01	1.70	2.02	2.35	2.02	2.15
2.35	1.85	2.35	2.50	2.35	2.35
2.68	1.98	2.69	2.61	2.69	2.51
3.02	2.09	3.03	2.72	3.03	2.64
3.35	2.19	3.36	2.81	3.36	2.78
4.03	2.36	4.03	2.96	4.03	3.01
4.70	2.51	4.71	3.07	4.71	3.20
5.37	2.65	5.38	3.17	5.38	3.37
6.04	2.76	6.05	3.25	6.05	3.52
6.71	2.85	6.72	3.32	6.72	3.66
7.38	2.93	7.40	3.37	7.40	3.77
8.05	3.01	8.07	3.42	8.07	3.87
8.72	3.08	8.74	3.45	8.74	3.95
9.39	3.13	9.41	3.49	9.41	4.03
10.06	3.19	10.09	3.52	10.09	4.09
10.74	3.23	10.76	3.54	10.76	4.14
11.41	3.27	11.43	3.56	11.43	4.19
12.08	3.31	12.10	3.58	12.10	4.22
12.75	3.33	12.78	3.60	12.78	4.25
13.42	3.34	13.45	3.60	13.45	4.27
15.10	3.36	15.13	3.62	15.13	4.29
16.77	3.34	16.81	3.62	16.81	4.27
18.45	3.28	18.49	3.61	18.49	4.24
20.13	3.22	20.17	3.56	20.17	4.18

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-7** Type: **3T** Depth (ft): **15 - 17 (Bot)**
Soil Type: **Lean Clay w/Sand & a Little Gravel (CL)**





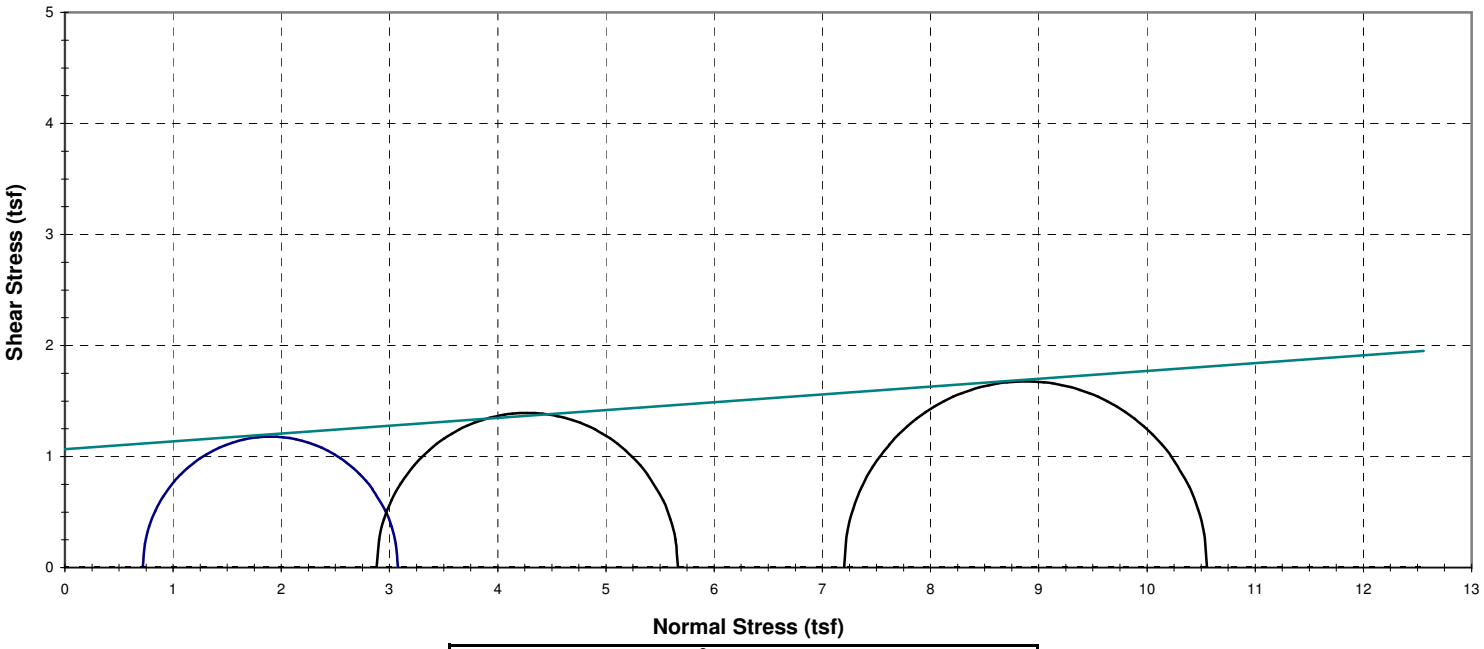
Failure Criterion:	**Max. Deviator Stress**
Angle of internal friction, ϕ_u =	**4.0 °**
Apparent Cohesion, c_u =	**1.07 (tsf)**

Test Date:	4/5/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	1.685	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.97	2.97	2.99		
Water Content (%)	12.8	12.9	14.6		
Dry Density (pcf)	121.9	121.6	117.3		
Void Ratio	0.38	0.38	0.43		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	2.36	2.79	3.36		
Ultimate Deviator Stress (tsf)	2.36	2.78	3.34		
Deviator Stress at Failure (tsf)	2.36	2.79	3.36		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	18.5	18.5	18.4		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 4.0 ° c_u= 1.07 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

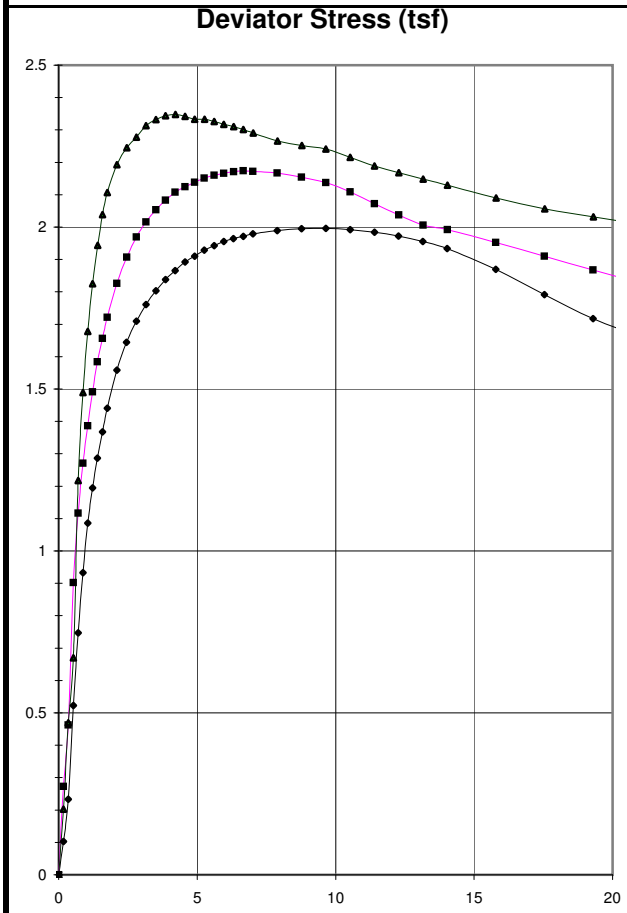
Sample No.: BH-7, Depth (ft.): 15 - 17 (Bot)

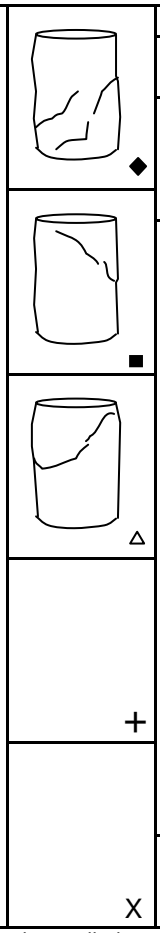
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.34	0.56	0.34	0.23	0.34	0.53
0.67	0.90	0.67	0.60	0.67	1.11
1.01	1.08	1.01	0.82	1.01	1.37
1.35	1.20	1.35	1.01	1.34	1.57
1.68	1.30	1.68	1.15	1.68	1.73
2.02	1.38	2.02	1.27	2.01	1.86
2.36	1.45	2.36	1.38	2.35	1.98
2.70	1.50	2.69	1.47	2.68	2.08
3.03	1.56	3.03	1.55	3.02	2.19
3.37	1.61	3.37	1.62	3.35	2.26
4.04	1.70	4.04	1.75	4.02	2.42
4.72	1.78	4.72	1.87	4.69	2.55
5.39	1.84	5.39	1.97	5.36	2.66
6.07	1.91	6.06	2.05	6.03	2.76
6.74	1.96	6.74	2.14	6.70	2.85
7.41	2.01	7.41	2.22	7.37	2.92
8.09	2.06	8.08	2.28	8.04	2.99
8.76	2.10	8.76	2.34	8.71	3.05
9.44	2.14	9.43	2.39	9.38	3.10
10.11	2.17	10.10	2.44	10.05	3.15
10.78	2.20	10.78	2.49	10.72	3.19
11.46	2.22	11.45	2.54	11.39	3.22
12.13	2.25	12.13	2.58	12.06	3.25
12.81	2.27	12.80	2.62	12.73	3.28
13.48	2.29	13.47	2.65	13.40	3.30
15.16	2.32	15.16	2.72	15.08	3.34
16.85	2.34	16.84	2.77	16.75	3.36
18.53	2.36	18.52	2.79	18.43	3.36
20.22	2.36	20.21	2.78	20.10	3.34

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-7** Type: **3T** Depth (ft): **34 - 36**
Soil Type: **Lean Clay w/Sand & a Trace of Gravel (CL)**





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, ϕ_u = **1.5 °**

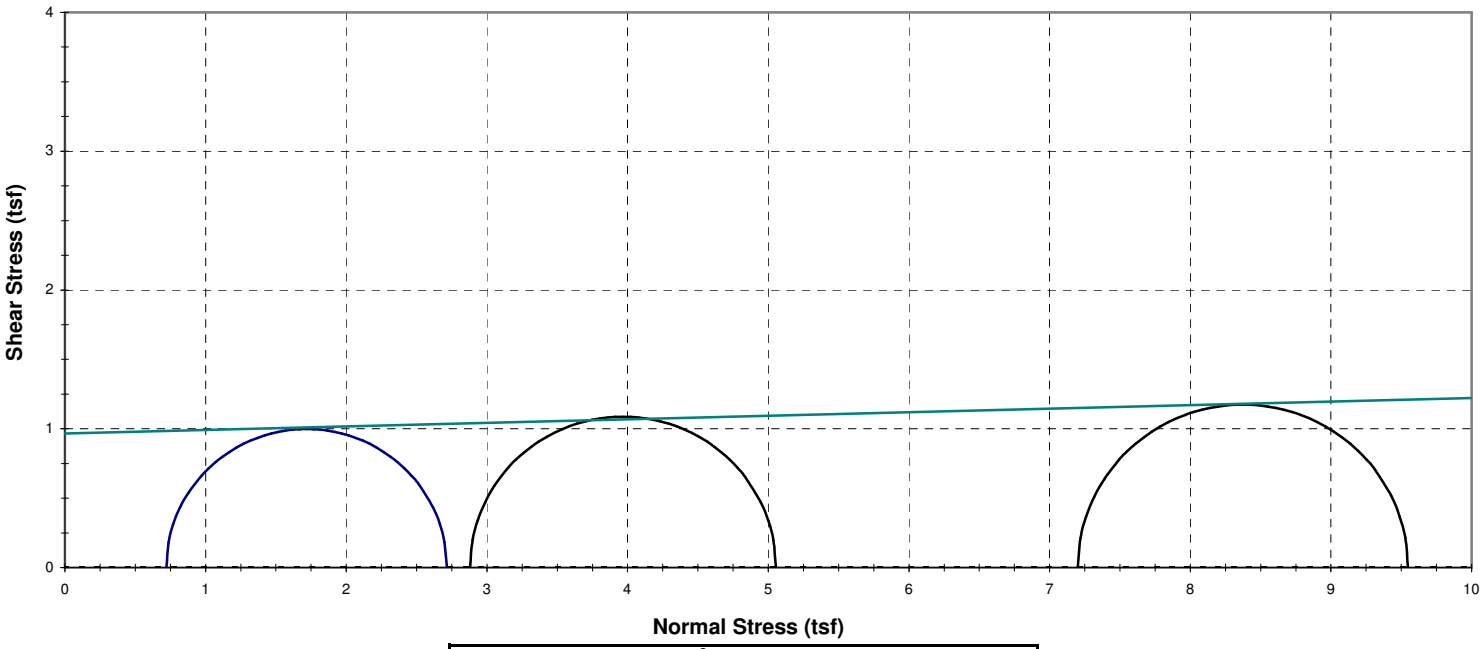
Apparent Cohesion, c_u = **0.97 (tsf)**

Test Date:	4/1/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	0.877	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	2.88	2.88	2.88		
Height (in)	5.70	5.70	5.70		
Water Content (%)	22.1	24.6	24.7		
Dry Density (pcf)	106.2	102.5	101.5		
Void Ratio	0.58	0.64	0.66		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	2.00	2.17	2.35		
Ultimate Deviator Stress (tsf)	1.66	1.83	2.01		
Deviator Stress at Failure (tsf)	2.00	2.17	2.35		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	9.6	6.7	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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 1.5 ° c_u= 0.97 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

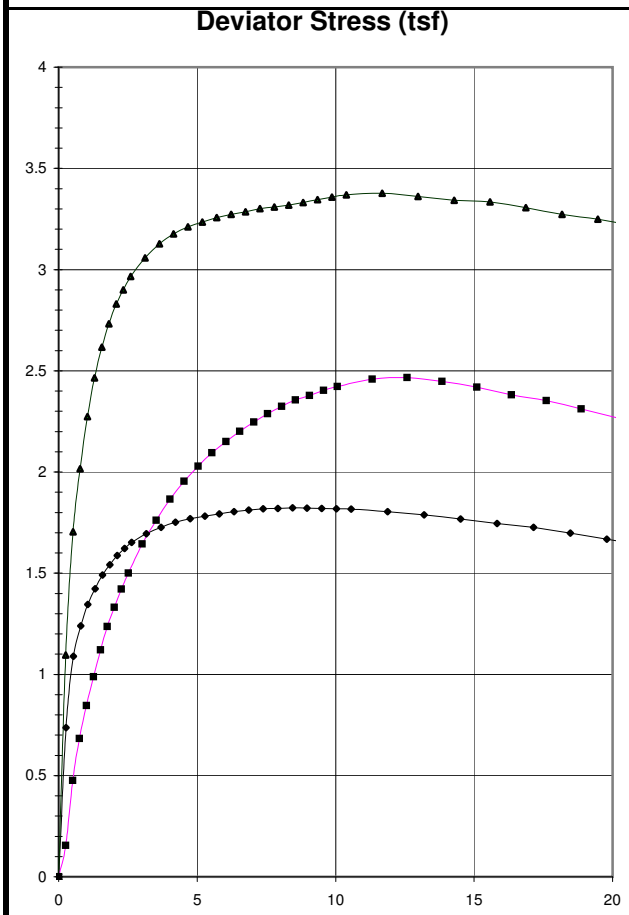
Sample No.: BH-7, Depth (ft.): 34 - 36

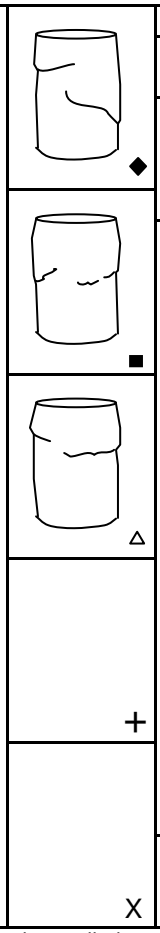
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.18	0.10	0.18	0.27	0.18	0.20
0.35	0.23	0.35	0.46	0.35	0.47
0.53	0.52	0.53	0.90	0.53	0.67
0.70	0.75	0.70	1.12	0.70	1.22
0.88	0.93	0.88	1.27	0.88	1.49
1.05	1.09	1.05	1.39	1.05	1.68
1.23	1.19	1.23	1.49	1.23	1.83
1.40	1.29	1.40	1.58	1.40	1.94
1.58	1.37	1.58	1.66	1.58	2.04
1.75	1.44	1.75	1.72	1.76	2.11
2.10	1.56	2.10	1.83	2.11	2.19
2.46	1.64	2.46	1.91	2.46	2.25
2.81	1.71	2.81	1.97	2.81	2.28
3.16	1.76	3.16	2.02	3.16	2.31
3.51	1.80	3.51	2.05	3.51	2.33
3.86	1.84	3.86	2.08	3.86	2.34
4.21	1.87	4.21	2.11	4.21	2.35
4.56	1.89	4.56	2.12	4.56	2.34
4.91	1.91	4.91	2.14	4.91	2.33
5.26	1.93	5.26	2.15	5.27	2.33
5.61	1.94	5.61	2.16	5.62	2.33
5.96	1.96	5.96	2.17	5.97	2.32
6.31	1.96	6.31	2.17	6.32	2.31
6.66	1.97	6.67	2.17	6.67	2.30
7.01	1.98	7.02	2.17	7.02	2.29
7.89	1.99	7.89	2.17	7.90	2.27
8.77	1.99	8.77	2.15	8.78	2.25
9.65	2.00	9.65	2.14	9.65	2.24
10.52	1.99	10.52	2.11	10.53	2.22
11.40	1.98	11.40	2.07	11.41	2.19
12.28	1.97	12.28	2.04	12.29	2.17
13.15	1.96	13.16	2.01	13.16	2.15
14.03	1.93	14.03	1.99	14.04	2.13
15.78	1.87	15.79	1.95	15.80	2.09
17.54	1.79	17.54	1.91	17.55	2.06
19.29	1.72	19.29	1.87	19.31	2.03

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-8** Type: **3T** Depth (ft): **10 - 12.2**
Soil Type: **Lean Clay w/Sand & a Trace of Gravel (CL)**





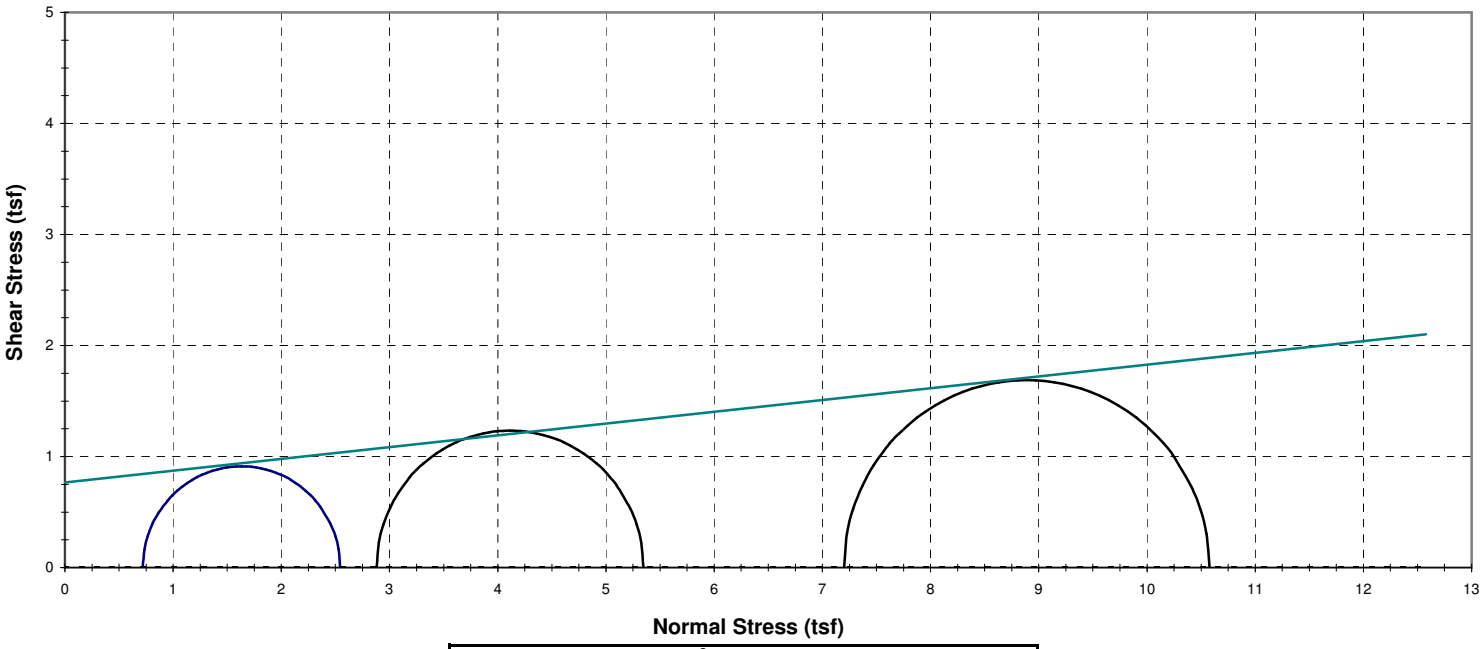
Failure Criterion:	**Max. Deviator Stress**
Angle of internal friction, ϕ_u =	**6.1 °**
Apparent Cohesion, c_u =	**0.77 (tsf)**

Test Date:	4/4/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	1.319	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	3.79	3.97	3.85		
Water Content (%)	14.3	16.6	21.0		
Dry Density (pcf)	120.0	115.9	107.5		
Void Ratio	0.40	0.45	0.56		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	1.82	2.47	3.38		
Ultimate Deviator Stress (tsf)	1.64	2.27	3.22		
Deviator Stress at Failure (tsf)	1.82	2.47	3.38		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	8.4	12.6	11.7		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 6.1 ° c_u= 0.77 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

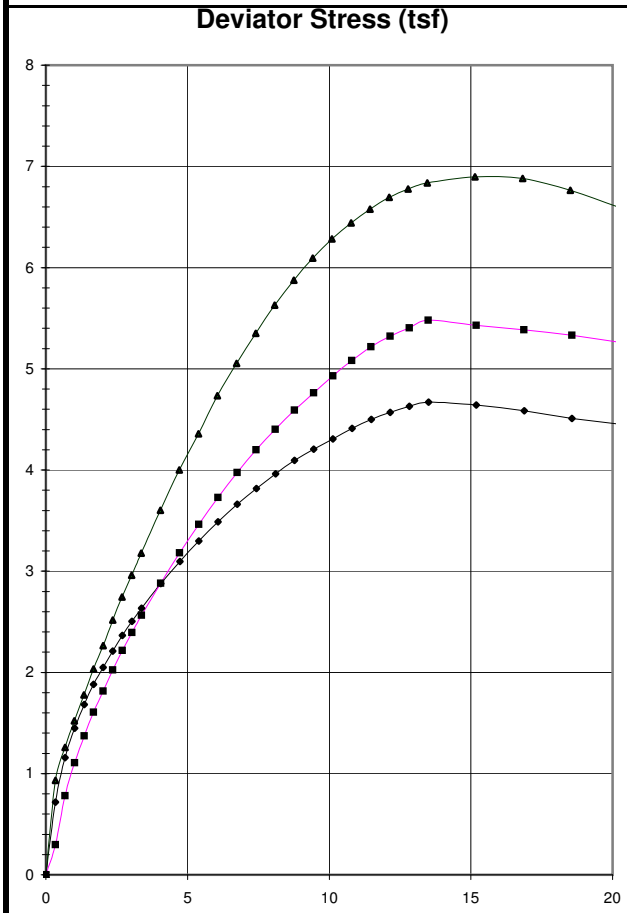
Sample No.: BH-8, Depth (ft.): 10 - 12.2

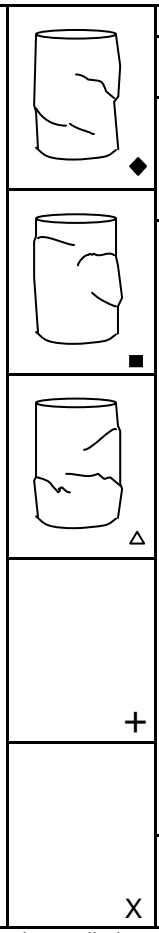
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.26	0.74	0.25	0.16	0.26	1.09
0.53	1.09	0.50	0.48	0.52	1.71
0.79	1.24	0.75	0.68	0.78	2.02
1.06	1.35	1.01	0.85	1.04	2.27
1.32	1.42	1.26	0.99	1.30	2.46
1.58	1.49	1.51	1.12	1.56	2.62
1.85	1.54	1.76	1.24	1.82	2.73
2.11	1.59	2.01	1.33	2.08	2.83
2.37	1.62	2.26	1.42	2.34	2.90
2.64	1.65	2.52	1.50	2.60	2.97
3.17	1.69	3.02	1.64	3.12	3.06
3.69	1.73	3.52	1.76	3.63	3.13
4.22	1.75	4.03	1.87	4.15	3.18
4.75	1.77	4.53	1.95	4.67	3.21
5.28	1.78	5.03	2.03	5.19	3.23
5.81	1.79	5.54	2.09	5.71	3.26
6.33	1.80	6.04	2.15	6.23	3.27
6.86	1.81	6.54	2.20	6.75	3.29
7.39	1.82	7.04	2.25	7.27	3.30
7.92	1.82	7.55	2.29	7.79	3.31
8.44	1.82	8.05	2.32	8.31	3.32
8.97	1.82	8.55	2.36	8.83	3.33
9.50	1.82	9.06	2.38	9.35	3.35
10.03	1.82	9.56	2.40	9.86	3.36
10.55	1.82	10.06	2.42	10.38	3.37
11.87	1.80	11.32	2.46	11.68	3.38
13.19	1.79	12.58	2.47	12.98	3.36
14.51	1.77	13.84	2.45	14.28	3.34
15.83	1.75	15.10	2.42	15.58	3.33
17.15	1.73	16.35	2.38	16.87	3.31
18.47	1.70	17.61	2.35	18.17	3.27
19.79	1.67	18.87	2.31	19.47	3.25
21.11	1.64	20.13	2.27	20.77	3.22

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-8** Type: **3T** Depth (ft): **39.6 - 41.2 (Mid)**
Soil Type: **Lean Clay w/Sand & a Little Gravel (CL)**





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, ϕ_u = **8.4 °**

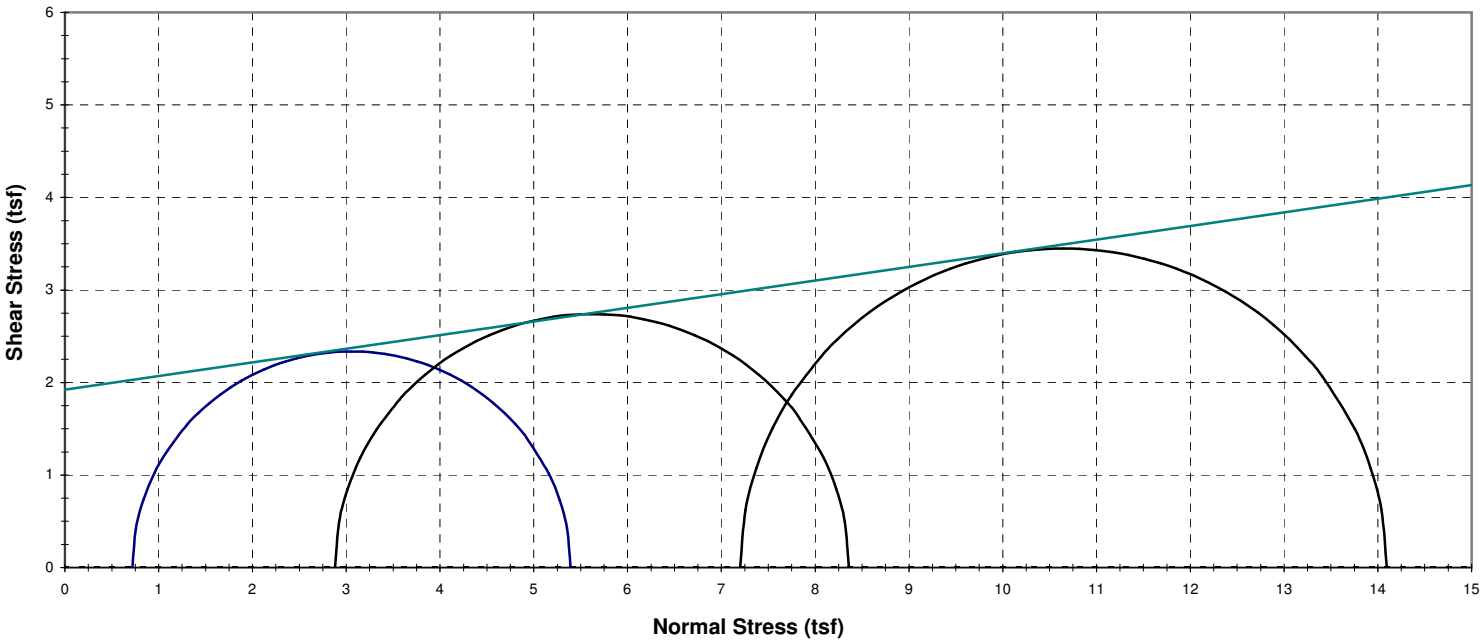
Apparent Cohesion, c_u = **1.92 (tsf)**

Test Date:	4/5/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	1.688	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.96	2.96	2.97		
Water Content (%)	11.0	12.8	13.5		
Dry Density (pcf)	128.1	124.6	122.2		
Void Ratio	0.31	0.35	0.37		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	4.67	5.48	6.90		
Ultimate Deviator Stress (tsf)	4.45	5.26	6.60		
Deviator Stress at Failure (tsf)	4.67	5.48	6.90		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	13.5	13.5	15.1		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 8.4 ° c_u= 1.92 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

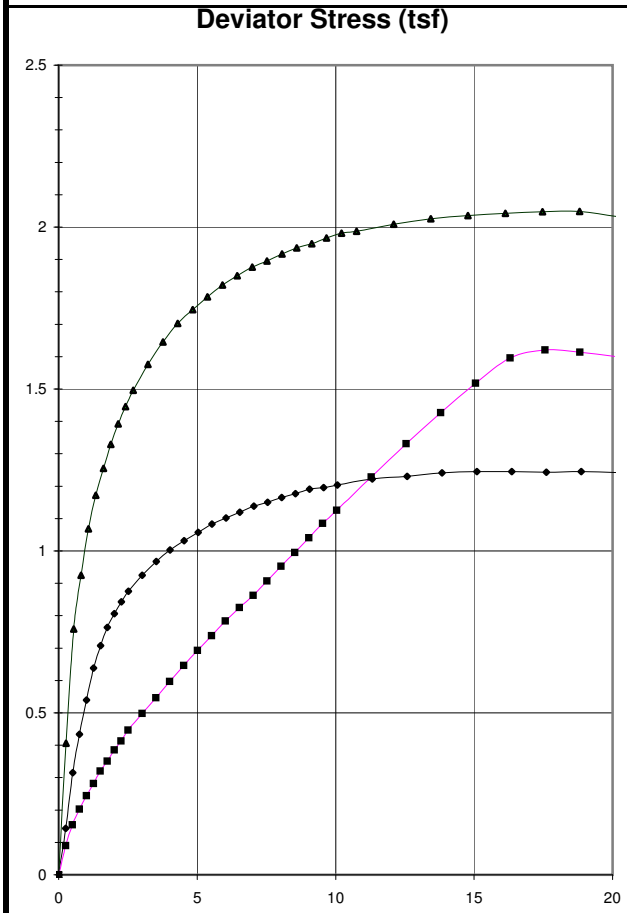
Sample No.: BH-8, Depth (ft.): 39.6 - 41.2 (Mid)

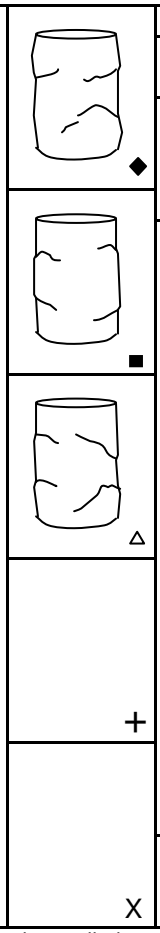
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.34	0.72	0.34	0.30	0.34	0.93
0.68	1.16	0.67	0.78	0.67	1.26
1.01	1.45	1.01	1.11	1.01	1.52
1.35	1.68	1.35	1.37	1.35	1.78
1.69	1.88	1.69	1.61	1.68	2.03
2.03	2.05	2.02	1.82	2.02	2.26
2.36	2.21	2.36	2.02	2.36	2.52
2.70	2.36	2.70	2.22	2.69	2.75
3.04	2.51	3.04	2.39	3.03	2.96
3.38	2.63	3.37	2.56	3.37	3.18
4.05	2.88	4.05	2.88	4.04	3.60
4.73	3.10	4.72	3.18	4.71	4.00
5.40	3.30	5.40	3.46	5.38	4.36
6.08	3.49	6.07	3.73	6.06	4.73
6.75	3.66	6.75	3.98	6.73	5.05
7.43	3.82	7.42	4.20	7.40	5.35
8.10	3.96	8.10	4.40	8.08	5.63
8.78	4.10	8.77	4.59	8.75	5.87
9.45	4.20	9.45	4.76	9.42	6.09
10.13	4.31	10.12	4.93	10.10	6.28
10.80	4.41	10.80	5.08	10.77	6.44
11.48	4.50	11.47	5.22	11.44	6.58
12.15	4.57	12.15	5.32	12.12	6.69
12.83	4.63	12.82	5.41	12.79	6.78
13.51	4.67	13.50	5.48	13.46	6.84
15.19	4.64	15.19	5.43	15.15	6.90
16.88	4.59	16.87	5.39	16.83	6.88
18.57	4.51	18.56	5.33	18.51	6.76
20.26	4.45	20.25	5.26	20.19	6.60

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-10** Type: **3T** Depth (ft): **15 - 17**
Soil Type: **Lean Clay w/Sand & a Trace of Gravel (CL)**





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, ϕ_u = **3.3 °**

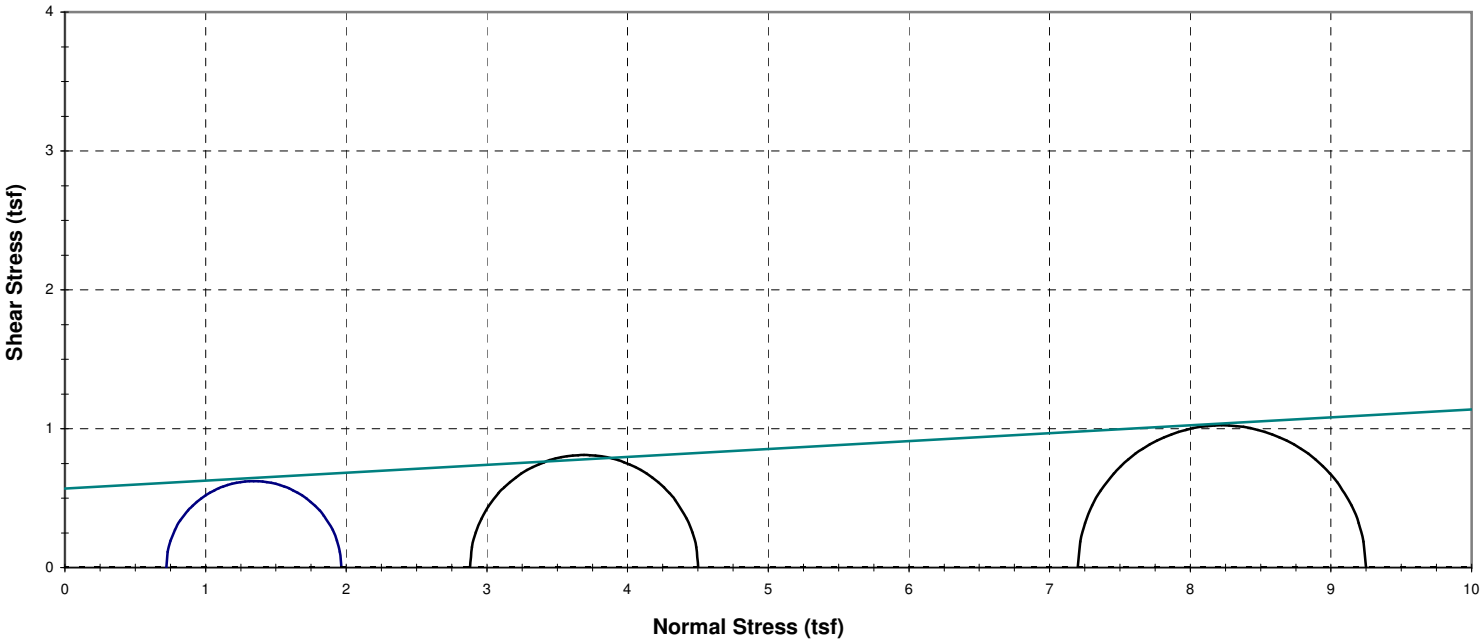
Apparent Cohesion, c_u = **0.57 (tsf)**

Test Date:	4/4/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	1.258	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	3.97	3.99	3.72		
Water Content (%)	21.4	19.4	19.1		
Dry Density (pcf)	110.5	110.6	110.1		
Void Ratio	0.52	0.52	0.53		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	1.25	1.62	2.05		
Ultimate Deviator Stress (tsf)	1.24	1.60	2.02		
Deviator Stress at Failure (tsf)	1.25	1.62	2.05		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	16.4	17.6	18.8		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 3.3 ° c_u= 0.57 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

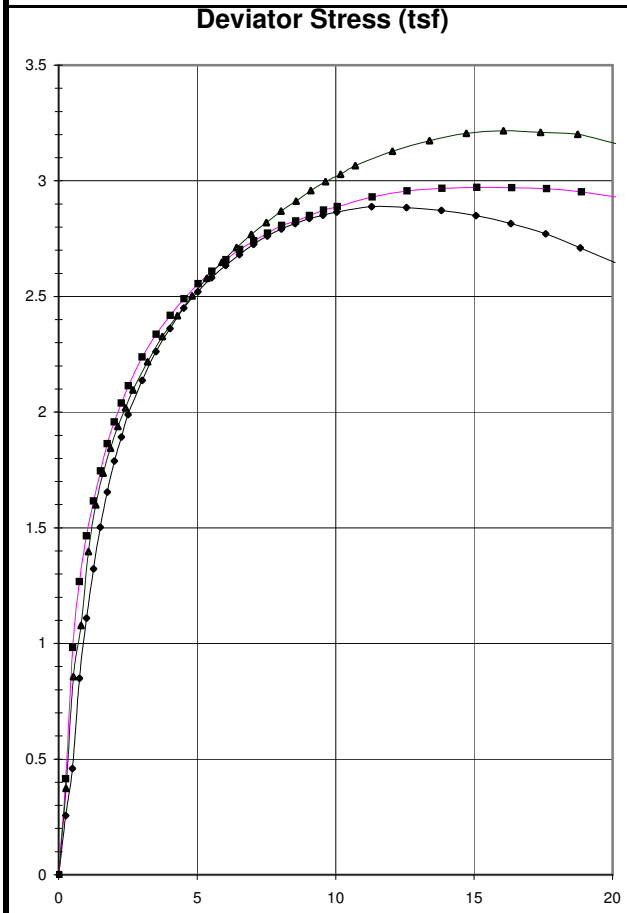
Sample No.: BH-10, Depth (ft.): 15 - 17

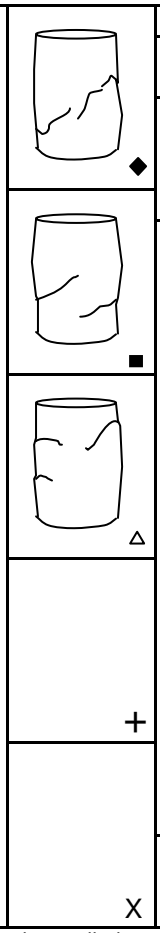
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.14	0.25	0.09	0.27	0.41
0.50	0.32	0.50	0.15	0.54	0.76
0.75	0.43	0.75	0.20	0.81	0.93
1.01	0.54	1.00	0.24	1.08	1.07
1.26	0.64	1.25	0.28	1.34	1.17
1.51	0.71	1.51	0.32	1.61	1.26
1.76	0.76	1.76	0.35	1.88	1.33
2.01	0.81	2.01	0.39	2.15	1.39
2.26	0.84	2.26	0.41	2.42	1.45
2.52	0.88	2.51	0.45	2.69	1.50
3.02	0.92	3.01	0.50	3.23	1.58
3.52	0.97	3.51	0.55	3.76	1.65
4.03	1.00	4.01	0.60	4.30	1.70
4.53	1.03	4.52	0.65	4.84	1.75
5.03	1.06	5.02	0.69	5.38	1.78
5.54	1.08	5.52	0.74	5.91	1.82
6.04	1.10	6.02	0.78	6.45	1.85
6.54	1.12	6.52	0.82	6.99	1.88
7.05	1.14	7.02	0.86	7.53	1.90
7.55	1.15	7.53	0.91	8.06	1.92
8.05	1.16	8.03	0.95	8.60	1.94
8.56	1.18	8.53	1.00	9.14	1.95
9.06	1.19	9.03	1.04	9.68	1.97
9.56	1.20	9.53	1.08	10.21	1.98
10.06	1.20	10.04	1.13	10.75	1.99
11.32	1.22	11.29	1.23	12.10	2.01
12.58	1.23	12.54	1.33	13.44	2.03
13.84	1.24	13.80	1.43	14.78	2.04
15.10	1.24	15.05	1.52	16.13	2.04
16.36	1.25	16.31	1.60	17.47	2.05
17.61	1.24	17.56	1.62	18.81	2.05
18.87	1.25	18.82	1.61	20.16	2.03
20.13	1.24	20.07	1.60	21.50	2.02

TRIAXIAL TEST ASTM: D 2850

Job No. **7835**
Date: **4/15/11**

Project: **Copperwood Mine - #GL-11006**
Boring #: Sample #: **BH-10** Type: **3T** Depth (ft): **25.5 - 27.5**
Soil Type: **Lean Clay w/Sand & a Trace of Gravel (CL)**





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, ϕ_u = **1.4 °**

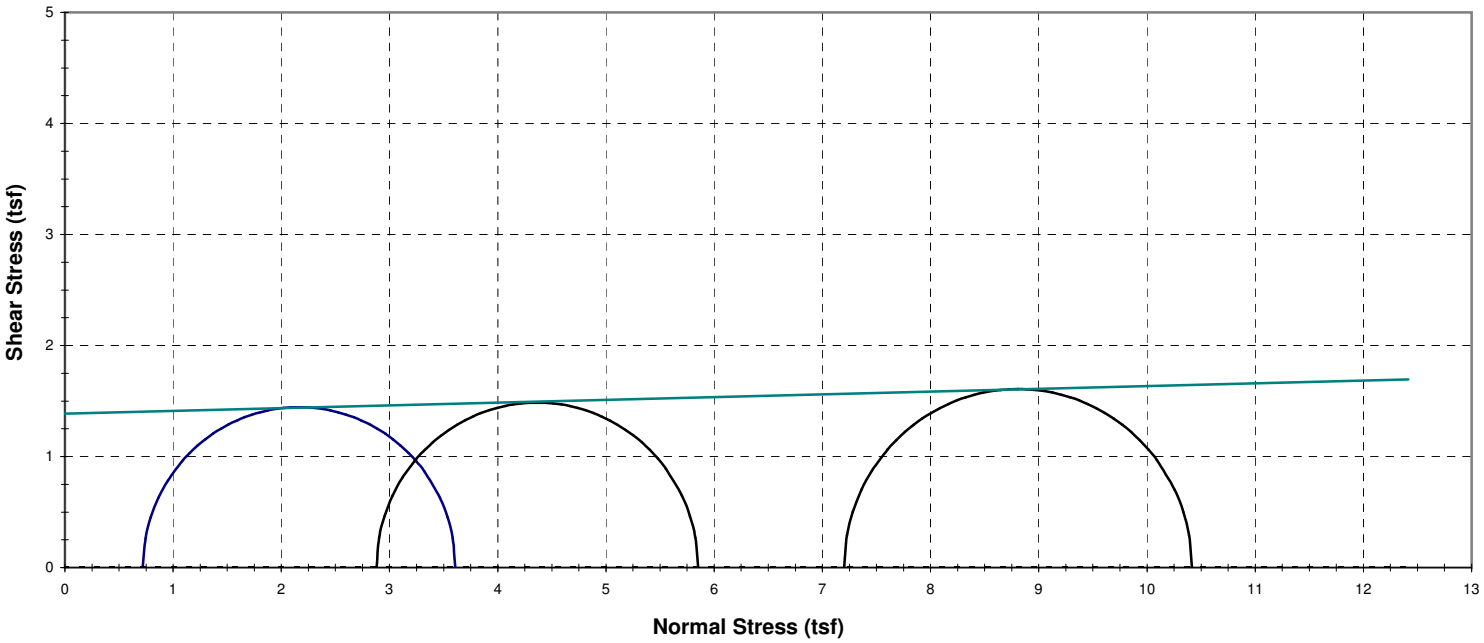
Apparent Cohesion, c_u = **1.39 (tsf)**

Test Date:	4/4/11	Liquid Limit:	
Test Type:	U-U	Plastic Limit:	
Strain Rate (in/min):	0.05	Plasticity Index:	
Strain Rate (%/min):	1.256	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	3.98	3.97	3.74		
Water Content (%)	14.3	15.0	15.0		
Dry Density (pcf)	121.7	119.4	119.7		
Void Ratio	0.38	0.41	0.40		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	2.89	2.97	3.22		
Ultimate Deviator Stress (tsf)	2.65	2.93	3.13		
Deviator Stress at Failure (tsf)	2.89	2.97	3.22		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	11.3	15.1	16.1		

"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: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 1.4 ° c_u= 1.39 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Job No.: 7835

Test Type: U-U

Project: Copperwood Mine - #GL-11006

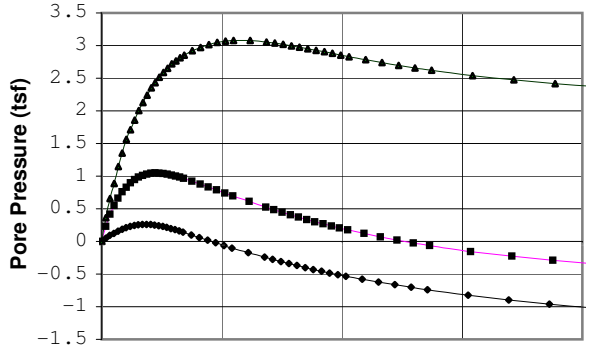
Sample No.: BH-10, Depth (ft.): 25.5 - 27.5

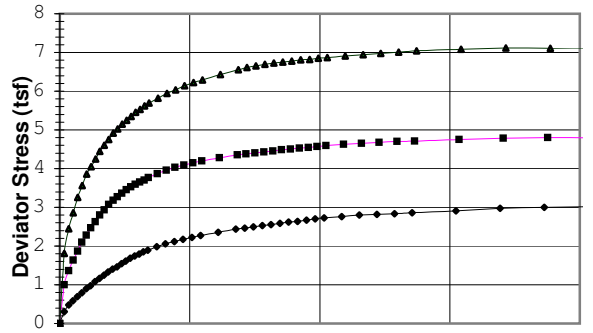
Sample 1		Sample 2		Sample 3	
Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)	Strain (%)	Deviator Stress (tsf)
0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.26	0.25	0.41	0.27	0.37
0.50	0.46	0.50	0.98	0.54	0.86
0.75	0.85	0.76	1.27	0.80	1.08
1.00	1.11	1.01	1.46	1.07	1.40
1.26	1.32	1.26	1.62	1.34	1.60
1.51	1.50	1.51	1.75	1.61	1.74
1.76	1.65	1.76	1.86	1.87	1.84
2.01	1.79	2.01	1.96	2.14	1.94
2.26	1.89	2.27	2.04	2.41	2.02
2.51	1.99	2.52	2.11	2.68	2.10
3.01	2.14	3.02	2.24	3.21	2.22
3.52	2.26	3.52	2.34	3.75	2.33
4.02	2.36	4.03	2.42	4.28	2.42
4.52	2.45	4.53	2.49	4.82	2.50
5.02	2.52	5.03	2.55	5.35	2.58
5.53	2.58	5.54	2.61	5.89	2.65
6.03	2.63	6.04	2.66	6.43	2.71
6.53	2.68	6.54	2.70	6.96	2.77
7.03	2.72	7.05	2.74	7.50	2.82
7.53	2.76	7.55	2.77	8.03	2.87
8.04	2.79	8.05	2.81	8.57	2.91
8.54	2.81	8.56	2.83	9.10	2.96
9.04	2.84	9.06	2.85	9.64	3.00
9.54	2.85	9.56	2.87	10.17	3.03
10.05	2.87	10.07	2.89	10.71	3.07
11.30	2.89	11.33	2.93	12.05	3.13
12.56	2.89	12.58	2.96	13.39	3.17
13.81	2.87	13.84	2.97	14.73	3.21
15.07	2.85	15.10	2.97	16.06	3.22
16.32	2.82	16.36	2.97	17.40	3.21
17.58	2.77	17.62	2.97	18.74	3.20
18.84	2.71	18.88	2.95	20.08	3.16
20.09	2.65	20.13	2.93	21.42	3.13

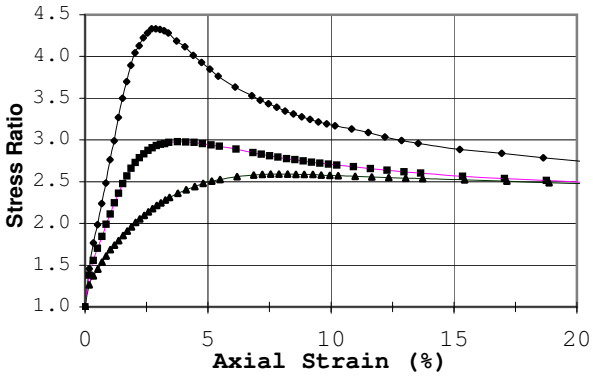
TRIAXIAL TEST ASTM: D 4767

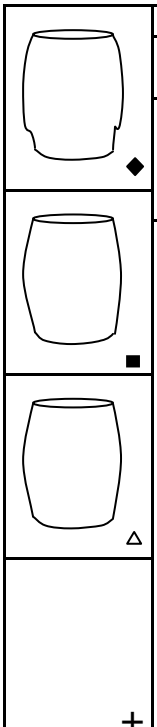
Job No. **7835**
Date: **4/19/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-02** Type: **3T** Depth (ft): **10'-12'**
Soil Type: **Lean Clay, plastic, some fine to medium sand (CL)**









Failure Criterion: **Max. Pore Pressure**

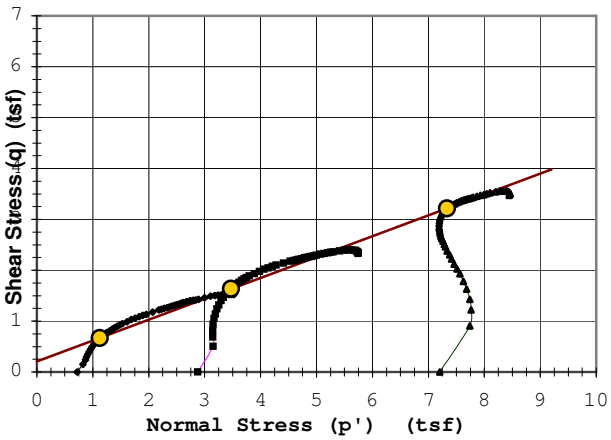
Angle of internal friction, **ϕ' =** **24.2 °**
Apparent Cohesion, **c' =** **0.23 (tsf)**

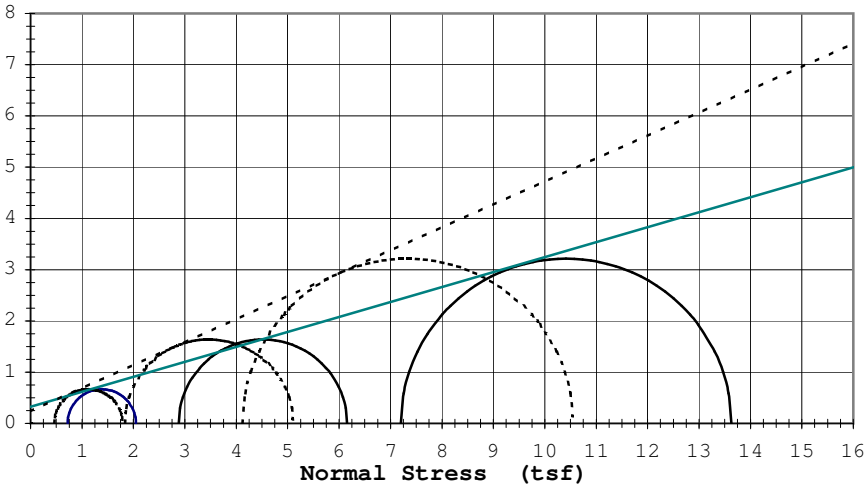
Test Date:	4/7/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.001475	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.45	1.45	1.45		
Height (in)	2.97	2.97	2.97		
Water Content (%)	15.7	15.6	15.5		
Dry Density (pcf)	118.3	118.5	118.4		
Void Ratio	0.42	0.42	0.42		
After Consolidation					
Diameter (in)	1.44	1.42	1.41		
Height (in)	2.95	2.93	2.91		
Water Content (%)	14.5	13.1	12.0		
Dry Density (pcf)	120.8	124.3	126.9		
Void Ratio	0.39	0.35	0.32		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	3.06	4.80	7.12		
Ultimate Deviator Stress (tsf)	3.04	4.65	6.95		
Deviator Stress at Failure (tsf)	1.33	3.28	6.43		
Max. Pore Pressure Buildup (tsf)	0.26	1.05	3.08		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	1.9	2.2	6.2		

"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: 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.





Rupture Envelope at Failure
α = 22.3 ° a = 0.2 (tsf)

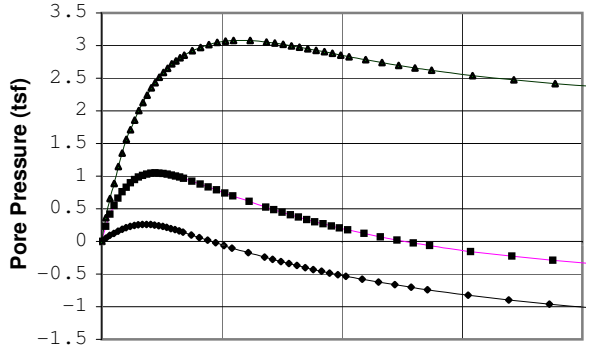
----------	Effective ϕ': 24.2 °	c'=	0.23 (tsf)
_____	Total ϕ': 16.3 °	c=	0.33 (tsf)

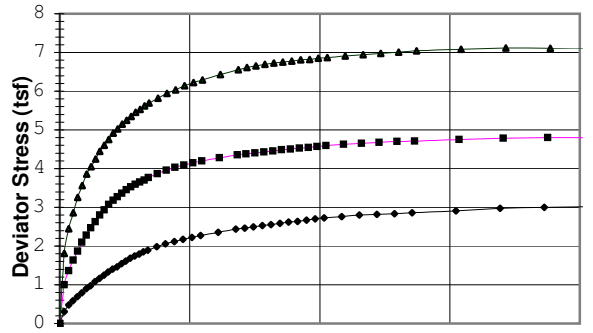
2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

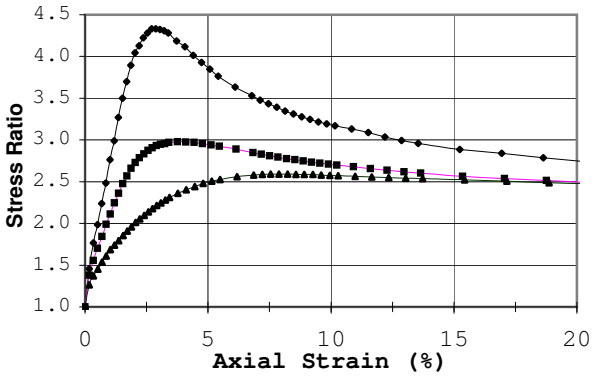
TRIAXIAL TEST ASTM: D 4767

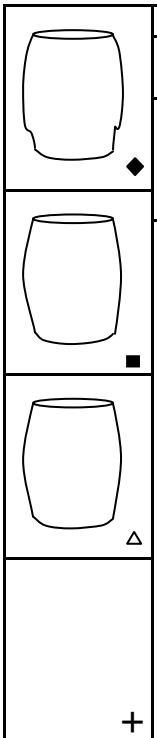
Job No. **7835**
Date: **4/19/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-02** Type: **3T** Depth (ft): **10'-12'**
Soil Type: **Lean Clay, plastic, some fine to medium sand (CL)**









Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, **ϕ' = 24.0 °**

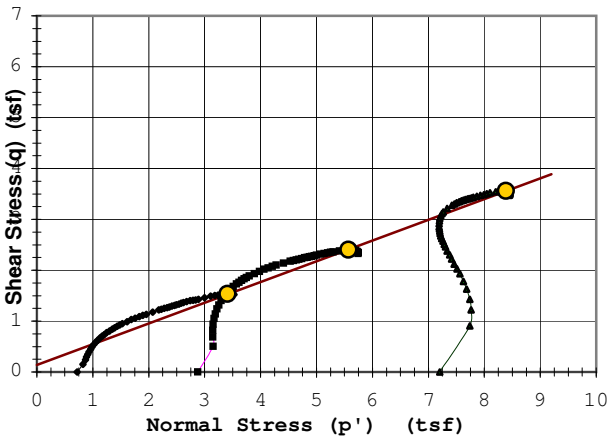
Apparent Cohesion, **c' = 0.15 (tsf)**

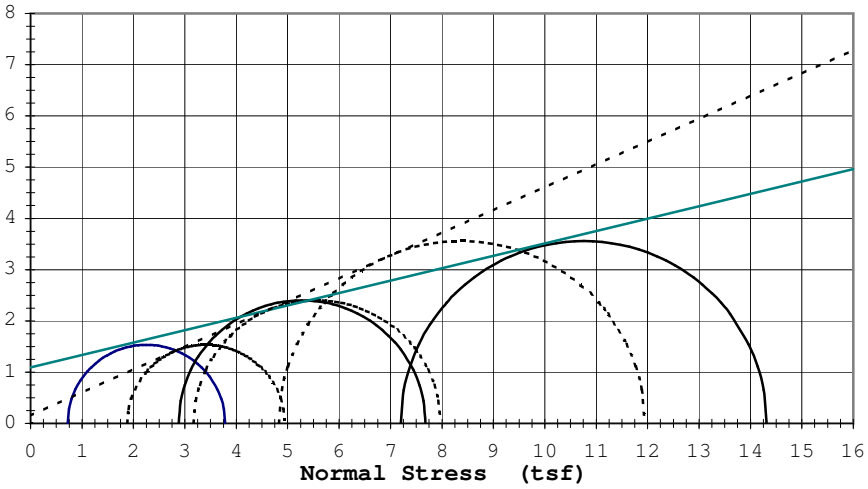
Test Date:	4/7/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.001475	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.45	1.45	1.45		
Height (in)	2.97	2.97	2.97		
Water Content (%)	15.7	15.6	15.5		
Dry Density (pcf)	118.3	118.5	118.4		
Void Ratio	0.42	0.42	0.42		
After Consolidation					
Diameter (in)	1.44	1.42	1.41		
Height (in)	2.95	2.93	2.91		
Water Content (%)	14.5	13.1	12.0		
Dry Density (pcf)	120.8	124.3	126.9		
Void Ratio	0.39	0.35	0.32		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	3.06	4.80	7.12		
Ultimate Deviator Stress (tsf)	3.04	4.65	6.95		
Deviator Stress at Failure (tsf)	3.06	4.80	7.12		
Max. Pore Pressure Buildup (tsf)	0.26	1.05	3.08		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	25.4	18.8	20.6		

"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.





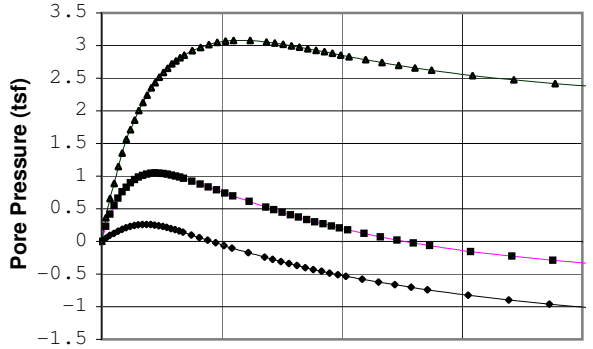
Rupture Envelope at Failure
α = 22.2 ° a = 0.1 (tsf)

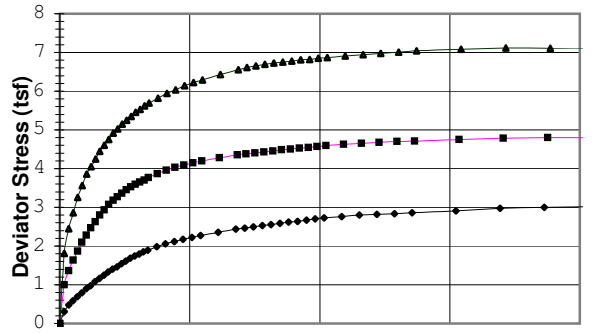
---------- Effective ϕ': 24.0 ° c'= 0.15 (tsf)
_____ Total ϕ': 13.6 ° c= 1.10 (tsf)

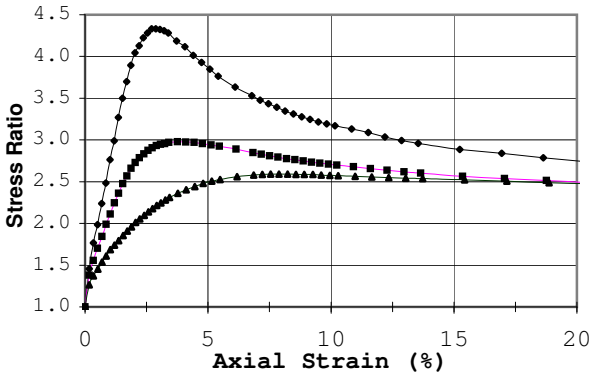
TRIAXIAL TEST ASTM: D 4767

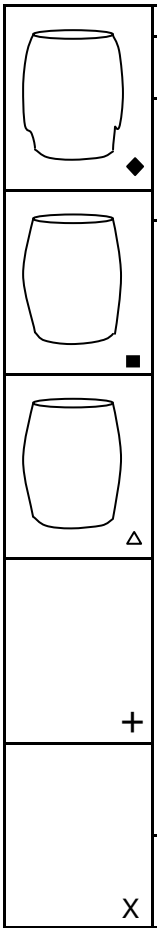
Job No. **7835**
Date: **4/19/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-02** Type: **3T** Depth (ft): **10'-12'**
Soil Type: **Lean Clay, plastic, some fine to medium sand (CL)**









Failure Criterion: **Given Strain of: 15%**

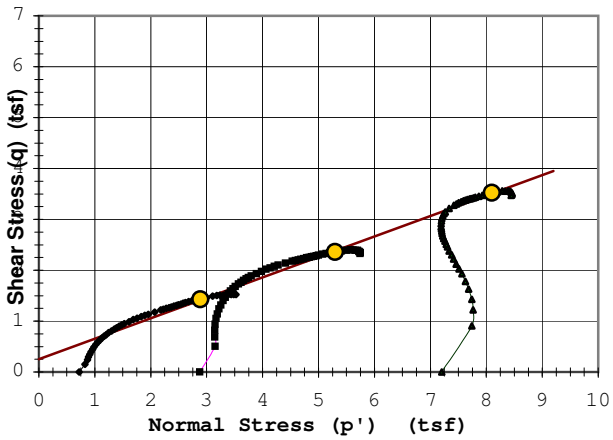
Angle of internal friction, **ϕ' =** **23.7 °**
Apparent Cohesion, **c' =** **0.28 (tsf)**

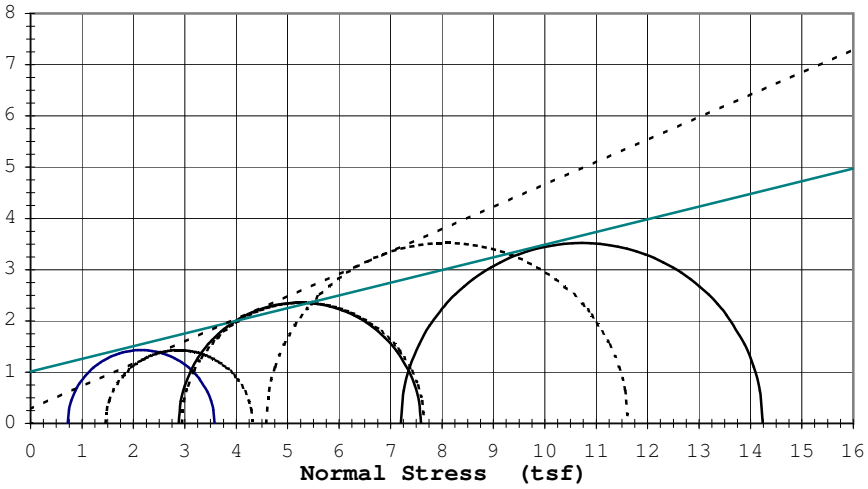
Test Date:	4/7/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.001475	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.45	1.45	1.45		
Height (in)	2.97	2.97	2.97		
Water Content (%)	15.7	15.6	15.5		
Dry Density (pcf)	118.3	118.5	118.4		
Void Ratio	0.42	0.42	0.42		
After Consolidation					
Diameter (in)	1.44	1.42	1.41		
Height (in)	2.95	2.93	2.91		
Water Content (%)	14.5	13.1	12.0		
Dry Density (pcf)	120.8	124.3	126.9		
Void Ratio	0.39	0.35	0.32		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	3.06	4.80	7.12		
Ultimate Deviator Stress (tsf)	3.04	4.65	6.95		
Deviator Stress at Failure (tsf)	2.86	4.71	7.04		
Max. Pore Pressure Buildup (tsf)	0.26	1.05	3.08		
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.





Rupture Envelope at Failure
α = 21.9 ° a = 0.3 (tsf)

----------	Effective ϕ': 23.7 °	c'=	0.28 (tsf)
_____	Total ϕ': 13.9 °	c=	1.01 (tsf)

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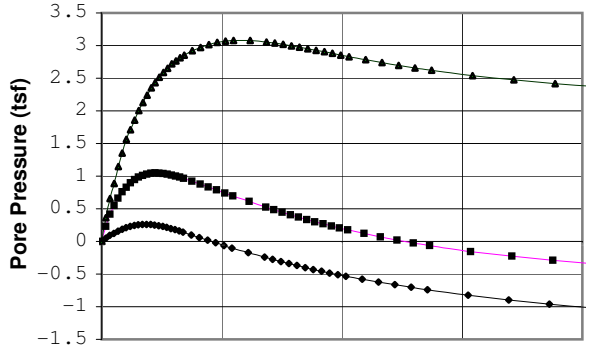
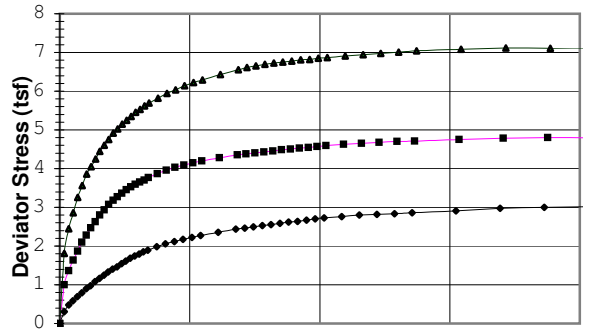
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

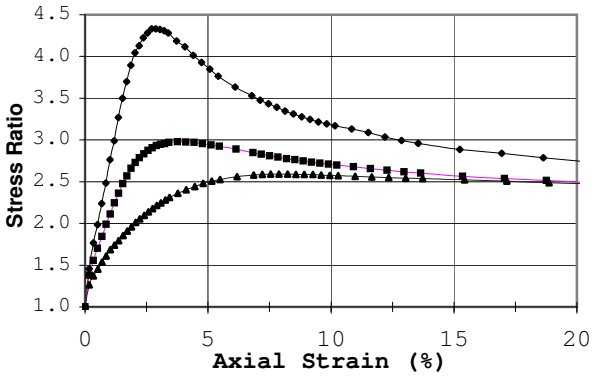
TRIAXIAL TEST ASTM: D 4767

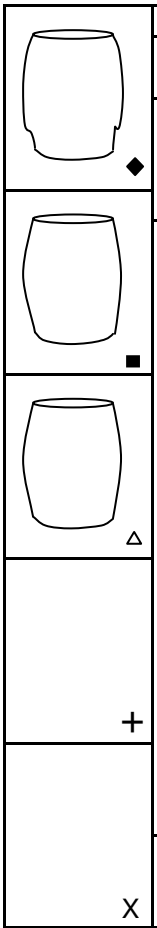
Job No. **7835**
Date: **4/19/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-02** Type: **3T** Depth (ft): **10'-12'**
Soil Type: **Lean Clay, plastic, some fine to medium sand (CL)**









Failure Criterion: **Max. Stress Ratio**

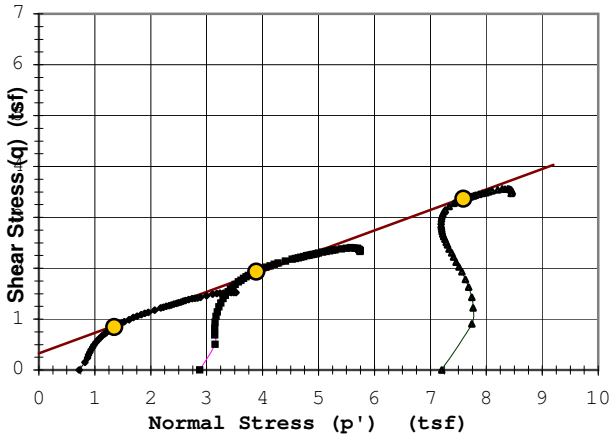
Angle of internal friction, **ϕ' =** **23.8 °**
Apparent Cohesion, **c' =** **0.35 (tsf)**

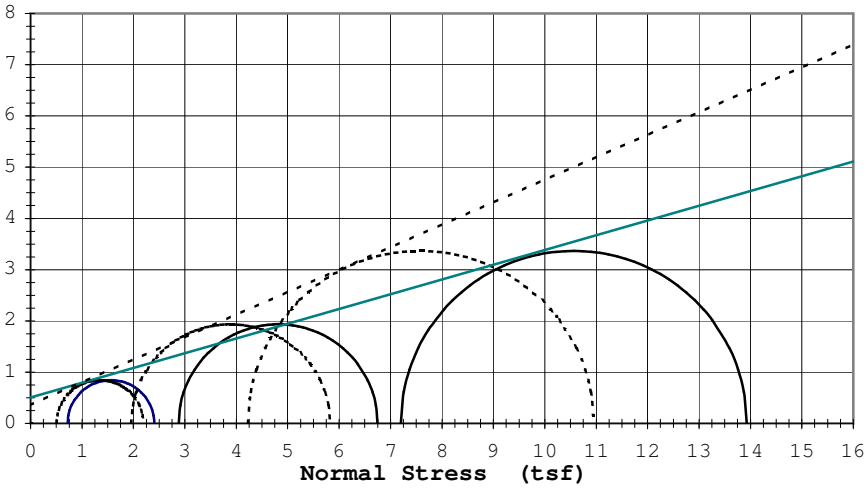
Test Date:	4/7/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.001475	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.69

Before Consolidation	A	B	C	D	E
Diameter (in)	1.45	1.45	1.45		
Height (in)	2.97	2.97	2.97		
Water Content (%)	15.7	15.6	15.5		
Dry Density (pcf)	118.3	118.5	118.4		
Void Ratio	0.42	0.42	0.42		
After Consolidation					
Diameter (in)	1.44	1.42	1.41		
Height (in)	2.95	2.93	2.91		
Water Content (%)	14.5	13.1	12.0		
Dry Density (pcf)	120.8	124.3	126.9		
Void Ratio	0.39	0.35	0.32		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	3.06	4.80	7.12		
Ultimate Deviator Stress (tsf)	3.04	4.65	6.95		
Deviator Stress at Failure (tsf)	1.69	3.87	6.73		
Max. Pore Pressure Buildup (tsf)	0.26	1.05	3.08		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	2.7	3.8	8.2		

"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: 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.





Rupture Envelope at Failure
α = 21.9 ° a = 0.3 (tsf)

----------	Effective ϕ': 23.8 °	c'=	0.35 (tsf)
_____	Total ϕ': 16.1 °	c=	0.51 (tsf)

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SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Triaxial Data

Job: **7835**

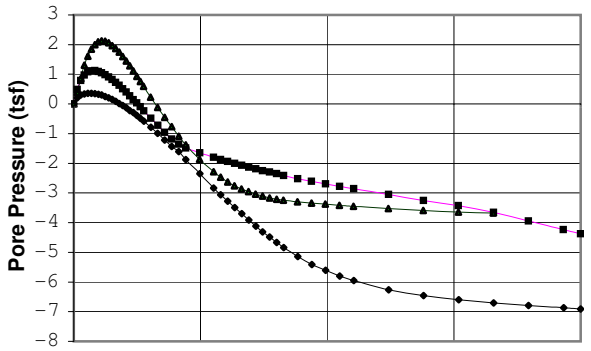
Boring: Sample: BH-02 Depth: 10'-12' Date: 4/19/11

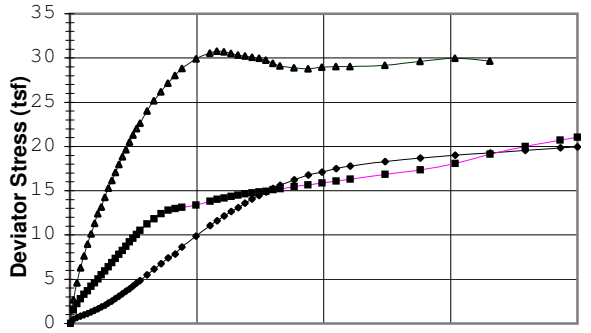
Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
0.17	0.31	0.05	0.17	1.00	0.23	0.17	1.81	0.36						
0.34	0.48	0.09	0.34	1.37	0.42	0.34	2.45	0.66						
0.51	0.59	0.12	0.51	1.63	0.55	0.52	2.86	0.89						
0.68	0.70	0.16	0.68	1.87	0.66	0.69	3.26	1.15						
0.85	0.79	0.18	0.85	2.10	0.76	0.86	3.56	1.35						
1.02	0.90	0.21	1.03	2.28	0.83	1.03	3.86	1.57						
1.19	0.98	0.23	1.19	2.47	0.90	1.20	4.05	1.71						
1.35	1.08	0.24	1.37	2.63	0.94	1.37	4.24	1.86						
1.52	1.17	0.25	1.54	2.80	0.98	1.54	4.44	2.01						
1.69	1.25	0.26	1.71	2.93	1.01	1.72	4.61	2.13						
1.86	1.33	0.26	1.88	3.07	1.03	1.89	4.76	2.24						
2.03	1.41	0.26	2.05	3.18	1.04	2.06	4.91	2.35						
2.20	1.46	0.25	2.22	3.28	1.05	2.23	5.02	2.43						
2.37	1.54	0.24	2.39	3.36	1.05	2.40	5.15	2.52						
2.54	1.61	0.23	2.56	3.45	1.04	2.57	5.24	2.59						
2.71	1.69	0.21	2.73	3.53	1.03	2.75	5.35	2.65						
2.88	1.74	0.20	2.90	3.60	1.02	2.92	5.45	2.72						
3.05	1.79	0.18	3.07	3.66	1.00	3.09	5.53	2.76						
3.22	1.85	0.16	3.24	3.70	0.98	3.26	5.62	2.82						
3.39	1.90	0.14	3.41	3.77	0.97	3.43	5.69	2.85						
3.73	1.98	0.10	3.76	3.87	0.92	3.77	5.82	2.92						
4.06	2.06	0.06	4.10	3.96	0.88	4.12	5.94	2.97						
4.40	2.11	0.02	4.44	4.03	0.83	4.46	6.03	3.01						
4.74	2.17	-0.02	4.78	4.09	0.79	4.80	6.14	3.05						
5.08	2.23	-0.06	5.12	4.15	0.74	5.15	6.22	3.07						
5.42	2.27	-0.10	5.46	4.20	0.70	5.49	6.29	3.08						
6.10	2.35	-0.17	6.14	4.28	0.61	6.18	6.43	3.08						
6.77	2.43	-0.24	6.83	4.35	0.53	6.86	6.55	3.05						
7.11	2.46	-0.27	7.17	4.38	0.48	7.21	6.61	3.04						
7.45	2.50	-0.31	7.51	4.41	0.45	7.55	6.65	3.02						
7.79	2.53	-0.34	7.85	4.43	0.41	7.89	6.69	3.00						
8.13	2.56	-0.37	8.19	4.45	0.37	8.23	6.73	2.98						
8.47	2.59	-0.40	8.53	4.49	0.34	8.58	6.75	2.95						
8.81	2.62	-0.43	8.87	4.51	0.30	8.92	6.78	2.93						
9.14	2.64	-0.46	9.22	4.53	0.27	9.26	6.81	2.91						
9.48	2.67	-0.48	9.56	4.55	0.24	9.61	6.82	2.88						
9.82	2.70	-0.51	9.90	4.57	0.21	9.95	6.85	2.86						
10.16	2.73	-0.54	10.24	4.59	0.18	10.29	6.87	2.83						
10.84	2.76	-0.58	10.92	4.63	0.12	10.98	6.91	2.79						
11.52	2.80	-0.62	11.60	4.65	0.07	11.66	6.94	2.74						
12.19	2.82	-0.66	12.29	4.68	0.02	12.35	6.97	2.70						
12.87	2.83	-0.70	12.97	4.70	-0.02	13.04	7.01	2.66						
13.55	2.86	-0.74	13.65	4.71	-0.06	13.72	7.04	2.62						
15.24	2.91	-0.82	15.36	4.75	-0.15	15.44	7.09	2.54						
16.94	2.98	-0.90	17.06	4.78	-0.23	17.15	7.11	2.47						
18.63	3.00	-0.96	18.77	4.80	-0.29	18.87	7.11	2.42						
20.32	3.01	-1.01	20.48	4.79	-0.34	20.58	7.12	2.37						
22.02	3.02	-1.07	22.18	4.78	-0.39	22.30	7.11	2.34						
23.71	3.05	-1.11	23.89	4.78	-0.43	24.02	7.08	2.30						
25.40	3.06	-1.16	25.60	4.75	-0.47	25.73	7.05	2.27						
27.10	3.05	-1.20	27.30	4.71	-0.50	27.45	7.02	2.25						
28.79	3.04	-1.24	29.01	4.69	-0.52	29.16	6.97	2.23						
30.12	3.04	-1.28	30.36	4.65	-0.53	30.00	6.95	2.23						

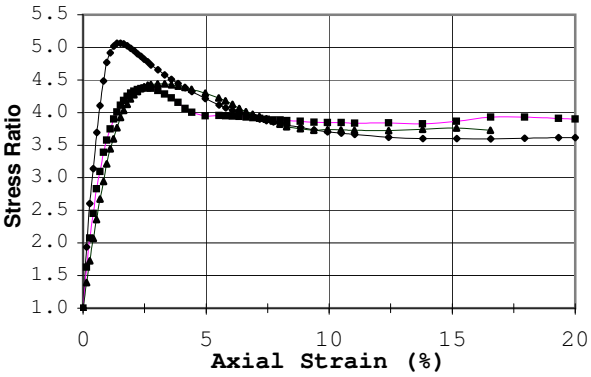
TRIAXIAL TEST ASTM: D 4767

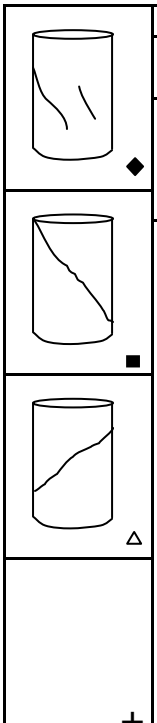
Job No. **7835**
Date: **4/21/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-7** Type: **3T** Depth (ft): **80-82**
Soil Type: **Silty Sand, fine to medium grained, with a trace of gravel (SM)**









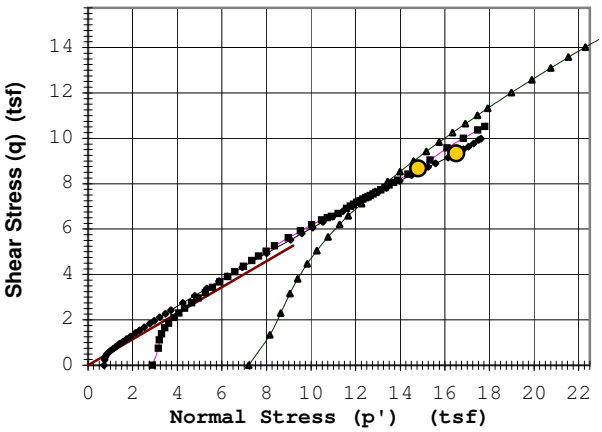
Failure Criterion:	Given Strain of: 15%
Angle of internal friction, ϕ' =	35.0 °
Apparent Cohesion, c' =	0.00 (tsf)

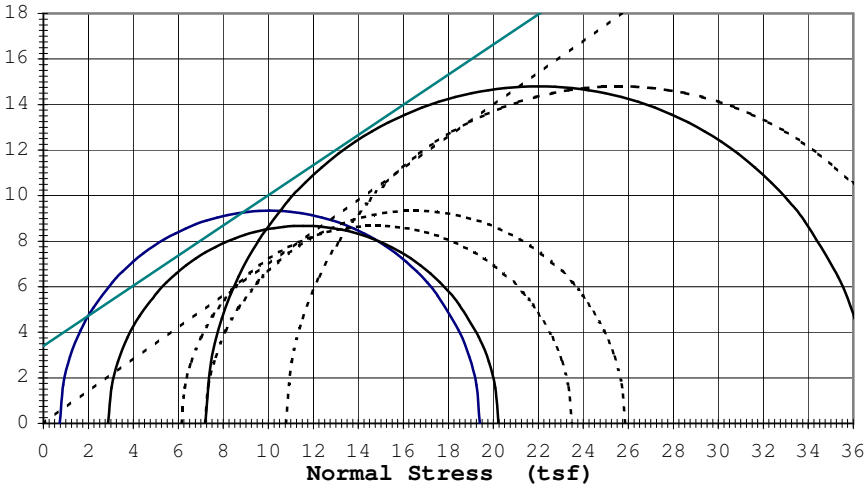
Test Date:	4/4/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00181	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.70

Before Consolidation	A	B	C	D	E
Diameter (in)	1.83	1.79	1.75		
Height (in)	3.65	3.65	3.64		
Water Content (%)	7.5	7.0	8.2		
Dry Density (pcf)	125.0	128.8	131.5		
Void Ratio	0.35	0.31	0.28		
After Consolidation					
Diameter (in)	1.82	1.78	1.73		
Height (in)	3.62	3.62	3.63		
Water Content (%)	12.4	10.4	9.2		
Dry Density (pcf)	126.4	131.6	134.9		
Void Ratio	0.33	0.28	0.25		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	19.97	21.05	30.76		
Ultimate Deviator Stress (tsf)	19.97	21.05	29.66		
Deviator Stress at Failure (tsf)	18.68	17.35	29.60		
Max. Pore Pressure Buildup (tsf)	0.36	1.12	2.12		
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: Specimen trimmed to given dimension; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared. Specimens were brittle with uneven sides.





Rupture Envelope at Failure	
α = 29.8 °	a = 0.0 (tsf)

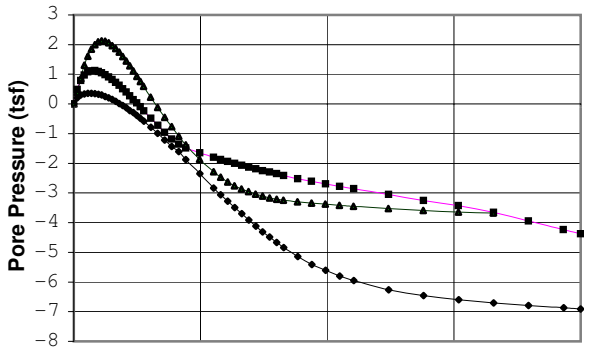
----------	Effective ϕ': 35.0 °	c'=	0.00 (tsf)
_____	Total ϕ': 33.5 °	c=	3.40 (tsf)

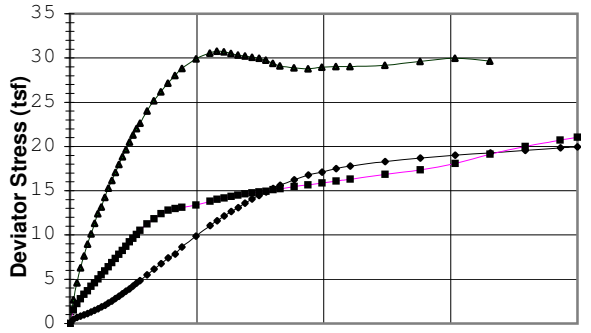
2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

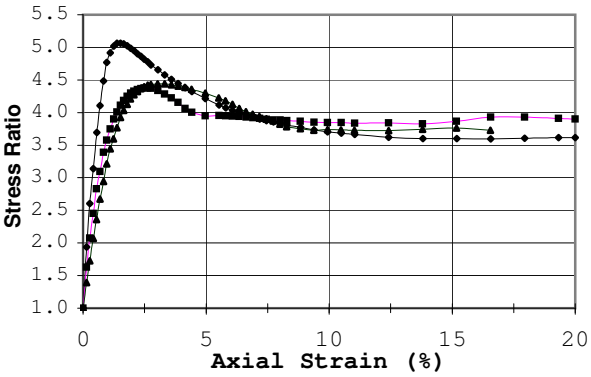
TRIAXIAL TEST ASTM: D 4767

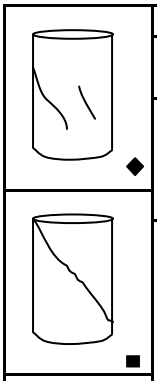
Job No. **7835**
Date: **4/21/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-7** Type: **3T** Depth (ft): **80-82**
Soil Type: **Silty Sand, fine to medium grained, with a trace of gravel (SM)**









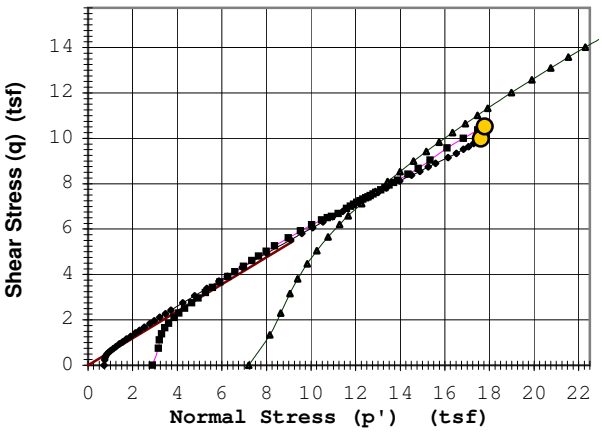
Failure Criterion:	Max. Deviator Stress
Angle of internal friction, ϕ' =	36.5 °
Apparent Cohesion, c' =	0.00 (tsf)

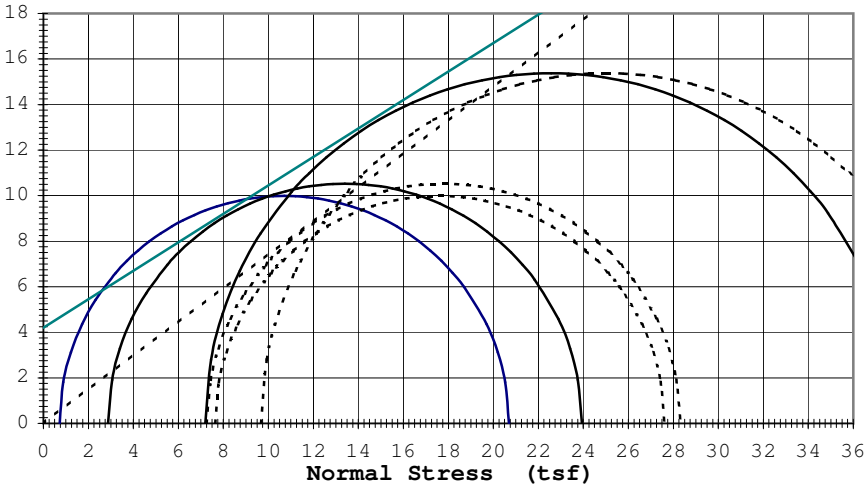
Test Date:	4/4/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00181	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.70

Before Consolidation	A	B	C	D	E
Diameter (in)	1.83	1.79	1.75		
Height (in)	3.65	3.65	3.64		
Water Content (%)	7.5	7.0	8.2		
Dry Density (pcf)	125.0	128.8	131.5		
Void Ratio	0.35	0.31	0.28		
After Consolidation					
Diameter (in)	1.82	1.78	1.73		
Height (in)	3.62	3.62	3.63		
Water Content (%)	12.4	10.4	9.2		
Dry Density (pcf)	126.4	131.6	134.9		
Void Ratio	0.33	0.28	0.25		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	19.97	21.05	30.76		
Ultimate Deviator Stress (tsf)	19.97	21.05	29.66		
Deviator Stress at Failure (tsf)	19.97	21.05	30.76		
Max. Pore Pressure Buildup (tsf)	0.36	1.12	2.12		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	20.0	20.0	5.8		

"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 trimmed to given dimension; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared. Specimens were brittle with uneven sides.





Rupture Envelope at Failure	
α = 30.7 °	a = 0.0 (tsf)

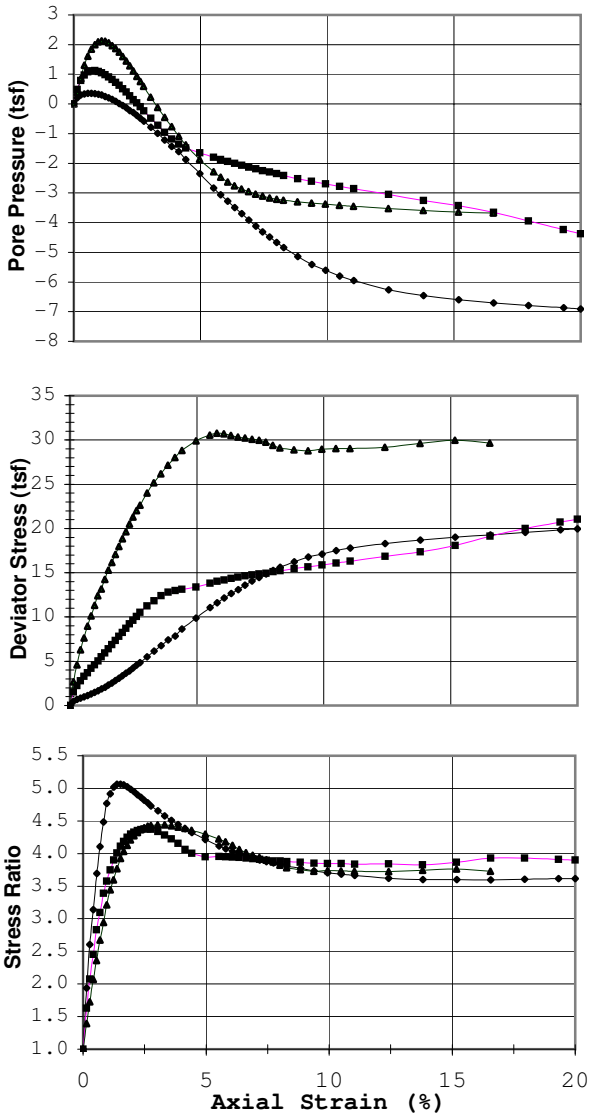
----------	Effective ϕ': 36.5 °	c'=	0.00 (tsf)
_____	Total ϕ': 32.0 °	c=	4.20 (tsf)

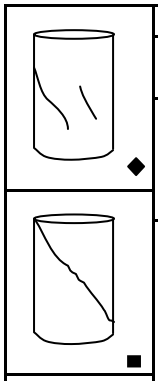
2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

TRIAXIAL TEST ASTM: D 4767

Job No. **7835**
Date: **4/21/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-7** Type: **3T** Depth (ft): **80-82**
Soil Type: **Silty Sand, fine to medium grained, with a trace of gravel (SM)**





Failure Criterion:	Max. Pore Pressure
Angle of internal friction, ϕ' =	33.1 °
Apparent Cohesion, c' =	0.04 (tsf)

Test Date:	4/4/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00181	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.70

Before Consolidation	A	B	C	D	E
Diameter (in)	1.83	1.79	1.75		
Height (in)	3.65	3.65	3.64		
Water Content (%)	7.5	7.0	8.2		
Dry Density (pcf)	125.0	128.8	131.5		
Void Ratio	0.35	0.31	0.28		
After Consolidation					
Diameter (in)	1.82	1.78	1.73		
Height (in)	3.62	3.62	3.63		
Water Content (%)	12.4	10.4	9.2		
Dry Density (pcf)	126.4	131.6	134.9		
Void Ratio	0.33	0.28	0.25		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	19.97	21.05	30.76		
Ultimate Deviator Stress (tsf)	19.97	21.05	29.66		
Deviator Stress at Failure (tsf)	1.12	4.20	12.41		
Max. Pore Pressure Buildup (tsf)	0.36	1.12	2.12		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	0.7	0.8	1.1		

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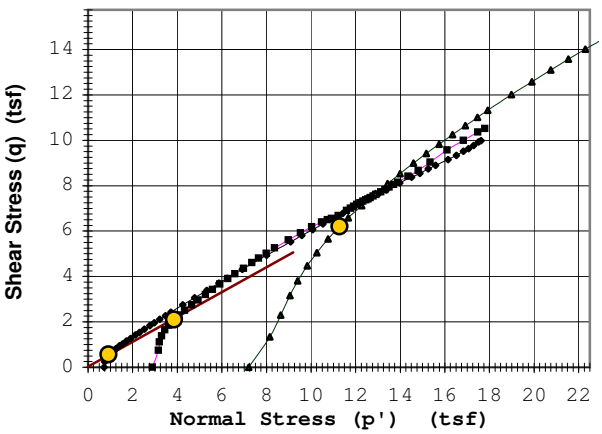
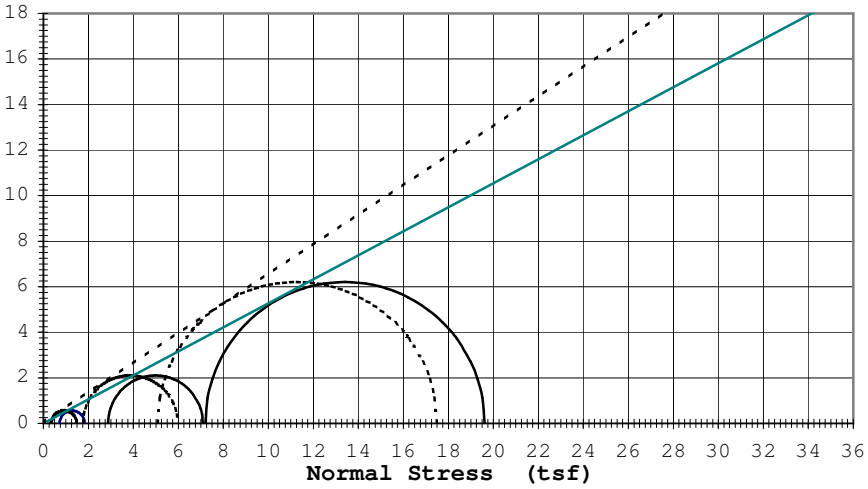
Remarks: Specimen trimmed to given dimension; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared. Specimens were brittle with uneven sides.





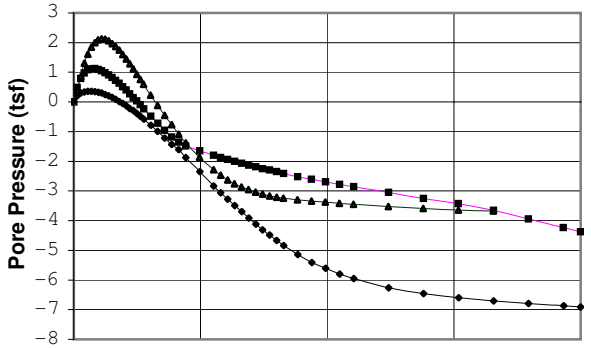
Rupture Envelope at Failure	
α = 28.6 °	a = 0.0 (tsf)

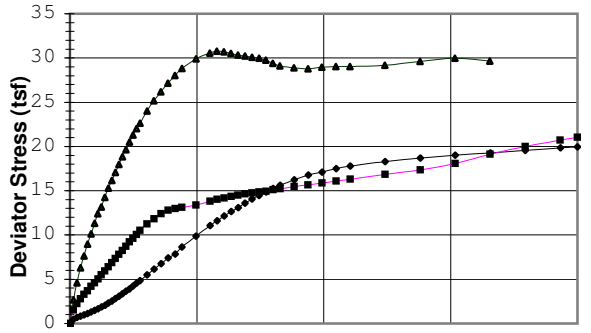
----------	Effective ϕ': 33.1 °	c'=	0.04 (tsf)
_____	Total ϕ': 27.8 °	c=	0.00 (tsf)

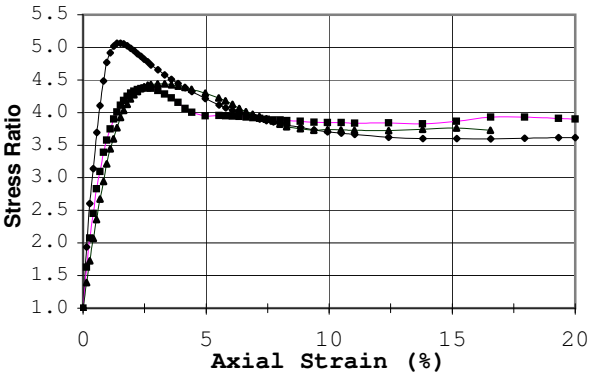
TRIAXIAL TEST ASTM: D 4767

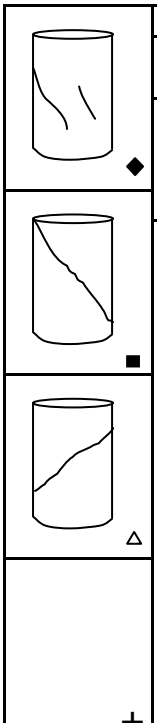
Job No. **7835**
Date: **4/21/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-7** Type: **3T** Depth (ft): **80-82**
Soil Type: **Silty Sand, fine to medium grained, with a trace of gravel (SM)**









Failure Criterion:	Max. Stress Ratio
Angle of internal friction, ϕ' =	39.0 °
Apparent Cohesion, c' =	0.05 (tsf)

Test Date:	4/4/11	Liquid Limit:	
Test Type:	CU w/pp	Plastic Limit:	
Strain Rate (in/min):	0.00181	Plasticity Index:	
Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):	2.70

Before Consolidation	A	B	C	D	E
Diameter (in)	1.83	1.79	1.75		
Height (in)	3.65	3.65	3.64		
Water Content (%)	7.5	7.0	8.2		
Dry Density (pcf)	125.0	128.8	131.5		
Void Ratio	0.35	0.31	0.28		
After Consolidation					
Diameter (in)	1.82	1.78	1.73		
Height (in)	3.62	3.62	3.63		
Water Content (%)	12.4	10.4	9.2		
Dry Density (pcf)	126.4	131.6	134.9		
Void Ratio	0.33	0.28	0.25		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	19.97	21.05	30.76		
Ultimate Deviator Stress (tsf)	19.97	21.05	29.66		
Deviator Stress at Failure (tsf)	2.30	10.04	24.01		
Max. Pore Pressure Buildup (tsf)	0.36	1.12	2.12		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	1.5	2.6	3.0		

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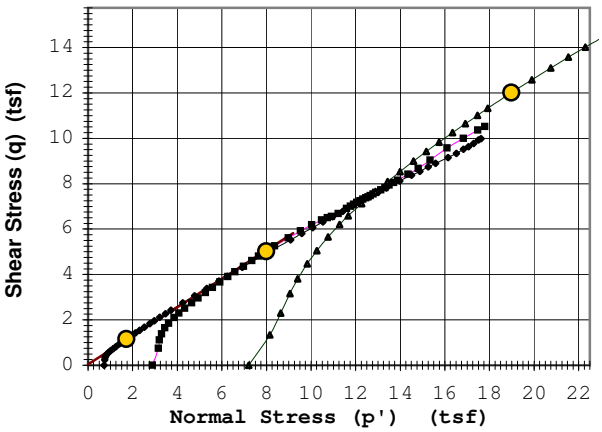
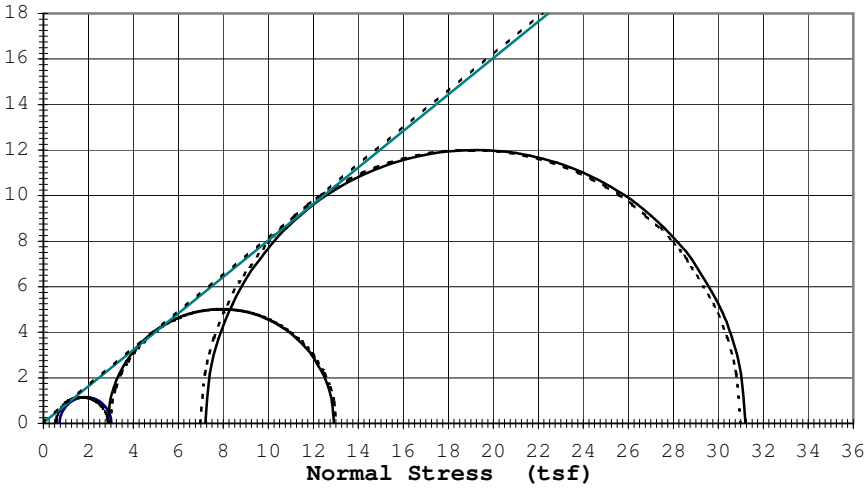
Remarks: Specimen trimmed to given dimension; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared. Specimens were brittle with uneven sides.





Rupture Envelope at Failure	
α = 32.2 °	a = 0.0 (tsf)

----------	Effective ϕ':	39.0 °	c'=	0.05 (tsf)
_____	Total ϕ':	38.7 °	c=	0.03 (tsf)

2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

Triaxial Data

Job: **7835**

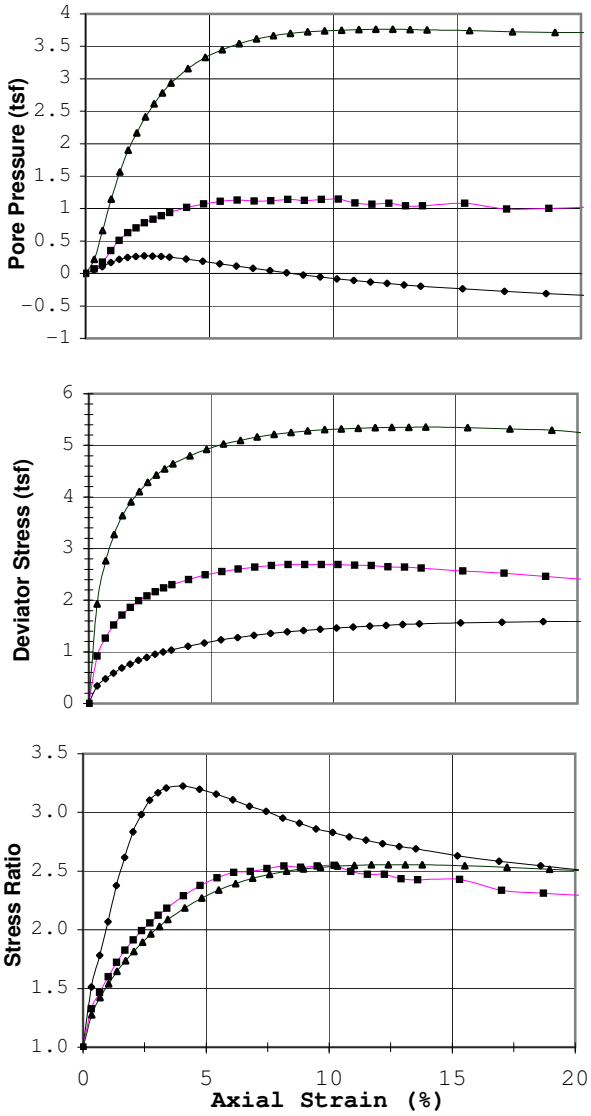
Boring: Sample: BH-7 Depth: 80-82 Date: 4/21/11

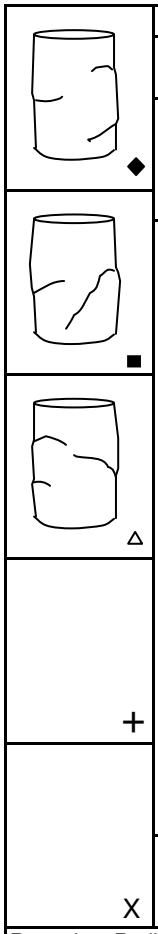
Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
0.14	0.48	0.21	0.14	1.51	0.48	0.14	2.69	0.39						
0.28	0.67	0.30	0.28	2.24	0.79	0.28	4.60	0.86						
0.41	0.82	0.34	0.42	2.77	0.97	0.41	6.31	1.30						
0.55	0.97	0.36	0.55	3.30	1.08	0.55	7.61	1.60						
0.69	1.12	0.36	0.69	3.70	1.12	0.69	8.95	1.85						
0.83	1.29	0.35	0.83	4.20	1.12	0.83	10.11	2.00						
0.97	1.48	0.33	0.97	4.59	1.10	0.97	11.31	2.09						
1.10	1.65	0.30	1.10	5.02	1.05	1.10	12.41	2.12						
1.24	1.89	0.25	1.24	5.50	0.98	1.24	13.18	2.12						
1.38	2.07	0.21	1.38	5.93	0.91	1.38	14.24	2.06						
1.52	2.30	0.15	1.52	6.41	0.82	1.52	15.31	1.97						
1.66	2.55	0.09	1.66	6.86	0.73	1.65	16.18	1.86						
1.79	2.84	0.01	1.79	7.32	0.63	1.79	17.06	1.74						
1.93	3.07	-0.05	1.93	7.81	0.51	1.93	17.98	1.60						
2.07	3.35	-0.13	2.07	8.23	0.41	2.07	18.84	1.45						
2.21	3.66	-0.22	2.21	8.73	0.28	2.21	19.65	1.29						
2.35	3.92	-0.29	2.35	9.21	0.14	2.34	20.50	1.11						
2.49	4.23	-0.39	2.49	9.60	0.03	2.48	21.29	0.93						
2.62	4.55	-0.48	2.62	10.04	-0.09	2.62	22.03	0.76						
2.76	4.84	-0.58	2.76	10.51	-0.24	2.76	22.65	0.60						
3.04	5.49	-0.78	3.04	11.23	-0.49	3.03	24.01	0.22						
3.31	6.13	-0.99	3.31	11.84	-0.72	3.31	25.17	-0.12						
3.59	6.78	-1.21	3.59	12.39	-0.96	3.59	26.20	-0.45						
3.87	7.43	-1.44	3.87	12.82	-1.18	3.86	27.15	-0.77						
4.14	7.85	-1.60	4.14	12.99	-1.36	4.14	28.04	-1.08						
4.42	8.63	-1.88	4.42	13.11	-1.48	4.41	28.80	-1.38						
4.97	9.87	-2.35	4.97	13.38	-1.65	4.96	29.89	-1.87						
5.52	11.06	-2.83	5.52	13.82	-1.80	5.52	30.57	-2.28						
5.80	11.62	-3.06	5.80	14.02	-1.87	5.79	30.76	-2.47						
6.08	12.14	-3.28	6.07	14.18	-1.94	6.07	30.70	-2.63						
6.35	12.64	-3.50	6.35	14.34	-2.00	6.34	30.51	-2.76						
6.63	13.09	-3.70	6.63	14.49	-2.07	6.62	30.33	-2.87						
6.90	13.58	-3.91	6.90	14.63	-2.13	6.90	30.21	-2.96						
7.18	14.05	-4.12	7.18	14.76	-2.19	7.17	30.10	-3.04						
7.46	14.46	-4.31	7.45	14.85	-2.25	7.45	29.96	-3.11						
7.73	14.87	-4.49	7.73	14.95	-2.30	7.72	29.76	-3.16						
8.01	15.24	-4.66	8.01	15.10	-2.35	8.00	29.38	-3.21						
8.28	15.62	-4.84	8.28	15.22	-2.41	8.27	29.09	-3.25						
8.84	16.24	-5.14	8.83	15.46	-2.52	8.83	28.88	-3.30						
9.39	16.76	-5.41	9.39	15.64	-2.61	9.38	28.78	-3.34						
9.94	17.10	-5.61	9.94	15.86	-2.69	9.93	28.95	-3.38						
10.49	17.49	-5.79	10.49	16.11	-2.78	10.48	29.03	-3.41						
11.05	17.80	-5.96	11.04	16.29	-2.86	11.03	29.05	-3.45						
12.43	18.31	-6.27	12.42	16.84	-3.05	12.41	29.19	-3.52						
13.81	18.68	-6.46	13.80	17.35	-3.26	13.79	29.60	-3.59						
15.19	19.04	-6.60	15.18	18.07	-3.42	15.17	29.97	-3.64						
16.57	19.27	-6.70	16.56	19.14	-3.66	16.55	29.66	-3.68						
17.95	19.55	-6.79	17.94	20.00	-3.95									
19.33	19.85	-6.87	19.32	20.72	-4.24									
20.00	19.97	-6.91	20.00	21.05	-4.38									

TRIAXIAL TEST ASTM: D 4767

Job No. **7835**
Date: **3/25/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-08** Type: **3T** Depth (ft): **14.6 - 16.8 (Top)**
Soil Type: **Sandy Lean Clay w/a Little Gravel (CL)**





Failure Criterion: **Given Strain of: 15%**

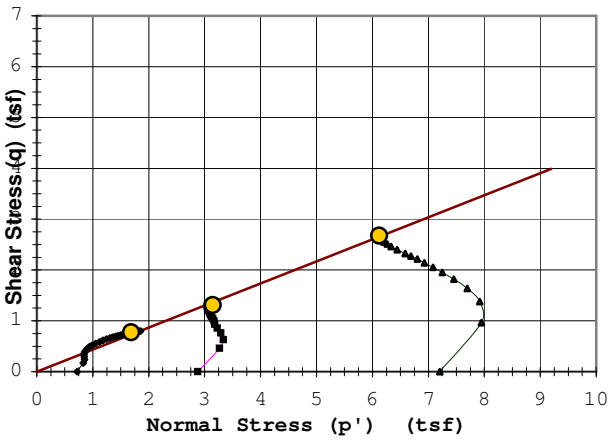
Angle of internal friction, **ϕ' = 25.7 °**
Apparent Cohesion, **c' = 0.00 (tsf)**

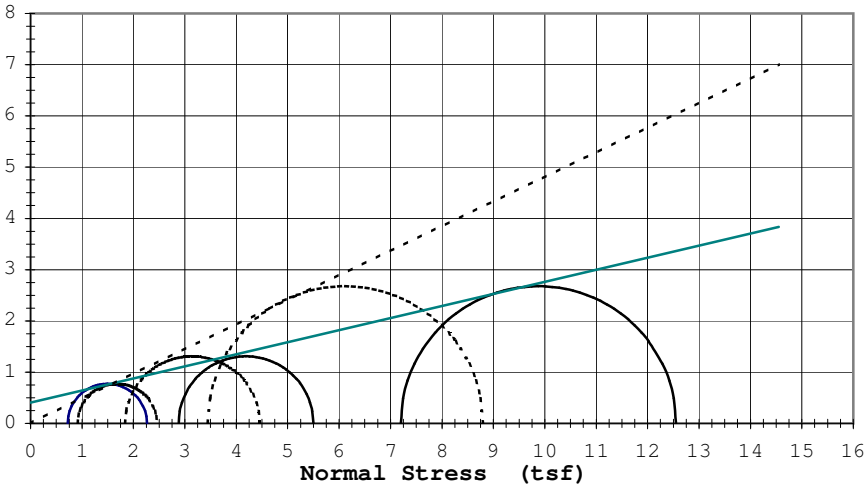
Test Date:	3/23/11	Liquid Limit:	41.8
Test Type:	CU w/pp	Plastic Limit:	14.1
Strain Rate (in/min):	0.0039	Plasticity Index:	27.7
Strain Rate (%/min):	0.132	Spec. Gravity (Assumed):	2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.98	2.98	2.98		
Water Content (%)	18.3	19.0	18.8		
Dry Density (pcf)	113.5	112.3	112.3		
Void Ratio	0.47	0.49	0.49		
After Consolidation					
Diameter (in)	1.44	1.42	1.39		
Height (in)	2.96	2.94	2.90		
Water Content (%)	17.2	16.0	13.2		
Dry Density (pcf)	114.5	117.1	123.7		
Void Ratio	0.46	0.43	0.35		
Back Pressure (tsf)	5.76	5.76	5.76		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	1.59	2.69	5.35		
Ultimate Deviator Stress (tsf)	1.59	2.40	5.22		
Deviator Stress at Failure (tsf)	1.54	2.62	5.35		
Max. Pore Pressure Buildup (tsf)	0.27	1.14	3.76		
Pore Pressure Parameter "B"	0.98	0.98	0.98		
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.





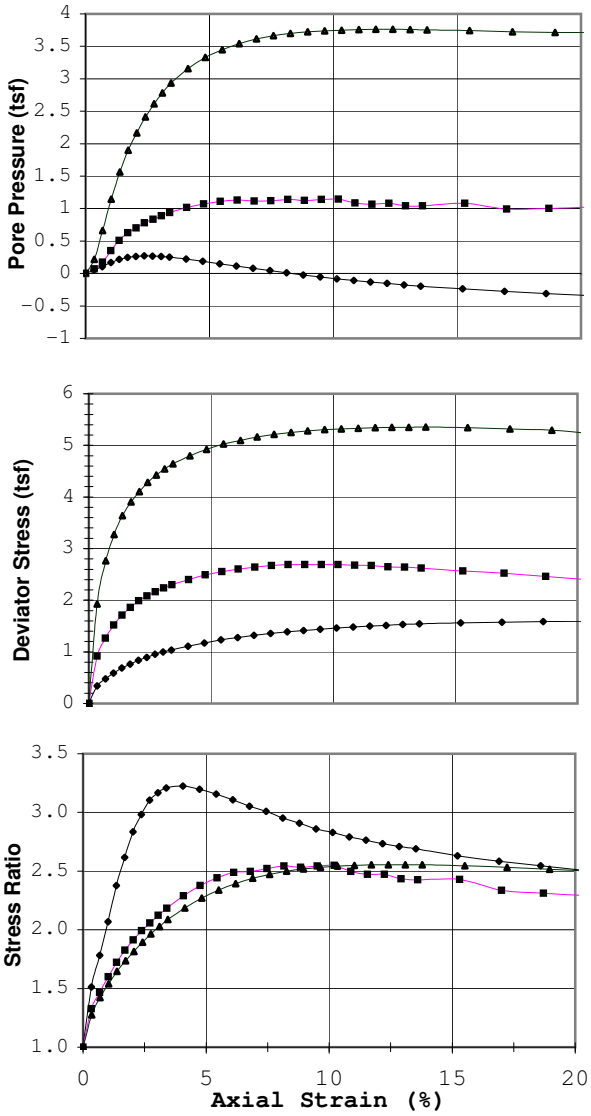
Rupture Envelope at Failure
α = 23.5 ° a = 0.0 (tsf)

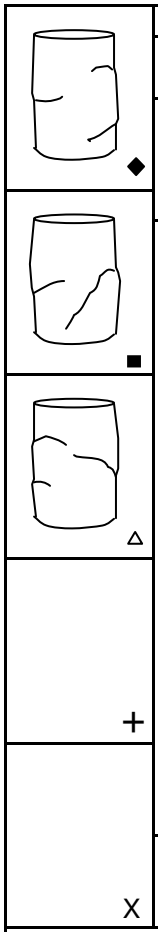
---------- Effective ϕ': 25.7 ° c'= 0.00 (tsf)
_____ Total ϕ': 13.2 ° c= 0.41 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. **7835**
Date: **3/25/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-08** Type: **3T** Depth (ft): **14.6 - 16.8 (Top)**
Soil Type: **Sandy Lean Clay w/a Little Gravel (CL)**





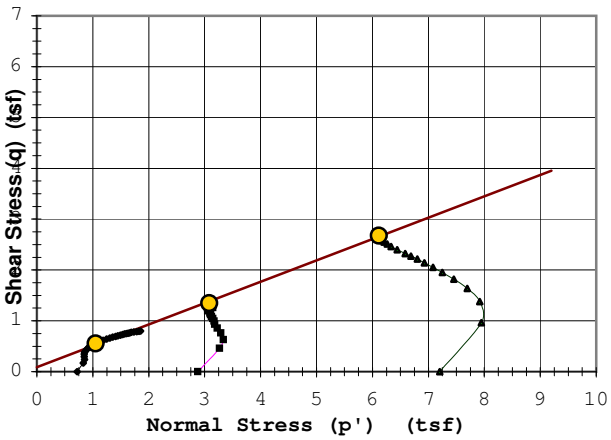
Failure Criterion:	**Max. Stress Ratio**
Angle of internal friction, **ϕ' =**	**24.9 °**
Apparent Cohesion, **c' =**	**0.10 (tsf)**

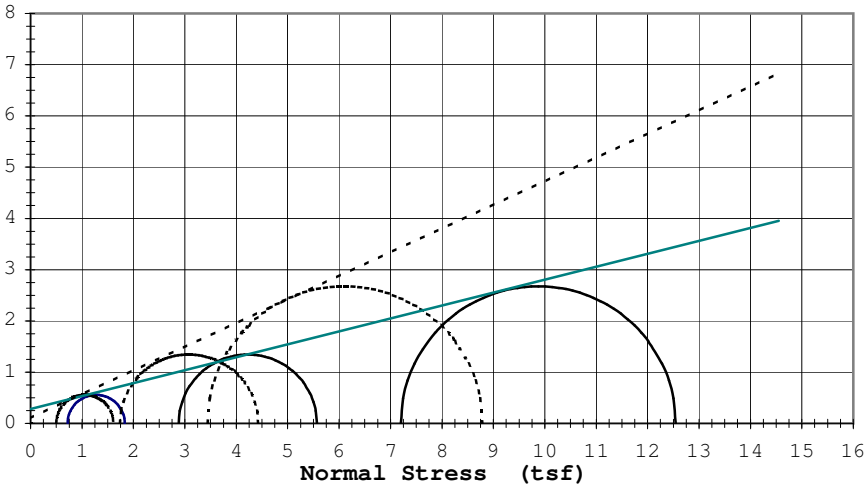
Test Date:	3/23/11	Liquid Limit:	41.8
Test Type:	CU w/pp	Plastic Limit:	14.1
Strain Rate (in/min):	0.0039	Plasticity Index:	27.7
Strain Rate (%/min):	0.132	Spec. Gravity (Assumed):	2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.98	2.98	2.98		
Water Content (%)	18.3	19.0	18.8		
Dry Density (pcf)	113.5	112.3	112.3		
Void Ratio	0.47	0.49	0.49		
After Consolidation					
Diameter (in)	1.44	1.42	1.39		
Height (in)	2.96	2.94	2.90		
Water Content (%)	17.2	16.0	13.2		
Dry Density (pcf)	114.5	117.1	123.7		
Void Ratio	0.46	0.43	0.35		
Back Pressure (tsf)	5.76	5.76	5.76		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	1.59	2.69	5.35		
Ultimate Deviator Stress (tsf)	1.59	2.40	5.22		
Deviator Stress at Failure (tsf)	1.11	2.69	5.35		
Max. Pore Pressure Buildup (tsf)	0.27	1.14	3.76		
Pore Pressure Parameter "B"	0.98	0.98	0.98		
Pct. Axial Strain at Failure	4.1	10.2	12.4		

"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.





Rupture Envelope at Failure	
α = 22.8 °	a = 0.1 (tsf)

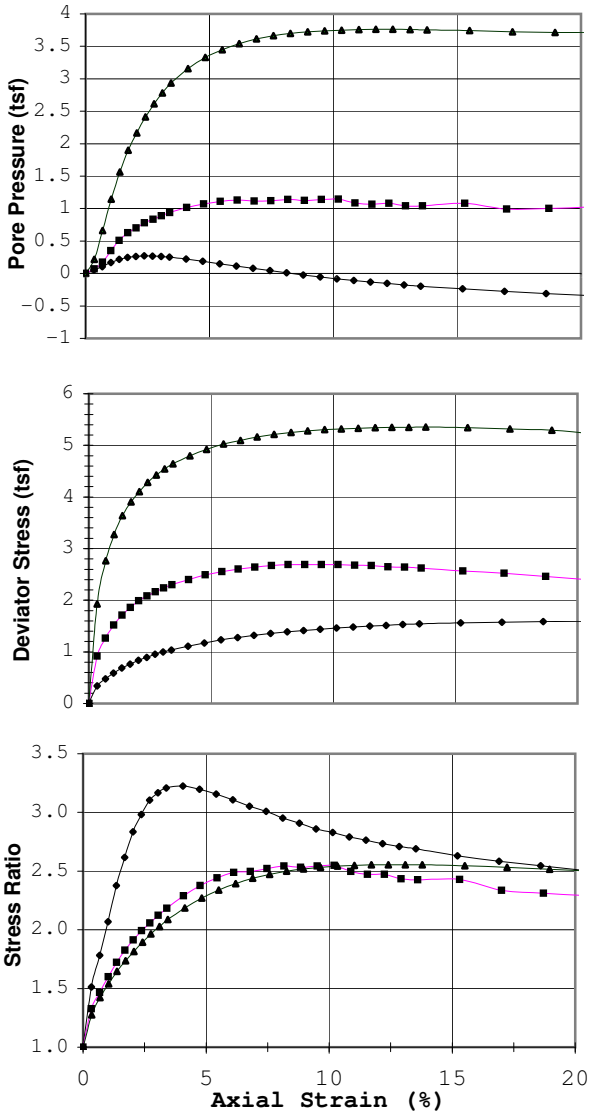
----------	Effective ϕ': 24.9 °	c'=	0.10 (tsf)
_____	Total ϕ': 14.2 °	c=	0.28 (tsf)

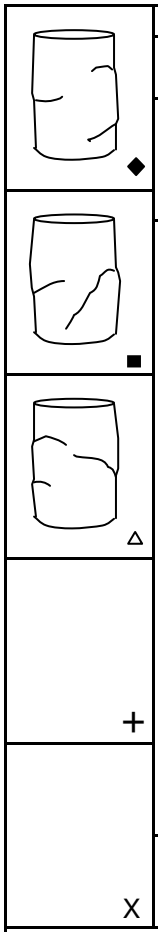
2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

TRIAXIAL TEST ASTM: D 4767

Job No. **7835**
Date: **3/25/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-08** Type: **3T** Depth (ft): **14.6 - 16.8 (Top)**
Soil Type: **Sandy Lean Clay w/a Little Gravel (CL)**





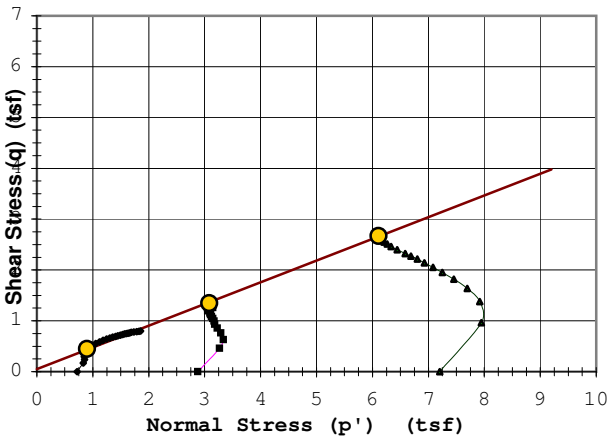
Failure Criterion:	**Max. Pore Pressure**
Angle of internal friction, **ϕ' =**	**25.3 °**
Apparent Cohesion, **c' =**	**0.06 (tsf)**

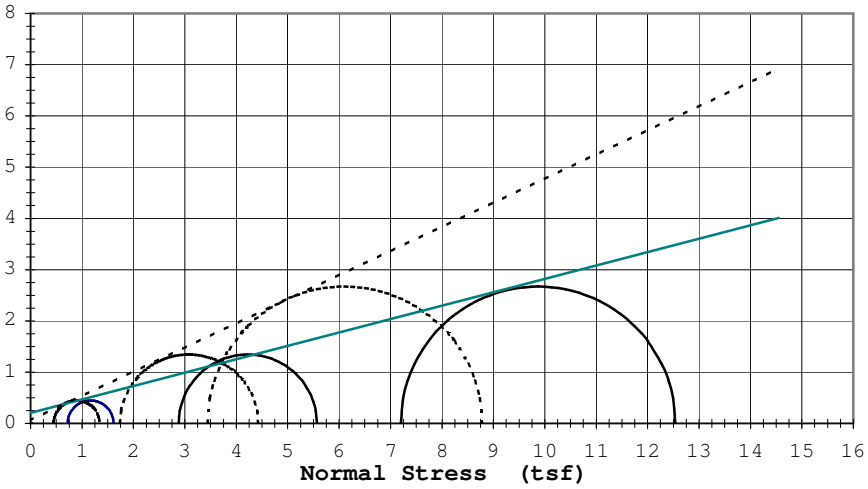
Test Date:	3/23/11	Liquid Limit:	41.8
Test Type:	CU w/pp	Plastic Limit:	14.1
Strain Rate (in/min):	0.0039	Plasticity Index:	27.7
Strain Rate (%/min):	0.132	Spec. Gravity (Assumed):	2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.98	2.98	2.98		
Water Content (%)	18.3	19.0	18.8		
Dry Density (pcf)	113.5	112.3	112.3		
Void Ratio	0.47	0.49	0.49		
After Consolidation					
Diameter (in)	1.44	1.42	1.39		
Height (in)	2.96	2.94	2.90		
Water Content (%)	17.2	16.0	13.2		
Dry Density (pcf)	114.5	117.1	123.7		
Void Ratio	0.46	0.43	0.35		
Back Pressure (tsf)	5.76	5.76	5.76		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	1.59	2.69	5.35		
Ultimate Deviator Stress (tsf)	1.59	2.40	5.22		
Deviator Stress at Failure (tsf)	0.89	2.69	5.34		
Max. Pore Pressure Buildup (tsf)	0.27	1.14	3.76		
Pore Pressure Parameter "B"	0.98	0.98	0.98		
Pct. Axial Strain at Failure	2.4	10.2	11.7		

"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.





Rupture Envelope at Failure	
α = 23.1 °	a = 0.1 (tsf)

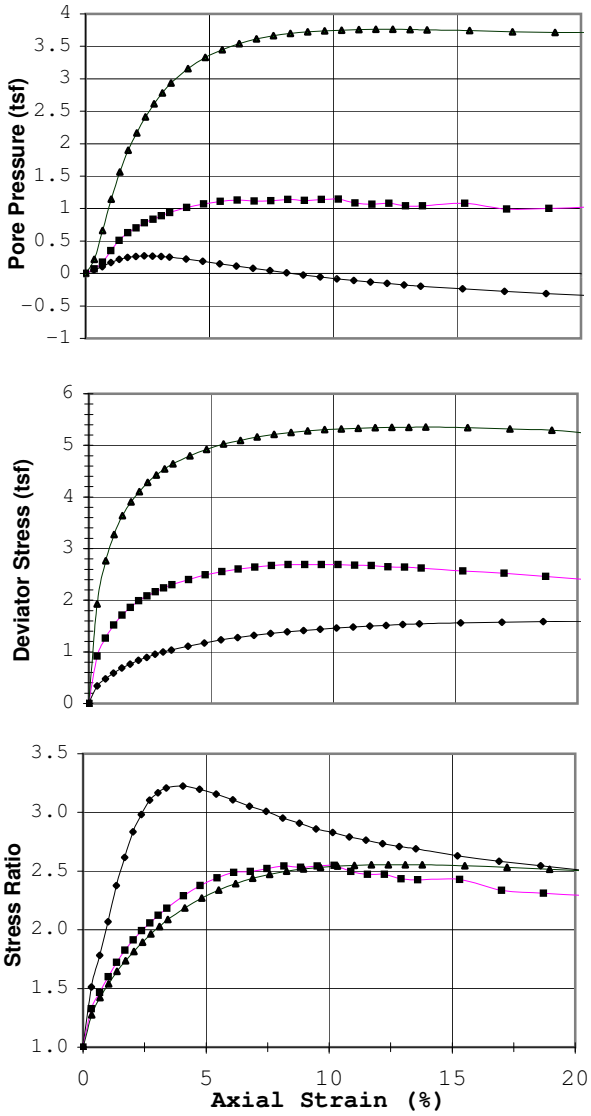
----------	Effective ϕ': 25.3 °	c'=	0.06 (tsf)
_____	Total ϕ': 14.7 °	c=	0.21 (tsf)

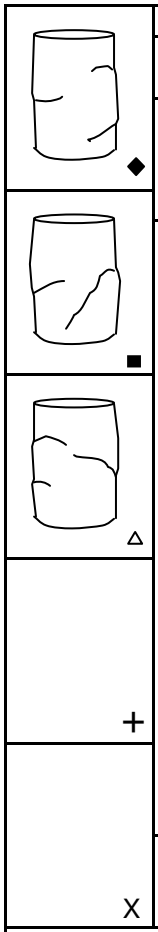
2401 W 66th Street
SOIL ENGINEERING TESTING, INC.
Richfield, Minnesota 55423-2031

TRIAXIAL TEST ASTM: D 4767

Job No. **7835**
Date: **3/25/11**

Project: **Copperwood Mine**
Boring #: Sample #: **BH-08** Type: **3T** Depth (ft): **14.6 - 16.8 (Top)**
Soil Type: **Sandy Lean Clay w/a Little Gravel (CL)**





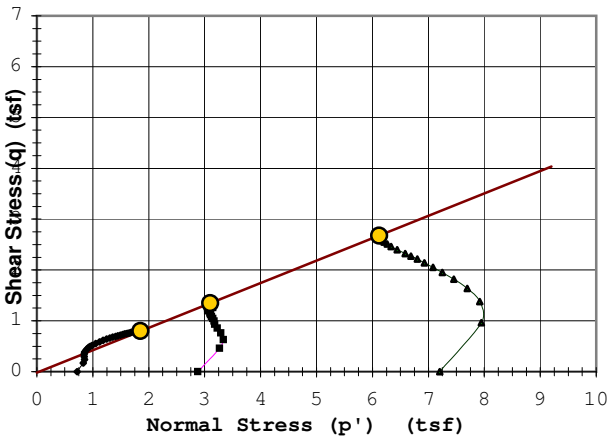
Failure Criterion:	**Max. Deviator Stress**
Angle of internal friction, **ϕ' =**	**26.1 °**
Apparent Cohesion, **c' =**	**0.00 (tsf)**

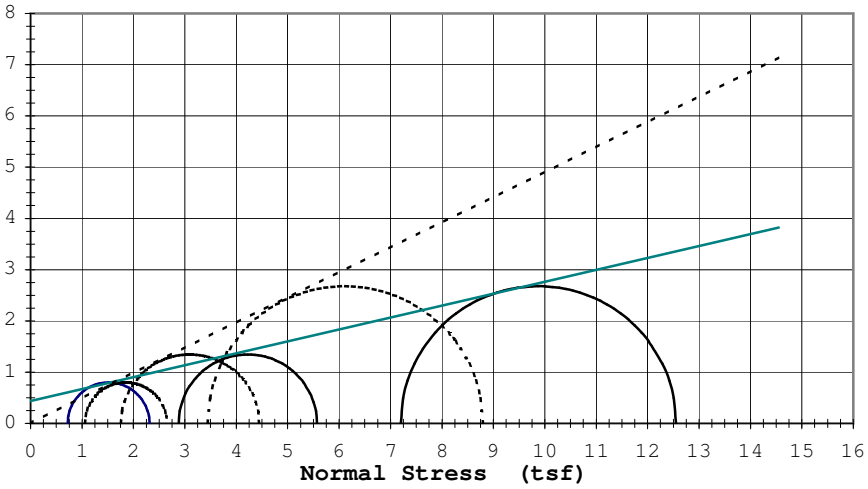
Test Date:	3/23/11	Liquid Limit:	41.8
Test Type:	CU w/pp	Plastic Limit:	14.1
Strain Rate (in/min):	0.0039	Plasticity Index:	27.7
Strain Rate (%/min):	0.132	Spec. Gravity (Assumed):	2.68

Before Consolidation	A	B	C	D	E
Diameter (in)	1.44	1.44	1.44		
Height (in)	2.98	2.98	2.98		
Water Content (%)	18.3	19.0	18.8		
Dry Density (pcf)	113.5	112.3	112.3		
Void Ratio	0.47	0.49	0.49		
After Consolidation					
Diameter (in)	1.44	1.42	1.39		
Height (in)	2.96	2.94	2.90		
Water Content (%)	17.2	16.0	13.2		
Dry Density (pcf)	114.5	117.1	123.7		
Void Ratio	0.46	0.43	0.35		
Back Pressure (tsf)	5.76	5.76	5.76		
Minor Principal Stress (tsf)	0.72	2.88	7.20		
Max. Deviator Stress (tsf)	1.59	2.69	5.35		
Ultimate Deviator Stress (tsf)	1.59	2.40	5.22		
Deviator Stress at Failure (tsf)	1.59	2.69	5.35		
Max. Pore Pressure Buildup (tsf)	0.27	1.14	3.76		
Pore Pressure Parameter "B"	0.98	0.98	0.98		
Pct. Axial Strain at Failure	20.3	8.8	13.8		

"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.





Rupture Envelope at Failure	
α = 23.8 °	a = 0.0 (tsf)

----------	Effective ϕ': 26.1 °	c'=	0.00 (tsf)
_____	Total ϕ': 13.1 °	c=	0.44 (tsf)

Triaxial Data

Job: **7835**

Boring: _____ Sample: BH-08 Depth: 14.6 - 16.8 (Top) Date: 3/25/11

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						
0.34	0.34	0.06	0.34	0.92	0.07	0.35	1.93	0.22						
0.68	0.48	0.11	0.68	1.26	0.17	0.69	2.76	0.66						
1.01	0.59	0.17	1.02	1.52	0.35	1.03	3.27	1.14						
1.35	0.69	0.22	1.36	1.71	0.51	1.38	3.64	1.56						
1.69	0.76	0.25	1.70	1.86	0.63	1.72	3.90	1.90						
2.03	0.84	0.26	2.04	1.99	0.70	2.07	4.10	2.17						
2.37	0.89	0.27	2.38	2.08	0.78	2.41	4.28	2.41						
2.71	0.95	0.27	2.72	2.16	0.84	2.76	4.43	2.61						
3.04	1.00	0.26	3.06	2.24	0.89	3.10	4.54	2.78						
3.38	1.04	0.25	3.40	2.30	0.94	3.45	4.64	2.94						
4.06	1.11	0.22	4.08	2.40	1.02	4.14	4.80	3.16						
4.73	1.17	0.19	4.76	2.49	1.07	4.83	4.92	3.33						
5.41	1.23	0.15	5.44	2.55	1.11	5.52	5.03	3.45						
6.09	1.28	0.11	6.12	2.60	1.13	6.20	5.10	3.54						
6.76	1.32	0.08	6.80	2.64	1.12	6.89	5.16	3.61						
7.44	1.36	0.04	7.48	2.67	1.12	7.58	5.21	3.66						
8.12	1.39	0.01	8.16	2.69	1.14	8.27	5.25	3.70						
8.79	1.42	-0.02	8.84	2.69	1.13	8.96	5.28	3.72						
9.47	1.44	-0.05	9.52	2.69	1.14	9.65	5.30	3.74						
10.14	1.46	-0.08	10.20	2.69	1.14	10.34	5.32	3.75						
10.82	1.48	-0.11	10.88	2.68	1.09	11.03	5.33	3.76						
11.50	1.50	-0.13	11.56	2.67	1.07	11.72	5.34	3.76						
12.17	1.52	-0.15	12.25	2.65	1.08	12.41	5.35	3.76						
12.85	1.53	-0.17	12.93	2.64	1.04	13.10	5.35	3.76						
13.53	1.54	-0.19	13.61	2.62	1.04	13.79	5.35	3.76						
15.22	1.56	-0.24	15.30	2.57	1.08	15.51	5.34	3.74						
16.91	1.58	-0.28	17.01	2.52	0.99	17.23	5.32	3.73						
18.60	1.59	-0.31	18.71	2.46	1.00	18.96	5.29	3.71						
20.29	1.59	-0.34	20.41	2.40	1.02	20.68	5.22	3.72						

Direct Shear Test

ASTM: D3080

Job No.: 7832

Project: **Copperwood Mine**

Boring No.: Sample No. **BH-02** Depth: **35.2-37.2**

Location: Sample Type: **TWT**

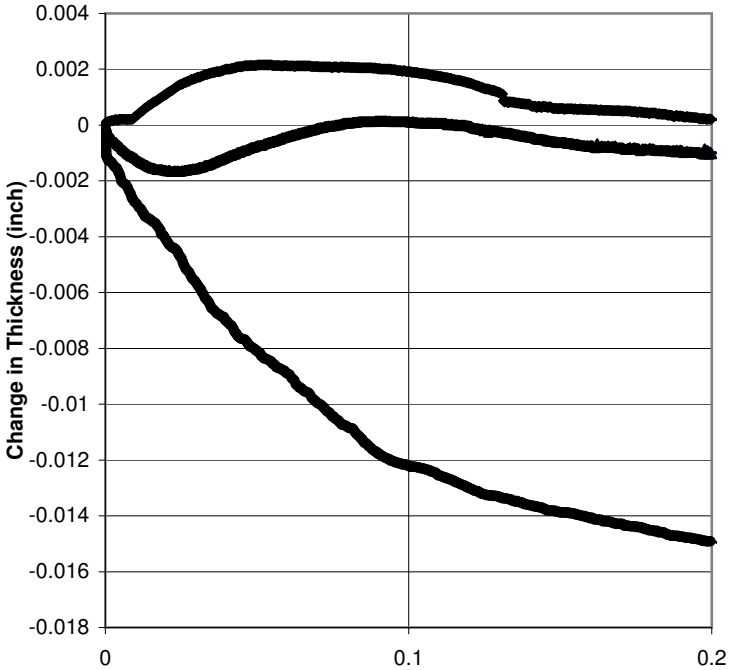
Soil Type: **Lean Clay, plastic, with fine - coarse sand, some fine - coarse gravel (CL)**

Test Date:	**3/24/2011**
Date Reported:	**4/10/2011**
Shear Rate	
0.00047 (in/min)	

Remarks: Specimens trimmed to given dimensions, Inundated after applying normal load. Consolidated and sheared to given displacements at constant rate of 0.00047inches/minute.

Liquid Limit:	
Plastic Limit:	
Plasticity Index:	
Specific Gravity (*):	**2.72**

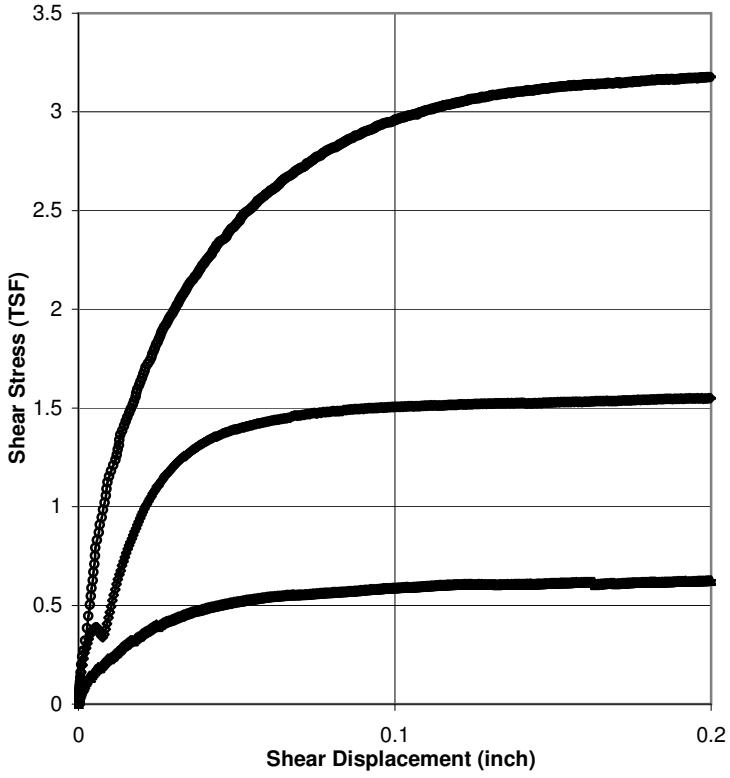
(*) = Assumed Specific Gravity

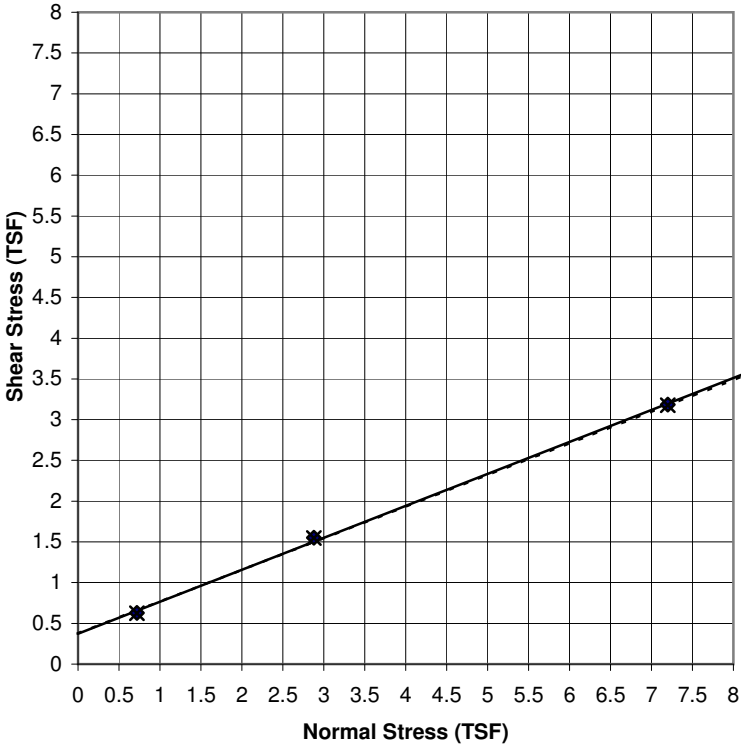


Failure Criterion:				
Max Stress	A	B	C	D
Initial	▲	◇	○	X
Diameter (In.)	2.51	2.51	2.51	
Thickness (In.)	0.85	0.85	0.85	
Water Content (%)	22.3	22.2	22.2	
Dry Density (pcf)	109.9	107.7	107.7	
Before Shear				
Thickness (In.)	0.82	0.81	0.77	
Water Content (%)	18.6	18.9	16.0	
Dry Density (pcf)	112.7	112.1	118.2	
Normal Stress	0.72	2.88	7.20	
Shear Stress	0.63	1.55	3.19	

"These tests 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."

Peak Conditions		At Given Shear Disp. Of: 0.2	
Friction Angle:	ϕ= **21.4 deg.**	Friction Angle:	ϕ= **21.3 deg.**
Apparent Cohesion	**0.375 TSF**	Apparent Cohesion	**0.375 TSF**





Direct Shear Test

ASTM: D3080

Job No.: 7832

Project: **Copperwood Mine**

Boring No.: Sample No. **BH-07** Depth: **45-47**

Location: Sample Type: **TWT**

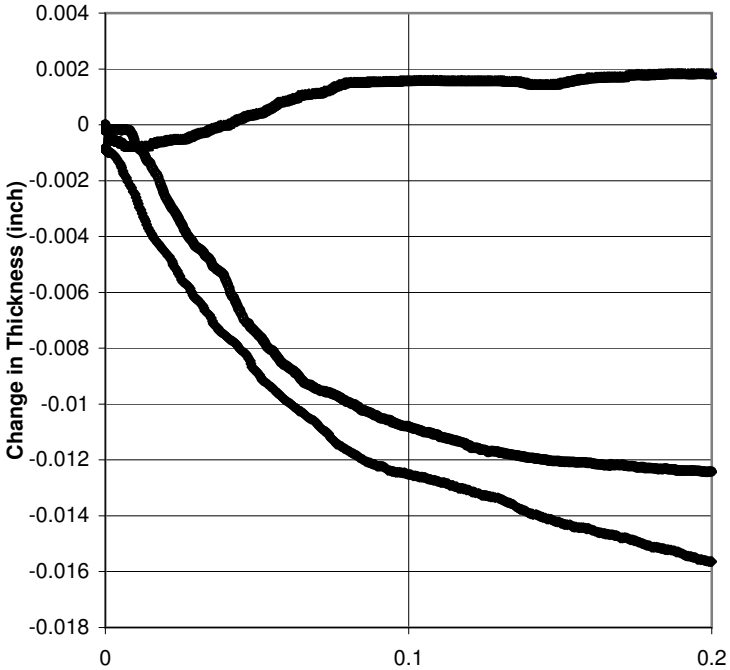
Soil Type: **Lean Clay, plastic, with fine - coarse sand, some fine gravel (CL)**

Test Date:	**3/9/2011**
Date Reported:	**4/15/2011**
Shear Rate	
0.00047 (in/min)	

Remarks: Specimens trimmed to given dimensions, Inundated after applying normal load. Consolidated and sheared to given displacements at constant rate of 0.00047inches/minute.

Liquid Limit:	
Plastic Limit:	
Plasticity Index:	
Specific Gravity (*):	**2.72**

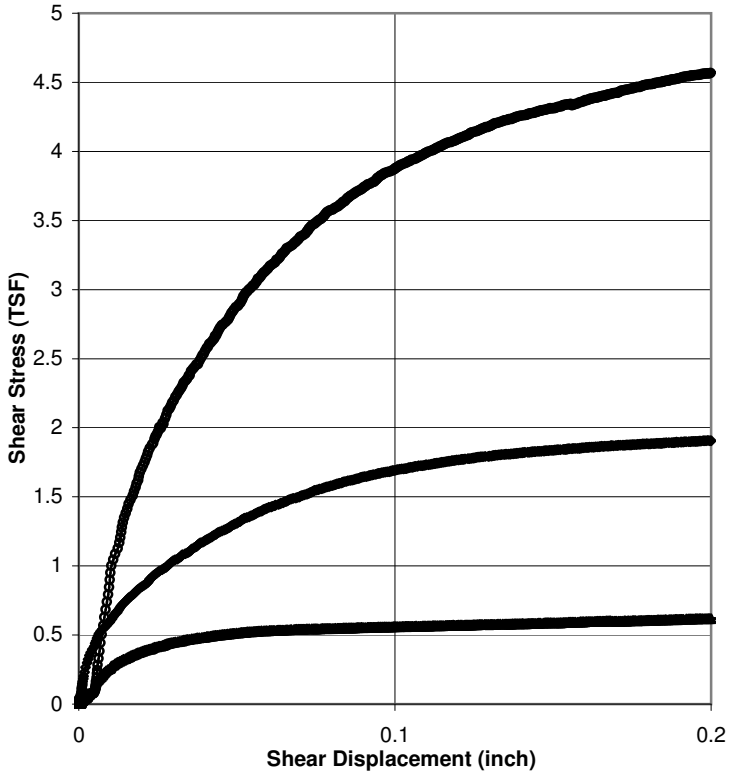
(*) = Assumed Specific Gravity

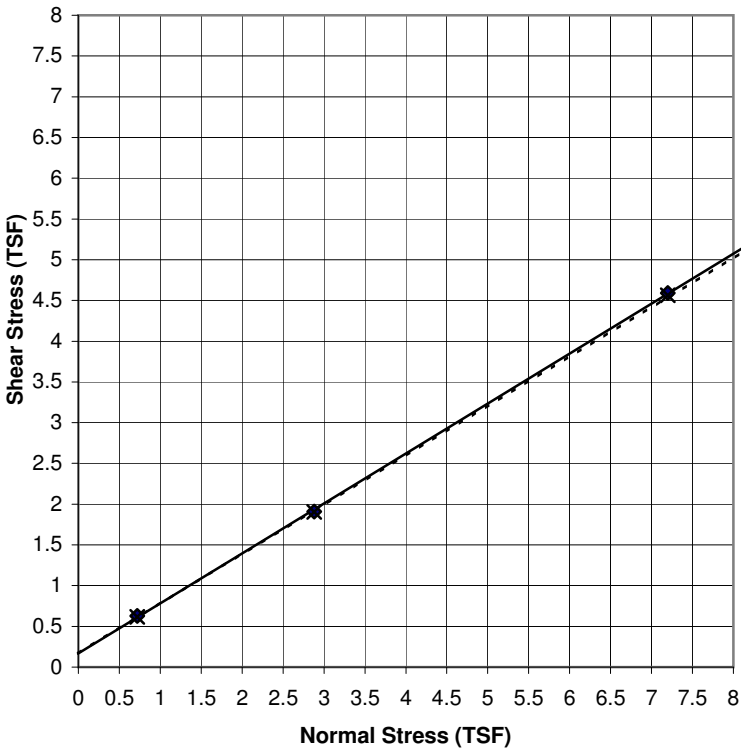


Failure Criterion:				
Max Stress	A	B	C	D
Initial	▲	◇	○	X
Diameter (In.)	2.51	2.51	2.51	
Thickness (In.)	0.85	0.85	0.85	
Water Content (%)	22.2	22.1	22.0	
Dry Density (pcf)	110.0	107.8	107.9	
Before Shear				
Thickness (In.)	0.83	0.81	0.79	
Water Content (%)	19.3	18.5	17.5	
Dry Density (pcf)	111.4	113.0	115.1	
Normal Stress	0.72	2.88	7.20	
Shear Stress	0.63	1.91	4.59	

"These tests 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."

Peak Conditions		At Given Shear Disp. Of: 0.199	
Friction Angle:	ϕ= **31.5 deg.**	Friction Angle:	ϕ= **31.3 deg.**
Apparent Cohesion	**0.169 TSF**	Apparent Cohesion	**0.167 TSF**





Direct Shear Test

ASTM: D3080

Job No.: 7832

Project: **Copperwood Mine**

Boring No.: Sample No. **BH-08** Depth: **19.6-21.8**

Location: Sample Type: **TWT**

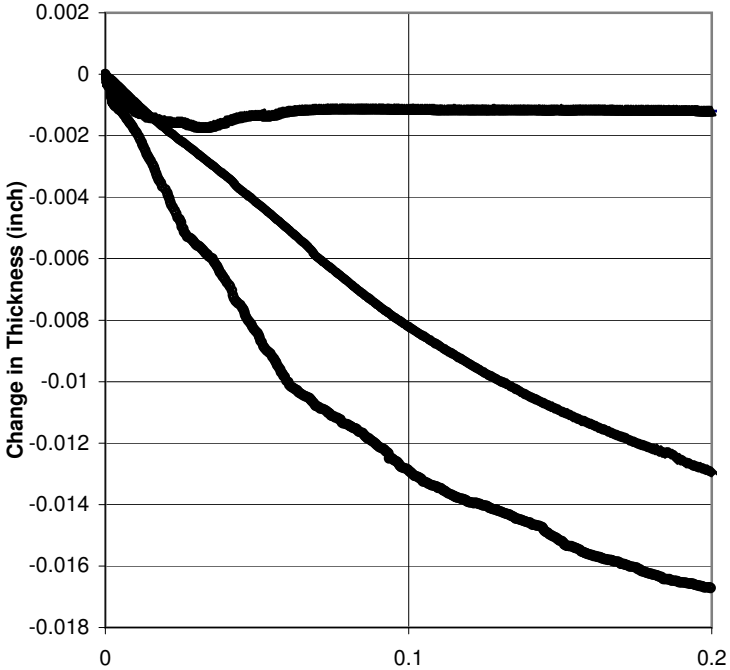
Soil Type: **Lean Clay, plastic, with fine - coarse sand, some fine gravel (CL)**

Test Date:	**3/31/2011**
Date Reported:	**4/14/2011**
Shear Rate	
0.00047 (in/min)	

Remarks: Specimens trimmed to given dimensions, Inundated after applying normal load. Consolidated and sheared to given displacements at constant rate of 0.00047inches/minute..

Liquid Limit:	
Plastic Limit:	
Plasticity Index:	
Specific Gravity (*):	**2.72**

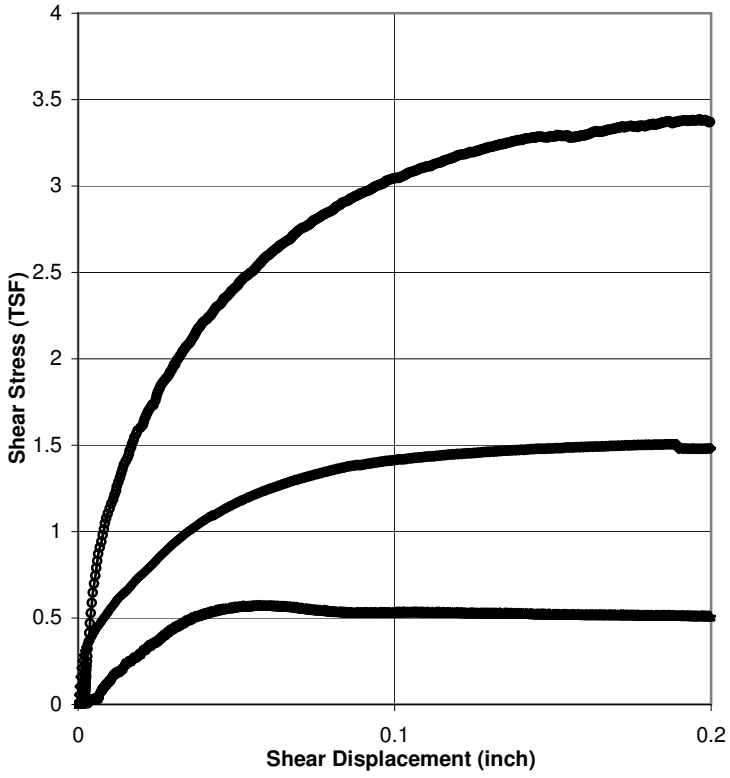
(*) = Assumed Specific Gravity

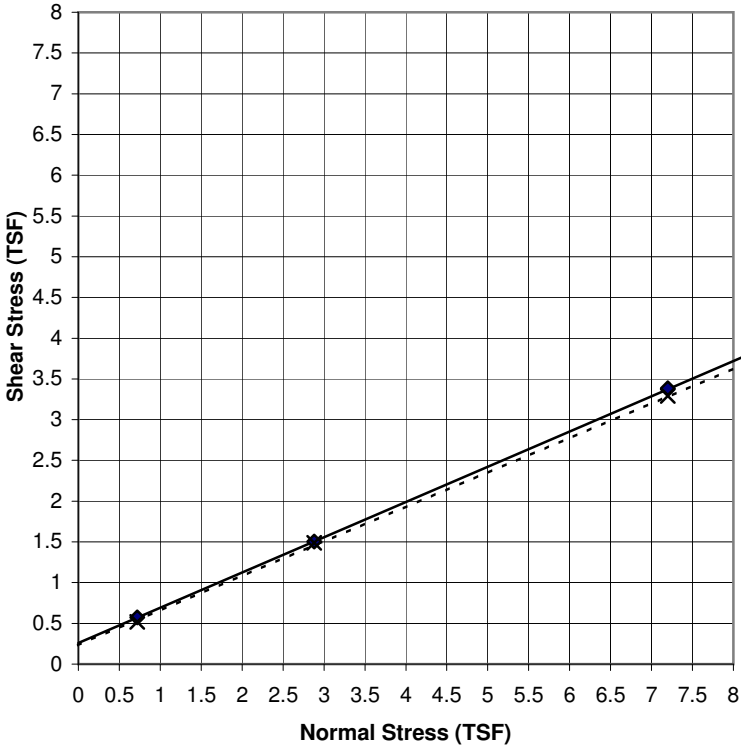


Failure Criterion:				
Max Stress	A	B	C	D
Initial	▲	◇	○	X
Diameter (In.)	2.51	2.51	2.51	
Thickness (In.)	0.85	0.85	0.85	
Water Content (%)	18.5	18.6	18.7	
Dry Density (pcf)	110.9	110.8	111.7	
Before Shear				
Thickness (In.)	0.82	0.80	0.77	
Water Content (%)	18.1	16.9	14.2	
Dry Density (pcf)	113.8	116.4	122.4	
Normal Stress	0.72	2.88	7.20	
Shear Stress	0.57	1.51	3.39	

"These tests 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."

Peak Conditions		At Given Shear Disp. Of: 0.16	
Friction Angle:	ϕ= **23.4 deg.**	Friction Angle:	ϕ= **23.0 deg.**
Apparent Cohesion	**0.259 TSF**	Apparent Cohesion	**0.232 TSF**





Knight Piésold CONSULTING

Appendix G

Previous Site Investigation Data

G-1 Previous Site Investigation Data – Test Pit Logs
G-2 Previous Site Investigation Data – Test Pit Photos
G-3 Previous Site Investigation Data – Borehole Logs
G-4 Previous Site Investigation Data – Index Data
G-5 Previous Site Investigation Data – Natural Moisture Content Data
G-6 Previous Site Investigation Data – Moisture Density Data

Knight Piésold CONSULTING

Appendix G-1

Previous Site Investigation Data – Test Pit Logs

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-5

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As Staked - Refer to test pit location drawing ELEV.: 781.65 +/-

RIG TYPE: John Deere 992E LC Excavator DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated BORING DEPTH: 15.0

DATE STARTED: Mar 8, 10 DATE COMPLETED: Mar 8, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.2'		781.7						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, with silt, some fine to coarse sand, trace fine gravel, moist								
				2									
				3									
				4									
				5			776.7						>4.5
				6									
				7									
				8									
				9									>4.5
				10			771.7						
				11									
				12									
				13									
				14									>4.5
				15	15.0' End of Test Pit		766.7						
				16									
				17									
				18									
				19									
				20			761.7						

AS-Auger Sample; BS-Bag Sample; RC-Rock-Core; GS-Grab Sample; PS-Piston Tube; 2SS-2" Split Spoon; 3SS-3" Split Spoon; 2ST-2" Shelby Tube; 3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: TP-5

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-6

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As Staked - Refer to test pit location drawing ELEV.: 799.07 +/-

RIG TYPE: John Deere 992E LC Excavator DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated BORING DEPTH: 16.0

DATE STARTED: Mar 9, 10 DATE COMPLETED: Mar 9, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.5'		799.1						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, trace fine to coarse sand, trace fine gravel, moist								
				2									
				3									
				4									
				5			794.1						
				6									
				7	...sand seam at 7.0' with little perched water								
				8									
				9									
				10			789.1						
				11									
				12									
				13									
				14									
				15			784.1						
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20			779.1						

I -AS-Auger Sample
B -BS-Bag Sample
R -RC-Rock-Core
G -GS-Grab Sample
P -PS-Piston Tube
X -2SS-2" Split Spoon
/ -3SS-3" Split Spoon
/ -2ST-2" Shelby Tube
/ -3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▽ after hours

BORING NO.: TP-6

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-7

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As Staked - Refer to test pit location drawing

ELEV.: 815.79 +/-

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Mar 9, 10 DATE COMPLETED: Mar 9, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6" (N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.5'		815.8						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt some fine to coarse sand, trace fine to coarse gravel, some cobbles, moist								
				2									
				3									
				4									
				5			810.8						2.25
				6									
				7									
				8									
				9									4.5
				10			805.8						
				11									
				12									
				13									
				14									4.5
				15			800.8						
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20			795.8						

[I] -AS-Auger Sample
[B] -BS-Bag Sample
[I] -RC-Rock-Core
[G] -GS-Grab Sample
[P] -PS-Piston Tube
[X] -2SS-2" Split Spoon
[/] -3SS-3" Split Spoon
[/] -2ST-2" Shelby Tube
[/] -3ST-3" Shelby Tube

▽ while drilling
▼ after drilling

▽ after hours

BORING NO.: TP-7

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-8

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As Staked - Refer to test pit location drawing ELEV.: 819.31 +/-

RIG TYPE: John Deere 992E LC Excavator DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated BORING DEPTH: 16.0

DATE STARTED: Mar 9, 10 DATE COMPLETED: Mar 9, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.3'		819.3						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, some fine to coarse sand, trace fine to coarse gravel, moist								
				2									
				3									
				4									
				5			814.3						2.75
				6									
				7									
				8									
				9									
				10			809.3						4.5
				11									
				12									
				13									
				14									
				15			804.3						
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20			799.3						

-AS-Auger Sample -GS-Grab Sample -3SS-3" Split Spoon
-BS-Bag Sample -PS-Piston Tube -2ST-2" Shelby Tube
-RC-Rock-Core -2SS-2" Split Spoon -3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-8

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-9

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As Staked - Refer to test pit location drawing

ELEV.: 836.09 +/-

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Mar 9, 10 DATE COMPLETED: Mar 9, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.3'		836.1						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, some fine to coarse sand, moist								
				2									
				3									
				4									
				5			831.1						
				6									
				7									
				8									
				9									
				10			826.1						
				11									
				12									
				13									
				14									
				15	15.0' End of Test Pit		821.1						
				16									
				17									
				18									
				19									
				20			816.1						

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-9

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-10

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As Staked - Refer to test pit location drawing

ELEV.: 839.42 +/-

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Mar 9, 10 DATE COMPLETED: Mar 9, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	τ (tsf)	q_a (tsf)
				0	TOPSOIL 0.3'		839.4						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, some fine to coarse sand, trace fine to coarse gravel, moist								
				2									
				3									
				4									
				5			834.4						2.5
				6									
				7									
				8									
				9									
				10			829.4						4.5
				11									
				12									
				13									
				14									4.5
				15	15.0' End of Test Pit		824.4						
				16									
				17									
				18									
				19									
				20			819.4						

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-10

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-11

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As Staked - Refer to test pit location drawing

ELEV.: 851.38 +/-

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Mar 8, 10 DATE COMPLETED: Mar 8, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.2'		851.4						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, some fine to coarse sand, trace fine gravel, moist								
				2									
				3									
				4									
				5			846.4						
				6									
				7									
				8									
				9									
				10			841.4						
				11									
				12									
				13									
				14									
				15	15.0' End of Test Pit		836.4						
				16									
				17									
				18									
				19									
				20			831.4						

-AS-Auger Sample -GS-Grab Sample -3SS-3" Split Spoon
-BS-Bag Sample -PS-Piston Tube -2ST-2" Shelby Tube
-RC-Rock-Core -2SS-2" Split Spoon -3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-11

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-12

CLIENT: Orvana Resources U.S. Corporation

BORING LOCATION: As Staked - Refer to test pit location drawing

ELEV.: 840.63 +/-

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 15.0

DATE STARTED: Mar 8, 10 DATE COMPLETED: Mar 8, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.2'		840.6						1.5
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, trace fine to coarse sand, trace fine gravel, moist								
				2									
				3									2.0
				4									
				5			835.6						3.25
				6									
				7									
				8									
				9									
				10			830.6						4.5
				11									
				12									
				13									
				14									4.5
				15	15.0' End of Boring		825.6						
				16									
				17									
				18									
				19									
				20			820.6						

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-12

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-13

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As Staked - Refer to test pit location drawing ELEV.: 869.71 +/-

RIG TYPE: John Deere 992E LC Excavator DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated BORING DEPTH: 15.0

DATE STARTED: Mar 8, 10 DATE COMPLETED: Mar 8, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.2'		869.7						
				1	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, some fine to coarse sand, trace fine gravel, moist								
				2									
				3									4.5
				4									
				5			864.7						
				6									
				7									
				8									
				9									
				10			859.7						4.5
				11									
				12									
				13									
				14									
				15	15.0' End of Test Pit		854.7						4.5
				16									
				17									
				18									
				19									
				20			849.7						

AS-Auger Sample; BS-Bag Sample; RC-Rock-Core; GS-Grab Sample; PS-Piston Tube; 2SS-2" Split Spoon; 3SS-3" Split Spoon; 2ST-2" Shelby Tube; 3ST-3" Shelby Tube

while drilling; after drilling

after hours

BORING NO.: TP-13

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-14

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As Staked - Refer to test pit location drawing

ELEV.: 878.86 +/-

RIG TYPE: John Deere 992E LC Excavator

DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated

BORING DEPTH: 16.0

DATE STARTED: Mar 8, 10

DATE COMPLETED: Mar 8, 10

REVIEWED BY: G. Stengard

DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	TOPSOIL 0.1'		878.9						
				1	(CL) LEAN CLAY, reddish brown, some silt, some fine to coarse sand, some fine to coarse gravel, moist								2.0
				2	...sand seam at 2.0' with little perched water								
				3									
				4									
				5			873.9						4.0
				6									
				7									
				8									
				9									
				10			868.9						
				11									
				12									
				13									
				14									
				15			863.9						
				16	16.0' End of Test Pit								
				17									
				18									
				19									
				20			858.9						

-AS-Auger Sample
-BS-Bag Sample
-RC-Rock-Core
-GS-Grab Sample
-PS-Piston Tube
-2SS-2" Split Spoon
-3SS-3" Split Spoon
-2ST-2" Shelby Tube
-3ST-3" Shelby Tube

while drilling
after drilling

after hours

BORING NO.: TP-14

COLEMAN ENGINEERING COMPANY
635 CIRCLE DRIVE
IRON MOUNTAIN, MICHIGAN 49801
Telephone: (906)-774-3440 Fax: (906)-774-7776

JOB NO.: 10022.GPJ

PROJECT: Copperwood Mine, Wakefield Township, MI

BORING NO.: TP-15

CLIENT: Orvana Resources U.S. Corporation

1 OF 1

BORING LOCATION: As Staked - Refer to test pit location drawing ELEV.: 810.45 +/-

RIG TYPE: John Deere 992E LC Excavator DRILL CREW: Lakes Excavating

DRILLING METHOD: Excavated BORING DEPTH: 15.0

DATE STARTED: Mar 8, 10 DATE COMPLETED: Mar 8, 10 REVIEWED BY: G. Stengard DATE: 4/12/10

HOLE CLOSURE: Excavated Soil

SAMPLE NUMBER	SPT VALUES BLOWS/6"(N)	RECOVERY	LEGEND	DEPTH (FT)	SOIL DESCRIPTION	WATER TABLE	ELEV. (FT)	COMMENTS	TEST RESULTS +4 -4 -200	MOISTURE CONTENT (%)	LL PL	T (tsf)	q_a (tsf)
				0	(CL) LEAN CLAY, reddish brown, medium plastic, some silt, some fine to coarse sand, trace fine to coarse gravel, moist		810.5						4.5
				1									
				2									
				3									
				4									
				5			805.5						
				6									
				7									
				8									
				9									
				10			800.5						
				11									
				12									
				13									
				14									
				15	15.0' End of Test Pit		795.5						
				16									
				17									
				18									
				19									
				20			790.5						

AS-Auger Sample; BS-Bag Sample; RC-Rock-Core; GS-Grab Sample; PS-Piston Tube; 2SS-2" Split Spoon; 3SS-3" Split Spoon; 2ST-2" Shelby Tube; 3ST-3" Shelby Tube

while drilling; after drilling

after hours

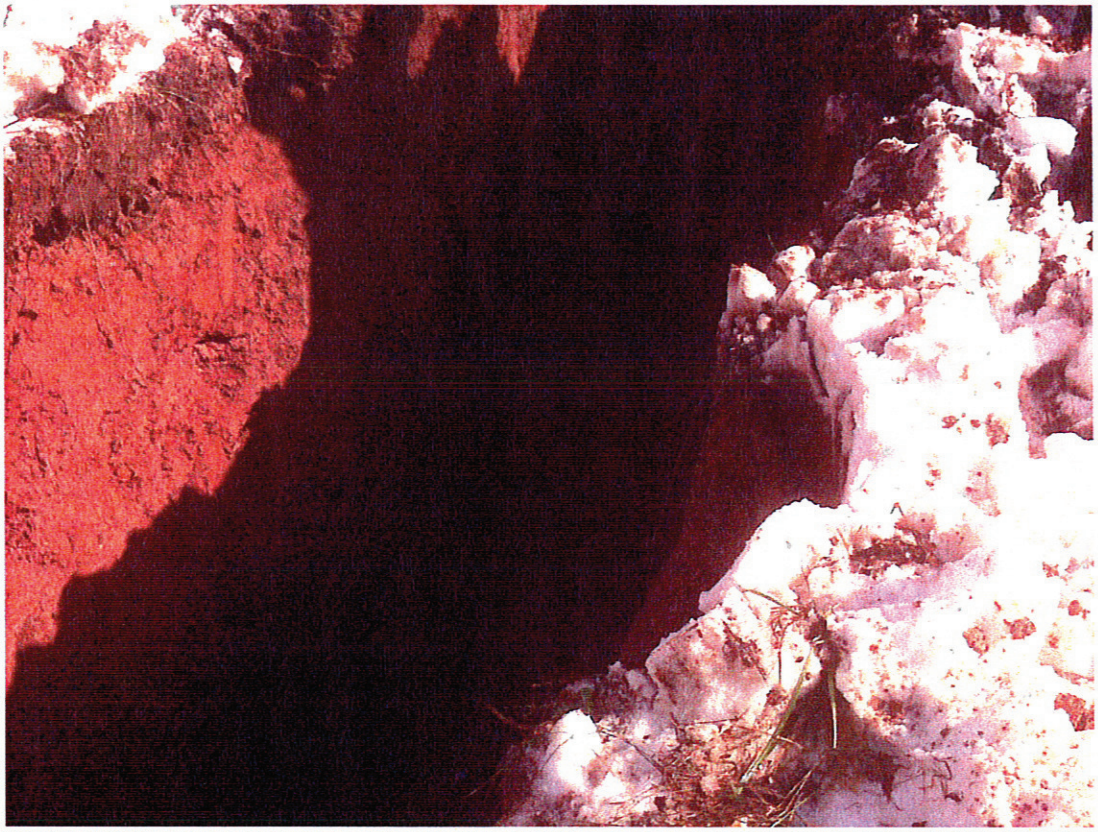
BORING NO.: TP-15

Knight Piésold CONSULTING

Appendix G-2

Previous Site Investigation Data – Test Pit Photos

TEST PIT #5



Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #6

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #7

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

TEST PIT #8

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

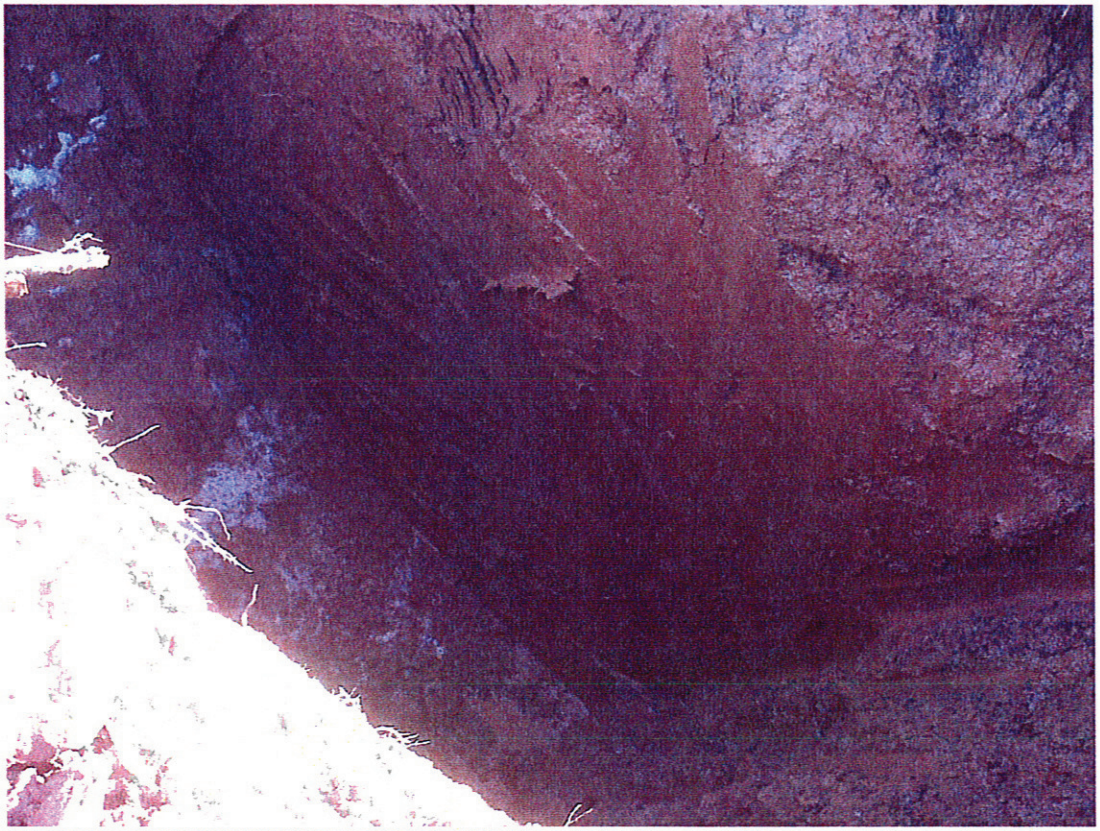
Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #9

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #10



Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #11

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

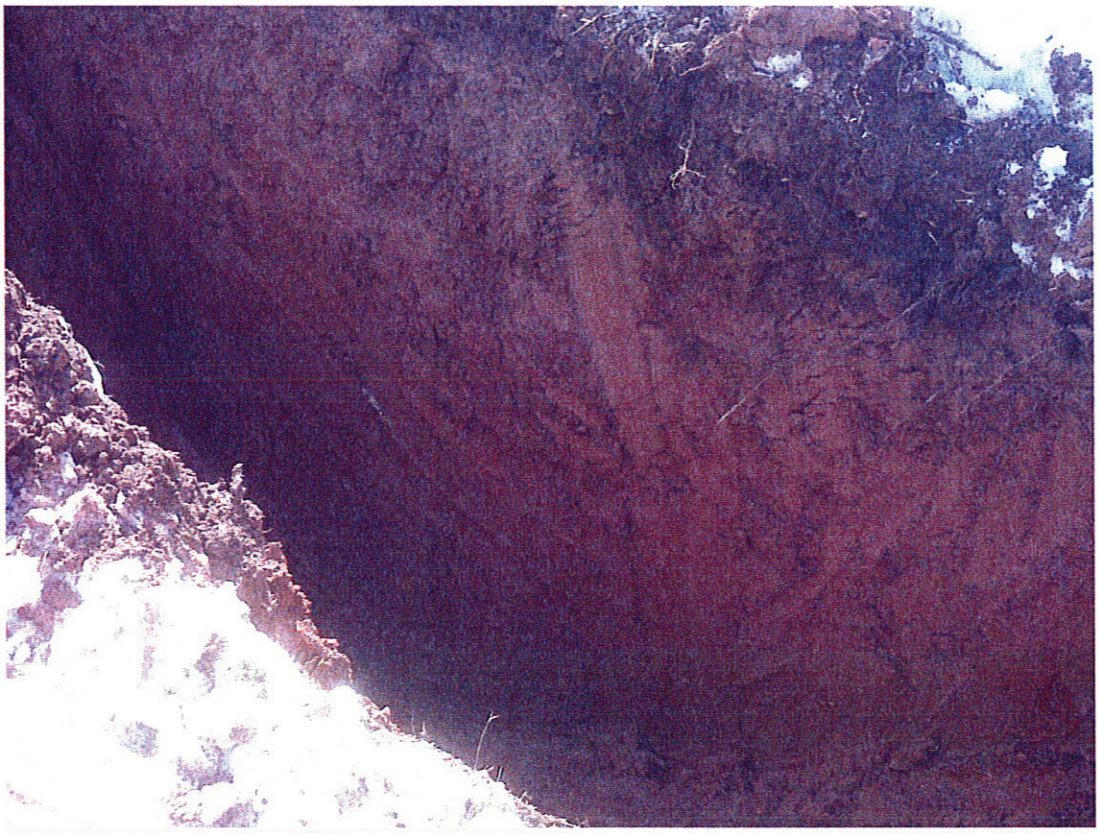
Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #12

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

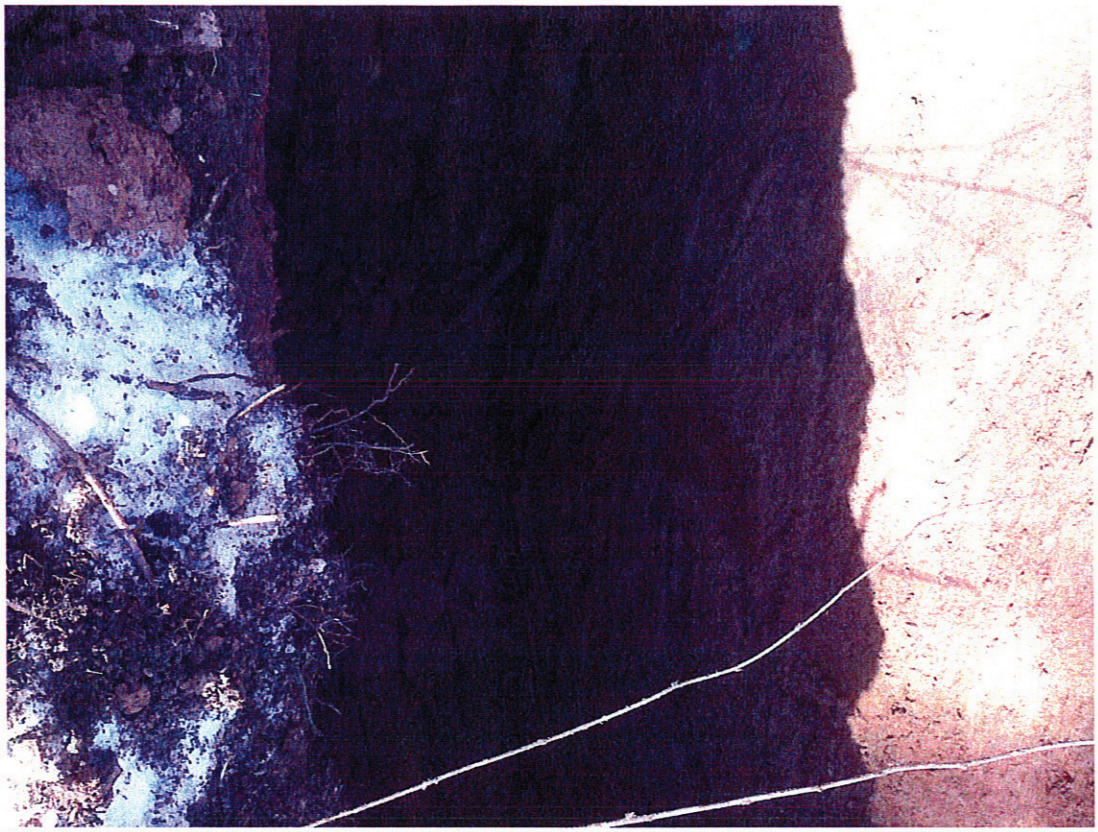
TEST PIT #13



Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #14



Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

TEST PIT #15

Coleman Engineering Company
200 E. Ayer Street
Ironwood, MI 49938

Copperwood Project
Orvana Resources US Corp
CEC Project #: GD10022

Knight Piésold CONSULTING

Appendix G-3

Previous Site Investigation Data – Borehole Logs

SOIL BORING LOG INFORMATION

Facility/Project Name	Weather	Boring Number
Copperwood - Project No. 200804342/60090372		CW-08-14

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
Boart Longyear - Chris	12/12/2008	12/12/2008	Sonic/Rotary

Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
	CW-08-14	Feet MSL	862.5 Feet MSL	6.0 Inches

Boring Location or Local Grid Origin (Check if estimated: ☐)
State Plane 699,674 N, 25,497,769 E S / C / N
1/4 of NW 1/4 of Section 7, T 49 N, R 45 W
Lat. ° ' "
Long. ° ' "
Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

Township	County	Civil Town/City/ or Village
Ironwood	Gogebic	Michigan North, Zone 2111

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 Sonic	84/84	2, 4, 6	Reddish-brown silty clay (CL) (2.5 YR 4/4) - trace to some fine to medium sand - medium to coarse gravel at 27.0 feet to 47.0 feet - wet at 27.0 feet - hard - till - massive matrix supported diamicton								
2 Sonic	120/120	8, 10, 12, 14, 16		CL							
3 Sonic	120/120	18, 20, 22, 24	Grain size sample at 20 to 25 feet - ML-CL							74.9	

Firm AECOM
401 S. Washington Square Lansing, MI 48933
Tel: 517-913-5800
Fax:

Boring Number CW-08-14

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
		26									
4 Sonic	120/120	28									
		30									
		32									
		34									
		36									
5 Sonic	120/120	38									
		40									
		42		CL							
		44									
		46									
6 Sonic	120/120	48									
		50									
		52									
		54									
		56									
7 Sonic	120/120	58									
		60	Dark reddish-brown silty clayey silt (CL-ML) - trace to little fine to medium sand and fine to medium gravel - moist - hard - till - massive matrix supported diamicton								
		62									
		64									

Boring Number CW-08-14

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
		66									
8 Sonic	120/120	68									
		70	Grain size sample at 68 to 70 feet - CL-ML	CL-ML						62.3	
		72									
		74									
		76									
9 Sonic	120/120	78									
		80	Reddish-brown fine sandy clayey silt (ML) - some fine to coarse sand and gravel - slightly moist to moist - hard - till - diamicton								
		82									
		84									
		86									
10 Sonic	120/120	88	Grain size sample at 88 to 90 feet -ML-SM	ML						46.7	
		90									
		92									
		94									
		96	Formation change - Copper Harbor Conglomerate at 96.5 feet	CHC							Copper Harbor Conglomerate

End of Boring at 97 feet.
Boring advanced from 0.0 feet to 97.0 feet with sonic rotary.
No rock coring completed.

CHC = Copper Harbor Conglomerate
Installed 2-inch diameter Schedule 40 PVC monitoring well at 67.0 feet

AECOM

WELL INSTALLATION DIAGRAM

PROJECT: Copperwood / Ironwood Township, Gogebic County, MI PROJECT NO. 200804342

BORING NO. **CW-08-14** DATE INSTALLED: Dec. 2008 DRILLERS: Boart/Longyear RIG: Sonic/Rotary

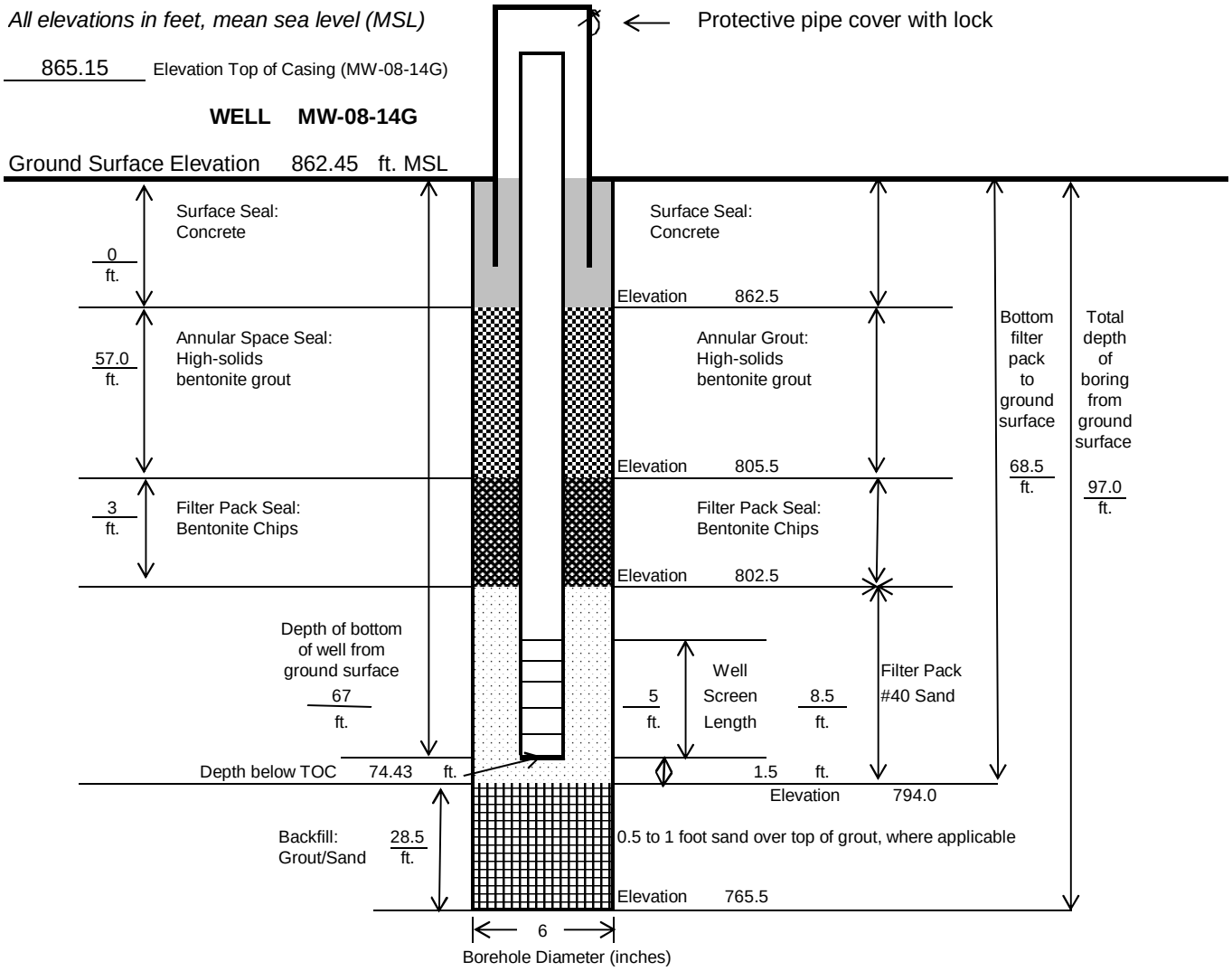
NORTHING: 699,673.78 EASTING 25,497,768.94 (Michigan State Plane Coordinates)

All elevations in feet, mean sea level (MSL)

865.15 Elevation Top of Casing (MW-08-14G)

WELL MW-08-14G

Ground Surface Elevation 862.45 ft. MSL



Notes:

Monitoring wells constructed of 2-inch diameter, flush-threaded Sch 40 PVC with 0.010-inch slot size.

Protector pipe constructed of 8-inch diameter steel pipe and is 5 feet in length.

SOIL BORING LOG INFORMATION

Facility/Project Name	Weather	Boring Number
Copperwood - Project No. 200804342/60090372		CW-10-120

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
Boart Longyear - Alvin Anderson	12/8/2010	12/9/2010	Sonic

Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-10-120G	MW-10-120	Feet MSL	902.8 Feet MSL	6.0 Inches

Boring Location or Local Grid Origin (Check if estimated: ☐)
State Plane 698,738 N, 25,449,792 E S/C/N
SW 1/4 of NE 1/4 of Section 7, T 49 N, R 45 W
Lat. ___ ° ___ ' ___ "
Long. ___ ° ___ ' ___ "
Local Grid Location (If applicable)
Feet ☐ N ☐ S Feet ☐ E ☐ W

Township	County	Civil Town/City/ or Village
Ironwood	Gogebic	Michigan North, Zone 2111

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 Sonic	60/60		Topsoil			3.0					
		2	Reddish-brown silty clay (CL) (2.5YR 4/6) - little to some fine to medium sand - trace to little sub-rounded to sub-angular gravel - moist - hard - till - massive natural support diamicton								
		4									
2 Sonic	120/120	6				3.5					
		8									
		10									
		12									
		14									
3 Sonic	180/180	16				3.75					
		18									
		20									
		22		CL-ML							
		24									

Firm AECOM
401 S. Washington Square Lansing, MI 48933
Tel: 517-913-5800
Fax:

Boring Number CW-10-120

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
		26									
		28									
4 Sonic	108/108	30				4.5					
		32									
		34									
		36									
		38									
5 Sonic	60/60	40									
		42	Reddish-brown silty clay (CL) (2.5YR 4/6) - medium to large rounded gravel at 42 to 44 feet	CL							
6 Sonic	132/132	44	Dark reddish-brown silty clay (CL) - little to some fine to medium sand - little to some fine to medium sub-angular gravel - moist to wet	CL							
		46									
		48	Formation Change Broken fragments of reddish-brown sandstone - Copper Harbor Conglomerate mixed in a silty clay matrix. Fragments continue from 48 to 80 feet: at 80 to 82 feet confirmed solid Copper Harbor conglomerate.								
		50									
		52									
		54									
7 Sonic	60/60	56									
		58									
8 Sonic	60/60	60									
		62									
		64									

SOIL BORING LOG INFORMATION

Boring Number CW-10-120

Sample Number and Type	Length Att (in)/ Recovered (in)		Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log			Soil Properties: Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
					CHC									
9 Sonic	96/84		66											
			68											
			70											
			72											
10 Sonic	84/72		74											
			76											
			78											
11 Sonic	24/18		80											
			82	End of Boring at 82 feet. Boring advanced from 0.0 feet to 82.0 feet with sonic rotary. Installed 2-inch diameter Schedule 40 PVC monitoring well at 48.0 feet.										

WELL INSTALLATION DIAGRAM

PROJECT: Copperwood / Ironwood Township, Gogebic County, MI PROJECT NO. 60179066

BORING NO. **CW-10-120** DATE INSTALLED: Dec. 2010 DRILLERS: Boart/Longyear RIG: Sonic 1517

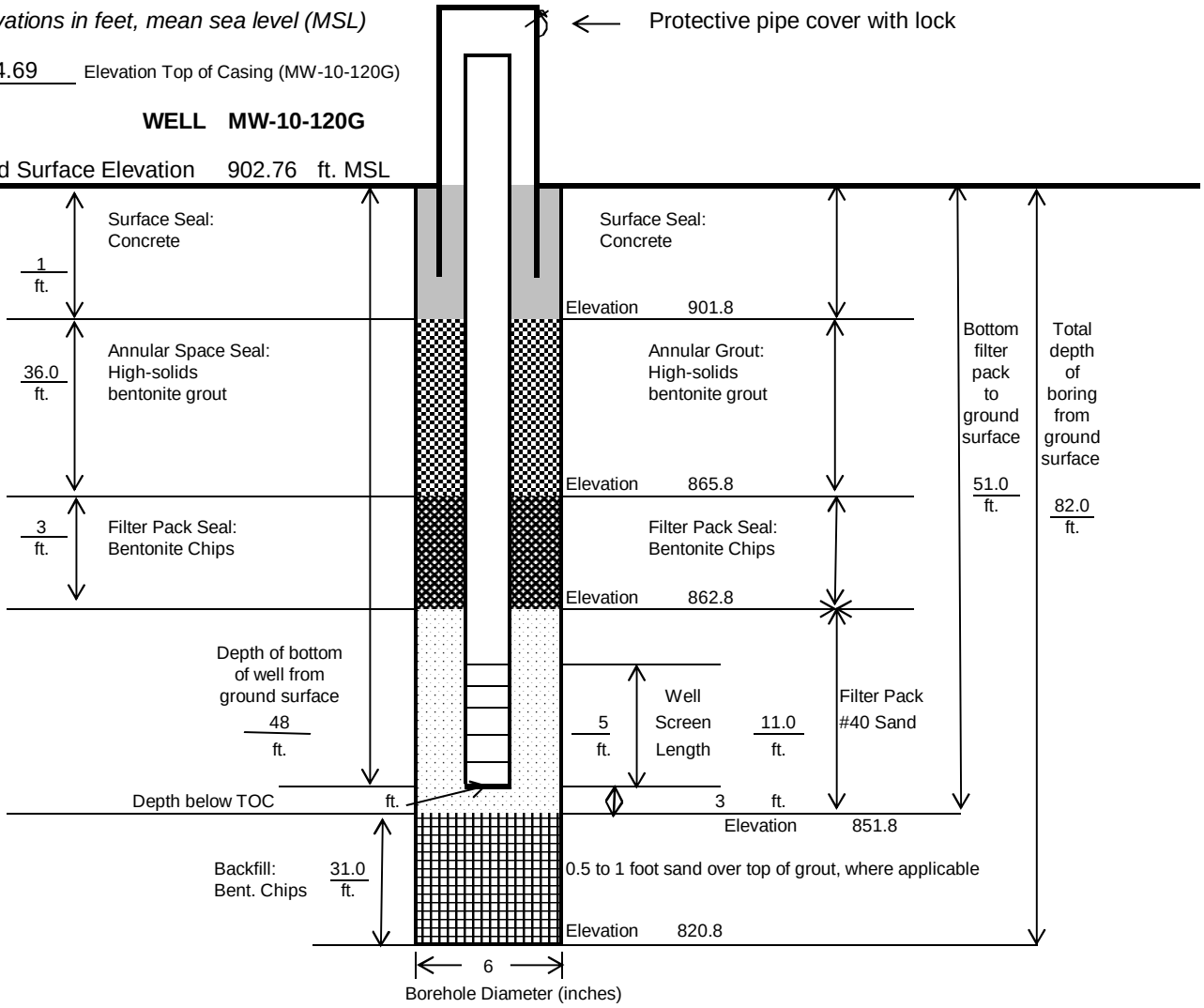
NORTHING: 698,737.80 EASTING 25,499,791.48 (Michigan State Plane Coordinates)

All elevations in feet, mean sea level (MSL)

904.69 Elevation Top of Casing (MW-10-120G)

WELL MW-10-120G

Ground Surface Elevation 902.76 ft. MSL



Notes:

Monitoring wells constructed of 2-inch diameter, flush-threaded Sch 40 PVC with 0.010-inch slot size.

Protector pipe constructed of 4-inch diameter steel pipe and is 7 feet in length.

SOIL BORING LOG INFORMATION

Facility/Project Name	Weather	Boring Number
Copperwood - Project No. 200804342/60090372		CW-10-124

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
Boart Longyear - Alvin Anderson	12/10/2010	12/11/2010	Sonic

Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-10-124G	MW-10-124	Feet MSL	815.1 Feet MSL	6.0 Inches

Boring Location or Local Grid Origin (Check if estimated: ☐)
State Plane 701,998 N, 25,498,377 E S/C/N
NE 1/4 of SW 1/4 of Section 6, T 49 N, R 45 W

Lat. ___ ° ___ ' ___ "
Long. ___ ° ___ ' ___ "

Local Grid Location (If applicable)
☐ N Feet ☐ S ☐ E Feet ☐ W

Township	County	Civil Town/City/ or Village
Ironwood	Gogebic	Michigan North, Zone 2111

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 Sonic	60/60	2, 4	Reddish-brown silty clay (CL) (2.5YR 4/4) - trace to some fine to medium sand - trace to some fine to medium sub-angular gravel - changes from hard to firm - moist to wet - till - massive matrix supported diamicton			4.0					
2 Sonic	120/120	6, 8, 10, 12, 14				3.5					
3 Sonic	180/120	16, 18, 20, 22, 24				4.0					

Firm AECOM
401 S. Washington Square Lansing, MI 48933
Tel: 517-913-5800
Fax:

SOIL BORING LOG INFORMATION

Boring Number CW-10-124

Sample Number and Type	Sample Length Att (in)/ Recovered (in)		Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log			Soil Properties: Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			26											
			28											
4 Sonic	180/180		30						4.0 - 2.0					
			32		CL									
			34											
			36											
			38											
			40											
			42											
			44											
5 Sonic	240/216		46						2.0 - 3.0					
			48											
			50											
			52											
			54											
			56											
			58											
			60											
			62											
			64											

Boring Number CW-10-124

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			Sand seam from 64 to 65 feet								
6 Sonic	240/228	66	Reddish-brown clayey silt (CL-ML) (2.5YR 4/4) - little to some fine to medium sand - little to some fine to medium sub-rounded gravel - occassional large gravel - 6-inch sand and gravel seam at 67 to 68 feet; 83 to 85 feet; 87 to 88 feet; 91 to 92 feet; 100 feet, 102 feet - wet - diamicton								
		68									
		70	Sand seam from 67 to 68 feet								
		72									
		74									
		76									
		78									
		80									
		82									
			Sand seam from 83 to 85 feet								
		84									
7 Sonic	240/216	86		CL-ML							
			Sand seam from 87 to 88 feet								
		88									
		90									
			Sand seam from 91 to 92 feet								
		92									
		94									
		96									
		98									
		100	Sand seam at 100 feet								
		102	Sand seam at 102 feet								
		104									

SOIL BORING LOG INFORMATION

Boring Number CW-10-124

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
8 Sonic	156/144	106	Dark reddish-brown sandy silt (ML) - trace clay - little fine to coarse sub-rounded gravel - moist - dense	ML		4.5					
		108									
		110									
		112									
		114									
		116									
9 Sonic	36/36	118									
		120									
10 Sonic	48/48	122	Formation Change Nonsuch Shale at 121 feet - dark green to black shale fragments - pulverized due to sonic drilling	NS							
		124									
			End of Boring at 125 feet. Boring advanced from 0.0 feet to 125 feet with sonic rotary. Installed 2-inch diameter Schedule 40 PVC monitoring well at 90.0 feet.								

WELL INSTALLATION DIAGRAM

PROJECT: Copperwood / Ironwood Township, Gogebic County, MI PROJECT NO. 60179066

BORING NO. **CW-10-124** DATE INSTALLED: Dec. 2010 DRILLERS: Boart/Longyear RIG: Sonic 1517

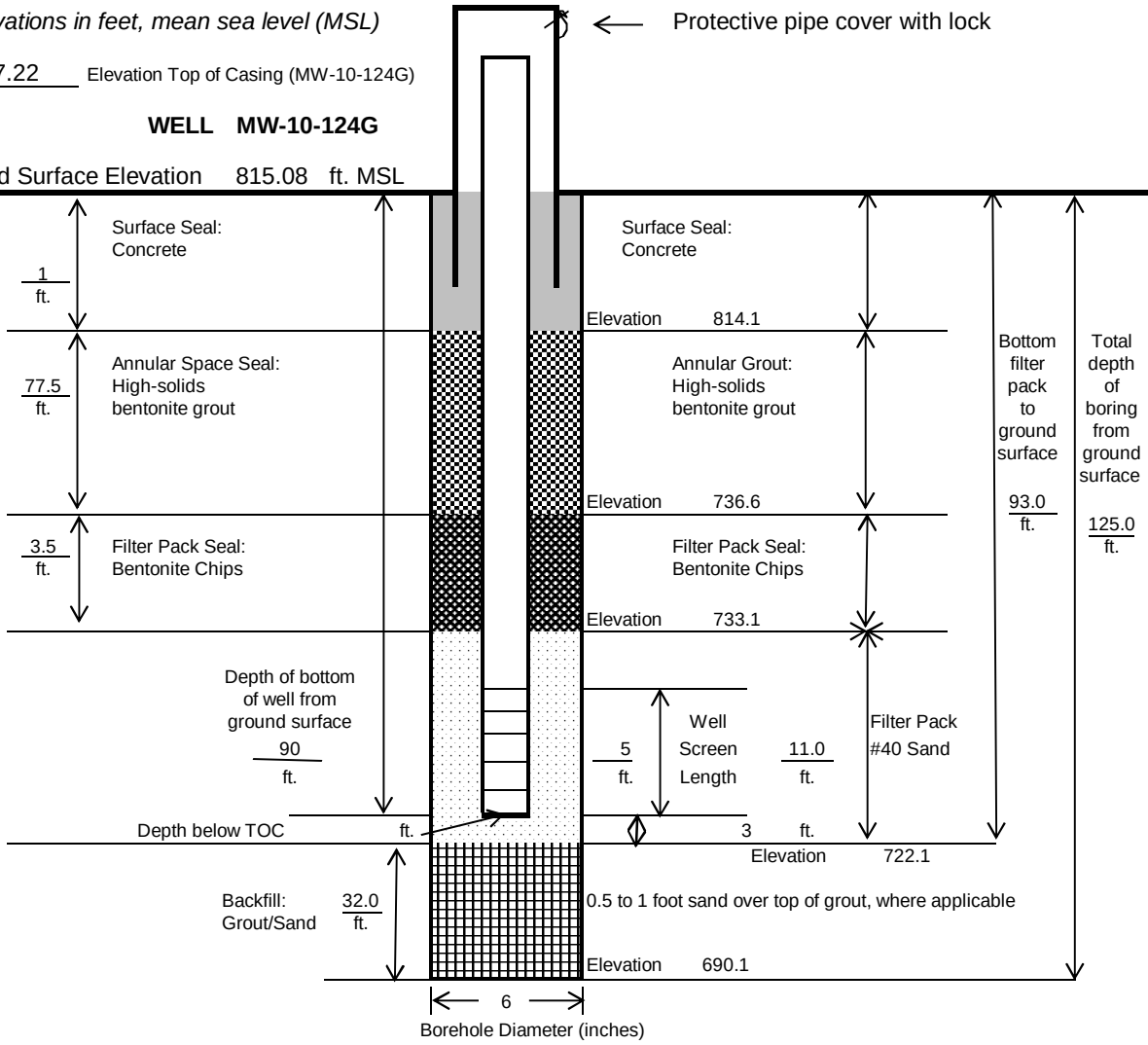
NORTHING: 701,998.24 EASTING 25,498,376.95 (Michigan State Plane Coordinates)

All elevations in feet, mean sea level (MSL)

817.22 Elevation Top of Casing (MW-10-124G)

WELL MW-10-124G

Ground Surface Elevation 815.08 ft. MSL



Notes:

Monitoring wells constructed of 2-inch diameter, flush-threaded Sch 40 PVC with 0.010-inch slot size.

Protector pipe constructed of 4-inch diameter steel pipe and is 7 feet in length.

SOIL BORING LOG INFORMATION

Facility/Project Name	Weather	Boring Number
Copperwood - Project No. 200804342/60090372		CW-10-134

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
Boart Longyear - Alvin Anderson	12/17/2010	12/17/2010	Sonic

Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
MW-10-134G	MW-10-134	Feet MSL	852.4 Feet MSL	6.0 Inches

Boring Location or Local Grid Origin (Check if estimated: ☐)
State Plane 701,228 N, 25,500,758 E S/C/N
NE 1/4 of SE 1/4 of Section 6, T 49 N, R 45 W
Lat. ___ ° ___ ' ___ "
Long. ___ ° ___ ' ___ "
Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

Township	County	Civil Town/City/ or Village
Ironwood	Gogebic	Michigan North, Zone 2111

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
1 Sonic	60/60		Reddish-brown silty clay (CL) (2.5 YR 4/4) - trace to some fine to medium sand - little to some fine to coarse sub-rounded gravel - moist - hard - till - massive matrix supported diamicton			4.0					
		2									
		4									
2 Sonic	120/120					4.0					
		6									
		8									
		10									
		12									
		14									
3 Sonic	120/96					3.0					
		16									
		18									
		20									
		22									
		24									

Firm AECOM
401 S. Washington Square Lansing, MI 48933
Tel: 517-913-5800
Fax:

SOIL BORING LOG INFORMATION

Boring Number CW-10-134

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Soil Properties: Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
4 Sonic	120/120	26				3.0					
		28									
		30									
		32									
		34									
5 Sonic	240/240	36		CL		4.0					
		38									
		40									
		42									
		44									
		46									
		48									
		50									
		52									
		54									
6 Sonic	240/240	56				3.5					
		58									
		60									
		62									
		64									

SOIL BORING LOG INFORMATION

Boring Number CW-10-134

Sample Number and Type	Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Compressive Strength (Qp)	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
		66									
		68									
		70									
		72	Dark reddish-brown fine to medium silty sand (SM) (2.5 YR 3/3) - moist to wet	SM							
		74									
7 Sonic	240/240	76	Dark reddish-brown fine to coarse silty sand (SM) (2.5YR 3/3) with medium to coarse sub-rounded gravel - wet	SM							
		78	Reddish-brown sandy silt (ML) (2.5 YR 4/4) - trace clay - trace fine gravel - dense - diamicton at 112 feet - occassional 6-inch seams sand/gravel to 115 feet								
		80									
		82									
		84									
		86									
		88									
		90									
		92									
		94									
8 Sonic	240/240	96									
		98		ML							
		100									
		102									
		104									

SOIL BORING LOG INFORMATION

Boring Number CW-10-134

Sample: Number and Type	Sample: Length Att (in)/ Recovered (in)	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Soil Properties: Compressive Strength (Qp)	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
		106									
		108									
		110									
		112									
		114									
9 Sonic	108/108	116									
		118									
		120	Formation Change Dark green to dark gray shale fragments in clay - nonesuch shale	NS							
		122									
		124	End of Boring at 124 feet. Boring advanced from 0.0 feet to 124.0 feet with sonic. No rock coring completed. Installed 2-inch diameter Schedule 40 PVC monitoring well to 76.0 feet.								

WELL INSTALLATION DIAGRAM

PROJECT: Copperwood / Ironwood Township, Gogebic County, MI PROJECT NO. 60179066

BORING NO. **CW-10-134** DATE INSTALLED: Dec. 2010 DRILLERS: Boart/Longyear RIG: Sonic 1517

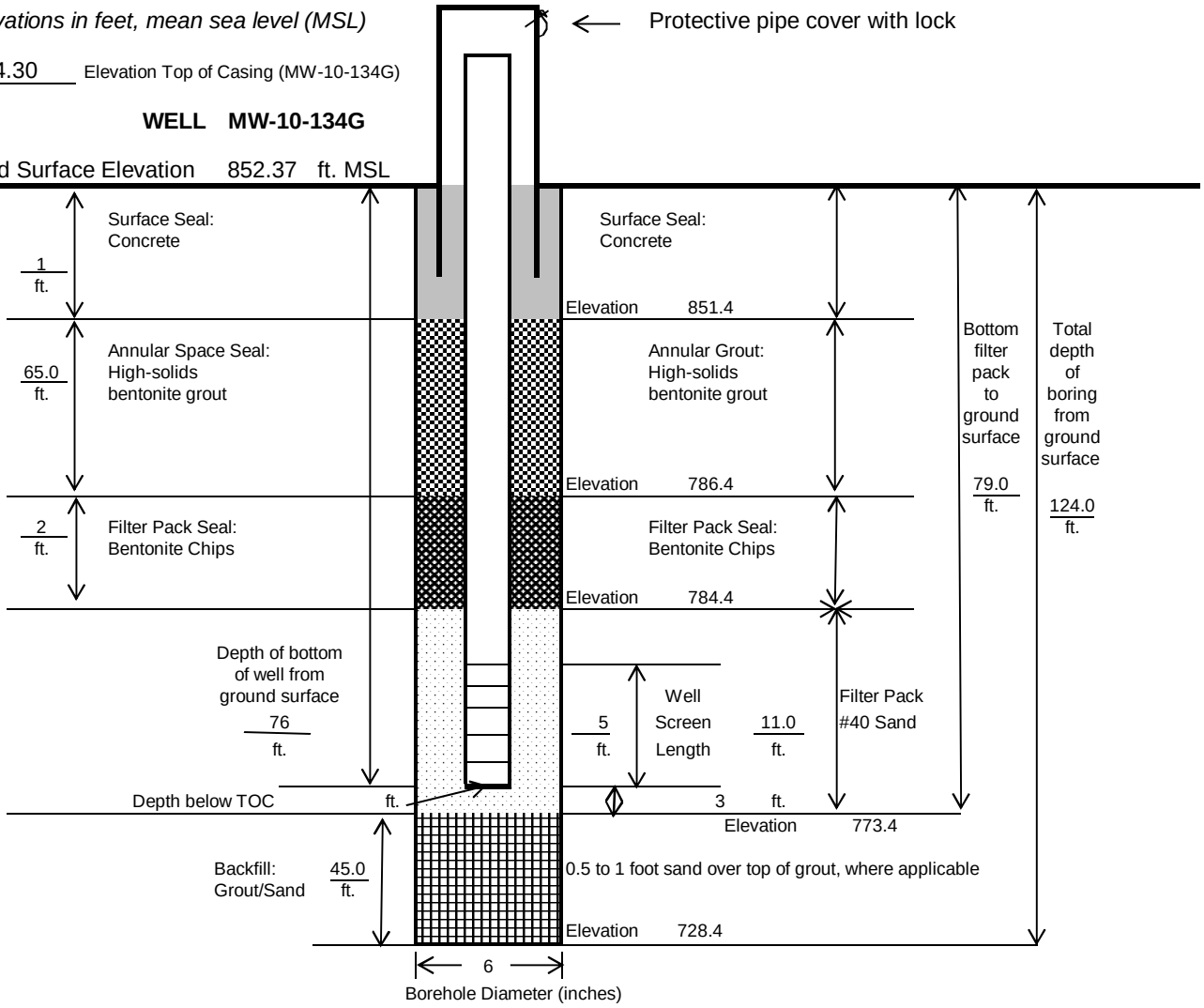
NORTHING: 701,227.73 EASTING 25,500,757.45 (Michigan State Plane Coordinates)

All elevations in feet, mean sea level (MSL)

854.30 Elevation Top of Casing (MW-10-134G)

WELL MW-10-134G

Ground Surface Elevation 852.37 ft. MSL



Notes:

Monitoring wells constructed of 2-inch diameter, flush-threaded Sch 40 PVC with 0.010-inch slot size.

Protector pipe constructed of 4-inch diameter steel pipe and is 7 feet in length.

Knight Piésold CONSULTING

Appendix G-4

Previous Site Investigation Data – Index Data

Boring No.	Depth (ft)	Classification	Permeability Test	Atterberg Limit			Modified Proctor		Moisture Content (%)	Remolded Uniaxial Compression
				LL	PL	PI	Density (pcf)	Moisture (%)		
SB-7	50	CL	No Test Required	**Test in Progress**			No Test Required		**Test in Progress**	No Test Required
SB-8	10	CL	No Test Required	22.6	13.9	8.7	No Test Required		**Test in Progress**	No Test Required
SB-8	20	CL	No Test Required	21.8	13.0	8.8	No Test Required		**Test in Progress**	No Test Required
SB-8	25	CL	No Test Required	**Test in Progress**			No Test Required		**Test in Progress**	No Test Required
Test Pits										
TP-1	0-5	CL	No Test Required	26.2	14.0	12.2	128.1	9.6	11.3	**Test in Progress**
TP-2	5-10	CL-ML	No Test Required	19.2	14.6	4.6	132.7	8.2	11.5	**Test in Progress**
TP-3	10-15	CL	No Test Required	21.8	13.8	8.0	135.5	7.4	9.5	**Test in Progress**
TP-4	10-15	CL-ML	No Test Required	19.9	13.7	6.2	135.3	7.8	10.7	**Test in Progress**
TP-5	10-15	CL	No Test Required	19.5	13.4	6.1	132.9	8.6	10.7	**Test in Progress**
TP-6	5-10	CL	No Test Required	24.1	13.0	11.1	131.4	8.8	14.6	**Test in Progress**
TP-7	10-15	CL	No Test Required	21.9	14.2	7.7	133.3	8.1	12.4	**Test in Progress**
TP-8	0-5	CL	No Test Required	27.0	13.5	13.5	127.7	10.1	13.7	**Test in Progress**
TP-9	10-15	CL	No Test Required	25.4	13.2	12.2	132.1	8.7	15.3	**Test in Progress**
TP-10	5-10	CL	No Test Required	22.0	12.9	9.1	131.0	9.3	12.9	**Test in Progress**
TP-11	0-5	CL	No Test Required	27.5	12.9	14.6	131.4	9.0	13.8	**Test in Progress**
TP-12	5-10	CL	No Test Required	25.2	14.3	10.9	133.8	8.2	14.5	**Test in Progress**

Boring No.	Depth (ft)	Classification	Permeability Test	Atterberg Limit			Modified Proctor		Moisture Content (%)	Remolded Uniaxial Compression
				LL	PL	PI	Density (pcf)	Moisture (%)		
TP-13	5-10	CL	No Test Required	26.5	14.0	12.5	133.8	8.5	12.9	**Test in Progress**
TP-14	5-10	CL	No Test Required	**Test in Progress**			129.2	10.5	14.9	**Test in Progress**
TP-15	10-15	CL	No Test Required	**Test in Progress**			133.7	8.2	9.4	**Test in Progress**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-5
Sample No: 3
Depth: 3
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:42:00

% of Original Sample Used
For Hydrometer Analysis: 95.9 %
Weight of Sample Dispersed: 65.5 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:42:30	0.5	45	19	6	39	58.9	0.01361	8.9	0.0574	56.5
8:43:00	1.0	44	19	6	38	57.4	0.01361	9.1	0.0411	55.1
8:44:00	2.0	39	19	6	33	49.9	0.01361	9.9	0.0303	47.8
8:47:00	5.0	33	19	6	27	40.8	0.01361	10.9	0.0201	39.1
8:57:00	15.0	28	19	6	22	33.3	0.01361	11.7	0.0120	31.9
9:12:00	30.0	25	19	6	19	28.7	0.01361	12.2	0.0087	27.5
9:42:00	60.0	22	19	6	16	24.2	0.01361	12.7	0.0063	23.2
10:42:00	120.0	20	19	6	14	21.2	0.01361	13.0	0.0045	20.3
12:42:00	240.0	18	19	6	12	18.1	0.01361	13.3	0.0032	17.4
16:42:00	480.0	17	19	6	11	16.6	0.01361	13.5	0.0023	15.9
8:42:00	1440.0	15	19	6	9	13.6	0.01361	13.8	0.0013	13.0

Tested By: Graham Donahue Date: 3/10/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown medium, plastic with silt, some fine to coarse sand, trace of fine gravel **Boring No.** TP-5

Shape: NA **Hardness:** NA **Sample No.** 3

Remarks: **Depth:** 3

Date Rec'd: 3/10/2010

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	0.00	0.0	100.0
4M	4.76	7.40	1.5	98.5
10M	2.00	12.60	2.6	95.9
40M	0.42	4.30	6.6	93.4 /* 89.6
100M	0.149	9.50	14.5	78.9 /* 75.7
200M	0.074	5.80	8.9	70.1 /* 67.2
Pan		9.30	14.2	55.9 /* 53.6

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 20.0 gm = 4.1% %

Material passing No. 10 mesh: weight = 470.3 gm = 95.9% %

Weight of Total Sample = 490.3 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

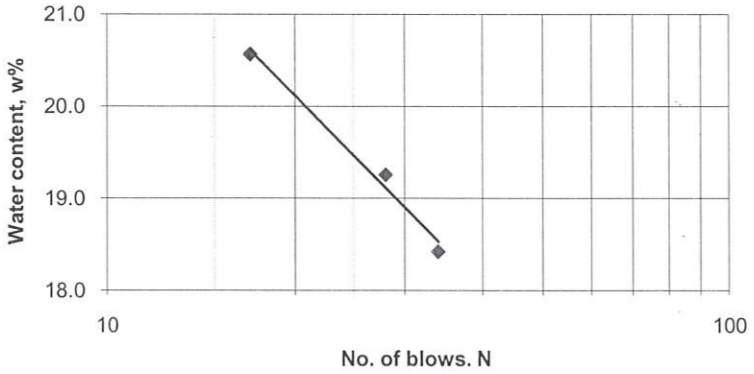
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, W. Silt So. F-C Sand, Tr. F Gravel**

Boring No.: **TP-5**
Sample No.: **3'**
Depth: **3'**

Liquid limit Determination

Can No.	7	30	2			
Wt. of wet soil +can (g)	26.72	25.24	29.98			
Wt. of dry soil + can (g)	25.74	23.74	28.67			
Wt. of can (g)	20.42	15.95	22.30			
Wt of dry soil (g)	5.32	7.79	6.37			
Wt of moisture (g)	0.98	1.50	1.31			
No of blows, N (g)	34	28	17			
Water content, *w* %	18.4	19.3	20.6			



Flow index F_i =
Liquid limit = **19.5**
Plastic limit = **13.4**
Plasticity index I_p = **6.1**

Plastic Limit Determination

Can no.	22	46				
Wt. of wet soil + can (g)	34.31	27.33				
Wt. of dry soil + can (g)	32.89	26.01				
Wt. of can (g)	22.39	16.04				
Wt. of dry soil (g)	10.5	9.97				
Wt. of moisture (g)	1.42	1.32				
Water content, $w\% = w_p$	13.5	13.2				

Tested by: **Daniel Absolon** **3/22/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-6
Sample No: 12
Depth: 12
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:36:00

% of Original Sample Used For Hydrometer Analysis: 97.6 %
Weight of Sample Dispersed: 62.8 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:36:30	0.5	49	19	6	43	67.8	0.01361	8.3	0.0555	66.2
8:37:00	1.0	45	19	6	39	61.5	0.01361	8.9	0.0406	60.0
8:38:00	2.0	42	19	6	36	56.8	0.01361	9.4	0.0295	55.4
8:41:00	5.0	37	19	6	31	48.9	0.01361	10.2	0.0194	47.7
8:51:00	15.0	32	19	6	26	41.0	0.01361	11.1	0.0117	40.0
9:06:00	30.0	29	19	6	23	36.3	0.01361	11.5	0.0084	35.4
9:36:00	60.0	26	19	6	20	31.5	0.01361	12.0	0.0061	30.8
10:36:00	120.0	24	19	6	18	28.4	0.01361	12.4	0.0044	27.7
12:36:00	240.0	22	19	6	16	25.2	0.01361	12.7	0.0031	24.6
16:36:00	480.0	20	19	6	14	22.1	0.01361	13.0	0.0022	21.5
8:36:00	1440.0	18	19	6	12	18.9	0.01361	13.3	0.0013	18.5

Tested By: Graham Donahue Date: 3/22/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) clay, brown medium plastic some silt, trace of fine to coarse sand, trace of fine gravel **Boring No.** TP-6

Shape: NA **Hardness:** NA **Sample No.** 12

Remarks: **Depth:** 12

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	0.00	0.0	100.0
4M	4.76	4.40	0.9	99.1
10M	2.00	7.20	1.5	97.6
40M	0.42	3.30	5.3	94.7 /* 92.4
100M	0.149	8.10	12.9	81.8 /* 79.8
200M	0.074	5.00	8.0	73.9 /* 72.1
Pan		4.80	7.6	66.2 /* 64.6

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 11.6 gm = 2.4% %

Material passing No. 10 mesh: weight = 462.3 gm = 97.6% %

Weight of Total Sample = 473.9 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

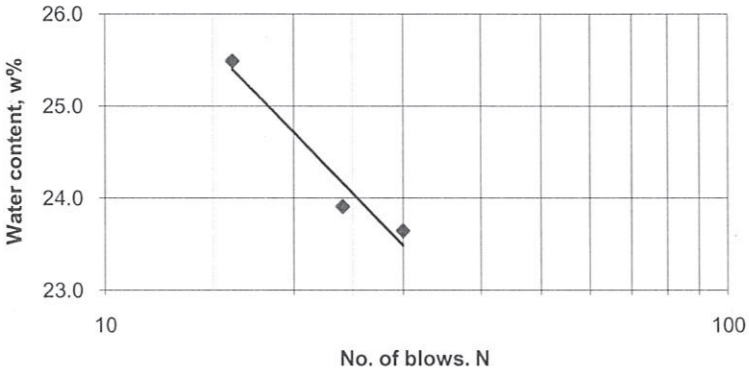
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt Tr. F-C Sand, Tr. F Gravel**

Boring No.: **TP-6**
Sample No.: **12'**
Depth: **12'**

Liquid limit Determination

Can No.	38	43	5			
Wt. of wet soil +can (g)	23.52	23.58	23.5			
Wt. of dry soil + can (g)	22.08	22.1	21.93			
Wt. of can (g)	15.99	15.91	15.77			
Wt of dry soil (g)	6.09	6.19	6.16			
Wt of moisture (g)	1.44	1.48	1.57			
No of blows, N (g)	30	24	16			
Water content, *w* %	23.6	23.9	25.5			



Flow index F_i =
Liquid limit = **24.1**
Plastic limit = **13.0**
Plasticity index I_p = **11.1**

Plastic Limit Determination

Can no.	11	14				
Wt. of wet soil + can (g)	30.55	32.7				
Wt. of dry soil + can (g)	29.36	31.51				
Wt. of can (g)	20.11	22.4				
Wt. of dry soil (g)	9.25	9.11				
Wt. of moisture (g)	1.19	1.19				
Water content, $w\% = w_p$	12.9	13.1				

Tested by: **Daniel Absolon 3/22/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-7
Sample No: 0-5
Depth: 0-5
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 9:00:00

% of Original Sample Used
For Hydrometer Analysis: 94.4 %
Weight of Sample Dispersed: 62.8 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
9:00:30	0.5	47	19	6	41	64.6	0.01361	8.6	0.0564	61.0
9:01:00	1.0	44	19	6	38	59.9	0.01361	9.1	0.0411	56.5
9:02:00	2.0	39	19	6	33	52.0	0.01361	9.9	0.0303	49.1
9:05:00	5.0	33	19	6	27	42.6	0.01361	10.9	0.0201	40.2
9:15:00	15.0	28	19	6	22	34.7	0.01361	11.7	0.0120	32.7
9:30:00	30.0	25	19	6	19	30.0	0.01361	12.2	0.0087	28.3
10:00:00	60.0	23	19	6	17	26.8	0.01361	12.5	0.0062	25.3
11:00:00	120.0	21	19	6	15	23.6	0.01361	12.9	0.0045	22.3
13:00:00	240.0	19	19	6	13	20.5	0.01361	13.2	0.0032	19.3
17:00:00	480.0	18	19	6	12	18.9	0.01361	13.3	0.0023	17.9
9:00:00	1440.0	16	19	6	10	15.8	0.01361	13.7	0.0013	14.9

Tested By: Graham Donahue Date: 3/22/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown, medium plastic some silt, some fine coarse sand, trace of fine coarse gravel **Boring No.** TP-7

Shape: NA **Hardness:** NA **Sample No.** 0-5

Remarks: **Depth:** 0-5

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	8.10	1.6	98.4
4M	4.76	7.40	1.5	96.9
10M	2.00	12.70	2.5	94.4
40M	0.42	3.60	5.7	94.3 /* 89.0
100M	0.149	8.00	12.7	81.5 /* 77.0
200M	0.074	5.70	9.1	72.5 /* 68.4
Pan		7.60	12.1	60.4 /* 57.0

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 28.1 gm = 5.6% %

Material passing No. 10 mesh: weight = 475.7 gm = 94.4% %

Weight of Total Sample = 503.8 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

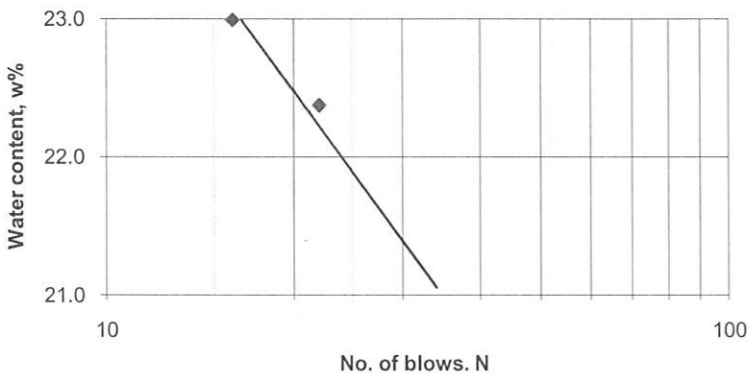
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt So. F-C Sand, Tr. F-C Gravel**

Boring No.: **TP-7**
Sample No.: **0-5'**
Depth: **0-5'**

Liquid limit Determination

Can No.	25	22	30			
Wt. of wet soil +can (g)	27.13	34.05	25.9			
Wt. of dry soil + can (g)	25.9	31.92	24.04			
Wt. of can (g)	20.04	22.40	15.95			
Wt of dry soil (g)	5.86	9.52	8.09			
Wt of moisture (g)	1.23	2.13	1.86			
No of blows, N (g)	34	22	16			
Water content, *w* %	21.0	22.4	23.0			



Flow index F_i =
Liquid limit = **21.9**
Plastic limit = **14.2**
Plasticity index I_p = **7.7**

Plastic Limit Determination

Can no.	11	14				
Wt. of wet soil + can (g)	30.06	33.2				
Wt. of dry soil + can (g)	28.82	31.86				
Wt. of can (g)	20.11	22.4				
Wt. of dry soil (g)	8.71	9.46				
Wt. of moisture (g)	1.24	1.34				
Water content, $w\% = w_p$	14.2	14.2				

Tested by: **Daniel Absolon** **3/23/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-8
Sample No: 10-15
Depth: 10-15
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:54:00

% of Original Sample Used
For Hydrometer Analysis: 93.8 %
Weight of Sample Dispersed: 64.1 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:54:30	0.5	53	19	6	47	72.6	0.01361	7.6	0.0531	68.1
8:55:00	1.0	49	19	6	43	66.4	0.01361	8.3	0.0392	62.3
8:56:00	2.0	44	19	6	38	58.7	0.01361	9.1	0.0290	55.1
8:59:00	5.0	38	19	6	32	49.4	0.01361	10.1	0.0193	46.4
9:09:00	15.0	33	19	6	27	41.7	0.01361	10.9	0.0116	39.1
9:24:00	30.0	30	19	6	24	37.1	0.01361	11.4	0.0084	34.8
9:54:00	60.0	28	19	6	22	34.0	0.01361	11.7	0.0060	31.9
10:54:00	120.0	27	19	6	21	32.4	0.01361	11.9	0.0043	30.4
12:54:00	240.0	25	19	6	19	29.3	0.01361	12.2	0.0031	27.5
16:54:00	480.0	23	19	6	17	26.3	0.01361	12.5	0.0022	24.6
8:54:00	1440.0	22	19	6	16	24.7	0.01361	12.7	0.0013	23.2

Tested By: Graham Donahue Date: 3/22/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown medium plastic, some silt, some fine to coarse sand, trace of fine to coarse gravel **Boring No.** TP-8

Shape: NA **Hardness:** NA **Sample No.** 10-15

Remarks: **Depth:** 10-15

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	13.00	3.0	97.0
4M	4.76	6.90	1.6	95.4
10M	2.00	7.20	1.7	93.8
40M	0.42	2.90	4.5	95.5 /* 89.5
100M	0.149	5.90	9.2	86.3 /* 80.9
200M	0.074	4.20	6.6	79.7 /* 74.8
Pan		6.10	9.5	70.2 /* 65.8

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 27.1 gm = 6.2% %

Material passing No. 10 mesh: weight = 408.9 gm = 93.8% %

Weight of Total Sample = 436.0 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

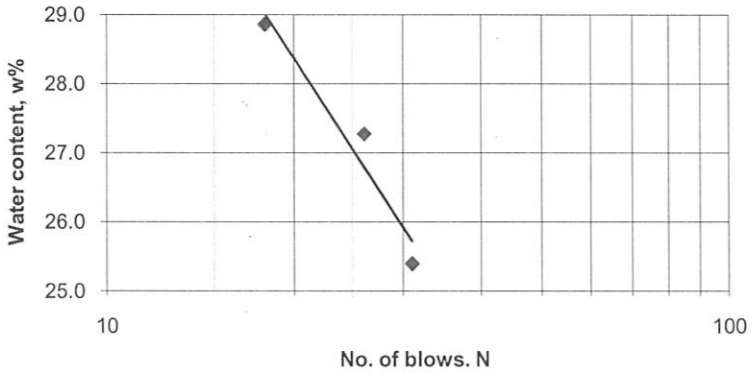
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt So. F-C Sand, Tr. F-C Gravel**

Boring No.: **TP-8**
Sample No.: **10-15'**
Depth: **10-15'**

Liquid limit Determination

Can No.	28	4	29			
Wt. of wet soil +can (g)	30.42	32.42	30.75			
Wt. of dry soil + can (g)	28.8	30.26	28.45			
Wt. of can (g)	22.42	22.34	20.48			
Wt of dry soil (g)	6.38	7.92	7.97			
Wt of moisture (g)	1.62	2.16	2.3			
No of blows, N (g)	31	26	18			
Water content, *w* %	25.4	27.3	28.9			



Flow index F_i =
Liquid limit = **27.0**
Plastic limit = **13.5**
Plasticity index I_p = **13.5**

Plastic Limit Determination

Can no.	20	8				
Wt. of wet soil + can (g)	31.84	32.19				
Wt. of dry soil + can (g)	30.72	31.01				
Wt. of can (g)	22.36	22.28				
Wt. of dry soil (g)	8.36	8.73				
Wt. of moisture (g)	1.12	1.18				
Water content, $w\% = w_p$	13.4	13.5				

Tested by: **Daniel Absolon 3/23/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-9
Sample No: 5-10
Depth: 5-10
Date Received: 3/10/10

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:24:00

% of Original Sample Used For Hydrometer Analysis: 97.3 %
Weight of Sample Dispersed: 63 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:24:30	0.5	50	20	5	45	70.7	0.01344	8.1	0.0541	68.8
8:25:00	1.0	49	20	5	44	69.1	0.01344	8.3	0.0387	67.3
8:26:00	2.0	45	20	5	40	62.9	0.01344	8.9	0.0284	61.2
8:29:00	5.0	40	20	5	35	55.0	0.01344	9.7	0.0187	53.5
8:39:00	15.0	33	20	5	28	44.0	0.01344	10.9	0.0115	42.8
8:54:00	30.0	30	20	5	25	39.3	0.01344	11.4	0.0083	38.2
9:24:00	60.0	28	20	5	23	36.1	0.01344	11.7	0.0059	35.2
10:24:00	120.0	25	20	5	20	31.4	0.01344	12.2	0.0043	30.6
12:24:00	240.0	23	20	5	18	28.3	0.01344	12.5	0.0031	27.5
16:24:00	480.0	21	20	5	16	25.1	0.01344	12.9	0.0022	24.5
8:24:00	1440.0	19	20	5	14	22.0	0.01344	13.2	0.0013	21.4

Tested By: Graham Donahue Date: 3/22/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL
(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown, medium plastic, some silt, some fine to coarse sand **Boring No.** TP-9

Shape: NA **Hardness:** NA **Sample No.** 5-10

Remarks: **Depth:** 5-10

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	0.00	0.0	100.0
4M	4.76	3.80	0.9	99.1
10M	2.00	7.00	1.7	97.4
40M	0.42	3.10	4.9	95.1 /* 92.6
100M	0.149	6.70	10.6	84.4 /* 82.2
200M	0.074	4.40	7.0	77.5 /* 75.4
Pan		5.70	9.0	68.4 /* 66.6

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 10.8 gm = 2.7% %

Material passing No. 10 mesh: weight = 395.6 gm = 97.3% %

Weight of Total Sample = 406.4 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

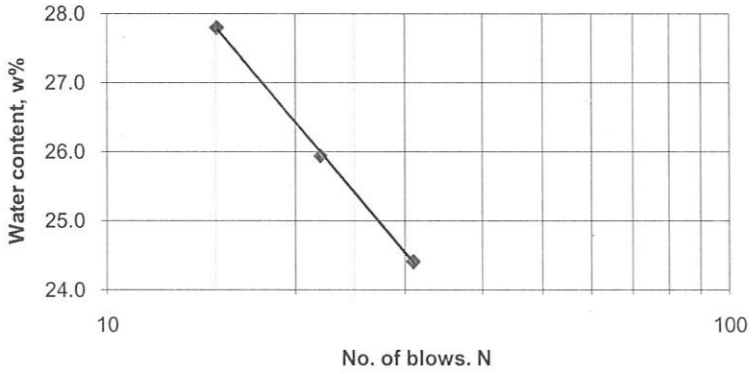
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt So. F-C Sand**

Boring No.: **TP-9**
Sample No.: **5-10'**
Depth: **5-10'**

Liquid limit Determination

Can No.	3	28	39			
Wt. of wet soil +can (g)	28.68	29.16	23.3			
Wt. of dry soil + can (g)	27.44	27.78	21.76			
Wt. of can (g)	22.36	22.46	16.22			
Wt of dry soil (g)	5.08	5.32	5.54			
Wt of moisture (g)	1.24	1.38	1.54			
No of blows, N (g)	31	22	15			
Water content, *w* %	24.4	25.9	27.8			



Flow index F_i =
Liquid limit = **25.4**
Plastic limit = **13.2**
Plasticity index I_p = **12.2**

Plastic Limit Determination

Can no.	18	36				
Wt. of wet soil + can (g)	29.06	23.82				
Wt. of dry soil + can (g)	28.04	22.90				
Wt. of can (g)	20.33	15.9				
Wt. of dry soil (g)	7.71	7.0				
Wt. of moisture (g)	1.02	0.92				
Water content, $w\% = w_p$	13.2	13.1				

Tested by: **Daniel Absolon 3/17/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-10
Sample No: 10-15
Depth: 10-15
Date Received: 3/17/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:49:00

% of Original Sample Used For Hydrometer Analysis: 95.7 %
Weight of Sample Dispersed: 64.7 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:49:30	0.5	49	20	5	44	67.3	0.01344	8.3	0.0548	64.4
8:50:00	1.0	45	20	5	40	61.2	0.01344	8.9	0.0401	58.6
8:51:00	2.0	41	20	5	36	55.1	0.01344	9.6	0.0294	52.7
8:54:00	5.0	35	20	5	30	45.9	0.01344	10.6	0.0196	43.9
9:04:00	15.0	29	20	5	24	36.7	0.01344	11.5	0.0118	35.1
9:19:00	30.0	27	20	5	22	33.7	0.01344	11.9	0.0085	32.2
9:49:00	60.0	24	20	5	19	29.1	0.01344	12.4	0.0061	27.8
10:49:00	120.0	22	20	5	17	26.0	0.01344	12.7	0.0044	24.9
12:49:00	240.0	20	20	5	15	23.0	0.01344	13.0	0.0031	22.0
16:49:00	480.0	18	20	5	13	19.9	0.01344	13.3	0.0022	19.0
8:49:00	1440.0	17	20	5	12	18.4	0.01344	13.5	0.0013	17.6

Tested By: Graham Donahue Date: 3/17/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown medium plastic, some silt, some fine to coarse sand **Boring No.** TP-10

Shape: NA **Hardness:** NA **Sample No.** 10.15

Remarks: **Depth:** 10.15

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	0.00	0.0	100.0
4M	4.76	8.10	1.9	98.1
10M	2.00	10.20	2.4	95.7
40M	0.42	3.20	4.9	95.1 /* 90.9
100M	0.149	6.10	9.4	85.6 /* 81.9
200M	0.074	3.90	6.0	79.6 /* 76.2
Pan		6.30	9.7	69.9 /* 66.8

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 18.3 gm = 4.3% %

Material passing No. 10 mesh: weight = 405 gm = 95.7% %

Weight of Total Sample = 423.3 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

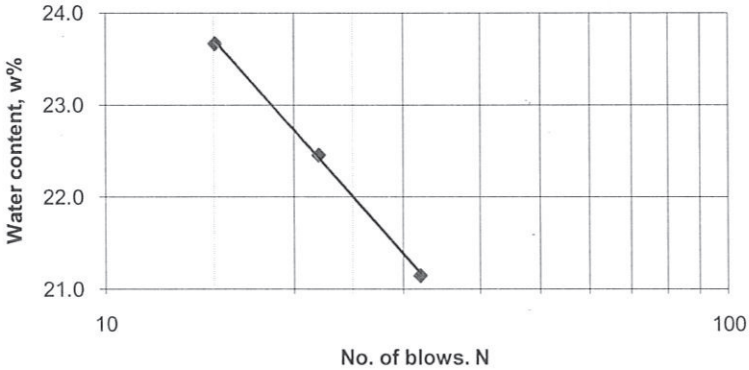
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt So. F-C Sand**

Boring No.: **TP-10**
Sample No.: **10-15'**
Depth: **10-15'**

Liquid limit Determination

Can No.	10	15	4			
Wt. of wet soil +can (g)	27.41	31.11	30.22			
Wt. of dry soil + can (g)	26.23	29.52	28.71			
Wt. of can (g)	20.65	22.44	22.33			
Wt of dry soil (g)	5.58	7.08	6.38			
Wt of moisture (g)	1.18	1.59	1.51			
No of blows, N (g)	32	22	15			
Water content, *w* %	21.1	22.5	23.7			



Flow index F_i =
Liquid limit = **22.0**
Plastic limit = **12.9**
Plasticity index I_p = **9.1**

Plastic Limit Determination

Can no.	9	34				
Wt. of wet soil + can (g)	25.42	32.58				
Wt. of dry soil + can (g)	24.33	31.41				
Wt. of can (g)	15.9	22.31				
Wt. of dry soil (g)	8.43	9.1				
Wt. of moisture (g)	1.09	1.17				
Water content, $w\% = w_p$	12.9	12.9				

Tested by: **Daniel Absolon 3/17/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-11
Sample No: 7
Depth: 7
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:54:00

% of Original Sample Used For Hydrometer Analysis: 95.4 %
Weight of Sample Dispersed: 63.6 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:54:30	0.5	51	20	5	46	71.6	0.01344	7.9	0.0534	68.3
8:55:00	1.0	48	20	5	43	66.9	0.01344	8.4	0.0390	63.9
8:56:00	2.0	44	20	5	39	60.7	0.01344	9.1	0.0287	57.9
8:59:00	5.0	37	20	5	32	49.8	0.01344	10.2	0.0192	47.5
9:09:00	15.0	32	20	5	27	42.0	0.01344	11.1	0.0116	40.1
9:24:00	30.0	31	20	5	26	40.5	0.01344	11.2	0.0082	38.6
9:54:00	60.0	29	20	5	24	37.4	0.01344	11.5	0.0059	35.6
10:54:00	120.0	27	20	5	22	34.2	0.01344	11.9	0.0042	32.7
12:54:00	240.0	25	20	5	20	31.1	0.01344	12.2	0.0030	29.7
16:54:00	480.0	23	20	5	18	28.0	0.01344	12.5	0.0022	26.7
8:54:00	1440.0	21	20	5	16	24.9	0.01344	12.9	0.0013	23.8

Tested By: Graham Donahue Date: 3/23/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown, medium plastic, some silt, some fine to coarse sand, trace of fine gravel **Boring No.** TP-11

Shape: NA **Hardness:** NA **Sample No.** 7

Remarks: **Depth:** 7

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1	25.4	0.00		
3/4	19.1	0.00	0.0	100.0
3/8	12.7	0.00	0.0	100.0
4M	4.76	8.00	2.1	97.9
10M	2.00	9.70	2.5	95.4
40M	0.42	2.50	3.9	96.1 /* 91.7
100M	0.149	6.20	9.7	86.3 /* 82.4
200M	0.074	3.80	6.0	80.3 /* 76.7
Pan		8.60	13.5	66.8 /* 63.8

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 17.7 gm = 4.6% %

Material passing No. 10 mesh: weight = 368.9 gm = 95.4% %

Weight of Total Sample = 386.6 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

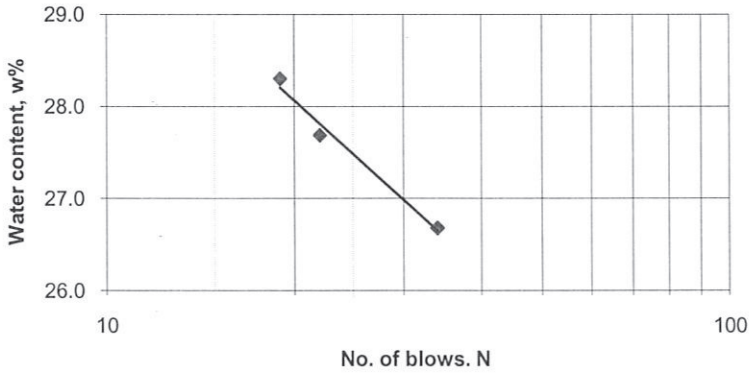
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt So. F-C Sand, Tr. F-Gravel**

Boring No.: **TP-11**
Sample No.: **7'**
Depth: **7'**

Liquid limit Determination

Can No.	43	20	5			
Wt. of wet soil +can (g)	22.33	29.99	23.17			
Wt. of dry soil + can (g)	20.98	28.34	21.54			
Wt. of can (g)	15.92	22.38	15.78			
Wt of dry soil (g)	5.06	5.96	5.76			
Wt of moisture (g)	1.35	1.65	1.63			
No of blows, N (g)	34	22	19			
Water content, *w* %	26.7	27.7	28.3			



Flow index F_i =
Liquid limit = **27.5**
Plastic limit = **12.9**
Plasticity index I_p = **14.6**

Plastic Limit Determination

Can no.	29	38				
Wt. of wet soil + can (g)	30.18	24.78				
Wt. of dry soil + can (g)	29.07	23.78				
Wt. of can (g)	20.49	16.0				
Wt. of dry soil (g)	8.58	7.78				
Wt. of moisture (g)	1.11	1.0				
Water content, $w\% = w_p$	12.9	12.9				

Tested by: **Daniel Absolon 3/17/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-12
Sample No: 3
Depth: 3
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:39:00

% of Original Sample Used For Hydrometer Analysis: 91.3 %
Weight of Sample Dispersed: 61.5 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature ° C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:39:30	0.5	47	20	5	42	67.6	0.01344	8.6	0.0557	61.7
8:40:00	1.0	44	20	5	39	62.8	0.01344	9.1	0.0405	57.3
8:41:00	2.0	40	20	5	35	56.3	0.01344	9.7	0.0296	51.4
8:44:00	5.0	34	20	5	29	46.7	0.01344	10.7	0.0197	42.6
8:54:00	15.0	29	20	5	24	38.6	0.01344	11.5	0.0118	35.3
9:09:00	30.0	27	20	5	22	35.4	0.01344	11.9	0.0085	32.3
9:39:00	60.0	25	20	5	20	32.2	0.01344	12.2	0.0061	29.4
10:39:00	120.0	22	20	5	17	27.4	0.01344	12.7	0.0044	25.0
12:39:00	240.0	20	20	5	15	24.1	0.01344	13.0	0.0031	22.0
16:39:00	480.0	18	20	5	13	20.9	0.01344	13.3	0.0022	19.1
8:39:00	1440.0	16	20	5	11	17.7	0.01344	13.7	0.0013	16.2

Tested By: Graham Donahue Date: 3/23/2010

Submitted By: Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown, medium plastic, some silt, trace of fine to coarse sand, trace of fine to coarse gravel **Boring No.** TP-12

Shape: NA **Hardness:** NA **Sample No.** 3

Remarks: **Depth:** 3

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1"	25.4	0.00		
3/4"	19.1	0.00	0.0	100.0
3/8"	9.5	0.00	0.0	100.0
4M	4.76	14.40	4.8	95.2
10M	2.00	11.80	3.9	91.3
40M	0.42	3.40	5.5	94.5 /* 86.3
100M	0.149	8.00	13.0	81.5 /* 74.4
200M	0.074	4.80	7.8	73.7 /* 67.3
Pan		4.90	8.0	65.7 /* 60.0

MECHANICAL ANALYSIS PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 26.2 gm = 8.7% %

Material passing No. 10 mesh: weight = 275.3 gm = 91.3% %

Weight of Total Sample = 301.5 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

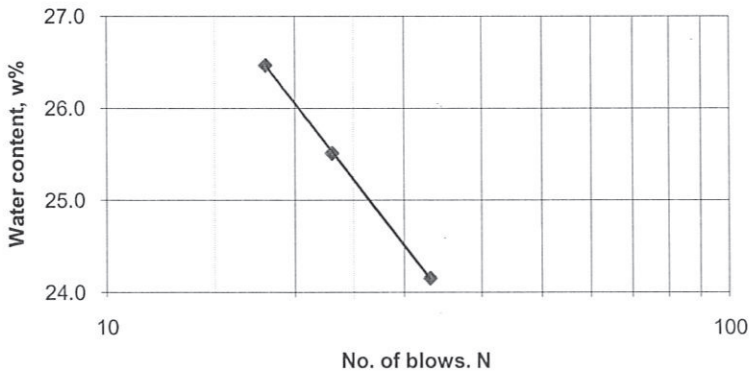
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt Tr. F-C Sand, Tr. F-Gravel**

Boring No.: **TP-12**
Sample No.: **3'**
Depth: **3'**

Liquid limit Determination

Can No.	19	42	16			
Wt. of wet soil +can (g)	28.89	24.02	29.72			
Wt. of dry soil + can (g)	27.61	22.39	28.14			
Wt. of can (g)	22.31	16.00	22.17			
Wt of dry soil (g)	5.30	6.39	5.97			
Wt of moisture (g)	1.28	1.63	1.58			
No of blows, N (g)	33	23	18			
Water content, *w* %	24.2	25.5	26.5			



Flow index F_i =
Liquid limit = **25.2**
Plastic limit = **14.3**
Plasticity index I_p = **10.9**

Plastic Limit Determination

Can no.	6	33				
Wt. of wet soil + can (g)	28.16	24.25				
Wt. of dry soil + can (g)	27.15	23.26				
Wt. of can (g)	20.24	16.22				
Wt. of dry soil (g)	6.91	7.04				
Wt. of moisture (g)	1.01	0.99				
Water content, $w\% = w_p$	14.6	14.1				

Tested by: **Daniel Absolon 3/23/10**

COLEMAN ENGINEERING COMPANY
635 Circle Drive
Iron Mountain, Michigan 49801
Telephone: (906) 774-3440 Fax: (906) 774-7776

PARTICLE-SIZE ANALYSIS OF SOILS - HYDROMETER

(ASTM D422)

Project Name: Copperwood C.E.C Job #: 10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Remarks:

Boring No: TP-13
Sample No: 7
Depth: 7
Date Received: 3/10/2010

Dispersing Agent Used: Sodium Hexametaphosphate

Amount: 125 ml
Hydrometer Number: 152 H
Specific Gravity (G): 2.70
Starting Time: 8:44:00

% of Original Sample Used For Hydrometer Analysis: 93.7 %
Weight of Sample Dispersed: 65.6 g.

Time	Elapsed Time Minutes (T)	Hydrometer Reading	Temperature °C	Correction (DR)	Corr. Hydrometer Reading (R)	Percent Soil in Suspension (P)	K, Values from Table III	L, Values from Table II	Calculated Grain Diameter, mm (d)	Percent of Total Sample C.G.D.
8:44:30	0.5	53	20	5	48	72.4	0.01344	7.6	0.0524	67.9
8:45:00	1.0	49	20	5	44	66.4	0.01344	8.3	0.0387	62.2
8:46:00	2.0	44	20	5	39	58.9	0.01344	9.1	0.0287	55.1
8:49:00	5.0	37	20	5	32	48.3	0.01344	10.2	0.0192	45.3
8:59:00	15.0	32	20	5	27	40.7	0.01344	11.1	0.0116	38.2
9:14:00	30.0	30	20	5	25	37.7	0.01344	11.4	0.0083	35.4
9:44:00	60.0	28	20	5	23	34.7	0.01344	11.7	0.0059	32.5
10:44:00	120.0	26	20	5	21	31.7	0.01344	12.0	0.0043	29.7
12:44:00	240.0	24	20	5	19	28.7	0.01344	12.4	0.0031	26.9
16:44:00	480.0	22	20	5	17	25.7	0.01344	12.7	0.0022	24.0
8:44:00	1440.0	21	20	5	16	24.1	0.01344	12.9	0.0013	22.6

Tested By: Graham Donahue Date: 3/23/2010

Submitted By: [signature] Date: 4-9-2010

Form #: 0422B Revision Date: 1/17/05

COLEMAN ENGINEERING COMPANY
200 E. Ayer Street
Ironwood, Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

PARTICLE-SIZE ANALYSIS OF SOILS - MECHANICAL

(ASTM D422)

Project Name: Copperwood **C.E.C. Job #:** GI-10022

Client: Orvana Minerals

Address: N10199 Lake Road Ironwood, MI 49938

Soil Description: (CL) Clay, brown medium plastic, some silt, some fine to coarse sand, trace of fine to coarse gravel **Boring No.** TP-13

Shape: NA **Hardness:** NA **Sample No.** 7

Remarks: **Depth:** 7

Date Rec'd: 3/10/2010

Sieve Size	Grain Diameter (mm)	Weight Retained Individual	Percent Retained Individual	Percent Finer
3"	76.2	0		
2"	50.8	0		
1 1/2"	37.5	0		
1"	25.4	0.00		
3/4"	19.1	0.00	0.0	100.0
3/8"	9.5	0.00	0.0	100.0
4M	4.76	20.10	4.5	95.5
10M	2.00	8.30	1.9	93.6
40M	0.42	3.30	5.0	95.0 /* 88.9
100M	0.149	6.20	9.5	85.5 /* 80.1
200M	0.074	4.40	6.7	78.8 /* 73.8
Pan		6.60	10.1	68.8 /* 64.4

MECHANICAL ANALYSIS
PORTION OF HYDROMETER ANALYSIS

***Percent Based on Total Sample**

Original Sample:

Material retained on No. 10 mesh: weight = 28.4 gm = 6.3% %

Material passing No. 10 mesh: weight = 418.9 gm = 93.7% %

Weight of Total Sample = 447.3 gm

Tested By: Graham Donahue **Date:** 3/22/2010

Submitted By: [signature] **Date:** 4-9-2010

Form: D422A Revision Date: 04/02/09

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

Job No.: **10022**
Date: **3/10/2010**

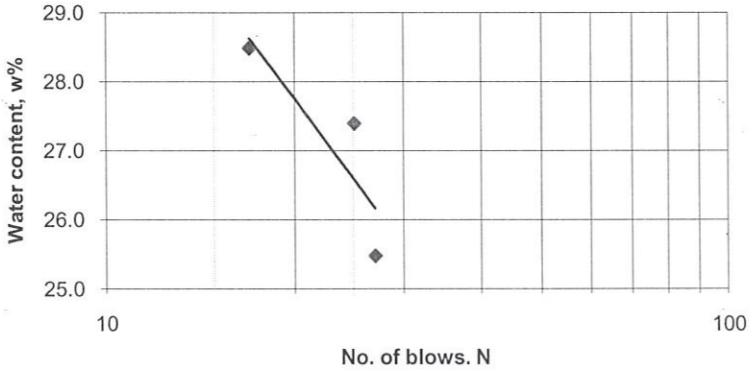
ATTERBERG LIMITS DETERMINATION

Project: **Copperwood**
Client: **Orvana Minerals**
Description of Soil: **(CL) Clay, Br. Medium Plastic, So. Silt So. F-C Sand, Tr. F-Gravel**

Boring No.: **TP-13**
Sample No.: **7'**
Depth: **7'**

Liquid limit Determination

Can No.	22	14	25			
Wt. of wet soil +can (g)	30.97	29.05	28.78			
Wt. of dry soil + can (g)	29.23	27.62	26.84			
Wt. of can (g)	22.40	22.40	20.03			
Wt of dry soil (g)	6.83	5.22	6.81			
Wt of moisture (g)	1.74	1.43	1.94			
No of blows, N (g)	27	25	17			
Water content, *w* %	25.5	27.4	28.5			



Flow index F_i =
Liquid limit = **26.5**
Plastic limit = **14.0**
Plasticity index I_p = **12.5**

Plastic Limit Determination

Can no.	19	7				
Wt. of wet soil + can (g)	32.35	28.8				
Wt. of dry soil + can (g)	31.13	27.77				
Wt. of can (g)	22.33	20.44				
Wt. of dry soil (g)	8.8	7.33				
Wt. of moisture (g)	1.22	1.03				
Water content, $w\% = w_p$	13.9	14.1				

Tested by: **Daniel Absolon 3/18/10**

Knight Piésold CONSULTING

Appendix G-5

Previous Site Investigation Data – Natural Moisture Content Data

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood

Client: Orvana Minerals Job No: 10022

Address: N10199 Lake Road Ironwood, MI 49938

Location of Project: Wakefield MI Date: 2/25/2010

Boring No.	TP-1	TP-2	TP-3	TP-4	TP-5
Sample No.	7'	3'	12'	7'	3'
Depth (ft.)	7'	3'	12'	7'	3'
Pan No.	62	52	26	16	77
Weight-Wet Sample & Tare (g)	931.5	987.6	362.5	721.0	646.8
Weight-Dry Sample & Tare (g)	871.8	921.4	341.1	662.6	594.4
Weight of Moisture (g)	59.7	66.2	21.4	58.4	52.4
Weight of Tare (g)	342.3	344.2	116.2	116.3	104.1
Weight of Dry Soil (g)	529.5	577.2	224.9	546.3	490.3
Moisture Content (%)	11.3	11.5	9.5	10.7	10.7

Boring No.	TP-6	TP-7	TP-8	TP-9	TP-10
Sample No.	12'	0'-5'	10'-15'	5'-10'	10'-15'
Depth (ft.)	12'	0'-5'	10'-15'	5'-10'	10'-15'
Pan No.	61	75	76	51	60
Weight-Wet Sample & Tare (g)	884.4	669.4	598.8	811.4	818.8
Weight-Dry Sample & Tare (g)	815.3	607.0	539.3	749.3	764.4
Weight of Moisture (g)	69.1	62.4	59.5	62.1	54.4
Weight of Tare (g)	341.4	103.2	103.3	342.9	341.1
Weight of Dry Soil (g)	473.9	503.8	436.0	406.4	423.3
Moisture Content (%)	14.6	12.4	13.6	15.3	12.9

Remarks:

Tested By: Dan Absolon & Mark Douglas Date: 2/25/2010

Submitted By: Date: 4-12-2010

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood, Michigan 49938
Telephone: (906)-932-5048 Fax: (906)-932-3213

MOISTURE CONTENT DETERMINATION

ASTM D-2216

Project Name: Copperwood

Client: Orvana Minerals Job No: 10022

Address: N10199 Lake Road Ironwood, MI 49938

Location of Project: Wakefield MI Date: 2/25/2010

Boring No.	TP-11	TP-12	TP-13	TP-14	TP-15
Sample No.	7'	3'	7'	12'	7'
Depth (ft.)	7'	3'	7'	12'	7'
Pan No.	56	2	59	1	66
Weight-Wet Sample & Tare (g)	781.7	454.5	848.1	532.2	960.6
Weight-Dry Sample & Tare (g)	728.4	410.8	790.6	478.2	907.6
Weight of Moisture (g)	53.3	43.7	57.5	54.0	53.0
Weight of Tare (g)	341.8	109.3	343.3	114.7	344.5
Weight of Dry Soil (g)	386.6	301.5	447.3	363.5	563.1
Moisture Content (%)	13.8	14.5	12.9	14.9	9.4

Boring No.					
Sample No.					
Depth (ft.)					
Pan No.					
Weight-Wet Sample & Tare (g)					
Weight-Dry Sample & Tare (g)					
Weight of Moisture (g)					
Weight of Tare (g)					
Weight of Dry Soil (g)					
Moisture Content (%)					

Remarks:

Tested By: Dan Absolon & Mark Douglas Date: 2/25/2010

Submitted By: [illegible signature] Date: 4-12-2010

Knight Piésold CONSULTING

Appendix G-6

Previous Site Investigation Data – Moisture Density Data

COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/18/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 5 **Sample No.** 5

Test Method ASTM D-1557 Method A

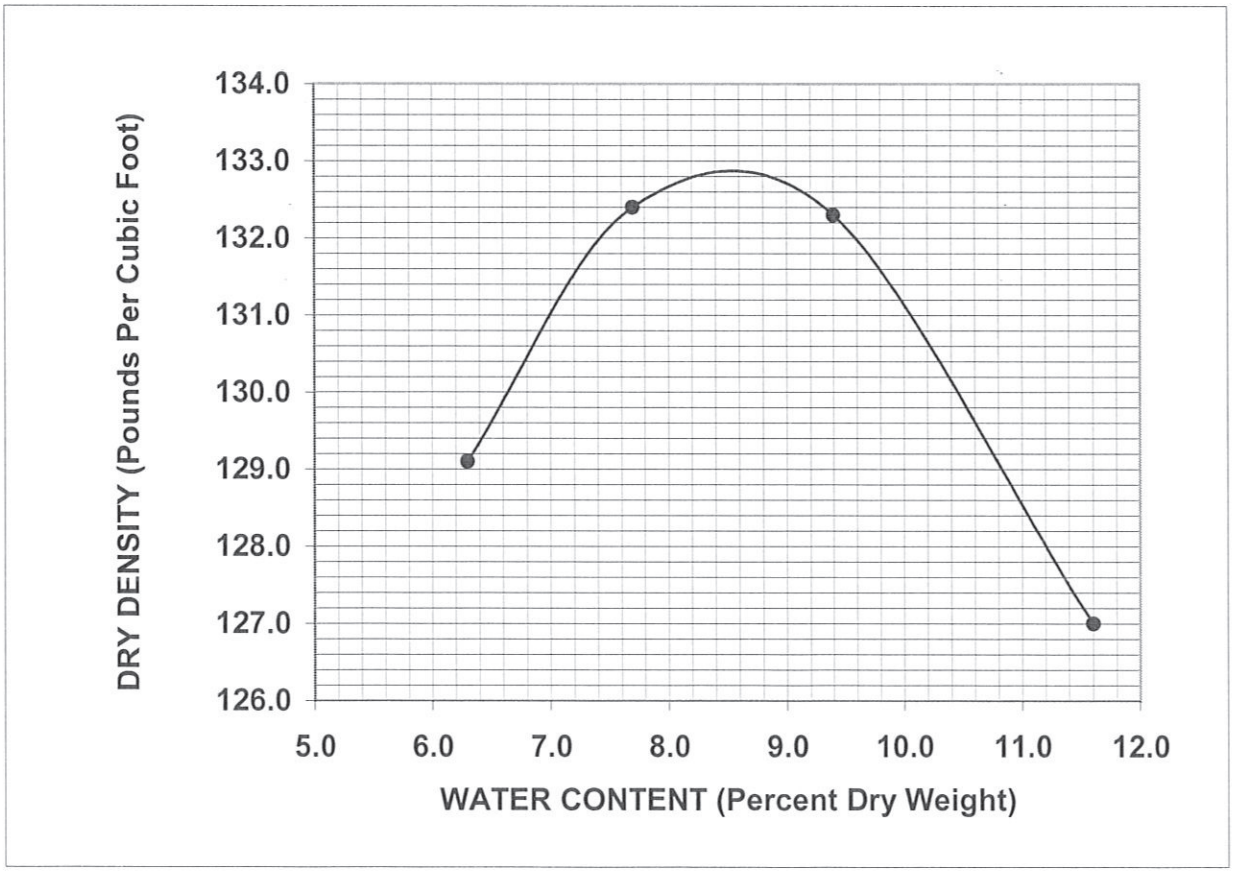
Description of Soil (CL)Clay, Br. Medium Plastic, w/Silt, So. F-C Sand, Tr. F-Gravel

Source of Material Test Pit # 5 10'-15'

TEST RESULTS

Maximum Dry Density 132.9 PCF

Optimum Water Content 8.6 %



COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/23/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 6 **Sample No.** 6

Test Method ASTM D-1557 Method A

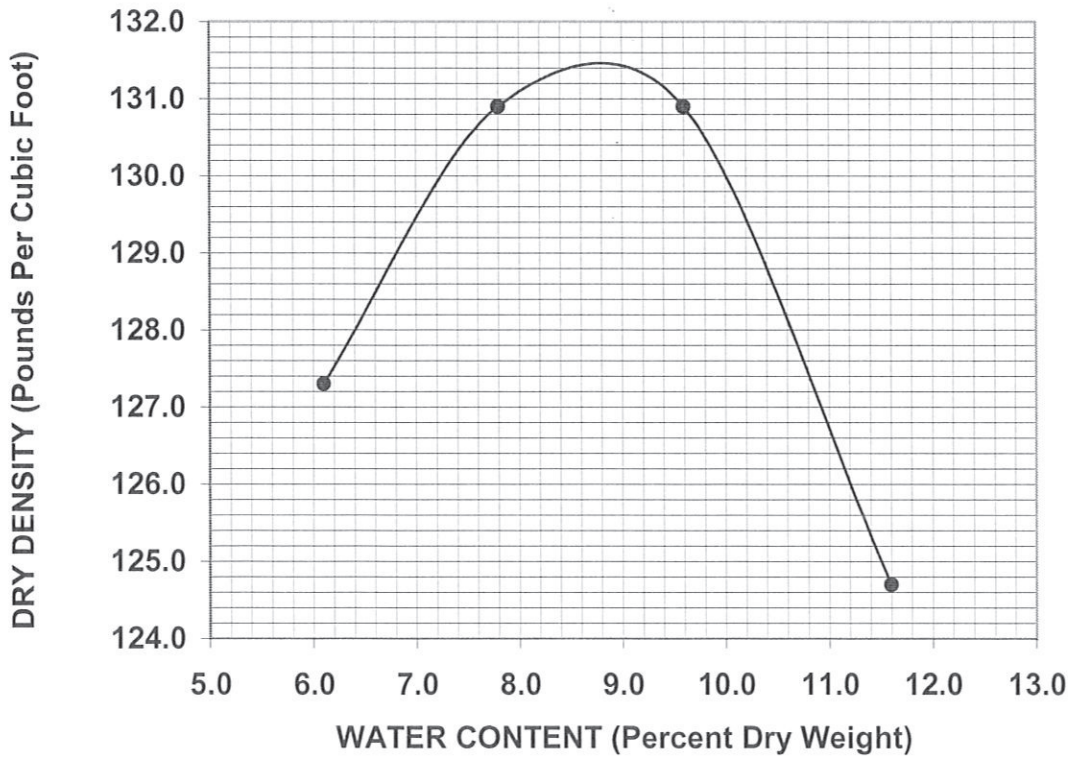
Description of Soil (CL)Clay, Br. Medium Plastic, So. Silt, Tr. F-C Sand, Tr. F-Gravel

Source of Material Test Pit # 6 5'-10'

TEST RESULTS

Maximum Dry Density 131.4 PCF

Optimum Water Content 8.8 %



COLEMAN ENGINEERING COMPANY
200 East Ayer Street
Ironwood Michigan 49938
Telephone: (906) 932-5048 Fax: (906) 932-3213

MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/23/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 7 **Sample No.** 7

Test Method ASTM D-1557 Method A

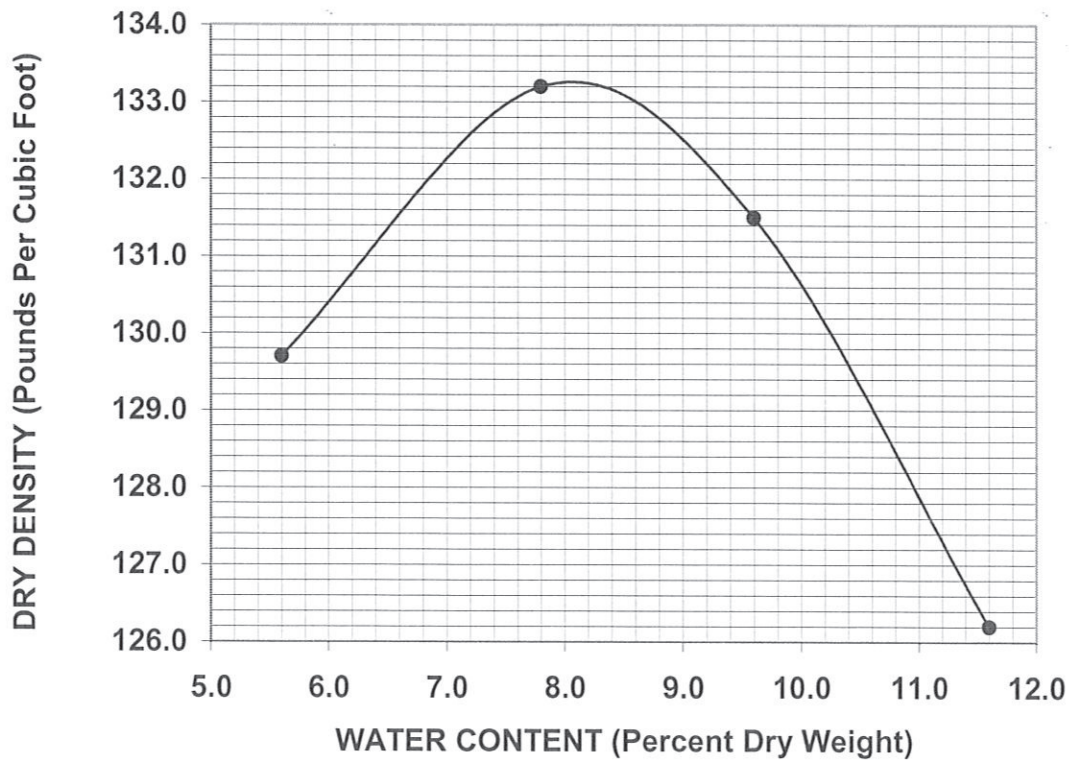
Description of Soil (CL) Clay, Br.Medium Plastic,So. Silt,So. F-C Sand, Tr. F-C Gravel

Source of Material Test Pit # 7 10'-15'

TEST RESULTS

Maximum Dry Density 133.3 PCF

Optimum Water Content 8.1 %



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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/23/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 8 **Sample No.** 8

Test Method ASTM D-1557 Method A

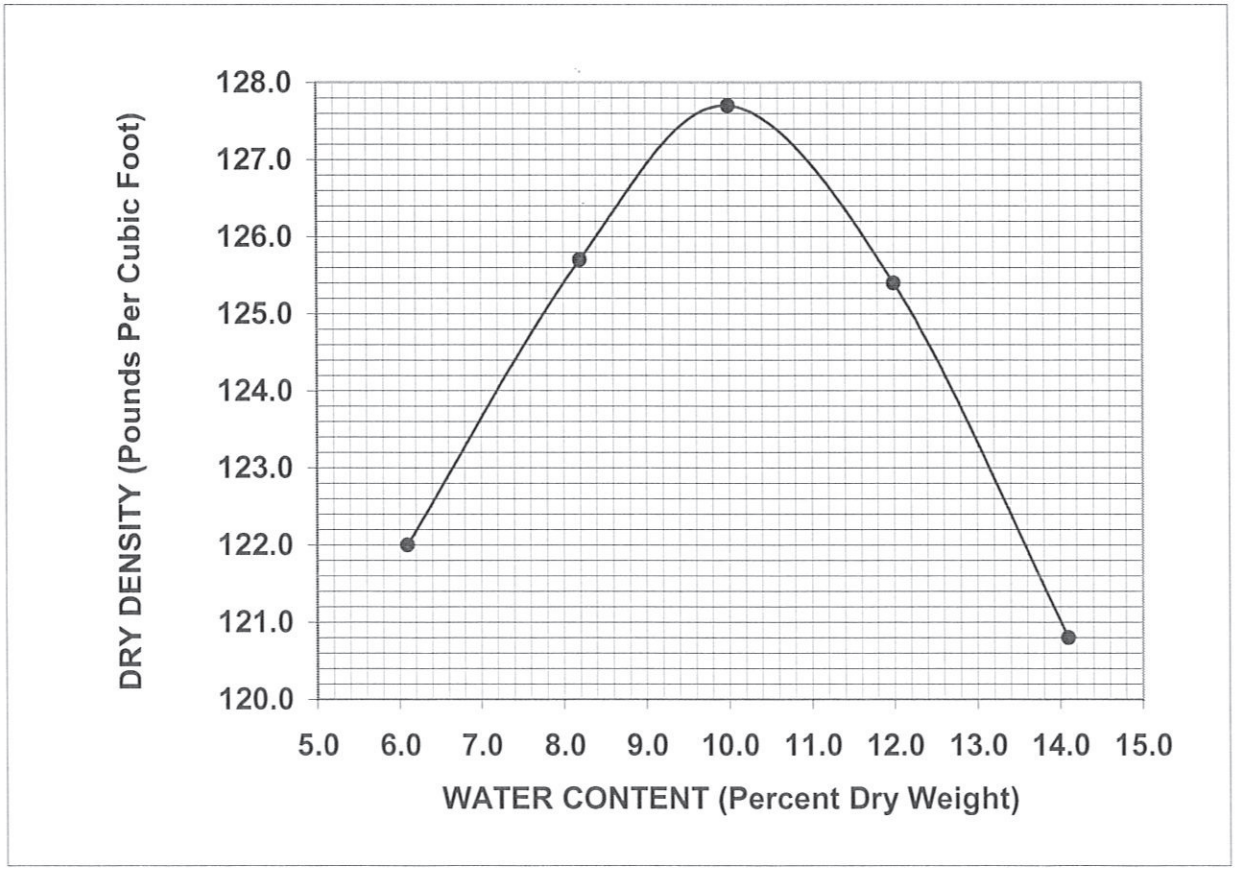
Description of Soil (CL)Clay, Br. Med. Plastic, So. Silt, So. F-C Sand, Tr. F-C Gravel

Source of Material Test Pit # 8 0'-5'

TEST RESULTS

Maximum Dry Density 127.7 PCF

Optimum Water Content 10.1 %



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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/24/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 9 **Sample No.** 9

Test Method ASTM D-1557 Method A

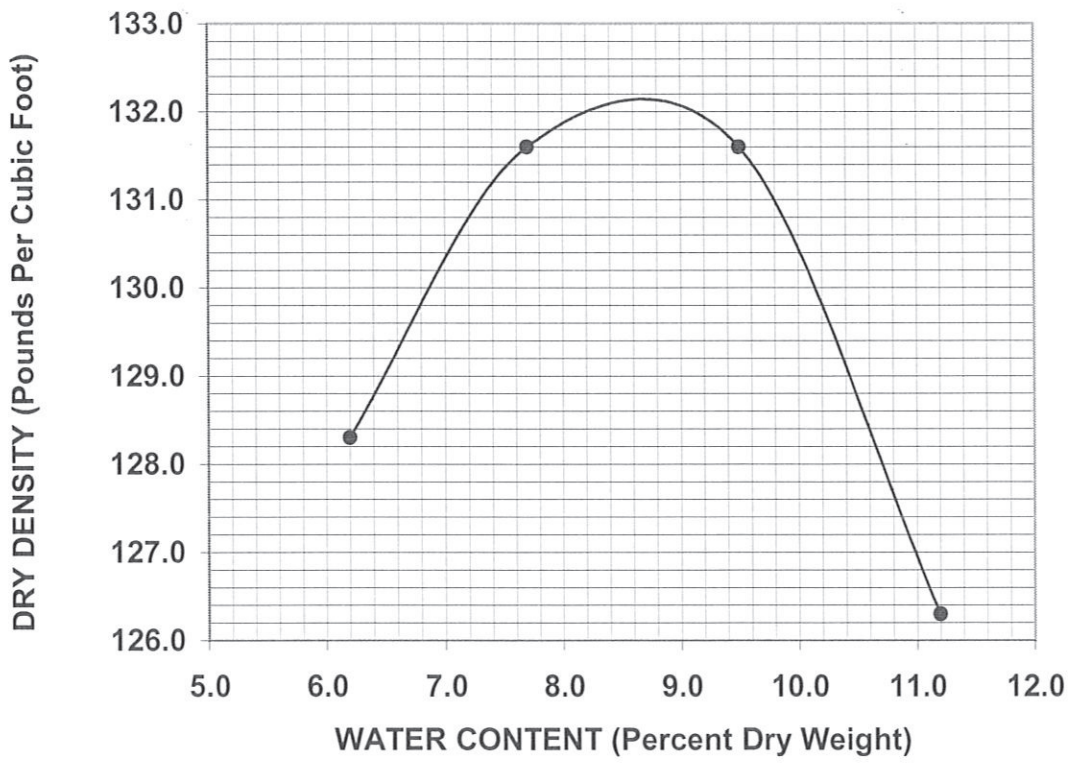
Description of Soil (CL)Clay, Br. Med. Plastic, So. Silt, So. F-C Sand,

Source of Material Test Pit # 9 10'-15'

TEST RESULTS

Maximum Dry Density 132.1 PCF

Optimum Water Content 8.7 %



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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/25/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 10 **Sample No.** 10

Test Method ASTM D-1557 Method A

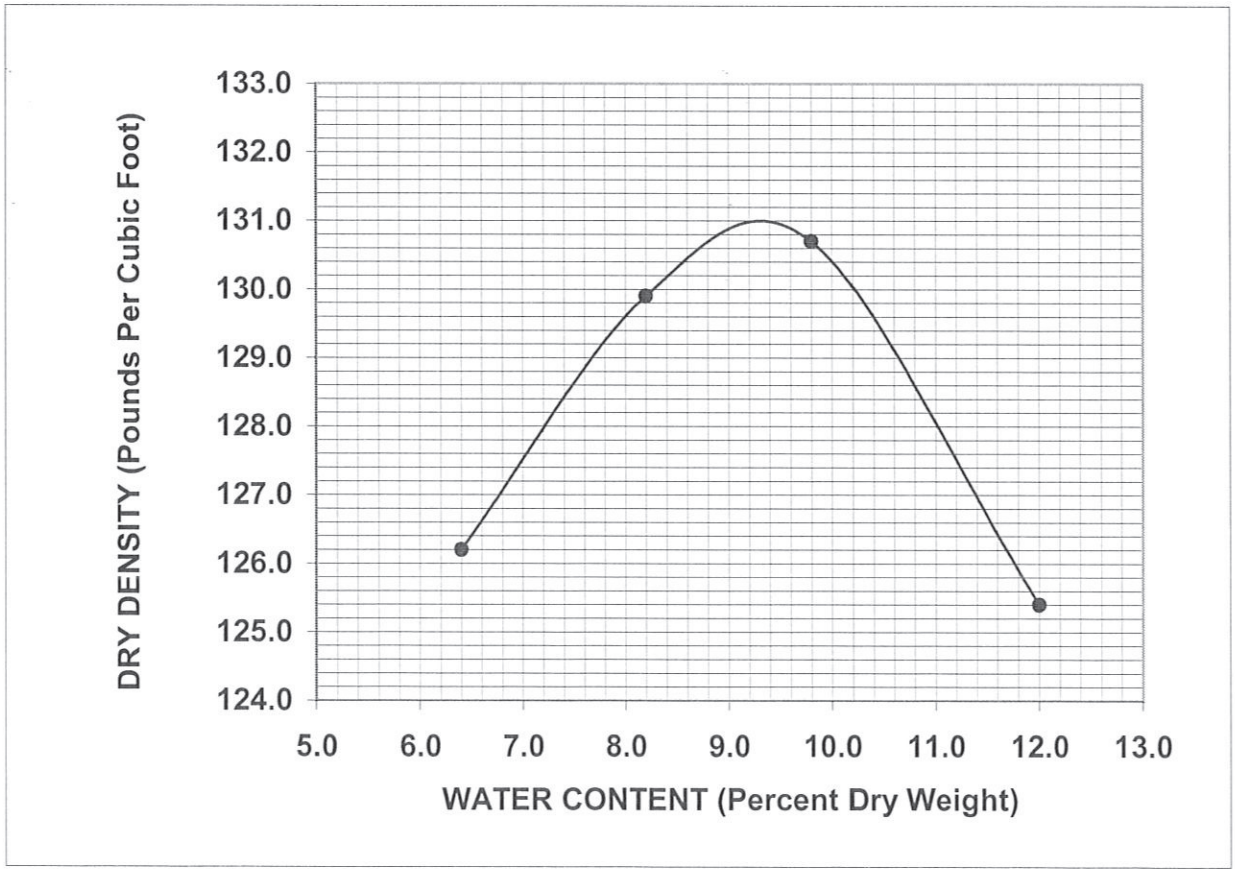
Description of Soil (CL) Clay, Br. Med. Plastic, So. Silt, So. F-C Sand

Source of Material Test Pit # 10 5'-10'

TEST RESULTS

Maximum Dry Density 131.0 PCF

Optimum Water Content 9.3 %



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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 3/26/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 11 **Sample No.** 11

Test Method ASTM D-1557 Method A

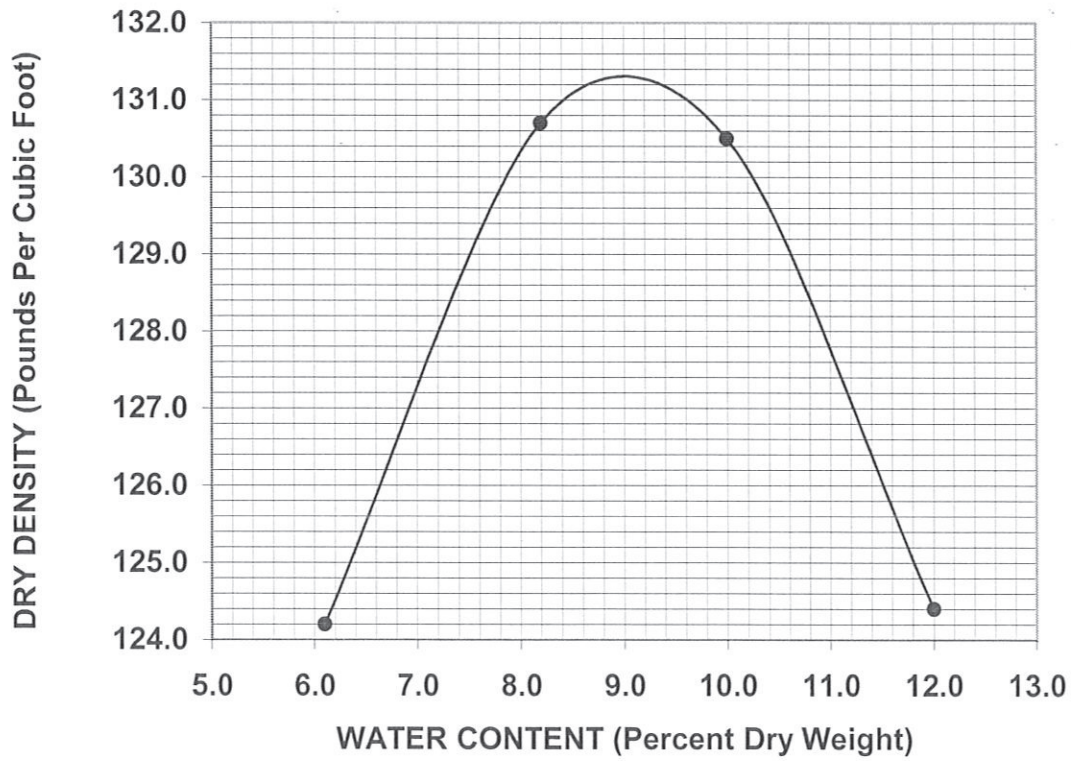
Description of Soil (CL)Clay, Br. Med. Plastic, SO. Silt, So. F-C Sand, Tr. F-Gravel

Source of Material Test Pit # 11 0'-5'

TEST RESULTS

Maximum Dry Density 131.4 PCF

Optimum Water Content 9.0 %



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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 4/2/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 12 **Sample No.** 12

Test Method ASTM D-1557 Method A

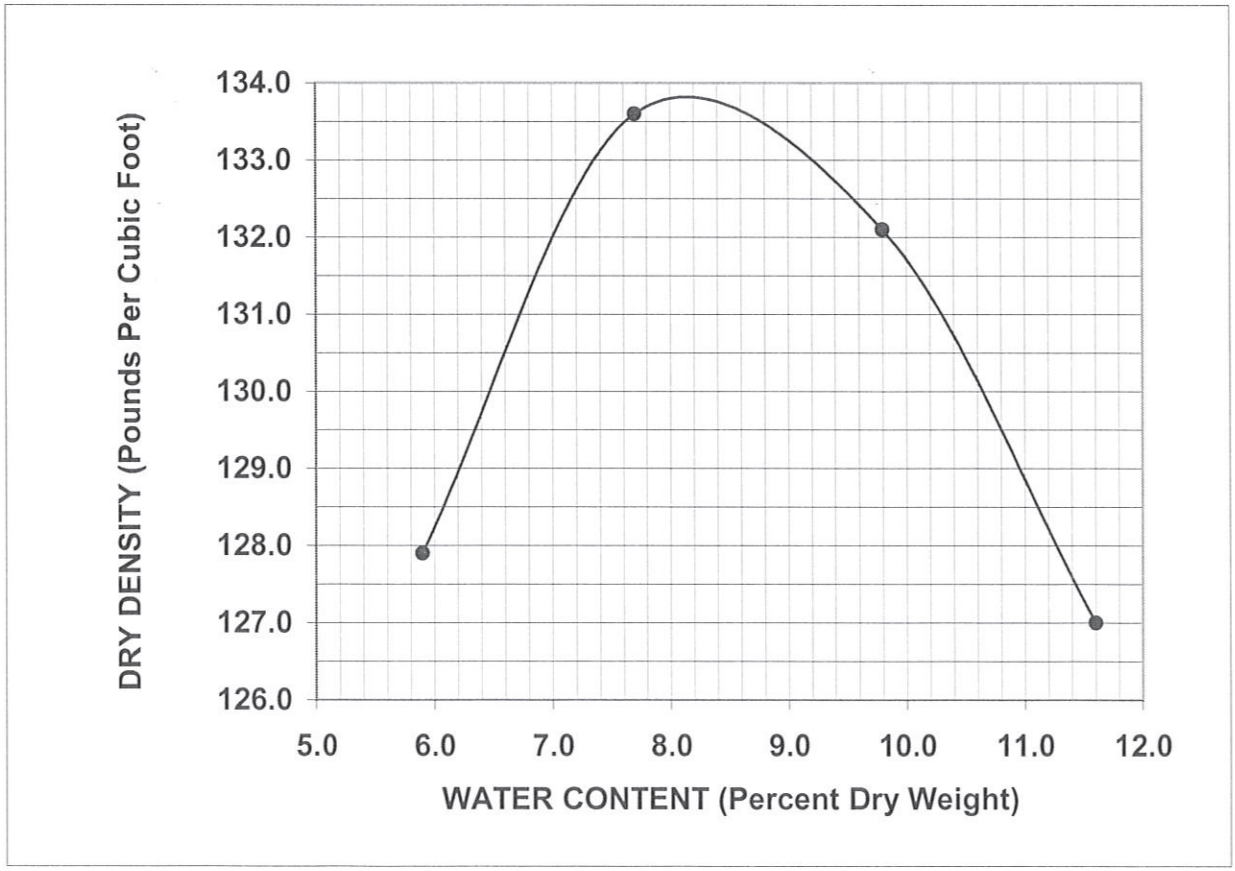
Description of Soil (CL) Clay, Br. Med. Plastic, So. Silt, Tr. F-C Sand, Tr. F-C Gravel

Source of Material Test Pit # 12 5'-10'

TEST RESULTS

Maximum Dry Density 133.8 PCF

Optimum Water Content 8.2 %



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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 4/5/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 13 **Sample No.** 13

Test Method ASTM D-1557 Method A

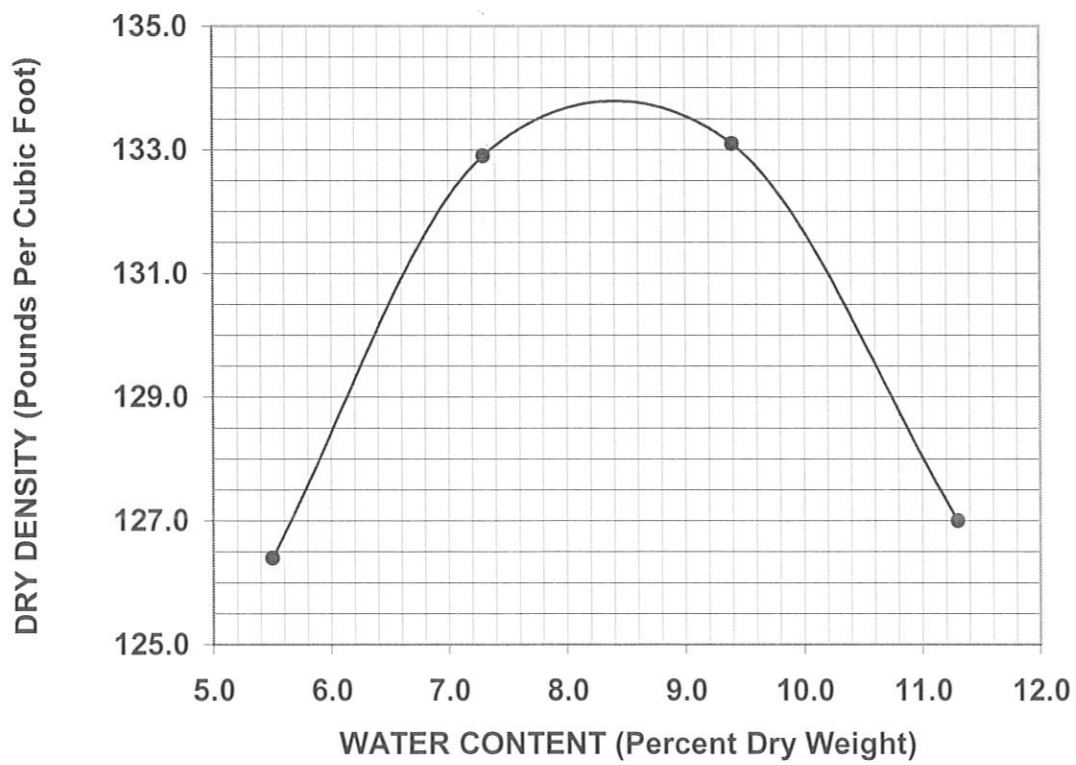
Description of Soil (CL) Clay, Br. Med. Plastic, So. Silt, So. F-C Sand, Tr. F-C Gravel

Source of Material Test Pit # 13 0'-5'

TEST RESULTS

Maximum Dry Density 133.8 PCF

Optimum Water Content 8.5 %



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200 East Ayer Street
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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 4/7/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 14 **Sample No.** 14

Test Method ASTM D-1557 Method A

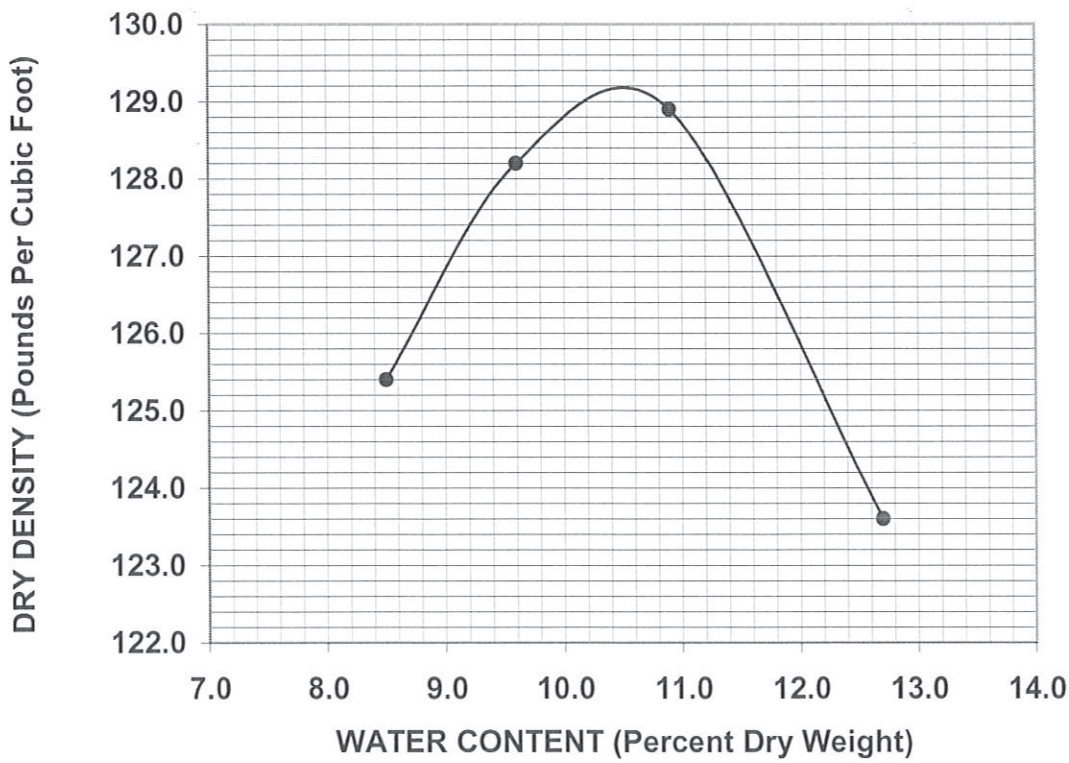
Description of Soil (CL) Clay, Br. Med. Plastic, So. Silt, So. F-C Sand, Tr. F-C Gravel

Source of Material Test Pit # 14 5'-10'

TEST RESULTS

Maximum Dry Density 129.2 PCF

Optimum Water Content 10.5 %



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200 East Ayer Street
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MOISTURE-DENSITY RELATIONSHIP

Job Number 10022 **Date** 4/8/2010

Client Orvana Minerals

Project Copperwood

Proctor No. 15 **Sample No.** 15

Test Method ASTM D-1557 Method A

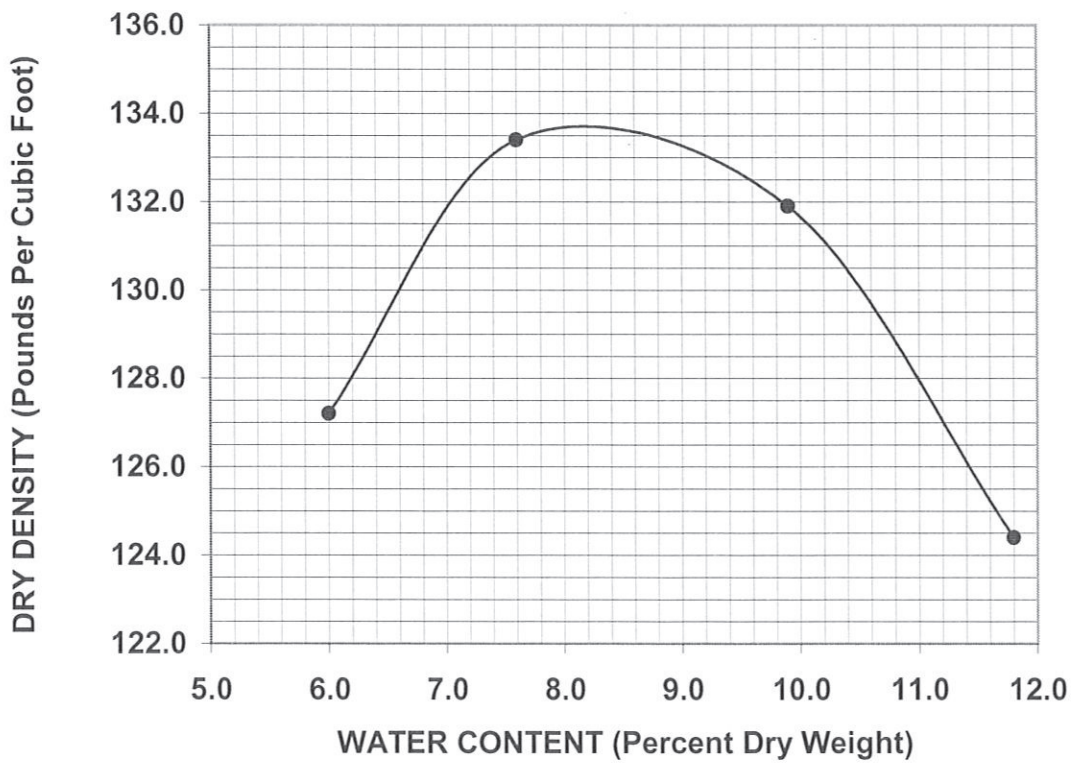
Description of Soil (CL) Clay, Br. Med. Plastic, So. Silt, So. F-C Sand, Tr. F-C Gravel

Source of Material Test Pit # 15 10'-15'

TEST RESULTS

Maximum Dry Density 133.7 PCF

Optimum Water Content 8.2 %



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Appendix C

Runoff and Infiltration through Tailings Disposal Facility Conceptual Closure Cover

C-1 SoilProp Output
C-2 HELP Modeling Output

Appendix C-1

SoilProp Output

```
************************************************
*              S O I L P R O P                 *
*A program to estimate soil hydraulic properties*
*     from particle size distribution data      *
*                                              *
*       COPYRIGHT  1990  Version 2.1           *
*  Environmental Systems and Technologies, Inc. *
*  P.O. Box 10457, Virginia 24062-0457         *
*               (703) 552-0685                 *
************************************************
```

```
************************************************
*                 Glacial Till                 *
************************************************
```

-------- PARTICLE SIZE DISTRIBUTION DATA --------

```
% clay  material    => 27.00
% fine silt         => 11.00
% medium silt       => 14.50
% coarse silt       => 13.50
% very fine sand    => 10.00
% fine sand         =>  8.40
% medium sand       =>  5.50
% coarse sand       =>  3.40
% very coarse sand  =>  2.20
% fine gravel       =>  3.30
% cobbles           =>  1.20

R^2 for log-normal fit => .9775


theta_s (cc/cc)     =>   .35
% error in theta_s  =>   .00
bulk density (g/cc) =>  1.73
% error in bulk den =>   .00

R^2 for V_G model  fit => .9728
```

Irreducible water saturation / water content estimated from retention data by SOILPROP

------ VAN GENUCHTEN RETENTION PARAMETERS -------

	Estimated value	Standard deviation
alpha (1/cm)	.111E-01	.529E-02
n	1.13	.384E-01
theta_r(cc/cc)	.112E-14	.277E-01
K_s (cm/d)	.133E+02	.248E+02

--------- PARAMETER CORRELATION MATRIX ----------

	alpha	n	theta_r
alpha	.100E+01		
n	-.333E+00	.100E+01	
theta_r	-.661E+00	.638E+00	.100E+01

Irreducible water saturation / water content
estimated from retention data by SOILPROP

------ BROOKS-COREY RETENTION PARAMETERS -------

	Estimated value	Standard deviation
h_d (cm)	87.0	40.1
lambda	.133	.377E-01
theta_r(cc/cc)	.112E-14	.277E-01
K_s (cm/d)	.133E+02	.248E+02

--------- PARAMETER CORRELATION MATRIX ----------

	h_d	lambda	theta_r
h_d	.100E+01		
lambda	.270E+00	.100E+01	
theta_r	.630E+00	.638E+00	.100E+01

Appendix C-2

Help Model Output

```
♀
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************



PRECIPITATION DATA FILE:    C:\CPRWD-1\DATA4.D4
TEMPERATURE DATA FILE:      C:\CPRWD-1\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\CPRWD-1\DATA13.D13
EVAPOTRANSPIRATION DATA:    c:\cprwd-1\DATA11B.D11
SOIL AND DESIGN DATA FILE:  C:\CPRWD-1\DATA10E.D10
OUTPUT DATA FILE:           C:\CPRWD-1\IG-9.OUT


TIME:  13: 0     DATE:   7/29/2011



******************************************************************************

     TITLE:  COPPERWOOD-TO BASE OF CLOSURE GRADING LAYER W/O DRAIN

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   7
          THICKNESS                   =      6.00   INCHES
          POROSITY                    =      0.4730 VOL/VOL
          FIELD CAPACITY              =      0.2220 VOL/VOL
          WILTING POINT               =      0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.4718 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.520000001000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	156.00	INCHES
POROSITY	=	0.3472	VOL/VOL
FIELD CAPACITY	=	0.2861	VOL/VOL
WILTING POINT	=	0.1785	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3472	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999999000E-07	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 1.% AND A SLOPE LENGTH OF 2200. FEET.

SCS RUNOFF CURVE NUMBER	=	60.80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.831	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.838	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.624	INCHES
INITIAL SNOW WATER	=	0.272	INCHES
INITIAL WATER IN LAYER MATERIALS	=	56.994	INCHES
TOTAL INITIAL WATER	=	57.266	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM COPPERWOOD MICHIGAN

STATION LATITUDE	=	46.68	DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50	
START OF GROWING SEASON (JULIAN DATE)	=	147	
END OF GROWING SEASON (JULIAN DATE)	=	264	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	9.40	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	80.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	82.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GRAND RAPIDS MICHIGAN

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.78	1.55	1.75	2.24	2.98	3.03
3.28	3.01	3.24	3.45	2.61	3.08

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SAULT STE. MARIE MICHIGAN

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
16.70	18.80	28.60	41.90	53.50	62.10
66.90	66.30	58.30	46.60	33.70	21.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SAULT STE. MARIE MICHIGAN
AND STATION LATITUDE = 46.68 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 50

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.68	1.68	1.81	2.26	2.88	3.13
	3.25	2.79	3.14	3.48	2.44	3.17
STD. DEVIATIONS	0.93	0.76	0.81	0.88	1.17	1.40
	1.60	1.29	1.83	1.72	1.12	1.20
RUNOFF						
TOTALS	0.436	0.969	5.132	2.495	0.663	0.176
	0.087	0.067	0.459	1.529	1.348	1.028
STD. DEVIATIONS	0.804	1.314	2.747	1.992	1.042	0.452
	0.252	0.235	0.913	1.683	1.103	1.071
EVAPOTRANSPIRATION						
TOTALS	0.296	0.270	0.292	0.924	3.214	3.325
	3.266	2.643	1.904	1.148	0.536	0.266
STD. DEVIATIONS	0.060	0.058	0.094	0.694	0.802	1.089
	1.352	1.262	0.686	0.241	0.171	0.066

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	0.0212	0.0193	0.0212	0.0206	0.0214	0.0167
	0.0065	0.0065	0.0108	0.0189	0.0209	0.0214
STD. DEVIATIONS	0.0000	0.0003	0.0000	0.0001	0.0003	0.0032
	0.0059	0.0065	0.0076	0.0052	0.0008	0.0002

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.9082	0.8444	0.8844	1.5373	2.3752	1.3421
	0.6720	0.6391	1.5813	3.7467	4.7740	2.0162
STD. DEVIATIONS	0.0507	0.0378	0.1444	0.7488	0.6792	0.7048
	0.7918	0.8208	1.6055	1.7305	1.2301	1.1750

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 50

	INCHES		CU. FEET	PERCENT
PRECIPITATION	32.71	(4.432)	118721.3	100.00
RUNOFF	14.390	(3.6957)	52234.45	43.998
EVAPOTRANSPIRATION	18.085	(2.2928)	65647.05	55.295
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.20536	(0.01534)	745.452	0.62790
AVERAGE HEAD ON TOP OF LAYER 2	1.777	(0.364)		
CHANGE IN WATER STORAGE	0.026	(2.1448)	94.38	0.079

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 50

	(INCHES)	(CU. FT.)
PRECIPITATION	2.75	9982.500
RUNOFF	5.224	18963.0430
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.000706	2.56448
AVERAGE HEAD ON TOP OF LAYER 2	6.000	
SNOW WATER	9.99	36246.1680

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4730

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1040

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FINAL WATER STORAGE AT END OF YEAR 50

LAYER	(INCHES)	(VOL/VOL)
1	2.8284	0.4714
2	54.1632	0.3472
SNOW WATER	1.574	

****
****

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Appendix D

Tailings Testing Results

D-1 Tailings Testing Results – Specific Gravity
D-2 Tailings Testing Results – Settling and Drying
D-3 Tailings Testing Results – Low-Stress Consolidation
D-4 Tailings Testing Results – Oedometer
D-5 Tailings Testing Results – Seepage Induced Consolidation (SIC) Testing Analyses

Appendix D-1

Tailings Testing Results – Specific Gravity

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Specific Gravity - Soil
ASTM D 854

Project	Copperwood	Project No.	DV101-00429/2
Date Staged	12/15/2010	Act. Code	300
Date Completed	12/18/2010	Lab No.	L2010-138
Tested By	db	Checked By	spb

Sample No.	WPC 2, Cycle 12		WPC 1, Cycle 12		WPC 1, Cycle 10		WPC-2, Cycle 10		WPC 1, Cycle 11	
Sample Prep. (Wet or Dry)	dry		dry		dry		dry		dry	
Flask No.	115		11		13		112		44	
1) Wt. of Flask + Soil										
2) Wt. of Flask										
3) Wt. of Soil (1-2)	35.01		35.11		35.35		35.27		36.08	
4) Calibrated Wt. of Flask + Water	352.57		353.47		364.39		346.66		354.95	
5) #3 + #4	387.58		388.58		399.74		381.93		391.03	
6) Wt. of Flask + Water + Soil	375.12		376.13		387.27		369.39		377.89	
7) Volume of Soil (5 - 6)	12.46		12.45		12.47		12.54		13.14	
8) Test Temperature, deg. C	21.5		21.4		21.5		21.5		21.5	
9) Temperature Correction, k	0.999679		0.999701		0.999679		0.999679		0.999679	
10) Specific Gravity ((3 / 7) * k)	2.809		2.819		2.834		2.812		2.745	
Reported Average, G_s @ 20 deg.C	2.81		2.82		2.83		2.81		2.74	
Tare	39		6		13		18		19	
Dry Soil + tare, g	145.99		148.48		151.24		153.44		154.10	
Tare, g	110.98		113.37		115.89		118.17		118.02	

General Notes: Line 9, k, is determined by dividing the density of water at test temperature recorded by the density of water at 20 deg. C.

Wet prep samples soaked overnight prior to application of vacuum.

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Specific Gravity - Soil
ASTM D 854

Project	Copperwood	Project No.	DV101-00429/2
Date Staged	2/1/2011	Act. Code	300
Date Completed	2/3/2011	Lab No.	L2010-138
Tested By	jk	Checked By	spb

Sample No.	WPC 2, Cycle 11		Comp 3, Test Zip 6, 7 & 8		WPC-3, 1/3		WPC, 2/3		WPC, 3/3	
Sample Prep. (Wet or Dry)	dry									
Flask No.	M3		42	116	116	113	2	112	4	11
1) Wt. of Flask + Soil										
2) Wt. of Flask										
3) Wt. of Soil (1-2)	35.54		44.76	45.07	32.47	32.55	32.07	32.28	32.84	32.44
4) Calibrated Wt. of Flask + Water	349.25		351.62	353.98	353.92	344.62	352.89	346.65	352.04	359.16
5) #3 + #4	384.79		396.38	399.05	386.39	377.17	384.96	378.93	384.88	391.60
6) Wt. of Flask + Water + Soil	372.03		380.35	383.04	374.89	365.60	373.56	367.49	372.99	380.16
7) Volume of Soil (5 - 6)	12.76		16.03	16.01	11.50	11.57	11.40	11.44	11.89	11.44
8) Test Temperature, deg. C	21.5		20.6	20.6	21.6	21.6	21.6	21.6	21.6	21.6
9) Temperature Correction, k	0.999679		0.999870	0.999870	0.999657	0.999657	0.999657	0.999657	0.999657	0.999657
10) Specific Gravity ((3 / 7) * k)	2.784		2.792	2.815	2.823	2.812	2.812	2.821	2.761	2.835
Reported Average, G_s @ 20 deg.C	2.78		2.80		2.82		2.82		2.80	
Tare	33		100	33	6	11	1	15	7	20
Dry Soil + tare, g	147.32		159.19	156.90	408.39	425.47	426.53	425.76	425.78	427.76
Tare, g	111.78		114.43	111.83	375.92	392.92	394.46	393.48	392.94	395.32

General Notes: Line 9, k, is determined by dividing the density of water at test temperature recorded by the density of water at 20 deg. C.

Wet prep samples soaked overnight prior to application of vacuum.

Knight Piésold
CONSULTING

Specific Gravity - Soil
ASTM D 854

Project	Copperwood	Project No.	DV101-00429/2
Date Staged	2/24/2011	Act. Code	300
Date Completed	2/27/2011	Lab No.	L2010-138
Tested By	jk	Checked By	spb

Sample No.	LP		CP		Conner Pit #2		WPC-4 Composite			
Sample Prep. (Wet or Dry)	dry		dry		dry					
Flask No.	1	42	112	116	2		116	11A		
1) Wt. of Flask + Soil										
2) Wt. of Flask										
3) Wt. of Soil (1-2)	33.22	33.97	32.34	33.70	34.06		34.84	34.74		
4) Calibrated Wt. of Flask + Water	352.65	351.48	346.67	353.94	352.91		354.10	359.40		
5) #3 + #4	385.87	385.45	379.01	387.64	386.97		388.94	394.14		
6) Wt. of Flask + Water + Soil	373.60	372.84	367.18	375.30	374.28		376.47	381.67		
7) Volume of Soil (5 - 6)	12.27	12.61	11.83	12.34	12.69		12.47	12.47		
8) Test Temperature, deg. C	21.3	21.4	21.3	21.3	21.3		20.5	20.5		
9) Temperature Correction, k	0.999724	0.999701	0.999724	0.999724	0.999724		0.999890	0.999890		
10) Specific Gravity ((3 / 7) * k)	2.707	2.693	2.733	2.730	2.683		2.794	2.786		
Reported Average, G_s @ 20 deg.C	2.70		2.73		2.68		2.79			
Tare	f	17	100	48	39		P10	P07		
Dry Soil + tare, g	179.06	182.40	146.66	230.33	144.94		150.91	147.48		
Tare, g	145.84	148.43	114.32	196.63	110.88		116.07	112.74		

General Notes: Line 9, k, is determined by dividing the density of water at test temperature recorded by the density of water at 20 deg. C.

Wet prep samples soaked overnight prior to application of vacuum.

Knight Piésold
CONSULTING

Specific Gravity - Soil
ASTM D 854

Project	Copperwood	Project No.	DV101-00429/2
Date Staged	4/19/2011	Act. Code	300
Date Completed	4/21/2011	Lab No.	L2011-22
Tested By	jk	Checked By	jdb

Sample No.	WPC-5, 2/4		WPC-5, 4/4							
Sample Prep. (Wet or Dry)	dry		dry		dry					
Flask No.	113		116							
1) Wt. of Flask + Soil										
2) Wt. of Flask										
3) Wt. of Soil (1-2)	31.77		31.29							
4) Calibrated Wt. of Flask + Water	344.70		354.00							
5) #3 + #4	376.47		385.29							
6) Wt. of Flask + Water + Soil	365.05		374.03							
7) Volume of Soil (5 - 6)	11.42		11.26							
8) Test Temperature, deg. C	20.2		20.2							
9) Temperature Correction, k	0.999956		0.999956							
10) Specific Gravity ((3 / 7) * k)	2.782		2.779							
Reported Average, G_s @ 20 deg.C										
Tare	J48		J16							
Dry Soil + tare, g	228.60		228.69							
Tare, g	196.83		197.4							

General Notes: Line 9, k, is determined by dividing the density of water at test temperature recorded by the density of water at 20 deg. C.

Wet prep samples soaked overnight prior to application of vacuum.

Knight Piésold CONSULTING

Appendix D-2

Tailings Testing Results – Settling and Drying

Knight Piésold CONSULTING	FLOW CONE VISCOSITY & SOLIDS CONTENT DETERMINATION	Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-1
	WPC-1 Composite (10,11,12	Location:	45% Solids
Test Date:	13-Jan-11 12:54 PM	Tested By:	jk/spb

FLOW CONE WATER DISCHARGE CALIBRATION

Trial No.	1.	2.	3.	Average
Time for complete water discharge (sec)	7.67	7.77	7.6	7.68

FLOW CONE TAILINGS DISCHARGE TESTS

Trial No.	1	2	3	
Time for tailings discharge (sec)				#DIV/0!

PERCENT SOLIDS AND MOISTURE CONTENT DETERMINATION

	Trial No.	1.	2.	3.	4.	Average
	Origin of Sample	Target WPC-1	Target	Target		
	Tare No.					
a.	Tare Weight (g)	419				
b.	Tare + Wet Sample Weight (g)	1513				
c.	Tare + Dry Sample Weight (g)	1170				
	Drying Time - From	6.27.06				
	- To	6.28.06				
d.	Moisture Loss [b-c] (g)	342.8				
e.	Dry Sample Weight [c-a] (g)	750.7				
	Initial Parameters from Previous Test					
f.	Tare (Cylinder or Beaker) Weight (g)	419				
g.	Tare + Initial Slurry Weight (g)	1513				
h.	Initial Slurry Weight (g)	1170				
i.	True Moisture Loss [h-e] (g)	419				
	PERCENT SOLIDS [e/h*100] (%)	64.2				
	MOISTURE CONTENT [i/e*100] (%)	55.9				

Comments:

64.2

Solids content percentages reported in trials 1, 2 & 3 will vary slightly for each specific test.

Knight Piésold CONSULTING

UNDRAINED SETTLING TEST

Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-1	Test Date:	1/13 - 1/29/11
	WPC-1 Composite (10,11,1	Location:	45% Solids	Tested By:	jdb

Initial Parameters

a. Cylinder (Tare) Weight =	219	g	d. Moisture Content (from drying test) =	**119.7**	%
b. Initial Slurry Volume =	885	ml	e. Initial Slurry Bulk Density [(c-a)/b] =	1.37	g/cm³
c. Tare + Initial Slurry Weight =	1436	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	663	g
Time of Readings 13-Jan-11	11:50 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	554	g

On-going Readings

			A.	B.	C.	D.	E.	F.	G.	H.
	Date of Reading	Time of Reading	Total Cylinder Weight (g)	Total Cylinder Volume (ml)	Settled Slurry Volume (ml)	Water Recovery [(B-C)/f] (%)	Volume Reduction of Solids [1-C/b] (%)	Slurry Bulk Density [(A-a-(B-C))/C] (g/cm³)	Slurry Dry Density [g/C] (g/cm³)	Moisture Content [(f-(B-C))/g] (%)
1.	13-Jan-11	12:57 PM	1437	875	875	0	1	1.39	0.63	119.73
2.	13-Jan-11	04:22 PM	1437	875	870	1	2	1.39	0.64	118.82
3.	14-Jan-11	10:25 AM	1437	875	850	4	4	1.40	0.65	115.21
4.	14-Jan-11	04:14 PM	1437	875	840	5	5	1.41	0.66	113.41
5.	15-Jan-11	10:28 AM	1437	875	822	8	7	1.42	0.67	110.16
6.	17-Jan-11	07:56 AM	1437	870	785	13	11	1.44	0.71	104.38
7.	18-Jan-11	07:47 AM	1436	870	770	15	13	1.45	0.72	101.67
8.	19-Jan-11	08:44 AM	1436	865	760	16	14	1.46	0.73	100.77
9.	20-Jan-11	11:49 AM	1437	865	745	18	16	1.47	0.74	98.06
10.	21-Jan-11	10:36 AM	1436	860	740	18	16	1.48	0.75	98.06
11.	22-Jan-11	12:00 PM	1436	860	732	19	17	1.49	0.76	96.61
11.	24-Jan-11	10:23 AM	1436	860	725	20	18	1.49	0.76	95.35
11.	25-Jan-11	09:52 AM	1436	860	720	21	19	1.50	0.77	94.45
11.	26-Jan-11	09:45 AM	1436	860	720	21	19	1.50	0.77	94.45
11.	27-Jan-11	08:45 AM	1436	860	720	21	19	1.50	0.77	94.45
11.	28-Jan-11	10:34 AM	1436	860	720	21	19	1.50	0.77	94.45

Knight Piésold CONSULTING

DRAINED SETTLING TEST AND FALLING HEAD PERMEABILITY TEST

Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-1	Test Date:	1/13 - 2/15/11
	WPC-1 Composite (10,11,12)	Location:	45% Solids	Tested By:	jk

Initial Parameters

a. Cylinder (Tare) Weight =	214	g	d. Moisture Content (from drying test) =	**121.5**	%
b. Initial Slurry Volume =	778	ml	e. Initial Slurry Bulk Density [(c-a)/b] =	1.41	g/cm³
c. Tare + Initial Slurry Weight =	1310	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	602	g
Time of Readings 13-Jan-11	11:52 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	495	g

On-going Readings

	Date of Reading	Time of Reading	A. Total Cylinder Weight (before decant) (g)	B. Total Cylinder Volume (ml)	C. Settled Slurry Volume (ml)	D. Water Volume [B-C] (ml)	E. Drainage Volume Collected (ml)	F. Decanted Water Volume (ml)	G. Slurry Bulk Density [(A-a-(B-C))/C] (g/cm³)	H. Slurry Dry Density [g/C] (g/cm³)
1.	13-Jan-11	12:56 PM	1301	770	770	0	9	0	1.41	0.64
2.	13-Jan-11	04:21 PM	1285	750	750	0	25	0	1.43	0.66
3.	14-Jan-11	10:23 AM	1245	710	690	20	65	17	1.47	0.72
4.	14-Jan-11	04:12 PM	1220	690	680	10	74	7	1.47	0.73
5.	15-Jan-11	10:26 AM	1191	660	640	20	96	10	1.50	0.77
6.	17-Jan-11	07:55 AM	1152	610	600	10	125	18	1.55	0.83
7.	18-Jan-11	07:46 AM	1122	590	590	0	136	0	1.54	0.84
8.	19-Jan-11	08:42 AM	1112	580	580	0	146	0	1.55	0.85
9.	20-Jan-11	11:48 AM	1103	570	570	0	156	0	1.56	0.87
10	21-Jan-11	10:34 AM	1096	565	565	0	162	0	1.56	0.88
11	22-Jan-11	12:00 PM	1091	560	560	0	168	0	1.57	0.88
12	24-Jan-11	10:20 AM	1087	555	555	0	172	0	1.57	0.89
13	25-Jan-11	09:50 AM	1084	550	550	0	174	0	1.58	0.90

Falling Head Permeability Test

	Data Readings, Ti (hours)	Initial Water Height, hi (cm)	Initial Solids Height, Hi (cm)	Finishing Time, Tf (hours)	Final Water Height, hf (cm)	Final Solids Height, Hf (cm)	Drainage Collected (ml)	Elapsed Time, T (hours)	Ave. Solids Thickness, H (cm)	Permeability k H/3600T*ln(hi/hf) (cm/sec)
1.	0.00	38.4	20.1	23.08	37.8	20.0	12	23.08	20.1	3.8E-06
2.	0.00	37.8	20.0	25.80	37.3	20.0	12	25.80	20.0	2.9E-06
3.	0.00	37.3	20.0	70.70	35.9	20.0	33	70.70	20.0	3.0E-06
4.	0.00	35.9	20.0	23.28	35.5	19.9	10	23.28	20.0	2.7E-06
5.	0.00	35.5	19.9	26.20	34.9	19.9	19	26.20	19.9	3.6E-06
6.	0.00	34.4	19.9	22.67	34.0	19.9	6	22.67	19.9	2.9E-06
									AVG.	3.1E-06

Knight Piésold CONSULTING

SETTLING AND DRYING TEST
(including Evaporation Control)

Project No. DV101-429/2

Project: Copperwood
WPC-1 Composite (10,11,12)

Sample No.: WPC-1
Location: 45% Solids

Test Date: 1/13 - 2/16/11
Tested By: jk

Initial Parameters for Settling and Drying Test

a.	Beaker (Tare) Weight =	389.73	g	d. Moisture Content (from drying test) =	**119.4**	%	
b.	Initial Slurry Volume =	775	cm³	e. Initial Slurry Bulk Density [(c-a)/b] =	1.45	g/cm³	
c.	Tare + Initial Slurry Weight =	1509.8	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	610	g	
	Time of Readings	13-Jan-11 11:51 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	510	g	
				h. Tailings Solids Specific Gravity =	2.80		
				i. Solids Volume [g/h] =	182.3	cm³	

Initial Parameters for Evaporation Control

x.	Beaker Tare Weight =	402	g
y.	Initial Weight of Beaker =	1417	g
z.	Beaker Cross-Sectional Area =	83.00	cm²

On-going Readings

			A.	B.	C.	D.	E.	F.	G.	H.	I.	J.		Evaporation Control		
	Date of Reading	Time of Reading	Total Remaining Weight (g)	Total Remaining Volume (cm³)	Settled Slurry Volume (cm³)	Decanted Water Volume (if any) (cm³)	Shrinkage Crack Volume (estimated) (cm³)	Net. Slurry Volume [C-E] (cm³)	Volume Reduction [(b-F)/b] (%)	Slurry Dry Density [g/F] (g/cm³)	Moisture Content [(A-a)/g]-1 (%)	Saturation (A-a-g)/(B-i) (%)	Comments	Total Weight After Decant (g)	Decanted Weight (if any) (g)	Evap. (mm)
1	13-Jan-11	12:55 PM	1509	775	750	0.0		750.0	3.2	0.68	119.3	100.0		1416	0	0
2	13-Jan-11	4:20 PM	1507	775	750	0.0		750.0	3.2	0.68	118.9	100.0		1414	0	0
3	14-Jan-11	10:20 AM	1495	750	710	35.1		710.0	8.4	0.72	116.5	100.0	Water Decanted	1398	0	2
4	14-Jan-11	4:20 PM	1457	725	700	9.8		700.0	9.7	0.73	109.0	100.0	Water Decanted	1394	0	3
5	15-Jan-11	10:00 AM	1435	700	675	18.0		675.0	12.9	0.76	104.8	100.0	Water Decanted	1378	0	5
6	17-Jan-11	8:00 AM	1387	650	650			650.0	16.1	0.79	95.4	100.0		1342	0	9
7	18-Jan-11	8:00 AM	1373	640	640			640.0	17.4	0.80	92.7	100.0		1324	0	11
8	19-Jan-11	8:30 AM	1358	620	620			620.0	20.0	0.82	89.8	100.0		1305	0	13
9	20-Jan-11	11:27 AM	1342	600	600			600.0	22.6	0.85	86.6	100.0		1285	0	16
10	21-Jan-11	10:30 AM	1328	595	595			595.0	23.2	0.86	83.8	100.0		1267	0	18
11	23-Jan-11	5:35 PM	1290	595	595		38	557.1	28.1	0.92	76.4	100.0	Measured in jar	1219	0	24
12	24-Jan-11	10:15 AM	1279	593	593		64	528.8	31.8	0.97	74.2	100.0	Measured in jar	1206	0	25
13	25-Jan-11	9:30 AM	1264	579	579		79	500.6	35.4	1.02	71.2	100.0	Measured in jar	1187	0	28
14	26-Jan-11	9:34 AM	1249	562	562		86	476.4	38.5	1.07	68.3	100.0	Measured in jar	1168	0	30
15	27-Jan-11	8:30 AM	1233	549	549		106	442.2	42.9	1.15	65.3	100.0	Measured in jar	1150	0	32
16	28-Jan-11	10:30 AM	1217	530	530		107	423.1	45.4	1.21	62.1	100.0	Measured in jar	1130	0	35
17	31-Jan-11	9:00 AM	1173	524	524		114	409.9	47.1	1.25	53.4	100.0	Measured in jar	1072	0	42
18	01-Feb-11	8:30 AM	1158	510	510		117	392.6	49.3	1.30	50.5	100.0	Measured in jar	1053	0	44
19	02-Feb-11	10:30 AM	1141	500	500		118	381.8	50.7	1.34	47.2	100.0	Measured in jar	1030	0	47
20	03-Feb-11	9:34 AM	1126	497	497		118	379.4	51.1	1.35	44.3	100.0	Measured in jar	1011	0	49
21	04-Feb-11	11:00 AM	1110	493	493		119	374.0	51.7	1.36	41.1	100.0	Measured specimen	989	0	52
22	07-Feb-11	11:39 AM	1065	473	473		116	357.7	53.8	1.43	32.2	93.8	Measured specimen	932	0	58
23	08-Feb-11	11:00 AM	1050	472	472		117	354.6	54.2	1.44	29.3	86.9	Measured specimen	913	0	61
24	09-Feb-11	10:00 AM	1035	471	471		117	353.5	54.4	1.44	26.5	78.9	Measured specimen	895	0	63
25	16-Feb-11	7:30 AM	940	470	470		118	352.3	54.5	1.45	7.9	23.7	Measured specimen	776	0	77

Notes:

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COPPERWOOD

SUMMARY OF TAILINGS SEDIMENTATION TEST RESULTS

TAILINGS COMPOSITE

Undrained Settling Test				Drained Settling Test					Settling and Drying Test			Additional
Solids Content (%)	Slurry Dry Density (g/cm³)	Total Water Recovery (%)	Portion of Initial Water Retained in Tailings prior to Onset of Evaporation (%)	Solids Content (%)	Slurry Dry Density (g/cm³)	Total Water Recovery (%)	Portion of Initial Water Retained in Tailings prior to Onset of Evaporation (%)	Average Permeability (cm/sec)	Solids Content (%)	Slurry Dry Density (g/cm³)	Total Evaporation (mm)	Water Recovered in Drained Test (%)
45.5	0.77	21.1	78.9	45.1	0.90	37.6	62.4	3.1E-06	45.6	1.45	77.2	16.4

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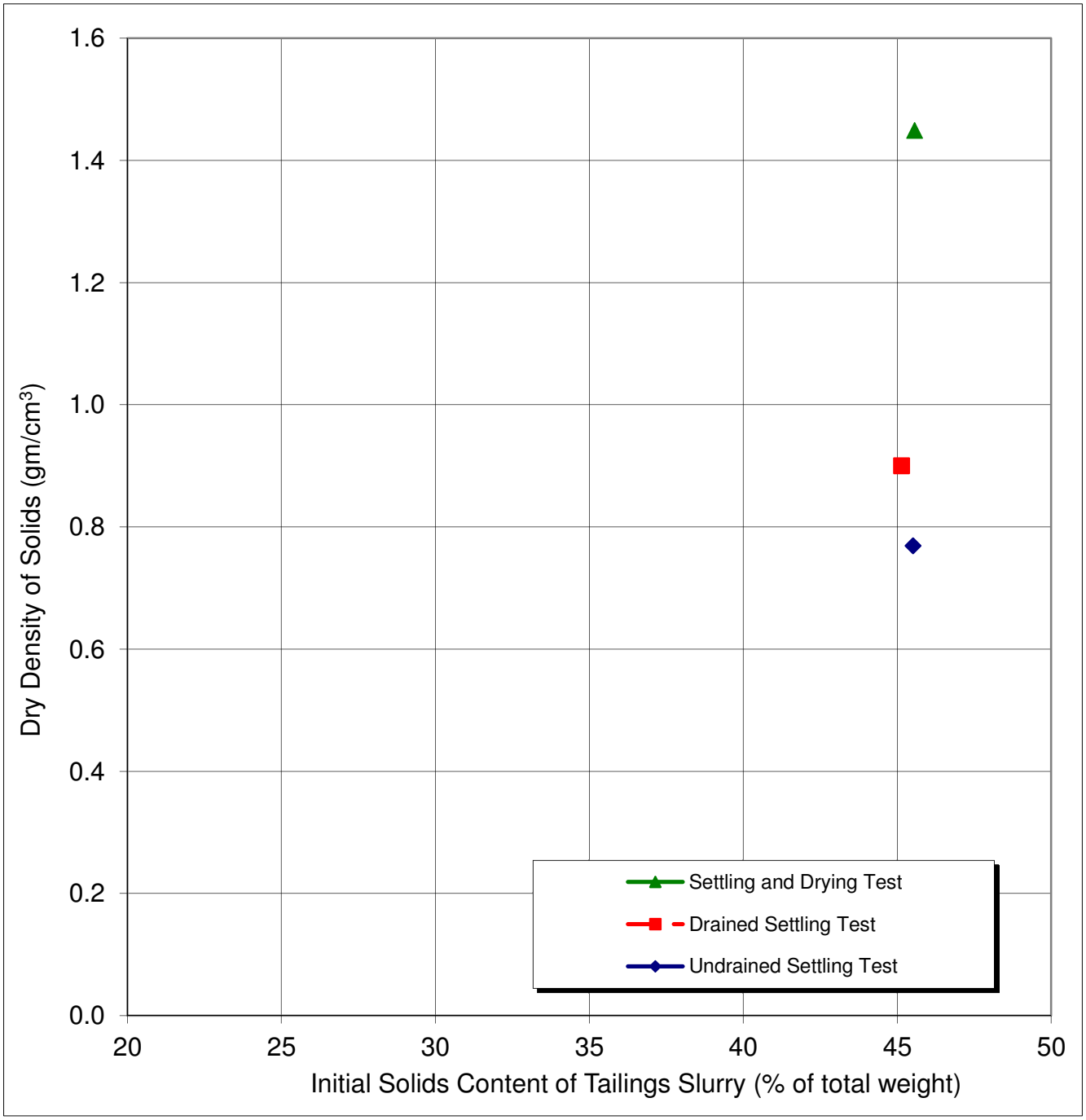
COPPERWOOD

TAILINGS DEPOSITION METHOD VS. DRY DENSITY
TAILINGS COMPOSITE



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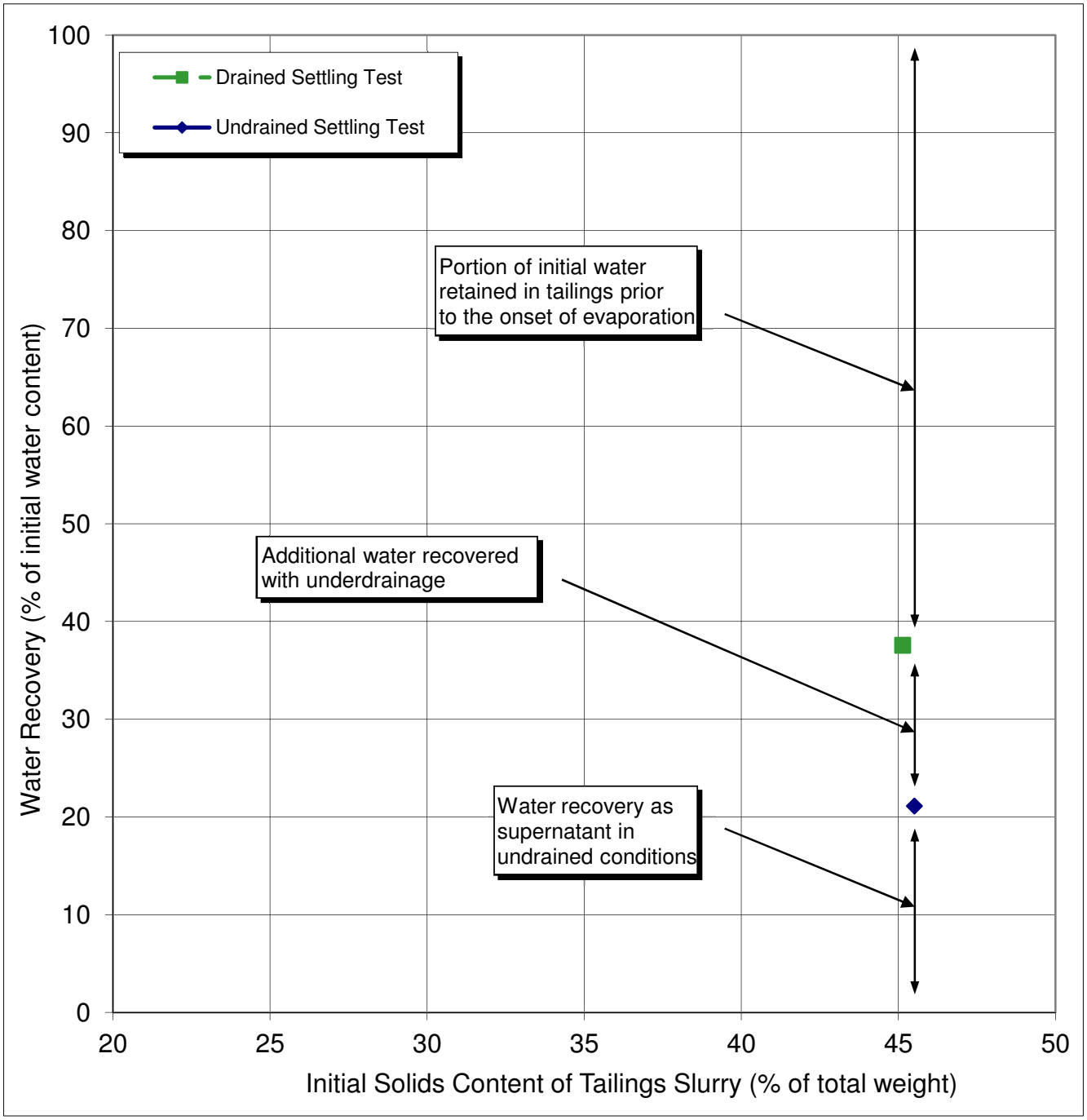
TAILINGS DEPOSITION METHOD VS. WATER RECOVERY
TAILINGS COMPOSITE



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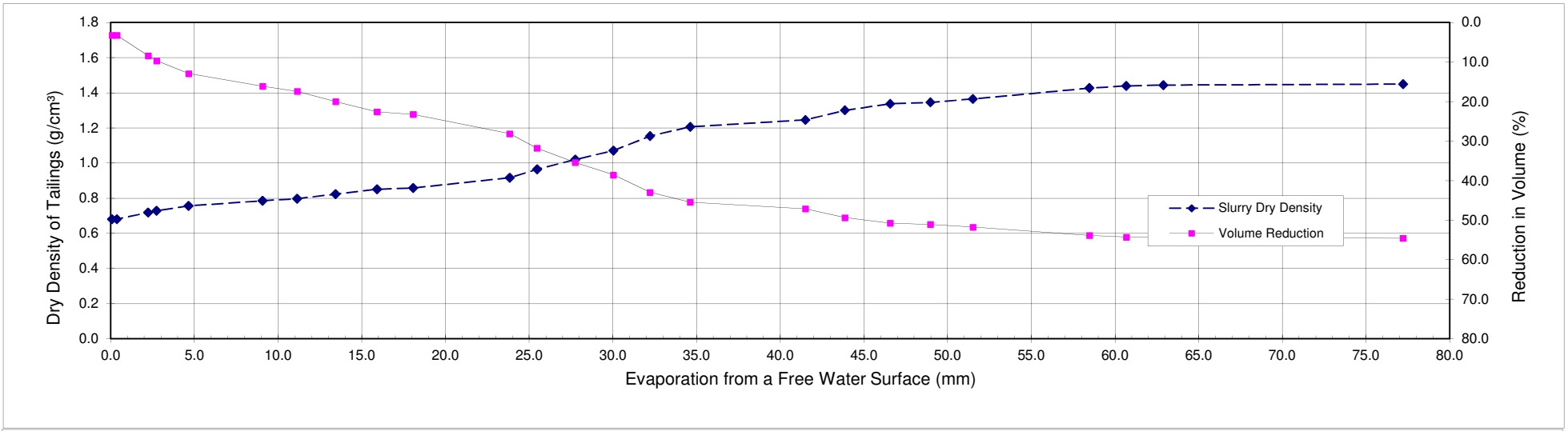
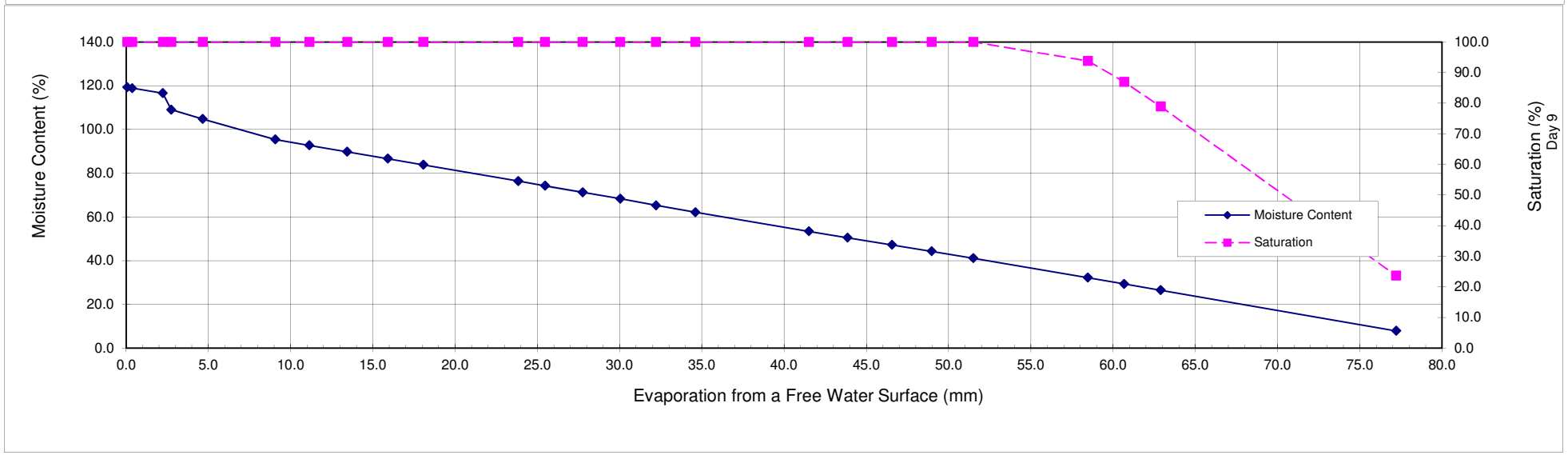
COPPERWOOD

VARIATION OF TAILINGS PARAMETERS WITH ONGOING EVAPORATION
WPC-1





Knight Piésold CONSULTING	FLOW CONE VISCOSITY & SOLIDS CONTENT DETERMINATION	Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-4
	WPC-4 Composite	Location:	50% Solids
Test Date:	14-Mar-11	Tested By:	jk/jdb

FLOW CONE WATER DISCHARGE CALIBRATION

Trial No.	1.	2.	3.	Average
Time for complete water discharge (sec)				#DIV/0!

FLOW CONE TAILINGS DISCHARGE TESTS

Trial No.	1	2	3	
Time for tailings discharge (sec)				#DIV/0!

PERCENT SOLIDS AND MOISTURE CONTENT DETERMINATION

	Trial No.	1.	2.	3.	4.	Average
	Origin of Sample	Target WPC-4	Target	Target		
	Tare No.					
a.	Tare Weight (g)	144				
b.	Tare + Wet Sample Weight (g)	498				
c.	Tare + Dry Sample Weight (g)	321				
	Drying Time - From	14-Mar-11				
	- To	15-Mar-11				
d.	Moisture Loss [b-c] (g)	176.6				
e.	Dry Sample Weight [c-a] (g)	177				
	Initial Parameters from Previous Test					
f.	Tare (Cylinder or Beaker) Weight (g)	144				
g.	Tare + Initial Slurry Weight (g)	498				
h.	Initial Slurry Weight (g)	354				
i.	True Moisture Loss [h-e] (g)	177				
	PERCENT SOLIDS [e/h*100] (%)	50.1				
	MOISTURE CONTENT [i/e*100] (%)	99.8				

Comments:

50.1

Solids content percentages reported in trials 1, 2 & 3 will vary slightly for each specific test.

Knight Piésold CONSULTING

UNDRAINED SETTLING TEST

Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-4	Test Date:	3/15-4/15/11
	WPC-4 Composite	Location:	50% Solids	Tested By:	jhk

Initial Parameters

a. Cylinder (Tare) Weight =	184	g	d. Moisture Content (from drying test) =	**99.6**	%
b. Initial Slurry Volume =	700	ml	e. Initial Slurry Bulk Density [(c-a)/b] =	1.46	g/cm³
c. Tare + Initial Slurry Weight =	1203	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	508	g
Time of Readings 15-Mar-11	10:50 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	511	g

On-going Readings

			A.	B.	C.	D.	E.	F.	G.	H.
	Date of Reading	Time of Reading	Total Cylinder Weight (g)	Total Cylinder Volume (ml)	Settled Slurry Volume (ml)	Water Recovery [(B-C)/f] (%)	Volume Reduction of Solids [1-C/b] (%)	Slurry Bulk Density [(A-a-(B-C))/C] (g/cm³)	Slurry Dry Density [g/C] (g/cm³)	Moisture Content [(f-(B-C))/g] (%)
1.	15-Mar-11	12:12 PM	1203	700	698	0	0	1.46	0.73	99.17
2.	15-Mar-11	01:32 PM	1203	700	693	1	1	1.46	0.74	98.19
3.	15-Mar-11	04:58 PM	1203	700	690	2	1	1.46	0.74	97.61
4.	16-Mar-11	10:33 AM	1203	695	680	3	3	1.48	0.75	96.63
5.	16-Mar-11	04:11 PM	1203	695	675	4	4	1.48	0.76	95.65
6.	17-Mar-11	11:30 AM	1203	695	660	7	6	1.49	0.77	92.71
7.	17-Mar-11	04:16 PM	1203	695	660	7	6	1.49	0.77	92.71
8.	18-Mar-11	10:59 AM	1203	695	650	9	7	1.50	0.79	90.75
9.	19-Mar-11	12:30 PM	1203	695	640	11	9	1.51	0.80	88.80
10.	21-Mar-11	10:10 AM	1203	695	620	15	11	1.52	0.82	84.88
11.	22-Mar-11	10:15 AM	1202	695	615	16	12	1.53	0.83	83.90
12	23-Mar-11	08:00 AM	1202	695	610	17	13	1.53	0.84	82.92
13	24-Mar-11	11:36 AM	1202	695	610	17	13	1.53	0.84	82.92
14	25-Mar-11	10:39 AM	1202	695	600	19	14	1.54	0.85	80.96
15	28-Mar-11	09:01 AM	1202	690	600	18	14	1.55	0.85	81.94
###	29-Mar-11	10:55 AM	1202	690	600	18	14	1.55	0.85	81.94
18	30-Mar-11	11:27 AM	1202	690	600	18	14	1.55	0.85	81.94
19	02-Apr-11	11:30 AM	1201	690	595	19	15	1.55	0.86	80.96
20	04-Apr-11	08:45 AM	1201	690	595	19	15	1.55	0.86	80.96
21	08-Apr-11	10:39 AM	1200	690	592	19	15	1.55	0.86	80.38
22	11-Apr-11	07:11 AM	1200	690	592	19	15	1.55	0.86	80.38
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DRAINED SETTLING TEST AND FALLING HEAD PERMEABILITY TEST

Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-4	Test Date:	3/15-4/15/11
	WPC-4 Composite	Location:	50% Solids	Tested By:	jk

Initial Parameters

a. Cylinder (Tare) Weight =	187	g	d. Moisture Content (from drying test) =	**99.5**	%
b. Initial Slurry Volume =	670	ml	e. Initial Slurry Bulk Density [(c-a)/b] =	1.46	g/cm³
c. Tare + Initial Slurry Weight =	1166	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	488	g
Time of Readings 15-Mar-11	10:57 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	491	g

On-going Readings

			A.	B.	C.	D.	E.	F.	G.	H.
	Date of Reading	Time of Reading	Total Cylinder Weight (before decant) (g)	Total Cylinder Volume (ml)	Settled Slurry Volume (ml)	Water Volume [B-C] (ml)	Drainage Volume Collected (ml)	Decanted Water Volume (ml)	Slurry Bulk Density [(A-a-(B-C))/C] (g/cm³)	Slurry Dry Density [g/C] (g/cm³)
1.	15-Mar-11	11:24 AM	1160	667	667	0	6	0	1.46	0.74
2.	15-Mar-11	12:12 PM	1154	655	655	0	11	0	1.48	0.75
3.	15-Mar-11	01:32 PM	1148	655	650	5	18	0	1.47	0.75
4.	15-Mar-11	03:23 PM	1141	650	640	10	25	0	1.47	0.77
5.	15-Mar-11	04:58 PM	1136	640	635	5	29	0	1.49	0.77
6.	16-Mar-11	10:40 AM	1109	610	595	15	57	12	1.52	0.82
7.	16-Mar-11	04:12 PM	1091	590	585	5	63	0	1.54	0.84
8.	17-Mar-11	11:33 AM	1075	575	560	15	79	12	1.56	0.88
9.	17-Mar-11	04:16 PM	1060	560	550	10	82	6	1.57	0.89
10	18-Mar-11	11:06 AM	1043	545	530	15	92	7	1.59	0.93
11	19-Mar-11	12:30 PM	1026	528	522	6	116	0	1.59	0.94
12	21-Mar-11	10:30 AM	1010	510	510	0	126	0	1.61	0.96
13	22-Mar-11	10:18 AM	1002	500	500	0	126	0	1.63	0.98
14	23-Mar-11	08:04 AM	998	500	500	0	131	0	1.62	0.98
15	24-Mar-11	11:34 AM	994	495	495	0	135	0	1.63	0.99
16	25-Mar-11	10:36 AM	991	492	492	0	137	0	1.63	1.00

Falling Head Permeability Test

	Data Readings, Ti (hours)	Initial Water Height, hi (cm)	Initial Solids Height, Hi (cm)	Finishing Time, Tf (hours)	Final Water Height, hf (cm)	Final Solids Height, Hf (cm)	Drainage Collected (ml)	Elapsed Time, T (hours)	Ave. Solids Thickness, H (cm)	Permeability k H/3600T*ln(hi/hf) (cm/sec)
1.	0.00	38.2	16.6	64.75	36.3	16.4	35	64.75	16.5	3.6E-06
2.	0.00	36.3	16.4	25.78	35.6	16.4	13	25.78	16.4	3.4E-06
3.	0.00	35.6	16.4	24.48	35.0	16.4	12	24.48	16.4	3.2E-06
4.	0.00	35.0	16.4	23.40	34.4	16.4	11	23.40	16.4	3.4E-06
5.	0.00	34.4	16.4	48.88	33.1	16.4	22	48.88	16.4	3.6E-06
6.	0.00	33.1	16.4	44.80	32.0	16.4	19	44.80	16.4	3.6E-06

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DRAINED SETTLING TEST AND FALLING HEAD PERMEABILITY TEST

Project No. DV101-429/2

Project:	Copperwood	Sample No.:	WPC-4	Test Date:	3/15-4/15/11
	WPC-4 Composite	Location:	50% Solids	Tested By:	jk

Initial Parameters

a. Cylinder (Tare) Weight =	187	g	d. Moisture Content (from drying test) =	**99.5**	%
b. Initial Slurry Volume =	670	ml	e. Initial Slurry Bulk Density [(c-a)/b] =	1.46	g/cm³
c. Tare + Initial Slurry Weight =	1166	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	488	g
Time of Readings 15-Mar-11	10:57 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	491	g

On-going Readings

			A.	B.	C.	D.	E.	F.	G.	H.
	Date of Reading	Time of Reading	Total Cylinder Weight (before decant) (g)	Total Cylinder Volume (ml)	Settled Slurry Volume (ml)	Water Volume [B-C] (ml)	Drainage Volume Collected (ml)	Decanted Water Volume (ml)	Slurry Bulk Density [(A-a-(B-C))/C] (g/cm³)	Slurry Dry Density [g/C] (g/cm³)
									AVG.	3.5E-06

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SETTLING AND DRYING TEST
(including Evaporation Control)

Project No. DV101-429/2

Project: Copperwood
WPC-4 Composite

Sample No.: WPC-4
Location: 50% Solids

Test Date: 3/15-4/18/11
Tested By: jhk

Initial Parameters for Settling and Drying Test

a.	Beaker (Tare) Weight =	398.07	g	d. Moisture Content (from drying test) =	**100.4**	%	
b.	Initial Slurry Volume =	675	cm³	e. Initial Slurry Bulk Density [(c-a)/b] =	1.44	g/cm³	
c.	Tare + Initial Slurry Weight =	1372	g	f. Weight of Water [(c-a)/(1+1/(d/100))] =	488	g	
	Time of Readings	15-Mar-11 10:47 AM		g. Weight of Solids [(c-a)/(1+d/100)] =	486	g	
				h. Tailings Solids Specific Gravity =	2.79		
				i. Solids Volume [g/h] =	174.2	cm³	

Initial Parameters for Evaporation Control

x.	Beaker Tare Weight =	400	g
y.	Initial Weight of Beaker =	1338	g
z.	Beaker Cross-Sectional Area =	85.28	cm²

On-going Readings

			A.	B.	C.	D.	E.	F.	G.	H.	I.	J.		Evaporation Control		
	Date of Reading	Time of Reading	Total Remaining Weight (g)	Total Remaining Volume (cm³)	Settled Slurry Volume (cm³)	Decanted Water Volume (if any) (cm³)	Shrinkage Crack Volume (estimated) (cm³)	Net. Slurry Volume [C-E] (cm³)	Volume Reduction [(b-F)/b] (%)	Slurry Dry Density [g/F] (g/cm³)	Moisture Content [(A-a)/g]-1 (%)	Saturation (A-a-g)/(B-i) (%)	Comments	Total Weight After Decant (g)	Decanted Weight (if any) (g)	Evap. (mm)
1	15-Mar-11	10:59 AM	1372	660	660	0.0		660.0	2.2	0.74	100.3	100.0		1338	0	0
2	15-Mar-11	11:21 AM	1370	660	655	0.0		655.0	3.0	0.74	100.0	100.0		1338	0	0
3	15-Mar-11	12:12 PM	1370	660	650	0.0		650.0	3.7	0.75	99.9	100.0		1336	0	0
4	15-Mar-11	1:32 PM	1369	655	650	0.0		650.0	3.7	0.75	99.7	100.0		1335	0	0
5	15-Mar-11	4:57 PM	1367	650	645	0.0		645.0	4.4	0.75	99.3	100.0		1332	0	1
6	16-Mar-11	10:30 AM	1358	625	615	21.2		615.0	8.9	0.79	97.4	100.0	Water Decanted	1319	0	2
7	16-Mar-11	4:10 PM	1333	600	610	5.6		610.0	9.6	0.80	92.4	100.0	Water Decanted	1315	0	3
8	17-Mar-11	11:29 AM	1316	600	590	11.4		590.0	12.6	0.82	88.9	100.0	Water Decanted	1298	0	5
9	17-Mar-11	4:16 PM	1302	590	585	0.0		585.0	13.3	0.83	86.0	100.0		1294	0	5
10	18-Mar-11	11:02 AM	1292	590	580	4.1		580.0	14.1	0.84	83.9	100.0	Water Decanted	1280	0	7
11	19-Mar-11	12:30 PM	1274	560	560			560.0	17.0	0.87	80.2	100.0		1261	0	9
12	21-Mar-11	10:25 AM	1249	540	540			540.0	20.0	0.90	75.0	99.6		1227	0	13
13	22-Mar-11	10:20 AM	1233	537	537			537.0	20.4	0.91	71.8	96.2		1206	0	16
14	23-Mar-11	7:57 AM	1219	530	530			530.0	21.5	0.92	68.9	94.1		1189	0	17
15	24-Mar-11	11:40 AM	1202		536		14	521.8	22.7	0.93	65.3	91.3	Pulling from sides	1167	0	20
16	25-Mar-11	10:42 AM	1187		528		22	505.6	25.1	0.96	62.3	91.3	Measured in jar	1149	0	22
17	28-Mar-11	8:55 AM	1148		517		38	479.4	29.0	1.01	54.2	86.4	Measured in jar	1101	0	28
18	29-Mar-11	11:04 AM	1135		500		42	458.0	32.1	1.06	51.6	88.3	Measured in jar	1083	0	30
19	30-Mar-11	10:54 AM	1121		492		47	444.8	34.1	1.09	48.7	87.5	Measured in jar	1066	0	32
20	31-Mar-11	10:50 AM	1108		482		50	431.9	36.0	1.13	46.1	86.9	Measured in jar	1048	0	34
21	02-Apr-11	11:30 AM	1081		475		63	411.4	39.1	1.18	40.6	83.2	Measured in jar	1014	0	38
22	04-Apr-11	8:29 AM	1057		461		71	390.6	42.1	1.24	35.6	79.9	Measured specimen	983	0	42
23	05-Apr-11	10:12 AM	1043		457		85	372.4	44.8	1.31	32.6	80.1	Measured specimen	965	0	44
24	06-Apr-11	12:20 PM	1027		451		97	354.0	47.6	1.37	29.4	79.5	Measured specimen	946	0	46
25	07-Apr-11	10:45 AM	1016		447		108	339.3	49.7	1.43	27.2	80.1	Measured specimen	932	0	48
26	08-Apr-11	10:43 AM	1005		443		113	330.8	51.0	1.47	24.8	77.0	Measured specimen	918	0	49
27	09-Apr-11	7:06 AM	970		441		131	309.5	54.2	1.57	17.6	63.2	Measured specimen	876	0	54
28	11-Apr-11	3:57 PM	952		440		134	306.0	54.7	1.59	13.9	51.3	Measured specimen	854	0	57
29	18-Apr-11	7:59 AM	901		439		134	304.7	54.9	1.60	3.4	12.5	Measured specimen	775	0	66
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SUMMARY OF TAILINGS SEDIMENTATION TEST RESULTS
WPC-4 TAILINGS COMPOSITE

Undrained Settling Test				Drained Settling Test					Settling and Drying Test			Additional
Solids Content (%)	Slurry Dry Density (g/cm³)	Total Water Recovery (%)	Portion of Initial Water Retained in Tailings prior to Onset of Evaporation (%)	Solids Content (%)	Slurry Dry Density (g/cm³)	Total Water Recovery (%)	Portion of Initial Water Retained in Tailings prior to Onset of Evaporation (%)	Average Permeability (cm/sec)	Solids Content (%)	Slurry Dry Density (g/cm³)	Total Evaporation (mm)	Water Recovered in Drained Test (%)
50.1	0.86	19.3	80.7	50.1	1.00	35.7	64.3	3.5E-06	49.9	1.60	66.0	16.4

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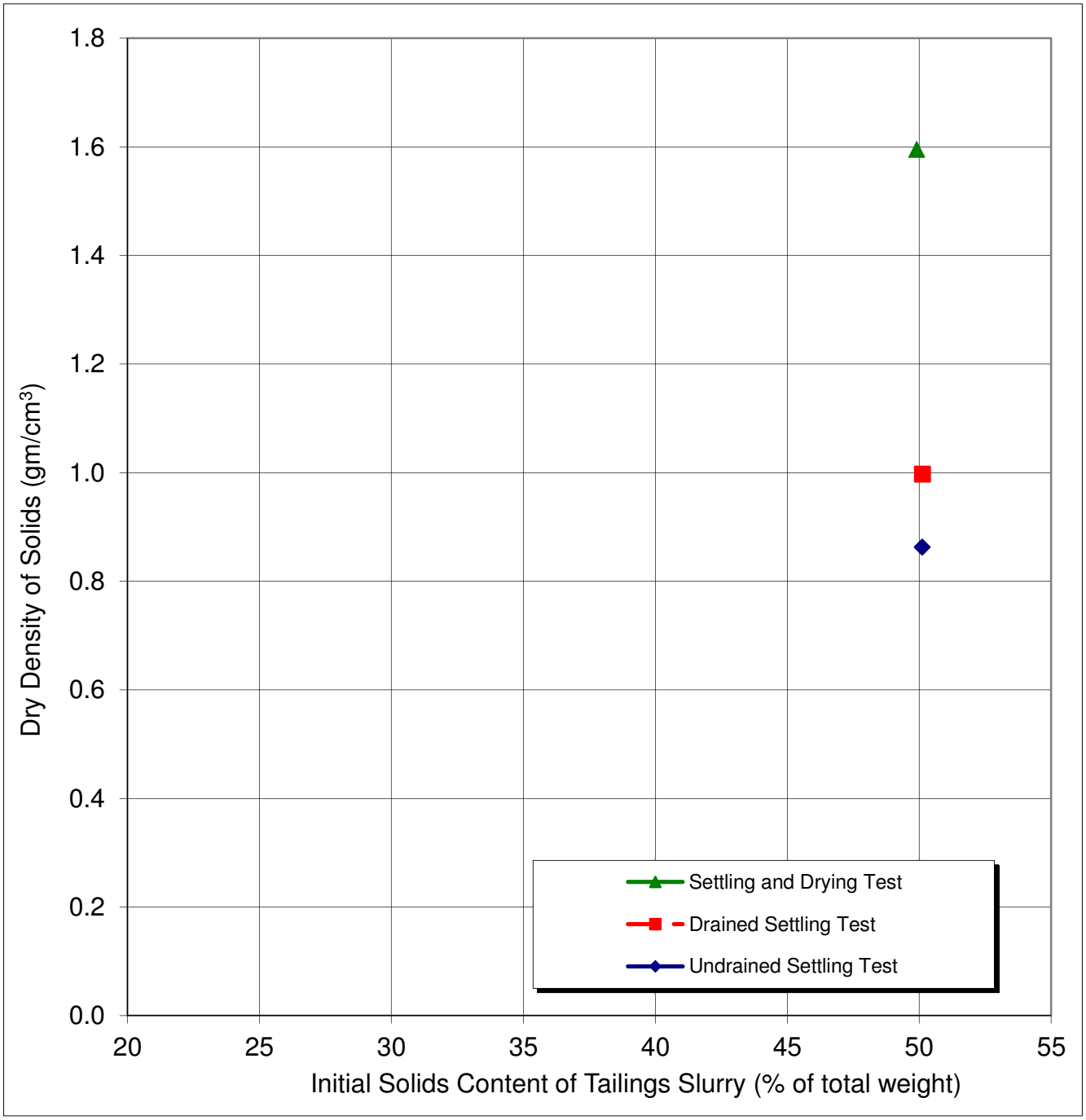
TAILINGS DEPOSITION METHOD VS. DRY DENSITY
WPC-4 TAILINGS COMPOSITE



G:\101\00429.02\Data Info\KP Lab Testing\AllLabTestingData\[Composite WPC-4 Tailings Density Tests Rev 0.xls]Graphs kgb 06-Jun-11 11:22 AM

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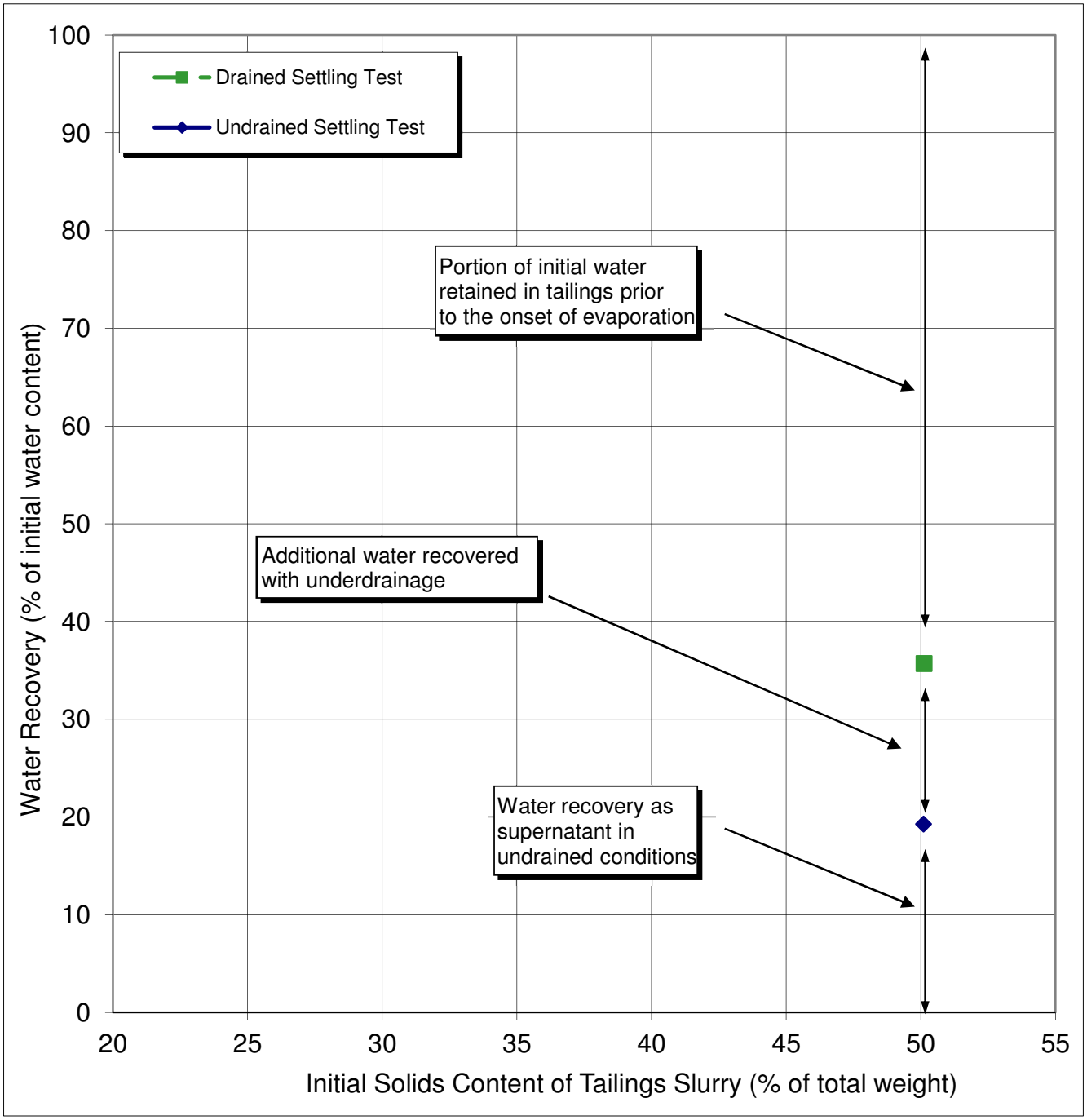
TAILINGS DEPOSITION METHOD VS. WATER RECOVERY
WPC-4 TAILINGS COMPOSITE



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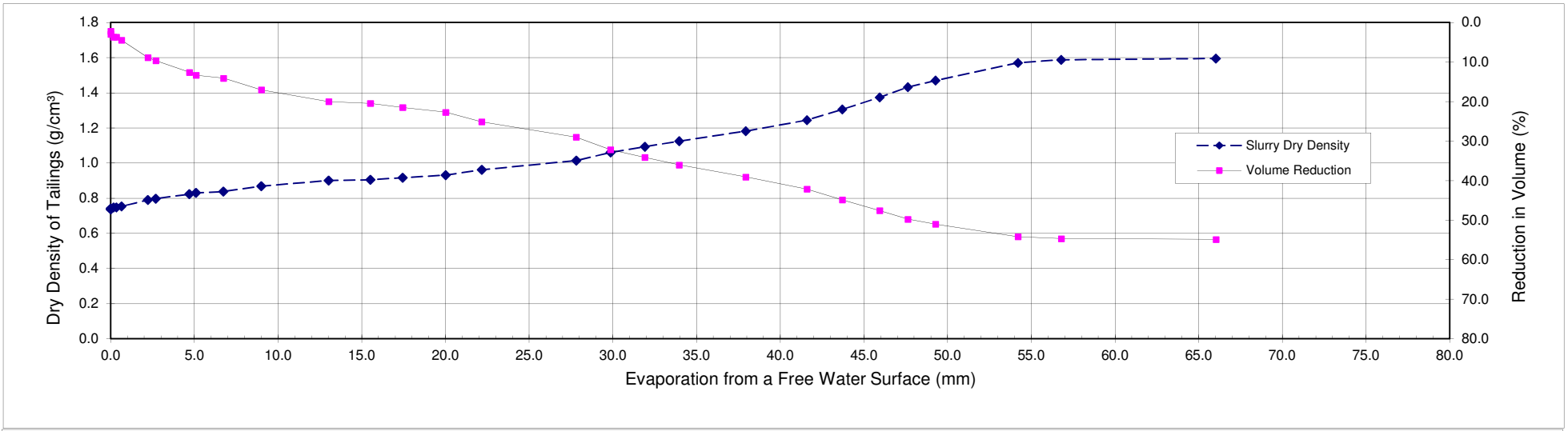
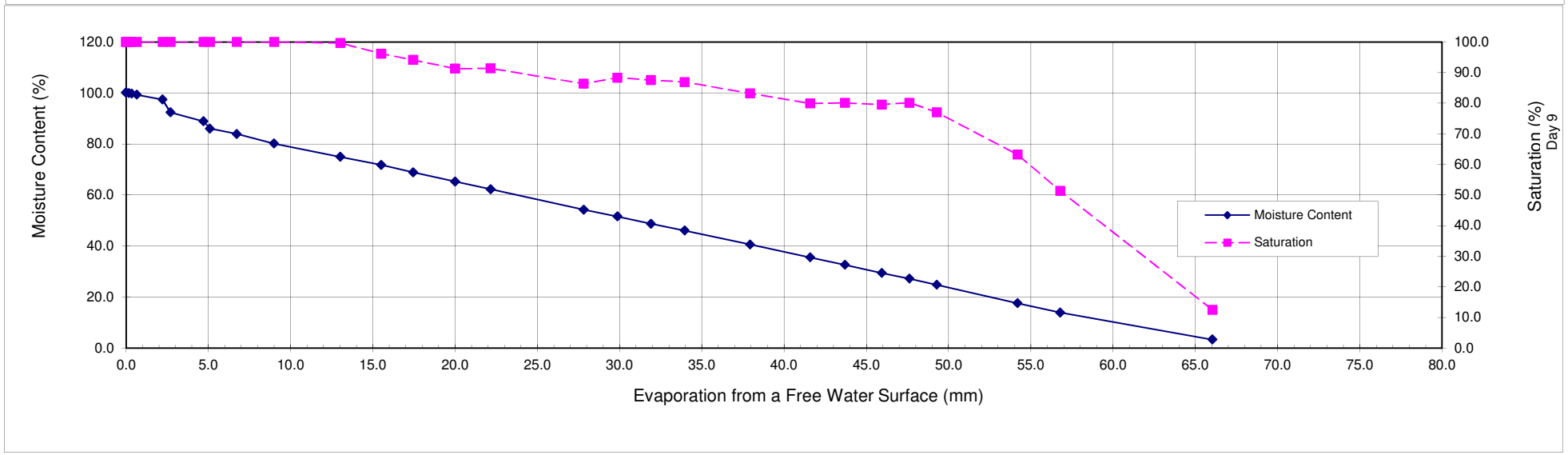
VARIATION OF TAILINGS PARAMETERS WITH ONGOING EVAPORATION
WPC-4





Appendix D-3

Tailings Testing Results – Low-Stress Consolidation

CONSOLIDATION TEST

PROJECT	:	Copperwood	DATE	:	7-Jul-10
SAMPLE	:	WPC-1	TESTED BY	:	jhk

* Weight of Container	:	0.0	PULP DENSITY	:	1.421
* Weight of Slurry + Container	:	1075.0	* S.G. SOLIDS	:	2.80
Weight of Slurry	:	1075.0	* S.G. LIQUOR	:	1.00
* Height to Bottom of Slurry	:	0.0	% WT. SOLIDS	:	46.08
* Height to Top of Slurry	:	279.0	Weight of Solids	:	495.3
Height of Slurry	:	279.0	Volume of water	:	579.7
* Internal dia. of Container	:	58.8			
Volume of Slurry	:	756.6			

BEFORE CONSOLIDATION			AFTER CONSOLIDATION			AFTER COMPLETE DRAINAGE		
* Settled Slurry Ht	:	213.0	* Settled Slurry Ht	:	182.0	* Settled Slurry Ht	:	NA
Ht of Water	:	66.0	Ht of Water	:	97.0	Ht of Water	:	279.0
Vol of Slurry	:	577.6	Vol of Slurry	:	493.5	Vol of Slurry	:	0.0
Vol of Water	:	179.0	Vol of Water	:	263.0	Vol of Water	:	756.6
Dry Density	:	0.858	Dry Density	:	1.004	Dry Density	:	#DIV/0!
Pulp Density	:	1.551	Pulp Density	:	1.645	Pulp Density	:	#DIV/0!
Void Ratio	:	2.265	Void Ratio	:	1.790	Void Ratio	:	#DIV/0!
Total Stress at Base	:	3.888	Total Stress at Base	:	3.888	Total Stress at Base	:	#DIV/0!
Eff. Stress at Base	:	1.152	Eff. Stress at Base	:	3.888	Eff. Stress at Base	:	#DIV/0!
Average Eff. Stress	:	0.576	Average Eff. Stress	:	1.944	Average Eff. Stress	:	#DIV/0!

DAY	TIME	ELAPSED TIME (hours)	(min)	(sec)	* SLURRY HEIGHT READING	SETTLEMENT OF SLURRY	* WEIGHT OF WATER & CONT	* WEIGHT OF CONT	VOLUME OF WATER	CUMUL. VOLUME OF WATER	HEIGHT OF SLURRY	VOLUME OF SLURRY	DRY DENSITY t/m^3	i VALUE (av ht)	PERMEABILITY (m/s)
16/03/10	09:41:00	<< START TIME		0	213.0	0.00	34.1	34.1	0.0	0.0	213.0	577.6	0.858		
16/03/10	09:41:06	0.00	0.10	6	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	0.000E+00
16/03/10	09:41:15	0.00	0.25	15	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	09:41:30	0.01	0.50	30	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	09:41:45	0.01	0.75	45	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	09:42:00	0.02	1.00	60	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	09:43:00	0.03	2.00	120	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	09:46:00	0.08	5.00	300	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	09:51:00	0.17	10.00	600	213.0	0.00	0.0	0.0	0.0	0.0	213.0	577.6	0.858	1.31	--
16/03/10	10:01:00	0.33	20.00	1200	212.5	0.50	0.0	0.0	0.0	0.0	212.5	576.3	0.860	1.31	--
16/03/10	10:11:00	0.50	30.00	1800	212.0	1.00	0.0	0.0	0.0	0.0	212.0	574.9	0.862	1.31	--
16/03/10	10:21:00	0.67	40.00	2400	212.0	1.00	0.0	0.0	0.0	0.0	212.0	574.9	0.862	1.32	--
16/03/10	10:31:00	0.83	50.00	3000	211.5	1.50	0.0	0.0	0.0	0.0	211.5	573.5	0.864	1.32	--
16/03/10	10:41:00	1.00	60.00	3600	211.0	2.00	0.0	0.0	0.0	0.0	211.0	572.2	0.866	1.32	--
16/03/10	11:11:00	1.50	90.00	5400	210.5	2.50	0.0	0.0	0.0	0.0	210.5	570.8	0.868	1.32	--
16/03/10	11:41:00	2.00	120.00	7200	210.0	3.00	0.0	0.0	0.0	0.0	210.0	569.5	0.870	1.33	--
16/03/10	12:41:00	3.00	180.00	10800	209.0	4.00	0.0	0.0	0.0	0.0	209.0	566.8	0.874	1.33	--
16/03/10	13:41:00	4.00	240.00	14400	208.0	5.00	0.0	0.0	0.0	0.0	208.0	564.0	0.878	1.34	--
16/03/10	14:41:00	5.00	300.00	18000	207.5	5.50	0.0	0.0	0.0	0.0	207.5	562.7	0.880	1.34	--
16/03/10	15:40:00	5.98	359.00	21540	207.0	6.00	0.0	0.0	0.0	0.0	207.0	561.3	0.882	1.35	--
16/03/10	16:42:00	7.02	421.00	25260	206.5	6.50	0.0	0.0	0.0	0.0	206.5	560.0	0.885	1.35	--
17/03/10	09:41:00	24.00	1440.00	86400	200.0	13.00	0.0	0.0	0.0	0.0	200.0	542.4	0.913	1.37	--
17/03/10	14:23:00	28.70	1722.00	103320	198.0	15.00	0.0	0.0	0.0	0.0	198.0	536.9	0.922	1.40	--
18/03/10	10:52:00	49.18	2951.00	177060	193.5	19.50	0.0	0.0	0.0	0.0	193.5	524.7	0.944	1.43	
19/03/10	11:20:00	73.65	4419.00	265140	189.0	24.00	0.0	0.0	0.0	0.0	189.0	512.5	0.966	1.46	
21/03/10	10:30:00	120.82	7249.00	434940	183.5	29.50	0.0	0.0	0.0	0.0	183.5	497.6	0.995	1.50	
22/03/10	10:22:00	144.68	8681.00	520860	182.0	31.00	0.0	0.0	0.0	0.0	182.0	493.5	1.004	1.53	
23/03/10	08:05:00	166.40	9984.00	599040	182.0	31.00	145.6	34.1	111.5	111.5	182.0	493.5	1.004	1.53	

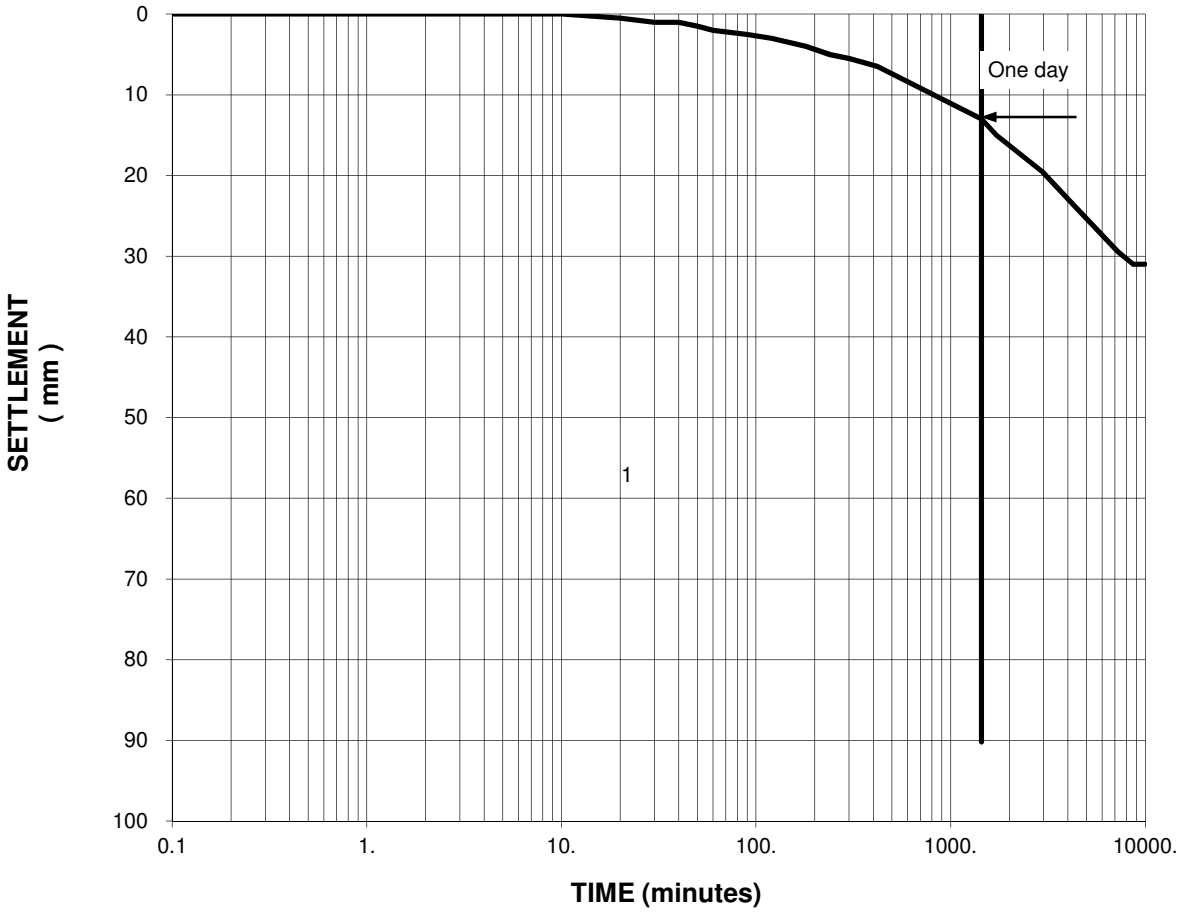
U value	Tv	Measured Value	ROW	X values	Y values	L values	H values	A	B	C	Time(h)	Cv	
													Mv
0.5	0.197	1.50	12	1.500	-0.079			0.194	-0.520	0.265	0.833	23.32	0.1064
				2.000	0.000	3.500	0.158						Kv
				2.500	0.176	4.000	0.255						9.025E-07
													Cc
0.6	0.287	1.80	12	1.500	-0.079			0.194	-0.520	0.265	0.905	31.24	0.8993
				2.000	0.000	3.500	0.158						
				2.500	0.176	4.000	0.255					27.28	

CONSOLIDATION TEST 1

ELAPSED TIME (minutes)	SETTLEMENT	PERMEABILITY m/s	DRY DENSITY t/m^3
0	0	0.000E+00	0.85752373
0.1	0	0.000E+00	0.85752373
0.25	0		0.85752373
0.5	0	--	0.85752373
0.75	0	--	0.85752373
1	0	--	0.85752373
2	0	--	0.85752373
5	0	--	0.85752373
10	0	--	0.85752373
20	0.5	--	0.85954143
30	1	--	0.86156865
40	1	--	0.86156865
50	1.5	--	0.86360546
60	2	--	0.86565192
90	2.5	--	0.8677081
120	3	--	0.86977407
180	4	--	0.87393567
240	5	--	0.87813728
300	5.5	--	0.88025327
359	6	--	0.88237949
421	6.5	--	0.884516
1440	13	--	0.91326277
1722	15	--	0.92248765
2951	19.5	0.000E+00	0.94394085
4419	24	0.000E+00	0.96641563
7249	29.5	0.000E+00	0.99538177
8681	31	0.000E+00	1.00358546
9984	31	0.000E+00	1.00358546

Cv	2.728E+01
Mv	1.064E-01
Kv	9.025E-07
Cc	8.993E-01

Figure X


0
10
20
30
40
50
60
70
80
90
100
SETTLEMENT
(mm)
0.1
1.
10.
100.
1000.
10000.
TIME (minutes)
One day
1

Appendix D-4

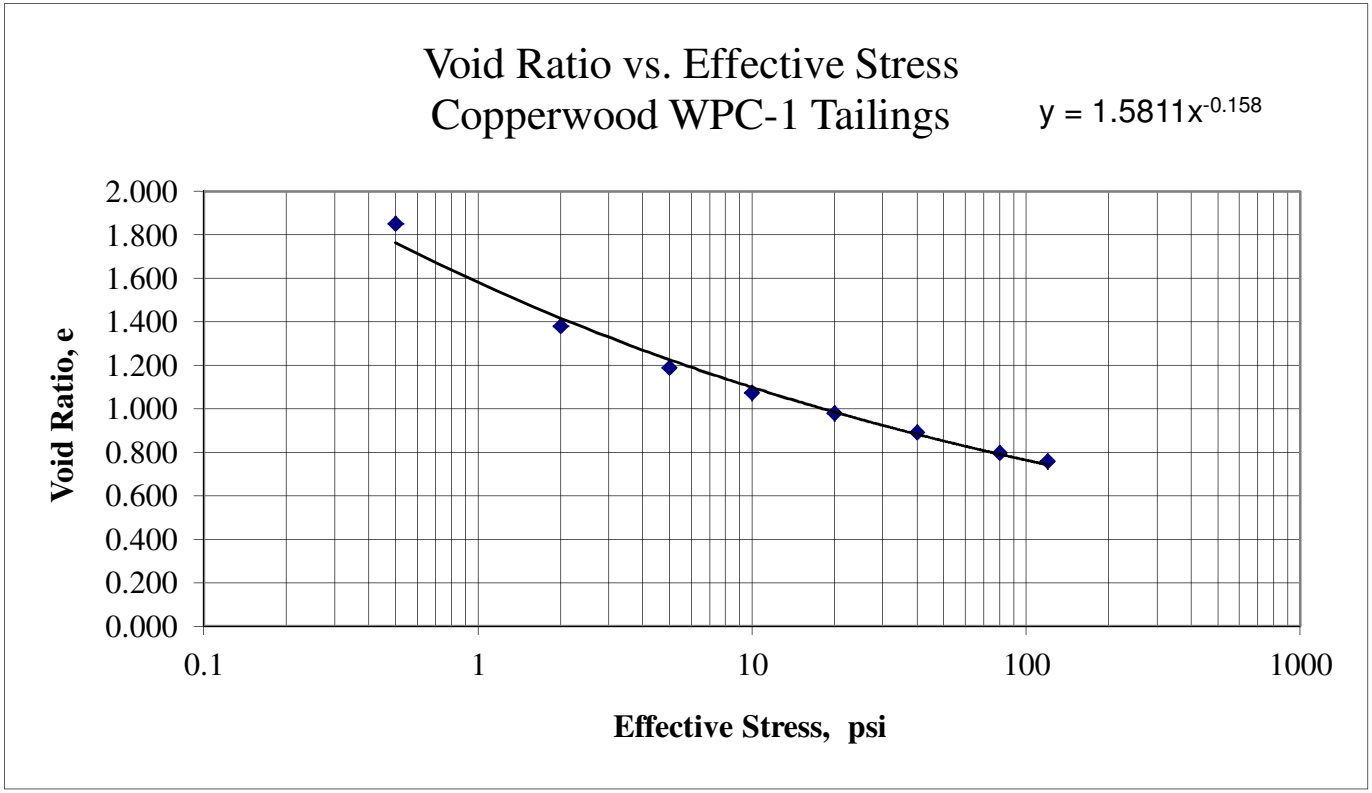
Tailings Testing Results – Oedometer

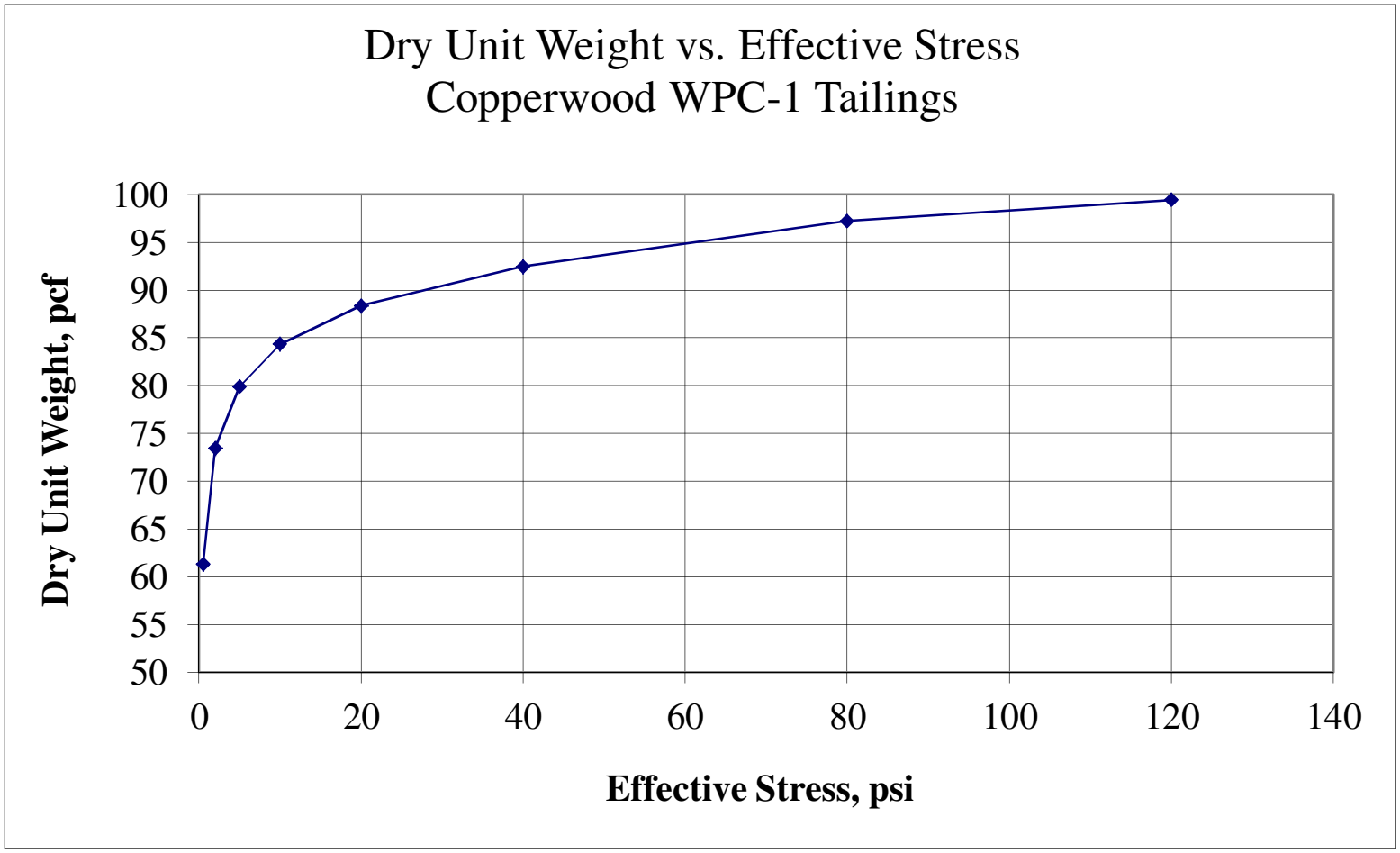
SLURRY CONSOLIDOMETER TEST RESULTS
COPPERWOOD
WPC-1 TAILINGS
DV101-429.02

		Consolidation Test Data - Double Ended Drainage								
STRESS	psi	Free	0.5	2	5	10	20	40	80	120
	psf		72	288	720	1440	2880	5760	11520	17280
	kPa		3	14	34	69	138	276	552	827
Volume Change, cc		279.5	6.9	87.9	35.5	21.6	17.5	16.3	17.3	7.4
Cumulative Volume Change, cc		279.5	286.4	374.3	409.8	431.4	448.9	465.2	482.5	489.9
Consolidated Slurry Volume, cm^3		537.4	530.5	442.6	407.1	385.5	368.0	351.7	334.4	327.0
Settled Void Ratio, e_c		1.889	1.852	1.379	1.189	1.072	0.978	0.891	0.798	0.758
Dry Unit Weight, pcf		60.5	61.3	73.5	79.9	84.3	88.4	92.5	97.2	99.4
Slurry Height, cm		6.446	6.364	5.309	4.883	4.624	4.414	4.219	4.011	3.922
Mean Slurry Height, H^2 mm			1025.6	851.6	649.3	564.9	510.6	465.8	423.3	393.4
Total Ht. Change, cm		3.353	3.436	4.490	4.916	5.175	5.385	5.581	5.788	5.877
Cumulative change in height, in.		1.320	1.353	1.768	1.935	2.037	2.120	2.197	2.279	2.314
Individual change in height, in.		1.320	0.033	0.415	0.168	0.102	0.083	0.077	0.082	0.035

SAMPLE PARAMETERS

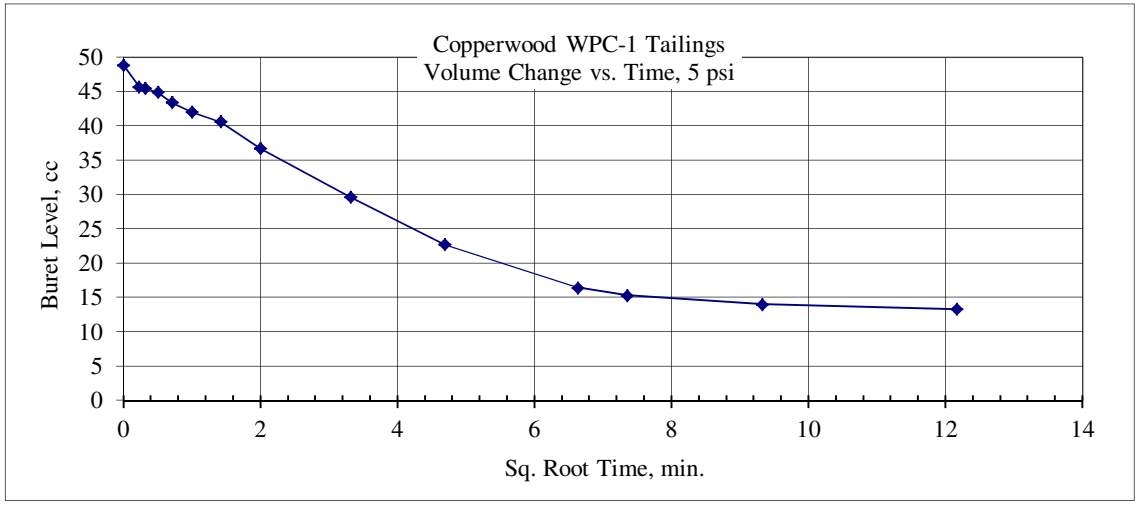
Specific Gravity	2.800		Ring Diameter (in./cm)	4.056	10.30
Slurry Mass w/tare, g	1408.60		Ring Area, cm^2		83.359
Tare, g	251.50		Ring Height (in./cm)	4.056	10.30
Slurry Mass, g	1157.10		Ring Volume, cm^3		858.79
Height of Slurry (in./cm)	3.858	9.80	**Post Test Specimen Data**		
Volume of Slurry, cc		816.86	Wet + Tare, g	1037.60	
Solids Content, %	45.0		Dry + Tare, g	896.70	
Wt. of Solids, g	520.8		Tare, g	375.90	
Ht. of Solids, cm		2.231	Wt. of Water, g	140.90	
Volume of Solids, cc	186.00		Wt. of Dry Solids, g	520.80	
Intial Void Ratio, e	3.392		Moisture Content, %	27.05	


Void Ratio vs. Effective Stress
Copperwood WPC-1 Tailings
y = 1.5811x-0.158
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Void Ratio, e
0.1
1
10
100
1000
Effective Stress, psi

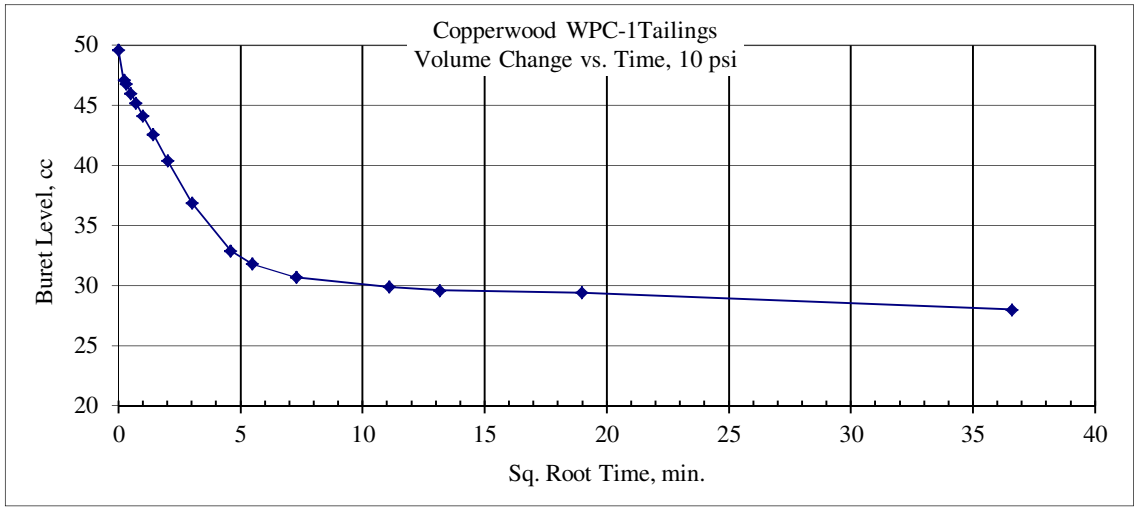

Dry Unit Weight vs. Effective Stress
Copperwood WPC-1 Tailings
Dry Unit Weight, pcf
100
95
90
85
80
75
70
65
60
55
50
0
20
40
60
80
100
120
140
Effective Stress, psi

WPC-1 Tailings
Orvana Resources US Corp
High Stress Consolidation Test

elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	48.8	1.2
0.05	0.22	45.7	4.3
0.10	0.32	45.5	4.5
0.25	0.50	44.9	5.1
0.50	0.71	43.4	6.6
1.00	1.00	42.0	8.0
2.00	1.41	40.6	9.4
4.00	2.00	36.7	13.3
11.00	3.32	29.6	20.4
22.00	4.69	22.7	27.3
44.00	6.63	16.4	33.6
54.00	7.35	15.3	34.7
87.00	9.33	14.0	36.0
148.00	12.17	13.3	36.7

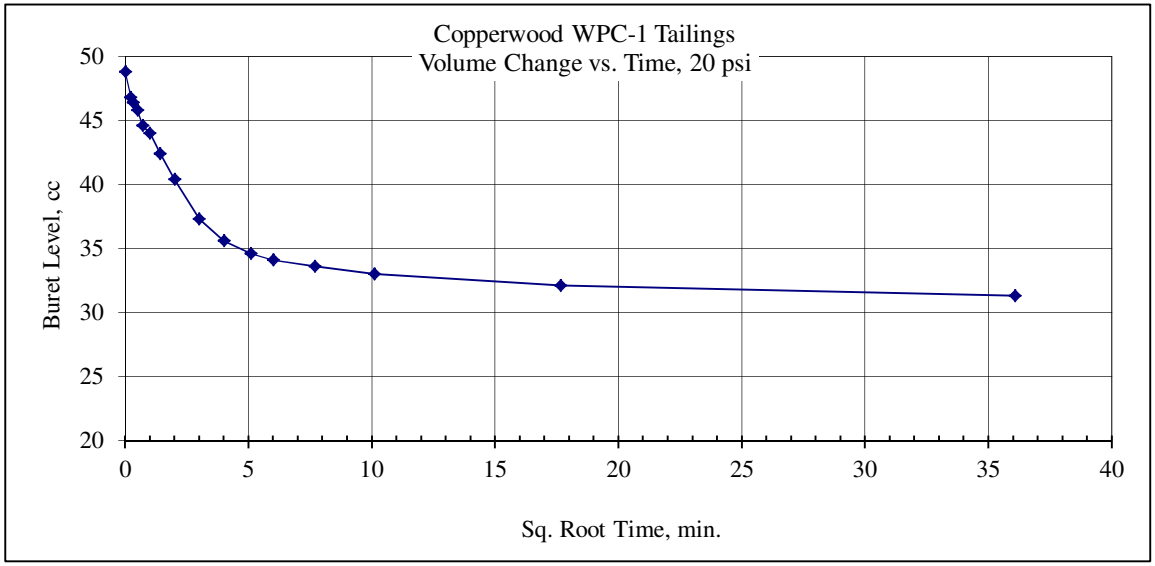


elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.6	0.4
0.05	0.22	47.1	2.9
0.10	0.32	46.8	3.2
0.25	0.50	46.0	4.0
0.50	0.71	45.2	4.8
1.00	1.00	44.1	5.9
2.00	1.41	42.6	7.4
4.00	2.00	40.4	9.6
9.00	3.00	36.9	13.1
21.00	4.58	32.9	17.1
30.00	5.48	31.8	18.2
53.00	7.28	30.7	19.3
123.00	11.09	29.9	20.1
173.00	13.15	29.6	20.4
360.00	18.97	29.4	20.6
1338.00	36.58	28.0	22.0

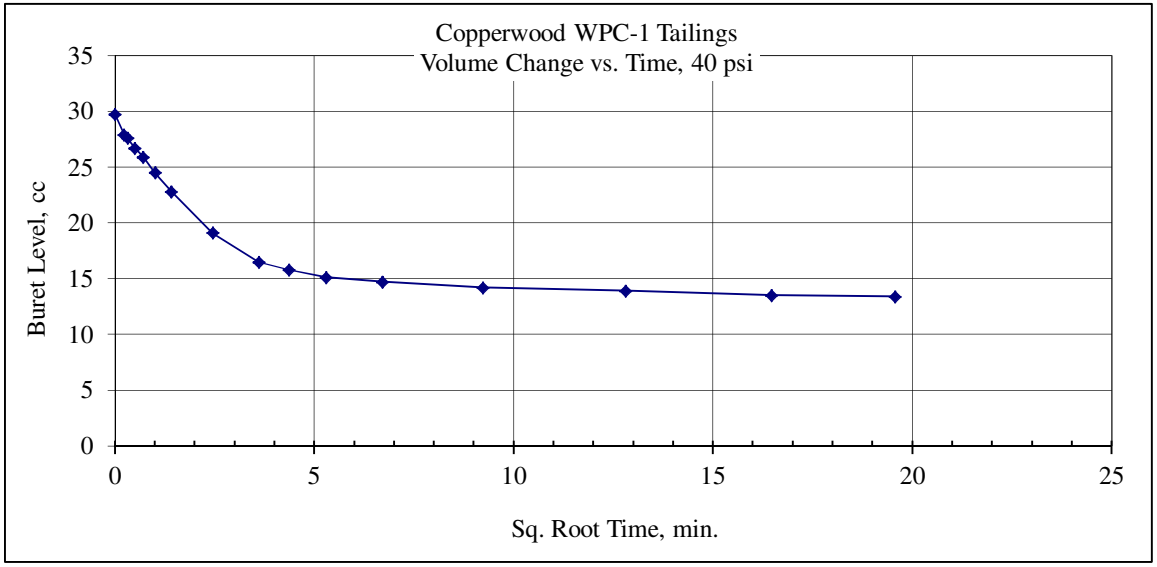


WPC-1 Tailings
Orvana Resources US Corp
High Stress Consolidation Test

elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	48.8	1.2
0.05	0.22	46.8	3.2
0.10	0.32	46.4	3.6
0.25	0.50	45.8	4.2
0.50	0.71	44.6	5.4
1.00	1.00	44.0	6.0
2.00	1.41	42.4	7.6
4.00	2.00	40.4	9.6
9.00	3.00	37.3	12.7
16.00	4.00	35.6	14.4
26.00	5.10	34.6	15.4
36.00	6.00	34.1	15.9
59.00	7.68	33.6	16.4
102.00	10.10	33.0	17.0
312.00	17.66	32.1	17.9
1302.00	36.08	31.3	18.7

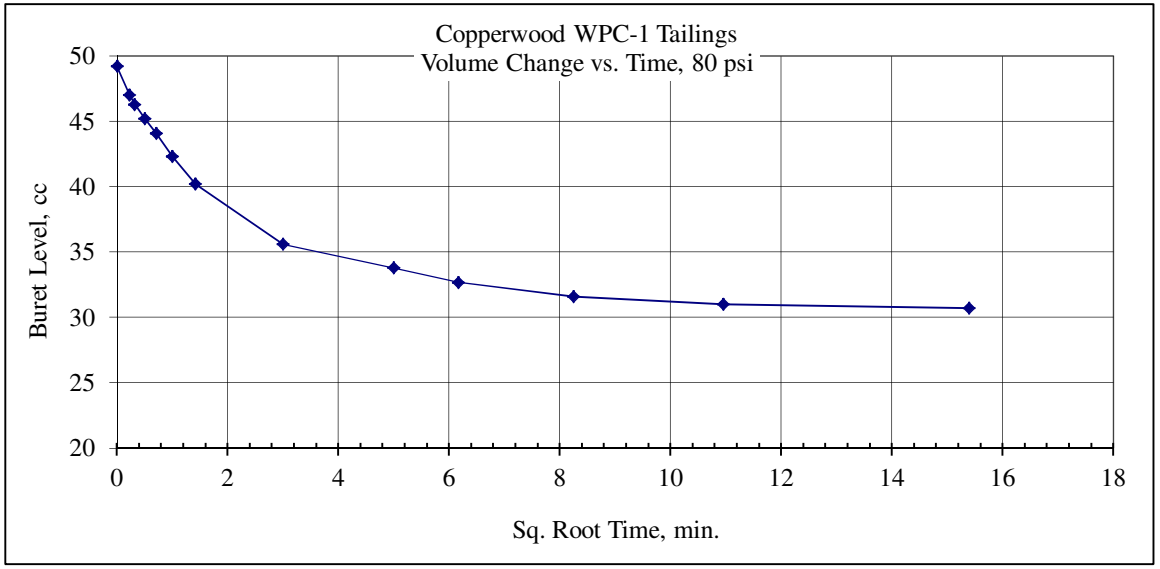


elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	29.7	20.3
0.05	0.22	27.9	22.1
0.10	0.32	27.6	22.4
0.25	0.50	26.7	23.3
0.50	0.71	25.9	24.1
1.00	1.00	24.5	25.5
2.00	1.41	22.8	27.2
6.00	2.45	19.1	30.9
13.00	3.61	16.5	33.5
19.00	4.36	15.8	34.2
28.00	5.29	15.1	34.9
45.00	6.71	14.7	35.3
85.00	9.22	14.2	35.8
164.00	12.81	13.9	36.1
271.00	16.46	13.5	36.5
383.00	19.57	13.4	36.6

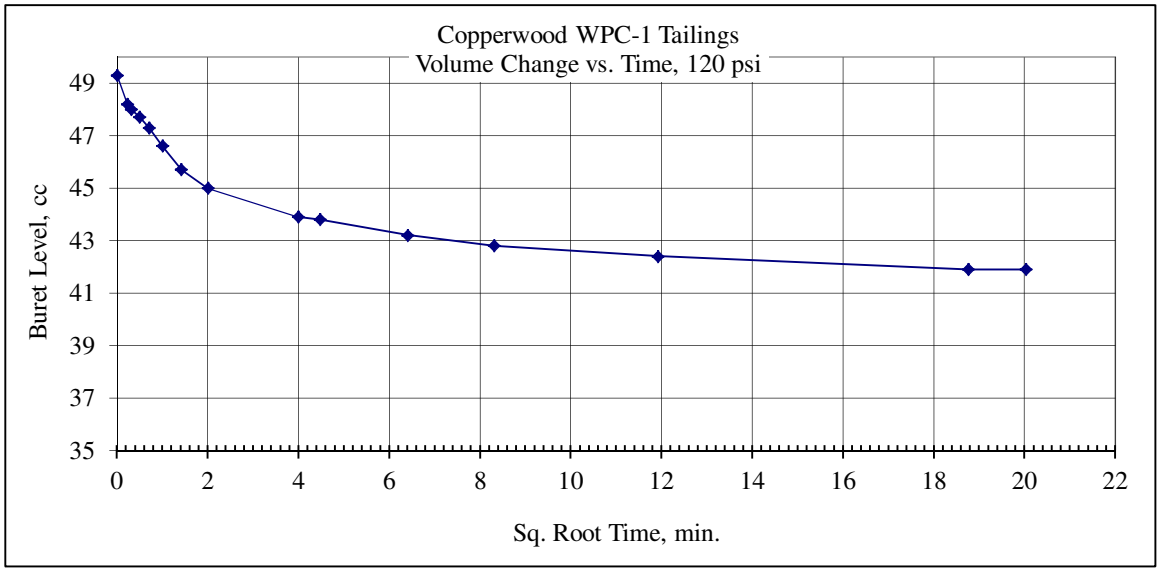


WPC-1 Tailings
Orvana Resources US Corp
High Stress Consolidation Test

elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.2	0.8
0.05	0.22	47.0	3.0
0.10	0.32	46.3	3.7
0.25	0.50	45.2	4.8
0.50	0.71	44.1	5.9
1.00	1.00	42.3	7.7
2.00	1.41	40.2	9.8
9.00	3.00	35.6	14.4
25.00	5.00	33.8	16.2
38.00	6.16	32.7	17.3
68.00	8.25	31.6	18.4
120.00	10.95	31.0	19.0
237.00	15.39	30.7	19.3
94.00	9.70	33.9	16.1
95.00	9.75	32.9	17.1
96.00	9.80	31.9	18.1



elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.3	0.7
0.05	0.22	48.2	1.8
0.10	0.32	48.0	2.0
0.25	0.50	47.7	2.3
0.50	0.71	47.3	2.7
1.00	1.00	46.6	3.4
2.00	1.41	45.7	4.3
4.00	2.00	45.0	5.0
16.00	4.00	43.9	6.1
20.00	4.47	43.8	6.2
41.00	6.40	43.2	6.8
69.00	8.31	42.8	7.2
142.00	11.92	42.4	7.6
352.00	18.76	41.9	8.1
401.00	20.02	41.9	8.1



RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2010-138
DEPTH		SAMPLE ID:	2010-138-1
SAMPLE NO.	WPC-1	TEST STARTED :	02/28/11
SAMPLE TYPE	Slurry	TEST FINISHED :	03/23/11
CONF. PRESSURE. (psi)	5	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1157.10	747.30
Wt. Wet Soil & Pan (g)	1157.10	747.30
Wt. Dry Soil & Pan (g)	520.80	520.80
Wt. Moisture Lost (g)	636.30	226.50
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	520.80	520.80
Moisture Content %	122.2	43.5
Wet Density (pcf)	88.4	114.6
Dry Density (pcf)	39.8	79.9

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	3.858	(cm)	9.799
Height Change (in)	1.935	(cm)	4.915
Consol. Height (in)	1.923	(cm)	4.884
Area After Consol. (sq in)	12.917	(sq cm)	83.339

Vol. Before Consol. (cu ft)	0.02885	Specific Gravity	2.8
Vol. Before Consol. (cc)	816.9	Assumed?	No
Change in Vol. (cc)	409.8		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	407.1	Init. Void Ratio	3.392
Vol. After Consol. (cu ft)	0.01438	Final Saturation	100.0
Effective Porosity %	77.23	Final Void Ratio	1.189
Pressure Difference (psi):	0.00		
C =	0.02125	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	39.4	1.2	38.2	38.2	
7.0	39.0	1.6	37.4	37.4	4.7E-07
19.0	38.0	2.7	35.3	35.3	4.7E-07
11.0	37.4	3.3	34.1	34.1	4.8E-07
31.0	35.8	4.8	31.0	31.0	4.7E-07
64.0	33.3	7.6	25.7	25.7	4.5E-07
			Avg.of All Rdgs.		**4.7E-07**
			Max.Hyd.Gradient:	7.7	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2010-138
DEPTH		SAMPLE ID:	2010-138-1
SAMPLE NO.	WPC-1	TEST STARTED :	02/28/11
SAMPLE TYPE	Slurry	TEST FINISHED :	03/23/11
CONF. PRESSURE. (psi)	10	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1157.10	725.70
Wt. Wet Soil & Pan (g)	1157.10	725.70
Wt. Dry Soil & Pan (g)	520.80	520.80
Wt. Moisture Lost (g)	636.30	204.90
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	520.80	520.80
Moisture Content %	122.2	39.3
Wet Density (pcf)	88.4	117.5
Dry Density (pcf)	39.8	84.3

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	3.858	(cm)	9.799
Height Change (in)	2.037	(cm)	5.174
Consol. Height (in)	1.821	(cm)	4.625
Area After Consol. (sq in)	12.916	(sq cm)	83.337

Vol. Before Consol. (cu ft)	0.02885	Specific Gravity	2.8
Vol. Before Consol. (cc)	816.9	Assumed?	No
Change in Vol. (cc)	431.4		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	385.5	Init. Void Ratio	3.392
Vol. After Consol. (cu ft)	0.01361	Final Saturation	100.0
Effective Porosity %	77.23	Final Void Ratio	1.072
Pressure Difference (psi):	0.00		
C =	0.02012	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	48.6	2.1	46.5	46.5	
8.0	48.2	2.5	45.7	45.7	3.2E-07
23.0	46.9	3.7	43.2	43.2	3.6E-07
10.0	46.4	4.3	42.1	42.1	3.8E-07
20.0	45.4	5.3	40.1	40.1	3.5E-07
66.0	42.8	8.0	34.8	34.8	3.1E-07
			Avg.of All Rdgs.		**3.5E-07**
			Max.Hyd.Gradient:	10.0	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2010-138
DEPTH		SAMPLE ID:	2010-138-1
SAMPLE NO.	WPC-1	TEST STARTED :	02/28/11
SAMPLE TYPE	Slurry	TEST FINISHED :	03/23/11
CONF. PRESSURE. (psi)	20	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1157.10	708.20
Wt. Wet Soil & Pan (g)	1157.10	708.20
Wt. Dry Soil & Pan (g)	520.80	520.80
Wt. Moisture Lost (g)	636.30	187.40
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	520.80	520.80
Moisture Content %	122.2	36.0
Wet Density (pcf)	88.4	120.2
Dry Density (pcf)	39.8	88.4

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	3.858	(cm)	9.799
Height Change (in)	2.120	(cm)	5.385
Consol. Height (in)	1.738	(cm)	4.415
Area After Consol. (sq in)	12.919	(sq cm)	83.353

Vol. Before Consol. (cu ft)	0.02885	Specific Gravity	2.8
Vol. Before Consol. (cc)	816.9	Assumed?	No
Change in Vol. (cc)	448.9		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	368.0	Init. Void Ratio	3.392
Vol. After Consol. (cu ft)	0.01299	Final Saturation	100.0
Effective Porosity %	77.23	Final Void Ratio	0.978
Pressure Difference (psi):	0.00		
C =	0.01920	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	52.8	3.1	49.7	49.7	
94.0	49.0	7.4	41.6	41.6	2.6E-07
26.0	48.1	8.2	39.9	39.9	2.2E-07
69.0	45.8	10.6	35.2	35.2	2.5E-07
33.0	44.9	11.6	33.3	33.3	2.3E-07
218.0	39.4	16.8	22.6	22.6	2.5E-07
			Avg.of All Rdgs.		**2.4E-07**
			Max.Hyd.Gradient:	10.3	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2010-138
DEPTH		SAMPLE ID:	2010-138-1
SAMPLE NO.	WPC-1	TEST STARTED :	02/28/11
SAMPLE TYPE	Slurry	TEST FINISHED :	03/23/11
CONF. PRESSURE. (psi)	40	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1157.10	691.90
Wt. Wet Soil & Pan (g)	1157.10	691.90
Wt. Dry Soil & Pan (g)	520.80	520.80
Wt. Moisture Lost (g)	636.30	171.10
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	520.80	520.80
Moisture Content %	122.2	32.9
Wet Density (pcf)	88.4	122.8
Dry Density (pcf)	39.8	92.5

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	3.858	(cm)	9.799
Height Change (in)	2.197	(cm)	5.580
Consol. Height (in)	1.661	(cm)	4.219
Area After Consol. (sq in)	12.919	(sq cm)	83.353

Vol. Before Consol. (cu ft)	0.02885	Specific Gravity	2.8
Vol. Before Consol. (cc)	816.9	Assumed?	No
Change in Vol. (cc)	465.2		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	351.7	Init. Void Ratio	3.392
Vol. After Consol. (cu ft)	0.01242	Final Saturation	100.0
Effective Porosity %	77.23	Final Void Ratio	0.891
Pressure Difference (psi):	0.00		
C =	0.01835	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	60.1	2.1	58.0	58.0	
15.0	59.6	2.7	56.9	56.9	1.7E-07
15.0	59.0	3.4	55.6	55.6	2.0E-07
33.0	57.9	4.5	53.4	53.4	1.6E-07
19.0	57.3	5.2	52.1	52.1	1.7E-07
55.0	55.5	7.0	48.5	48.5	1.7E-07
			Avg.of All Rdgs.		**1.8E-07**
			Max.Hyd.Gradient:	13.6	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2010-138
DEPTH		SAMPLE ID:	2010-138-1
SAMPLE NO.	WPC-1	TEST STARTED :	02/28/11
SAMPLE TYPE	Slurry	TEST FINISHED :	03/23/11
CONF. PRESSURE. (psi)	80	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1157.10	674.60
Wt. Wet Soil & Pan (g)	1157.10	674.60
Wt. Dry Soil & Pan (g)	520.80	520.80
Wt. Moisture Lost (g)	636.30	153.80
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	520.80	520.80
Moisture Content %	122.2	29.5
Wet Density (pcf)	88.4	126.0
Dry Density (pcf)	39.8	97.2

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	3.858	(cm)	9.799
Height Change (in)	2.279	(cm)	5.789
Consol. Height (in)	1.579	(cm)	4.011
Area After Consol. (sq in)	12.921	(sq cm)	83.369

Vol. Before Consol. (cu ft)	0.02885	Specific Gravity	2.8
Vol. Before Consol. (cc)	816.9	Assumed?	No
Change in Vol. (cc)	482.5		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	334.4	Init. Void Ratio	3.392
Vol. After Consol. (cu ft)	0.01181	Final Saturation	100.0
Effective Porosity %	77.23	Final Void Ratio	0.798
Pressure Difference (psi):	0.00		
C =	0.01744	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	59.6	2.2	57.4	57.4	
45.0	58.7	3.4	55.3	55.3	1.0E-07
32.0	58.0	4.1	53.9	53.9	1.0E-07
45.0	57.3	4.9	52.4	52.4	7.9E-08
1037.0	42.8	19.6	23.2	23.2	9.9E-08
			Avg.of All Rdgs.		**9.6E-08**
			Max.Hyd.Gradient:	14.1	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2010-138
DEPTH		SAMPLE ID:	2010-138-1
SAMPLE NO.	WPC-1	TEST STARTED :	02/28/11
SAMPLE TYPE	Slurry	TEST FINISHED :	03/23/11
CONF. PRESSURE. (psi)	120	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1157.10	667.20
Wt. Wet Soil & Pan (g)	1157.10	667.20
Wt. Dry Soil & Pan (g)	520.80	520.80
Wt. Moisture Lost (g)	636.30	146.40
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	520.80	520.80
Moisture Content %	122.2	28.1
Wet Density (pcf)	88.4	127.4
Dry Density (pcf)	39.8	99.4

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	3.858	(cm)	9.799
Height Change (in)	2.314	(cm)	5.878
Consol. Height (in)	1.544	(cm)	3.922
Area After Consol. (sq in)	12.922	(sq cm)	83.371

Vol. Before Consol. (cu ft)	0.02885	Specific Gravity	2.8
Vol. Before Consol. (cc)	816.9	Assumed?	No
Change in Vol. (cc)	489.9		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	327.0	Init. Void Ratio	3.392
Vol. After Consol. (cu ft)	0.01155	Final Saturation	100.0
Effective Porosity %	77.23	Final Void Ratio	0.758
Pressure Difference (psi):	0.00		
C =	0.01705	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

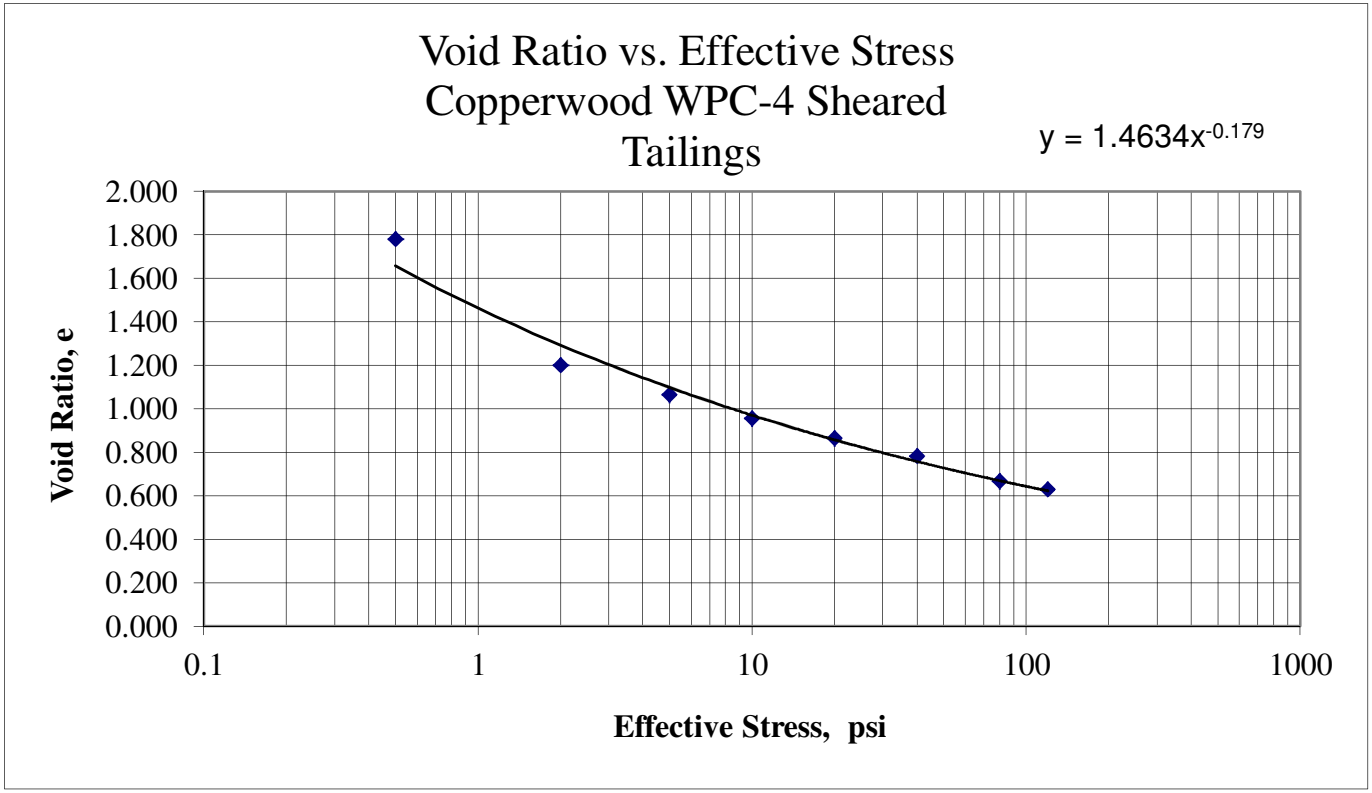
Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	84.0	1.1	82.9	82.9	
15.0	83.5	1.6	81.9	81.9	1.0E-07
101.0	80.8	4.4	76.4	76.4	8.5E-08
89.0	78.7	6.8	71.9	71.9	8.4E-08
96.0	76.4	9.1	67.3	67.3	8.5E-08
51.0	75.2	10.3	64.9	64.9	8.8E-08
			Avg.of All Rdgs.		**8.6E-08**
			Max.Hyd.Gradient:	21.0	

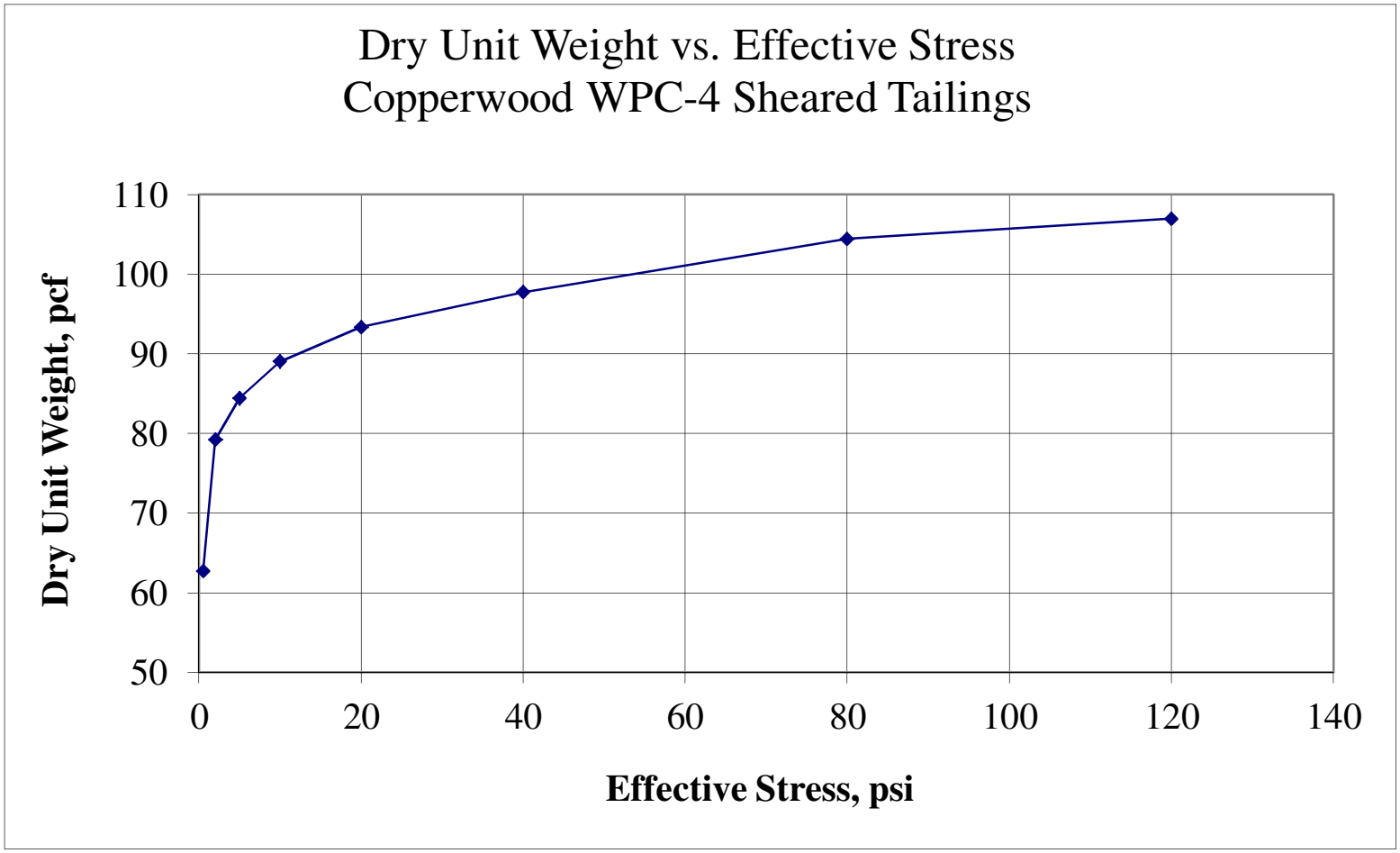
SLURRY CONSOLIDOMETER TEST RESULTS
COPPERWOOD
WPC-4 SHEARED TAILINGS
DV101-429.02

		Consolidation Test Data - Double Ended Drainage								
STRESS	psi	Free	0.5	2	5	10	20	40	80	120
	psf		72	288	720	1440	2880	5760	11520	17280
	kPa		3	14	34	69	138	276	552	827
Volume Change, cc		193.3	10.9	138.5	32.5	25.7	21.6	20.0	27.3	9.5
Cumulative Volume Change, cc		279.5	204.2	342.7	375.2	400.9	422.5	442.5	469.8	479.3
Consolidated Slurry Volume, cm^3		675.2	664.3	525.8	493.3	467.6	446.0	426.0	398.7	389.2
Settled Void Ratio, e_c		1.824	1.779	1.199	1.064	0.956	0.866	0.782	0.668	0.628
Dry Unit Weight, pcf		61.7	62.7	79.2	84.4	89.0	93.4	97.7	104.4	107.0
Slurry Height, cm		8.100	7.969	6.308	5.918	5.610	5.351	5.111	4.783	4.669
Mean Slurry Height, H^2 mm			1614.0	1274.0	934.2	830.6	750.8	684.0	611.8	558.4
Total Ht. Change, cm		2.319	2.450	4.111	4.501	4.809	5.068	5.308	5.636	5.750
Cumulative change in height, in.		0.913	0.964	1.619	1.772	1.893	1.995	2.090	2.219	2.264
Individual change in height, in.		0.913	0.051	0.654	0.153	0.121	0.102	0.094	0.129	0.045

SAMPLE PARAMETERS

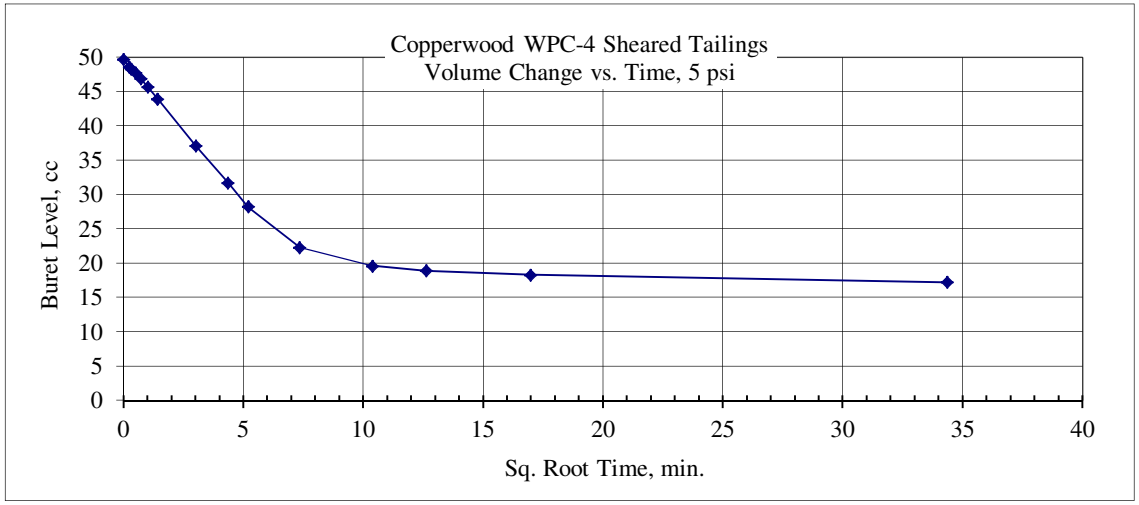
Specific Gravity	2.790		Ring Diameter (in./cm)	4.056	10.30
Slurry Mass w/tare, g	1838.40		Ring Area, cm^2		83.359
Tare, g	535.09		Ring Height (in./cm)	4.056	10.30
Slurry Mass, g	1303.31		Ring Volume, cm^3		858.79
Height of Slurry (in./cm)	4.102	10.42	**Post Test Specimen Data**		
Volume of Slurry, cc		868.53	Wet + Tare, g	934.40	
Solids Content, %	51.1		Dry + Tare, g	783.10	
Wt. of Solids, g	667.0		Tare, g	116.10	
Ht. of Solids, cm		2.868	Wt. of Water, g	151.30	
Volume of Solids, cc	239.07		Wt. of Dry Solids, g	667.00	
Intial Void Ratio, e	2.633		Moisture Content, %	22.68	


Void Ratio vs. Effective Stress
Copperwood WPC-4 Sheared
Tailings
y = 1.4634x-0.179
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Void Ratio, e
0.1
1
10
100
1000
Effective Stress, psi

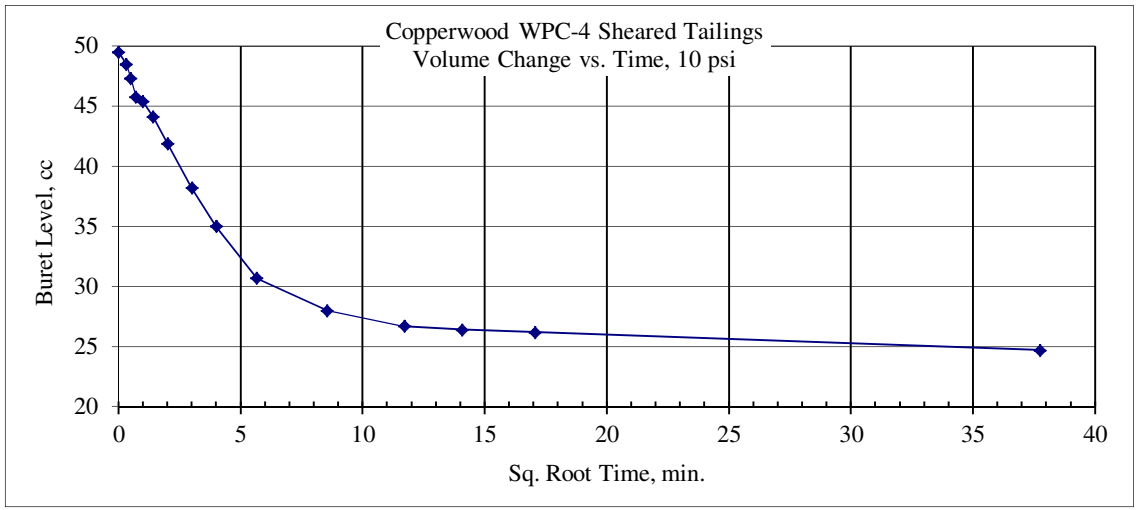

Dry Unit Weight vs. Effective Stress
Copperwood WPC-4 Sheared Tailings
Dry Unit Weight, pcf
110
100
90
80
70
60
50
0
20
40
60
80
100
120
140
Effective Stress, psi

WPC-4 Sheared Tailings
Orvana Resources US Corp
High Stress Consolidation Test

elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.7	0.3
0.05	0.22	48.6	1.4
0.10	0.32	48.3	1.7
0.25	0.50	47.7	2.3
0.50	0.71	46.9	3.1
1.00	1.00	45.7	4.3
2.00	1.41	43.9	6.1
9.00	3.00	37.1	12.9
19.00	4.36	31.7	18.3
27.00	5.20	28.2	21.8
54.00	7.35	22.3	27.7
108.00	10.39	19.6	30.4
159.00	12.61	18.9	31.1
288.00	16.97	18.3	31.7
1180.00	34.35	17.2	32.8

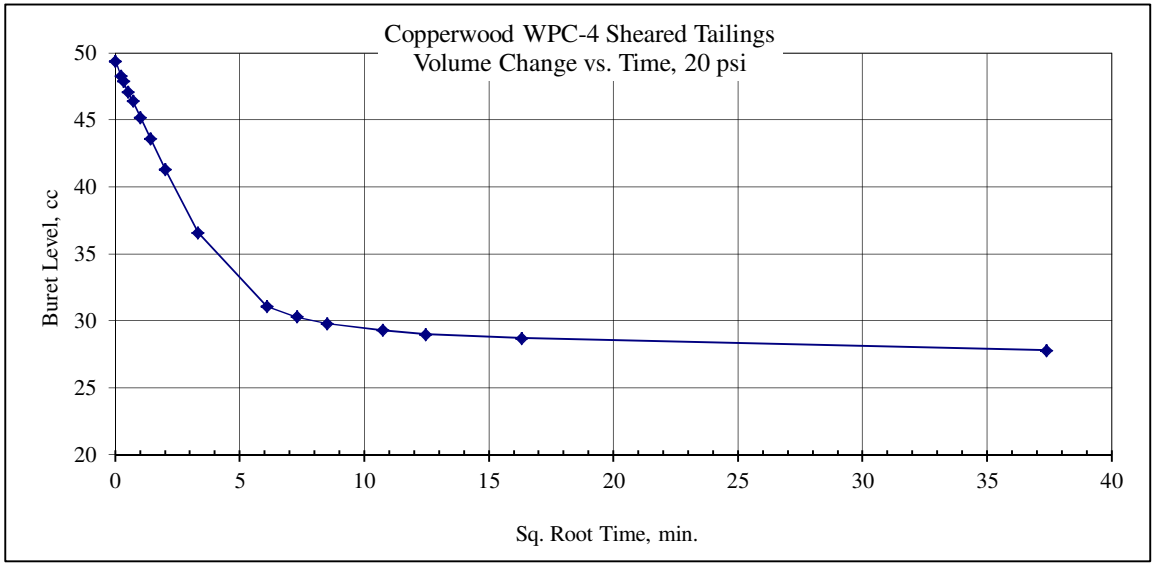


elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.5	0.5
0.10	0.32	48.5	1.5
0.25	0.50	47.3	2.7
0.50	0.71	45.8	4.2
1.00	1.00	45.4	4.6
2.00	1.41	44.1	5.9
4.00	2.00	41.9	8.1
9.00	3.00	38.2	11.8
16.00	4.00	35.0	15.0
32.00	5.66	30.7	19.3
73.00	8.54	28.0	22.0
137.00	11.70	26.7	23.3
198.00	14.07	26.4	23.6
291.00	17.06	26.2	23.8
1425.00	37.75	24.7	25.3

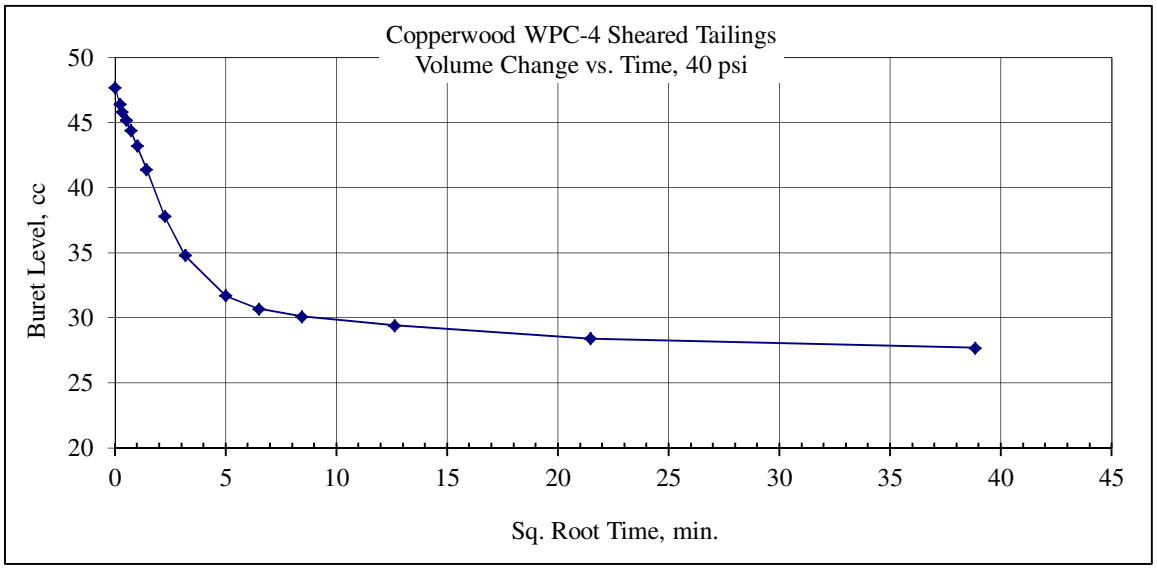


WPC-4 Sheared Tailings
Orvana Resources US Corp
High Stress Consolidation Test

elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.4	0.6
0.05	0.22	48.3	1.7
0.10	0.32	47.9	2.1
0.25	0.50	47.1	2.9
0.50	0.71	46.4	3.6
1.00	1.00	45.2	4.8
2.00	1.41	43.6	6.4
4.00	2.00	41.3	8.7
11.00	3.32	36.6	13.4
37.00	6.08	31.1	18.9
53.00	7.28	30.3	19.7
72.00	8.49	29.8	20.2
115.00	10.72	29.3	20.7
155.00	12.45	29.0	21.0
266.00	16.31	28.7	21.3
1396.00	37.36	27.8	22.2

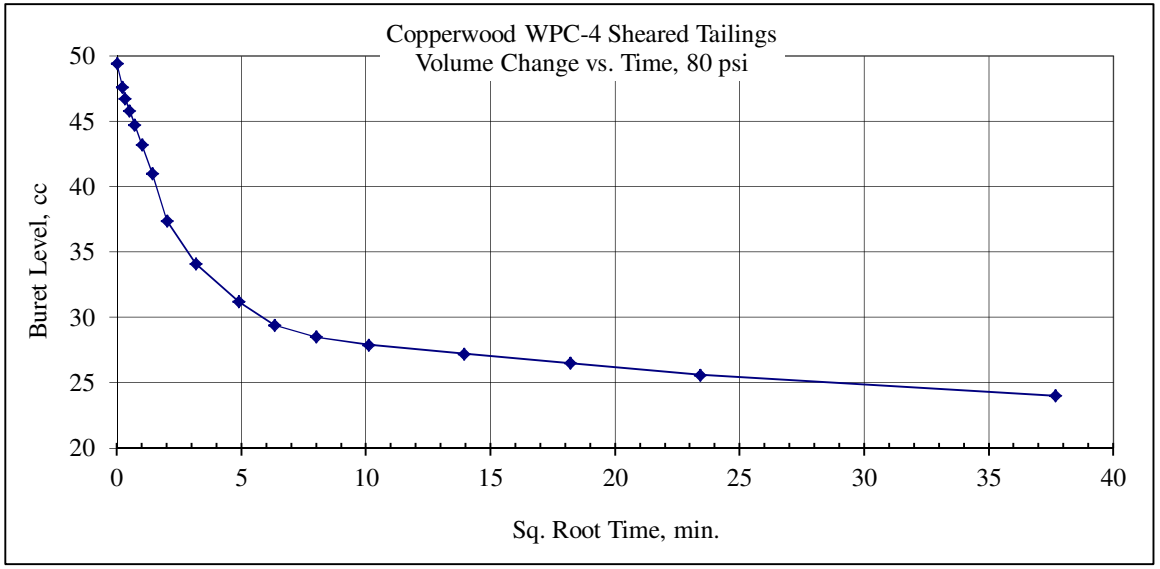


elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	47.7	2.3
0.05	0.22	46.4	3.6
0.10	0.32	45.8	4.2
0.25	0.50	45.2	4.8
0.50	0.71	44.4	5.6
1.00	1.00	43.2	6.8
2.00	1.41	41.4	8.6
5.00	2.24	37.8	12.2
10.00	3.16	34.8	15.2
25.00	5.00	31.7	18.3
42.00	6.48	30.7	19.3
71.00	8.43	30.1	19.9
159.00	12.61	29.4	20.6
460.00	21.45	28.4	21.6
1507.00	38.82	27.7	22.3

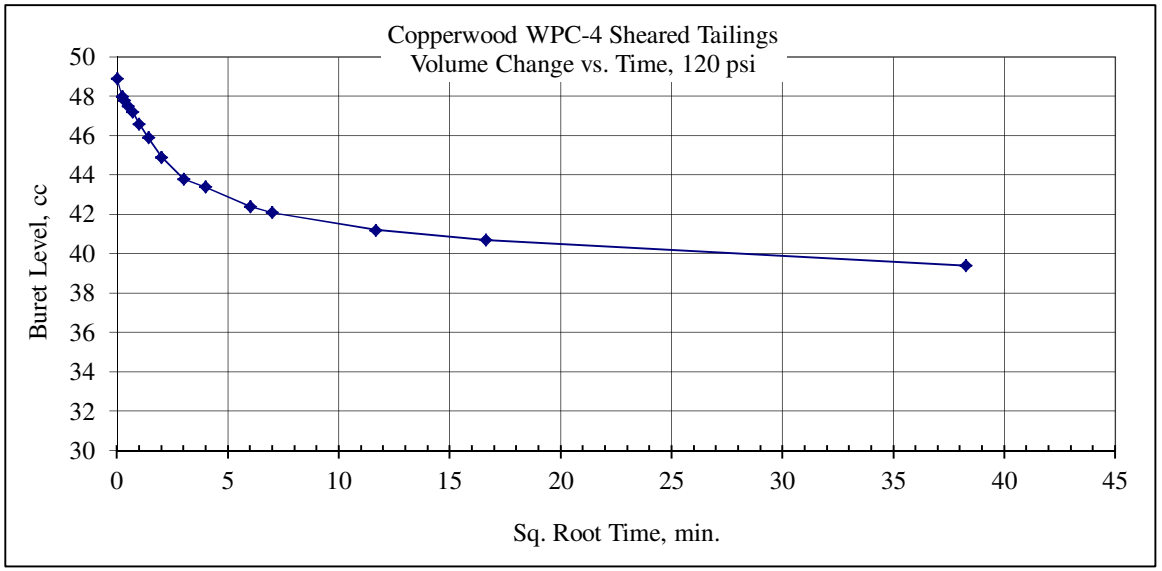


WPC-4 Sheared Tailings
Orvana Resources US Corp
High Stress Consolidation Test

elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	49.4	0.6
0.05	0.22	47.6	2.4
0.10	0.32	46.7	3.3
0.25	0.50	45.8	4.2
0.50	0.71	44.7	5.3
1.00	1.00	43.2	6.8
2.00	1.41	41.0	9.0
4.00	2.00	37.4	12.6
10.00	3.16	34.1	15.9
24.00	4.90	31.2	18.8
40.00	6.32	29.4	20.6
64.00	8.00	28.5	21.5
102.00	10.10	27.9	22.1
194.00	13.93	27.2	22.8
331.00	18.19	26.5	23.5
548.00	23.41	25.6	24.4
1420.00	37.68	24.0	26.0



elapsed time min.	sq. root time min.	Change in Volume (50 - cc)	Cell Buret Level cc
0.00	0.00	48.9	1.1
0.05	0.22	48.0	2.0
0.10	0.32	47.8	2.2
0.25	0.50	47.5	2.5
0.50	0.71	47.2	2.8
1.00	1.00	46.6	3.4
2.00	1.41	45.9	4.1
4.00	2.00	44.9	5.1
9.00	3.00	43.8	6.2
16.00	4.00	43.4	6.6
36.00	6.00	42.4	7.6
49.00	7.00	42.1	7.9
136.00	11.66	41.2	8.8
276.00	16.61	40.7	9.3
1463.00	38.25	39.4	10.6



RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2011-022
DEPTH		SAMPLE ID:	2011-022-4
SAMPLE NO.	WPC-4, Sheared	TEST STARTED :	03/29/11
SAMPLE TYPE	Slurry	TEST FINISHED :	04/22/11
CONF. PRESSURE. (psi)	5	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1303.30	928.10
Wt. Wet Soil & Pan (g)	1303.30	928.10
Wt. Dry Soil & Pan (g)	667.00	667.00
Wt. Moisture Lost (g)	636.30	261.10
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	667.00	667.00
Moisture Content %	95.4	39.1
Wet Density (pcf)	93.7	117.4
Dry Density (pcf)	47.9	84.4

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	4.102	(cm)	10.419
Height Change (in)	1.772	(cm)	4.501
Consol. Height (in)	2.330	(cm)	5.918
Area After Consol. (sq in)	12.920	(sq cm)	83.357

Vol. Before Consol. (cu ft)	0.03067	Specific Gravity	2.79
Vol. Before Consol. (cc)	868.5	Assumed?	No
Change in Vol. (cc)	375.2		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	493.3	Init. Void Ratio	2.633
Vol. After Consol. (cu ft)	0.01742	Final Saturation	100.0
Effective Porosity %	72.47	Final Void Ratio	1.064
Pressure Difference (psi):	0.00		
C =	0.02574	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	49.6	2.4	47.2	47.2	
36.0	47.7	4.7	43.0	43.0	4.8E-07
25.0	46.4	6.0	40.4	40.4	4.6E-07
38.0	44.7	7.9	36.8	36.8	4.6E-07
39.0	43.0	9.7	33.3	33.3	4.8E-07
89.0	39.9	13.2	26.7	26.7	4.6E-07
			Avg.of All Rdgs.		**4.7E-07**
			Max.Hyd.Gradient:	7.6	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2011-022
DEPTH		SAMPLE ID:	2011-022-4
SAMPLE NO.	WPC-4, Sheared	TEST STARTED :	03/29/11
SAMPLE TYPE	Slurry	TEST FINISHED :	04/22/11
CONF. PRESSURE. (psi)	10	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1303.30	902.40
Wt. Wet Soil & Pan (g)	1303.30	902.40
Wt. Dry Soil & Pan (g)	667.00	667.00
Wt. Moisture Lost (g)	636.30	235.40
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	667.00	667.00
Moisture Content %	95.4	35.3
Wet Density (pcf)	93.7	120.5
Dry Density (pcf)	47.9	89.0

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	4.102	(cm)	10.419
Height Change (in)	1.893	(cm)	4.808
Consol. Height (in)	2.209	(cm)	5.611
Area After Consol. (sq in)	12.917	(sq cm)	83.343

Vol. Before Consol. (cu ft)	0.03067	Specific Gravity	2.79
Vol. Before Consol. (cc)	868.5	Assumed?	No
Change in Vol. (cc)	400.9		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	467.6	Init. Void Ratio	2.633
Vol. After Consol. (cu ft)	0.01651	Final Saturation	100.0
Effective Porosity %	72.47	Final Void Ratio	0.956
Pressure Difference (psi):	0.00		
C =	0.02441	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	49.8	1.4	48.4	48.4	
21.0	49.0	2.4	46.6	46.6	3.2E-07
30.0	47.8	3.6	44.2	44.2	3.1E-07
16.0	47.2	4.3	42.9	42.9	3.3E-07
26.0	46.2	5.3	40.9	40.9	3.2E-07
			Avg.of All Rdgs.		**3.2E-07**
			Max.Hyd.Gradient:	8.5	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2011-022
DEPTH		SAMPLE ID:	2011-022-4
SAMPLE NO.	WPC-4, Sheared	TEST STARTED :	03/29/11
SAMPLE TYPE	Slurry	TEST FINISHED :	04/22/11
CONF. PRESSURE. (psi)	20	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1303.30	880.80
Wt. Wet Soil & Pan (g)	1303.30	880.80
Wt. Dry Soil & Pan (g)	667.00	667.00
Wt. Moisture Lost (g)	636.30	213.80
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	667.00	667.00
Moisture Content %	95.4	32.1
Wet Density (pcf)	93.7	123.3
Dry Density (pcf)	47.9	93.4

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	4.102	(cm)	10.419
Height Change (in)	1.995	(cm)	5.067
Consol. Height (in)	2.107	(cm)	5.352
Area After Consol. (sq in)	12.917	(sq cm)	83.342

Vol. Before Consol. (cu ft)	0.03067	Specific Gravity	2.79
Vol. Before Consol. (cc)	868.5	Assumed?	No
Change in Vol. (cc)	422.5		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	446.0	Init. Void Ratio	2.633
Vol. After Consol. (cu ft)	0.01575	Final Saturation	100.0
Effective Porosity %	72.47	Final Void Ratio	0.866
Pressure Difference (psi):	0.00		
C =	0.02328	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	49.8	2.7	47.1	47.1	
17.0	49.4	3.4	46.0	46.0	2.3E-07
9.0	49.2	3.6	45.6	45.6	1.6E-07
34.0	48.3	4.9	43.4	43.4	2.5E-07
113.0	45.5	8.2	37.3	37.3	2.3E-07
106.0	43.3	11.0	32.3	32.3	2.3E-07
			Avg.of All Rdgs.		**2.2E-07**
			Max.Hyd.Gradient:	8.7	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2011-022
DEPTH		SAMPLE ID:	2011-022-4
SAMPLE NO.	WPC-4, Sheared	TEST STARTED :	03/29/11
SAMPLE TYPE	Slurry	TEST FINISHED :	04/22/11
CONF. PRESSURE. (psi)	40	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1303.30	860.80
Wt. Wet Soil & Pan (g)	1303.30	860.80
Wt. Dry Soil & Pan (g)	667.00	667.00
Wt. Moisture Lost (g)	636.30	193.80
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	667.00	667.00
Moisture Content %	95.4	29.1
Wet Density (pcf)	93.7	126.1
Dry Density (pcf)	47.9	97.7

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	4.102	(cm)	10.419
Height Change (in)	2.090	(cm)	5.309
Consol. Height (in)	2.012	(cm)	5.110
Area After Consol. (sq in)	12.921	(sq cm)	83.363

Vol. Before Consol. (cu ft)	0.03067	Specific Gravity	2.79
Vol. Before Consol. (cc)	868.5	Assumed?	No
Change in Vol. (cc)	442.5		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	426.0	Init. Void Ratio	2.633
Vol. After Consol. (cu ft)	0.01504	Final Saturation	100.0
Effective Porosity %	72.47	Final Void Ratio	0.782
Pressure Difference (psi):	0.00		
C =	0.02223	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	65.3	3.0	62.3	62.3	
30.0	64.3	3.9	60.4	60.4	1.7E-07
46.0	63.1	5.2	57.9	57.9	1.5E-07
130.0	59.8	8.6	51.2	51.2	1.5E-07
1005.0	44.3	24.0	20.3	20.3	1.5E-07
94.0	43.3	25.0	18.3	18.3	1.8E-07
89.0	42.6	25.7	16.9	16.9	1.4E-07
			Avg.of All Rdgs.		**1.6E-07**
			Max.Hyd.Gradient:	12.0	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2011-022
DEPTH		SAMPLE ID:	2011-022-4
SAMPLE NO.	WPC-4, Sheared	TEST STARTED :	03/29/11
SAMPLE TYPE	Slurry	TEST FINISHED :	04/22/11
CONF. PRESSURE. (psi)	80	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1303.30	833.50
Wt. Wet Soil & Pan (g)	1303.30	833.50
Wt. Dry Soil & Pan (g)	667.00	667.00
Wt. Moisture Lost (g)	636.30	166.50
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	667.00	667.00
Moisture Content %	95.4	25.0
Wet Density (pcf)	93.7	130.5
Dry Density (pcf)	47.9	104.4

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	4.102	(cm)	10.419
Height Change (in)	2.219	(cm)	5.636
Consol. Height (in)	1.883	(cm)	4.783
Area After Consol. (sq in)	12.921	(sq cm)	83.366

Vol. Before Consol. (cu ft)	0.03067	Specific Gravity	2.79
Vol. Before Consol. (cc)	868.5	Assumed?	No
Change in Vol. (cc)	469.8		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	398.7	Init. Void Ratio	2.633
Vol. After Consol. (cu ft)	0.01408	Final Saturation	100.0
Effective Porosity %	72.47	Final Void Ratio	0.668
Pressure Difference (psi):	0.00		
C =	0.02080	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	56.3	5.8	50.5	50.5	
27.0	55.9	6.2	49.7	49.7	8.9E-08
81.0	54.8	7.5	47.3	47.3	9.2E-08
156.0	52.7	9.7	43.0	43.0	9.2E-08
1077.0	41.8	19.8	22.0	22.0	9.4E-08
			Avg.of All Rdgs.		**9.2E-08**
			Max.Hyd.Gradient:	10.5	

RIGID WALL PERMEABILITY TEST

ASTM D 5856-02

Falling Head / Increasing Tailwater Pressure

CLIENT:	Orvana Resources US Corp		
PROJECT:	Copperwood	PROJECT NO. :	DV101-429.02
BORING NO.		LAB NO. :	L2011-022
DEPTH		SAMPLE ID:	2011-022-4
SAMPLE NO.	WPC-4, Sheared	TEST STARTED :	03/29/11
SAMPLE TYPE	Slurry	TEST FINISHED :	04/22/11
CONF. PRESSURE. (psi)	120	SATURATED TEST:	YES

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	1303.30	824.00
Wt. Wet Soil & Pan (g)	1303.30	824.00
Wt. Dry Soil & Pan (g)	667.00	667.00
Wt. Moisture Lost (g)	636.30	157.00
Wt. of Pan Only (g)	0.00	0.00
Wt. of Dry Soil (g)	667.00	667.00
Moisture Content %	95.4	23.5
Wet Density (pcf)	93.7	132.2
Dry Density (pcf)	47.9	107.0

Init. Diameter (in)	4.056	(cm)	10.302
Init. Area (sq in)	12.921	(sq cm)	83.359
Init. Height (in)	4.102	(cm)	10.419
Height Change (in)	2.264	(cm)	5.751
Consol. Height (in)	1.838	(cm)	4.669
Area After Consol. (sq in)	12.922	(sq cm)	83.372

Vol. Before Consol. (cu ft)	0.03067	Specific Gravity	2.79
Vol. Before Consol. (cc)	868.5	Assumed?	No
Change in Vol. (cc)	479.3		
Cell Exp. (cc)	0.0	Init. Saturation	100.0
Vol. After Consol. (cc)	389.2	Init. Void Ratio	2.633
Vol. After Consol. (cu ft)	0.01375	Final Saturation	100.0
Effective Porosity %	72.47	Final Void Ratio	0.628
Pressure Difference (psi):	0.00		
C =	0.02030	Buret Constant, a	0.315
k, cm/s = C/t*log(h1/h2)		Buret Stand	20

Permeability Test Trials

Time min.	Cap Elevation cm	Pedestal Elevation cm	Elevation Head cm	Total Head cm	Permeability k cm/sec
0.0	60.3	2.7	57.6	57.6	
102.0	58.8	4.3	54.5	54.5	8.0E-08
98.0	57.6	5.8	51.8	51.8	7.6E-08
1023.0	46.8	16.2	30.6	30.6	7.6E-08
126.0	45.8	17.2	28.6	28.6	7.9E-08
276.0	44.1	19.3	24.8	24.8	7.6E-08
			Avg.of All Rdgs.		**7.7E-08**
			Max.Hyd.Gradient:	12.0	

Knight Piésold CONSULTING

Appendix D-5

Tailings Testing Results – Seepage Induced Consolidation (SIC) Testing Analyses

Dobroslav Znidarčić, Ph.D. **Geotechnical Engineer**

13733 Stone Cir. #102, Broomfield, CO 80020, Phone: 303-673-9766

Dobroslav Znidarčić

Consolidation Test Results for Slurry Samples
WPC1 Composite

Prepared for:

Knight Piésold and Co.
1580 Lincoln Street, Suite 1000
Denver, CO 80203

March 17, 2010

Introduction

This report presents the results of the consolidation testing for a slurry sample. We received about a liter of a disturbed sample designated as WPC1 Composite.

The sample had soft consistency with the initial water and solids contents:

Sample	Water Content	Solids Content
WPC1 Composite	125%	44.4%

The sample was first thoroughly mixed and poured into the testing cell. The Seepage Induced Consolidation Tests (SICT) and the step loading tests were performed on the sample. In all calculations the specific gravity was G_s=2.797. The Seepage Induced Consolidation Test and analysis procedures are described in the attachment to this report

Material Characteristics

The void ratio corresponding to the zero effective stress was found to be:

Sample	Void ratio @ σ'=0
WPC1 Composite	2.51

The test results are presented in Tables 1 and 2 and in Figure 1.

The model parameters A, B, Z, C and D in Table 1 define the compressibility and hydraulic conductivity relationships given by the following expressions, and presented in the figures

Compressibility $e = A (\sigma' + Z)^B$

Hydraulic Conductivity $k = C e^D$

where e is the void ratio, k is the hydraulic conductivity. The values for the parameters A, Z and C depend on the system of units and are given for SI units.

Table 1 – Consolidation model parameters

Sample	A	B	Z(kPa)	C(m/sec)	D
WPC1 Composite	1.82	-0.149	0.116	$3.93 * 10^{-9}$	3.19

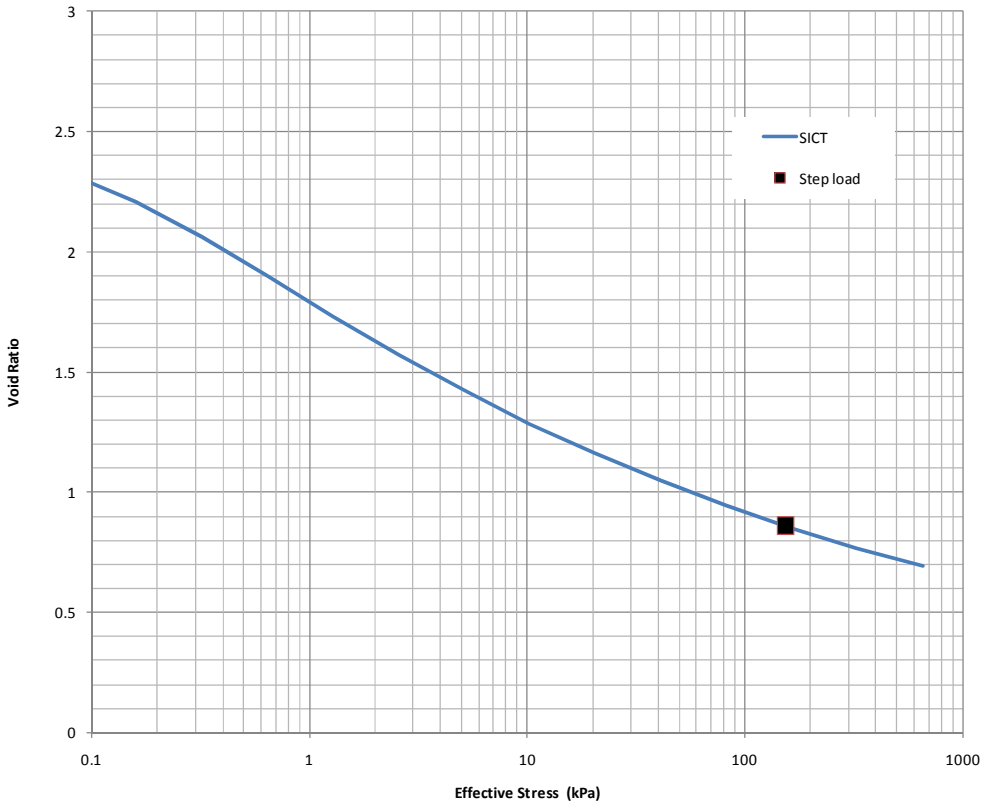
Table 2 – SICTA results for WPC1 Composite sample

KP-WPC1 Composite	

Seepage Induced Consolidation Results :	
Unit Weight of Water	9.81
Unit Weight of Solids	27.44
Initial Height of the Sample	0.0242
Void Ratio at zero effective stress	2.51
Top Effective Stress	0.07
Darcian Velocity	1.74E-07
Final Height of the Sample	0.0204
Final Bottom Effective Stress	1.26

Step Loading Test Results :	
Void Ratio	0.86
Effective Stress	155
Permeability Coefficient	2.43E-09

PARAMETER ESTIMATION RESULTS	
Parameter A	1.8214
Parameter B	-0.14877
Parameter Z	0.11584
Parameter C	3.93E-09
Parameter D	3.19047
Number of Iterations	9
Total Normalized Difference	2.46E-05



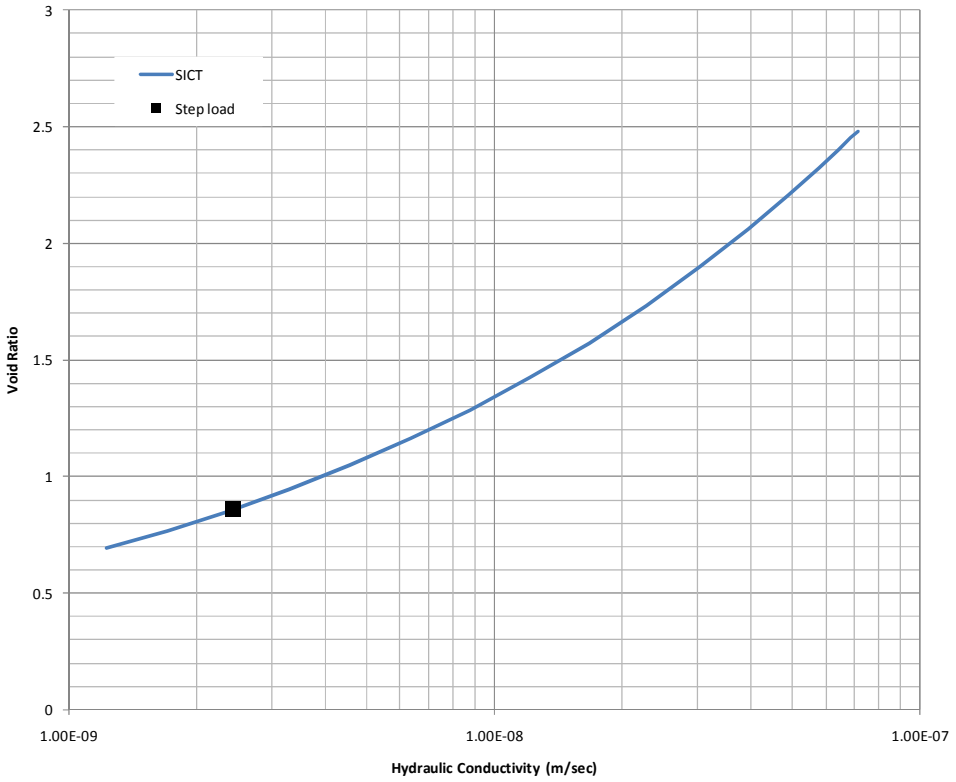


Figure 1 Compressibility and Permeability Characteristics for WPC1 Composite sample

Seepage Induced Consolidation Test (SICT)

The seepage induced consolidation test is an experimental procedure used for determining the consolidation characteristics of soft soils and soil like materials (slurry mine waste, dredged spoils, sludge from waste water treatment plants etc.). The testing procedure consists of three steps.

In the first step the void ratio at the effective stress zero is determined by allowing a slurry column about 0.05 m high to consolidate under its own weight. The average void ratio of the settled slurry is considered the void ratio at the effective stress of zero, or the void ratio at which the soil is formed and the consolidation theory (as opposed to the sedimentation theory) applies.

In the second step, seepage at a constant flow rate is applied through the soil by means of a flow pump and the sample is allowed to consolidate completely, i.e. until the steady state is reached. The steady state is determined from the pressure difference across the sample that is continuously monitored during the test. At steady state, the pressure difference and the final height of the sample are recorded. It is recognized that during this phase of the test the void ratio within the sample is non-uniform and this is correctly accounted for in the test analysis.

In the third step the sample is consolidated under the maximum desired stress level and the hydraulic conductivity is measured with the flow pump using a low flow rate to maintain sample uniformity during the test. At the end of the test the sample is dried and the total volume of solids is determined.

The analysis of the test is performed using the software package SICTA (Seepage Induced Consolidation Test Analysis). The procedure is based on the inverse problem solution approach and the theory used is compatible with the finite strain nonlinear consolidation theory (i.e. no simplifying or restrictive assumptions are made in the analysis). The input data for the SICTA program are all obtained from the described test. The output gives five parameters A, B, Z, C and D that define the consolidation properties for the sample. The compressibility and hydraulic conductivity relations with the five parameters are defined as:

Compressibility $e = A\,(\sigma' + Z)^B$

Hydraulic Conductivity $k = C\,e^D$

The more detailed description of the testing equipment and testing and analysis procedures can be found in the following publications:

Abu-Hejleh, A.N., and Znidarcic, D., 1992, User Manual for Computer Program SICTA, Prepared for Florida Institute of Phosphate Research, University of Colorado, Boulder, 122 pp.

Znidarcic, D., Abu-Hejleh, A.N., Fairbanks, T. and Robertson A., 1992, Seepage-Induced Consolidation Test; Equipment Description and Users Manual, Prepared for Florida Institute of Phosphate Research, University of Colorado, Boulder, 52 pp.

Abu-Hejleh, A.N. and Znidarcic, D., 1994, Estimation of the Consolidation Constitutive Relations, Computer Methods and Advances in Geomechanics, Siriwardane & Zaman (eds) Balkema, Rotterdam, pp. 499-504.

Abu-Hejleh, A. N. and Znidarcic, D., 1996, Consolidation Characteristics of Phosphatic Clays, Journal of Geotechnical Engineering, ASCE, New-York, Vol. 122, No. 4. pp. 295-301.

Dobroslav Znidarčić, Ph.D. **Geotechnical Engineer**

13733 Stone Cir. #102, Broomfield, CO 80020, Phone: 303-673-9766

Dobroslav Znidarčić

Consolidation Test Results for Slurry Samples
WPC-4 Flocculated

Prepared for:

Knight Piésold and Co.
1580 Lincoln Street, Suite 1000
Denver, CO 80203

April 17, 2011

Introduction

This report presents the results of the consolidation testing for a slurry sample. We received about a liter of a disturbed sample designated as WPC-4 Composite Fully Sheared that was Flocculated before testing .

The sample had soft consistency with the initial water and solids contents:

Sample	Water Content	Solids Content
WPC4 Composite	99.2%	50.2%

The sample was first thoroughly mixed, flocculant was added to the sample until a clear flocculation and sedimentation was observed and then poured into the testing cell. The Seepage Induced Consolidation Tests (SICT) and the step loading tests were performed on the sample. In all calculations the specific gravity was G_s=2.78. The Seepage Induced Consolidation Test and analysis procedures are described in the attachment to this report

Material Characteristics

The void ratio corresponding to the zero effective stress was found to be:

Sample	Void ratio @ σ'=0
WPC4 Flocculated	4.09

The test results are presented in Tables 1 and 2 and in Figure 1.

The model parameters A, B, Z, C and D in Table 1 define the compressibility and hydraulic conductivity relationships given by the following expressions, and presented in the figures

Compressibility $e = A (\sigma' + Z)^B$

Hydraulic Conductivity $k = C e^D$

where e is the void ratio, k is the hydraulic conductivity. The values for the parameters A, Z and C depend on the system of units and are given for SI units.

Table 1 – Consolidation model parameters

Sample	A	B	Z(kPa)	C(m/sec)	D
WPC1 Composite	2.24	-0.176	0.033	$4.74 * 10^{-9}$	3.79

Table 2 – SICTA results for WPC4 Flocculated sample

WPC-4 Flocculated

Seepage Induced Consolidation Results :

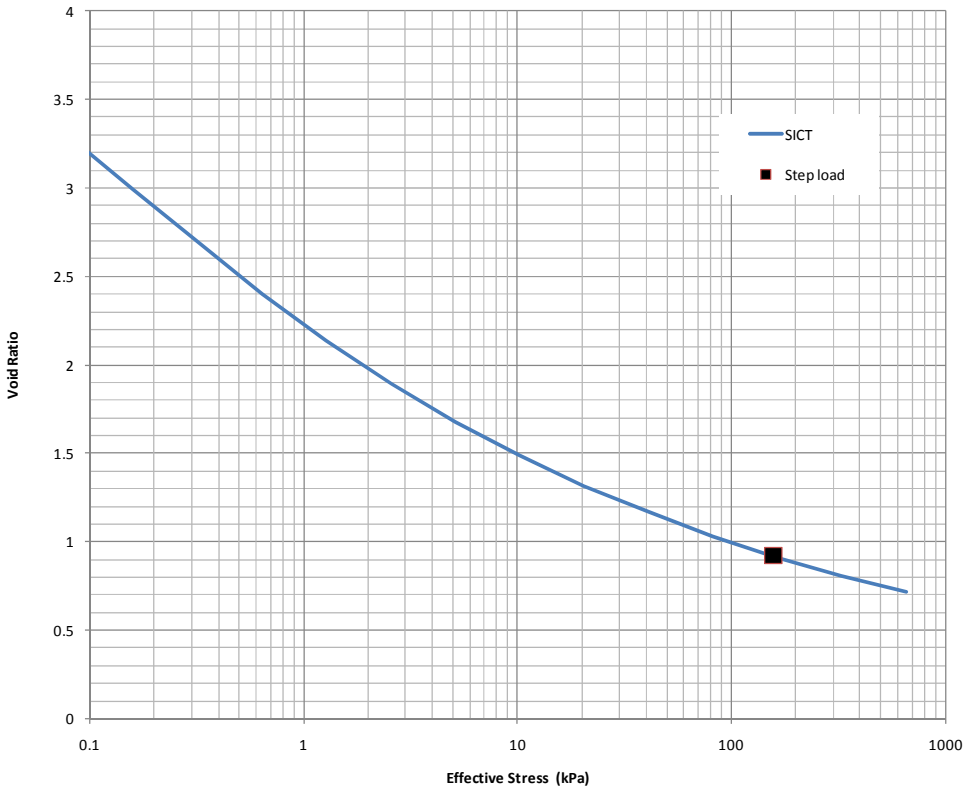
Unit Weight of Water	9.81
Unit Weight of Solids	27.27
Initial Height of the Sample	0.022
Void Ratio at zero effective stress	4.092
Top Effective Stress	0.07
Darcian Velocity	8.68E-07
Final Height of the Sample	0.0159
Final Bottom Effective Stress	0.877

Step Loading Test Results :

Void Ratio	0.92
Effective Stress	157.2
Permeability Coefficient	3.46E-09

PARAMETER ESTIMATION RESULTS

Parameter A	2.24083
Parameter B	-0.17601
Parameter Z	0.03267
Parameter C	4.74E-09
Parameter D	3.78702
Number of Iterations	8
Total Normalized Difference	7.94E-05



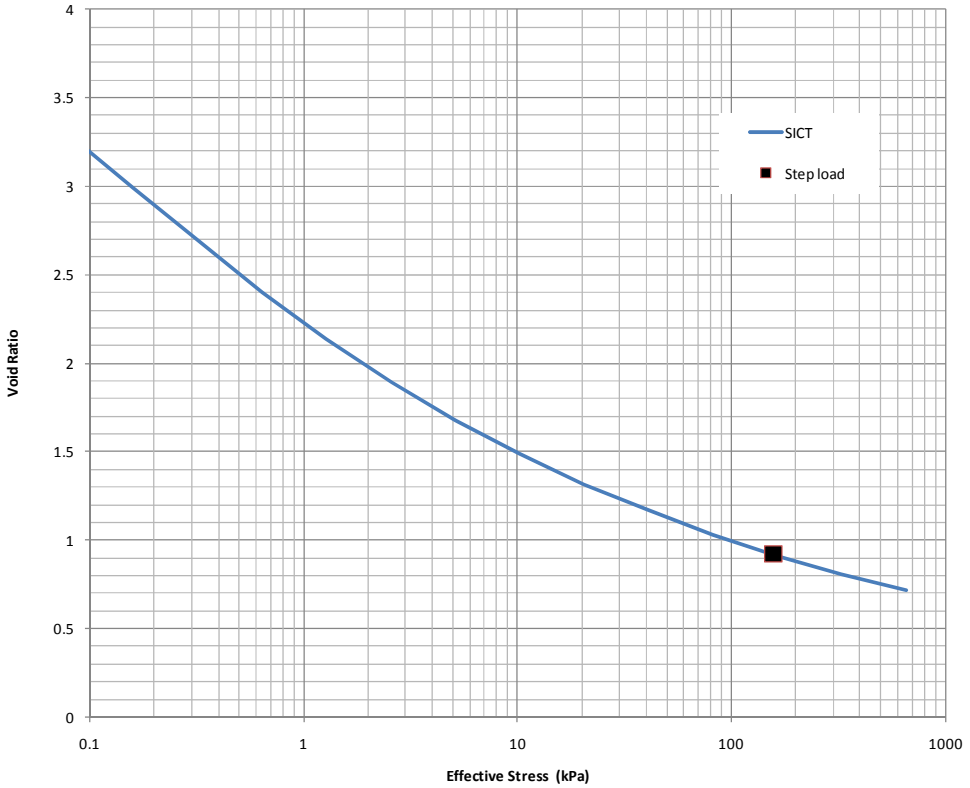


Figure 1 Compressibility and Permeability Characteristics for WPC4 Flocculated sample

Seepage Induced Consolidation Test (SICT)

The seepage induced consolidation test is an experimental procedure used for determining the consolidation characteristics of soft soils and soil like materials (slurry mine waste, dredged spoils, sludge from waste water treatment plants etc.). The testing procedure consists of three steps.

In the first step the void ratio at the effective stress zero is determined by allowing a slurry column about 0.05 m high to consolidate under its own weight. The average void ratio of the settled slurry is considered the void ratio at the effective stress of zero, or the void ratio at which the soil is formed and the consolidation theory (as opposed to the sedimentation theory) applies.

In the second step, seepage at a constant flow rate is applied through the soil by means of a flow pump and the sample is allowed to consolidate completely, i.e. until the steady state is reached. The steady state is determined from the pressure difference across the sample that is continuously monitored during the test. At steady state, the pressure difference and the final height of the sample are recorded. It is recognized that during this phase of the test the void ratio within the sample is non-uniform and this is correctly accounted for in the test analysis.

In the third step the sample is consolidated under the maximum desired stress level and the hydraulic conductivity is measured with the flow pump using a low flow rate to maintain sample uniformity during the test. At the end of the test the sample is dried and the total volume of solids is determined.

The analysis of the test is performed using the software package SICTA (Seepage Induced Consolidation Test Analysis). The procedure is based on the inverse problem solution approach and the theory used is compatible with the finite strain nonlinear consolidation theory (i.e. no simplifying or restrictive assumptions are made in the analysis). The input data for the SICTA program are all obtained from the described test. The output gives five parameters A, B, Z, C and D that define the consolidation properties for the sample. The compressibility and hydraulic conductivity relations with the five parameters are defined as:

Compressibility $e = A\,(\sigma' + Z)^B$

Hydraulic Conductivity $k = C\,e^D$

The more detailed description of the testing equipment and testing and analysis procedures can be found in the following publications:

Abu-Hejleh, A.N., and Znidarcic, D., 1992, User Manual for Computer Program SICTA, Prepared for Florida Institute of Phosphate Research, University of Colorado, Boulder, 122 pp.

Znidarcic, D., Abu-Hejleh, A.N., Fairbanks, T. and Robertson A., 1992, Seepage-Induced Consolidation Test; Equipment Description and Users Manual, Prepared for Florida Institute of Phosphate Research, University of Colorado, Boulder, 52 pp.

Abu-Hejleh, A.N. and Znidarcic, D., 1994, Estimation of the Consolidation Constitutive Relations, Computer Methods and Advances in Geomechanics, Siriwardane & Zaman (eds) Balkema, Rotterdam, pp. 499-504.

Abu-Hejleh, A. N. and Znidarcic, D., 1996, Consolidation Characteristics of Phosphatic Clays, Journal of Geotechnical Engineering, ASCE, New-York, Vol. 122, No. 4. pp. 295-301.

Dobroslav Znidarčić, Ph.D. **Geotechnical Engineer**

13733 Stone Cir. #102, Broomfield, CO 80020, Phone: 303-673-9766

Dobroslav Znidarčić

Consolidation Test Results for Slurry Samples
WPC-4Composite Fully Sheared

Prepared for:

Knight Piésold and Co.
1580 Lincoln Street, Suite 1000
Denver, CO 80203

March 22, 2011

Introduction

This report presents the results of the consolidation testing for a slurry sample. We received about a liter of a disturbed sample designated as WPC-4 Composite Fully Sheared.

The sample had soft consistency with the initial water and solids contents:

Sample	Water Content	Solids Content
WPC4 Composite	99.2%	50.2%

The sample was first thoroughly mixed and poured into the testing cell. The Seepage Induced Consolidation Tests (SICT) and the step loading tests were performed on the sample. In all calculations the specific gravity was G_s=2.78. The Seepage Induced Consolidation Test and analysis procedures are described in the attachment to this report

Material Characteristics

The void ratio corresponding to the zero effective stress was found to be:

Sample	Void ratio @ σ'=0
WPC4 Composite	2.40

The test results are presented in Tables 1 and 2 and in Figure 1.

The model parameters A, B, Z, C and D in Table 1 define the compressibility and hydraulic conductivity relationships given by the following expressions, and presented in the figures

Compressibility $e = A (\sigma' + Z)^B$

Hydraulic Conductivity $k = C e^D$

where e is the void ratio, k is the hydraulic conductivity. The values for the parameters A, Z and C depend on the system of units and are given for SI units.

Table 1 – Consolidation model parameters

Sample	A	B	Z(kPa)	C(m/sec)	D
WPC1 Composite	2.42	-0.227	1.04	$4.60 * 10^{-9}$	2.93

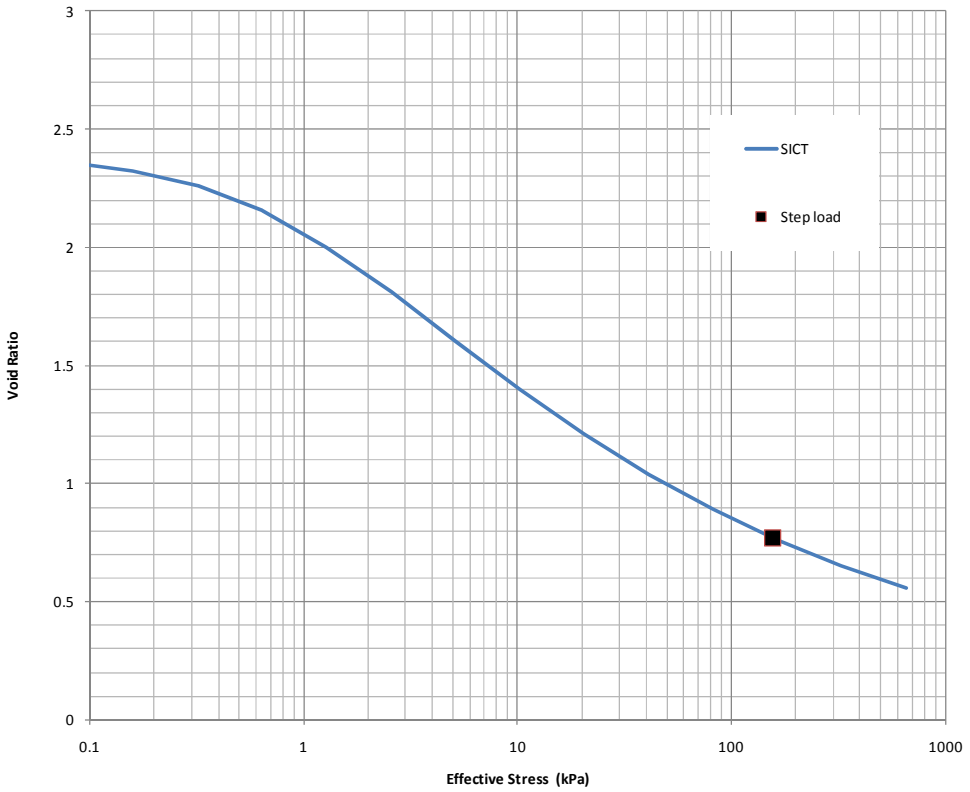
Table 2 – SICTA results for WPC4 Composite sample

KP-WPC-4 Composite Fully Sheared @ 50.2%solids	

Seepage Induced Consolidation Results :	
Unit Weight of Water	9.81
Unit Weight of Solids	27.27
Initial Height of the Sample	0.0283
Void Ratio at zero effective stress	2.4
Top Effective Stress	0.07
Darcian Velocity	1.74E-07
Final Height of the Sample	0.0264
Final Bottom Effective Stress	1.23

Step Loading Test Results :	
Void Ratio	0.769
Effective Stress	157
Permeability Coefficient	2.13E-09

PARAMETER ESTIMATION RESULTS	
Parameter A	2.4226
Parameter B	-0.22665
Parameter Z	1.04221
Parameter C	4.60E-09
Parameter D	2.93349
Number of Iterations	5
Total Normalized Difference	3.03E-05



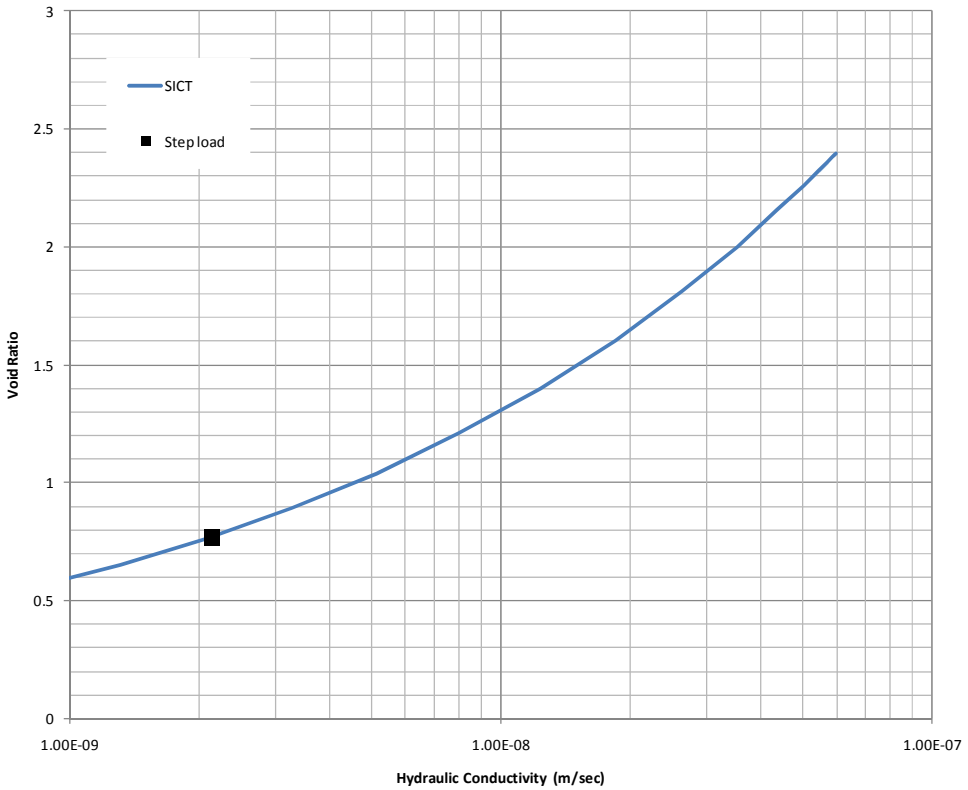


Figure 1 Compressibility and Permeability Characteristics for WPC4Composite sample

Seepage Induced Consolidation Test (SICT)

The seepage induced consolidation test is an experimental procedure used for determining the consolidation characteristics of soft soils and soil like materials (slurry mine waste, dredged spoils, sludge from waste water treatment plants etc.). The testing procedure consists of three steps.

In the first step the void ratio at the effective stress zero is determined by allowing a slurry column about 0.05 m high to consolidate under its own weight. The average void ratio of the settled slurry is considered the void ratio at the effective stress of zero, or the void ratio at which the soil is formed and the consolidation theory (as opposed to the sedimentation theory) applies.

In the second step, seepage at a constant flow rate is applied through the soil by means of a flow pump and the sample is allowed to consolidate completely, i.e. until the steady state is reached. The steady state is determined from the pressure difference across the sample that is continuously monitored during the test. At steady state, the pressure difference and the final height of the sample are recorded. It is recognized that during this phase of the test the void ratio within the sample is non-uniform and this is correctly accounted for in the test analysis.

In the third step the sample is consolidated under the maximum desired stress level and the hydraulic conductivity is measured with the flow pump using a low flow rate to maintain sample uniformity during the test. At the end of the test the sample is dried and the total volume of solids is determined.

The analysis of the test is performed using the software package SICTA (Seepage Induced Consolidation Test Analysis). The procedure is based on the inverse problem solution approach and the theory used is compatible with the finite strain nonlinear consolidation theory (i.e. no simplifying or restrictive assumptions are made in the analysis). The input data for the SICTA program are all obtained from the described test. The output gives five parameters A, B, Z, C and D that define the consolidation properties for the sample. The compressibility and hydraulic conductivity relations with the five parameters are defined as:

Compressibility $e = A\,(\sigma' + Z)^B$

Hydraulic Conductivity $k = C\,e^D$

The more detailed description of the testing equipment and testing and analysis procedures can be found in the following publications:

Abu-Hejleh, A.N., and Znidarcic, D., 1992, User Manual for Computer Program SICTA, Prepared for Florida Institute of Phosphate Research, University of Colorado, Boulder, 122 pp.

Znidarcic, D., Abu-Hejleh, A.N., Fairbanks, T. and Robertson A., 1992, Seepage-Induced Consolidation Test; Equipment Description and Users Manual, Prepared for Florida Institute of Phosphate Research, University of Colorado, Boulder, 52 pp.

Abu-Hejleh, A.N. and Znidarcic, D., 1994, Estimation of the Consolidation Constitutive Relations, Computer Methods and Advances in Geomechanics, Siriwardane & Zaman (eds) Balkema, Rotterdam, pp. 499-504.

Abu-Hejleh, A. N. and Znidarcic, D., 1996, Consolidation Characteristics of Phosphatic Clays, Journal of Geotechnical Engineering, ASCE, New-York, Vol. 122, No. 4. pp. 295-301.

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Appendix E

Copperwood Project, Process Water Balance, Revision 1, memorandum prepared by Knight Piésold and Co., July 25, 2011

Knight Piésold CONSULTING

Knight Piésold and Co.

1580 Lincoln Street, Suite 1000
Denver, Colorado 80203-1512 USA
Telephone: (303) 629-8788
Facsimile: (303) 629-8789
E-mail: *denver@knightpiesold.com*

Memorandum

Date: July 25, 2011

To: Orvana Resources U.S. Corporation
10199 Lake Rd.
Ironwood, MI 49938

Attn: Mr. Bill Williams

Subject: Copperwood Project
Process Water Balance, Revision 1

KP Project No.: DV101.00429.02
KP Doc. No.: DV-11-0487

From: Mr. John Dwyer

Dear Mr. Williams:

This is intended as the final revision to Knight Piésold and Co.'s (Knight Piésold) *Preliminary Operational Water Balance*, issued for the Copperwood Project Tailings Disposal Facility (TDF) on April 12, 2011. As a follow-up to the issuance of the preliminary water balance, and discussions with Orvana Resources U.S. Corporation (Orvana) and its other consultants for the project, this revision is based on:

- The April 19, 2011 mine production schedule provided by Marston & Marston (M&M).
- Process water requirements for the mill (estimated based on the requirements for the previous production schedule).
- Mine dewatering estimates provided by AECOM.
- Seepage induced consolidation (SIC) testing of the flocculated WPC-4 tailings.

This input information to the process water balance is presented in Tables 1 and 2.

Water released from the tailings, after deposition within the TDF, was estimated by Knight Piésold, based on seepage induced consolidation (SIC) testing of the flocculated WPC-4 tailings samples received from Orvana. Based on the consolidated densities from the initial SIC testing of the flocculated sample, the current TDF configuration will store approximately 32 million tons (Mt) of tailings at an ultimate dry density of 1.07 short tons/cubic yard (t/yd^3), and is based on approximately 14.25 years of production.

The following is a description of the logic used to develop the water balance model as well as the results of the analysis.

1.0 SITE WATER AND TAILINGS DISPOSAL FACILITY SUPERNATANT POND

1.1 Site Water and Proposed Use

Based on discussions of the initial water balance, the general operating strategy assumes that the supernatant pond will be maintained at a depth of between 8 and 12 feet (ft) shortly after the start-up period. This will help to maintain discharge and makeup water requirements within a reasonable range during operations, and will avoid accumulating a large amount of water in the TDF that will require treatment at closure. As before, the water balance model was developed to reclaim and re-use as much water as possible from the TDF.

Process water at the mill will be primarily sourced from the release of water from liquid/solid separation and consolidation of the deposited tailings in the TDF, mine dewatering, net precipitation falling directly on the surface of the TDF, and makeup from Lake Superior. The water sourced from the mine is expected to contain dissolved metals and anions, and will therefore require treatment. The TDF supernatant may also contain dissolved metals, anions, suspended solids, and residual process flotation reagents. The specific

amount of the reclaim water from the TDF that may require treatment is beyond the scope of this report. Any excess reclaim water from the TDF that is not reused in the process is expected to require treatment, and likely polishing, prior to release.

Following the end of operations, the intent is to treat and release any remaining water in the TDF supernatant pond prior to constructing a closure cover over the final tailings surface.

1.2 Tailings Disposal Facility Supernatant Pond Operation

As mentioned above, the TDF supernatant pond is considered to be a primary source of makeup water for operation of the mill. The TDF has been designed to contain, in the supernatant pond, all direct precipitation contributing to the facility interior basin, additional incident precipitation resulting from the 72-hour/half-PMP storm event, and any water liberated from deposited tailings.

Supernatant water will be removed by decant towers installed along the upstream face of the embankment and conveyed to a sump downstream of the dam. From this point, water will be pumped to the mill for re-use in the process or pumped to the treatment plant for treatment and discharge. Some portion of the reclaim water may require treatment before reuse in the mill. Water from flocculent addition at the tailings slurry inlet to the TDF will also be decanted and report to the decant sump for pumping back to the flocculent circuit; however, the flocculent circuit has been considered as a closed loop and therefore these waters have not been included in the process water balance.

During the winter months (December through March) it is estimated that up to 3 ft of ice may form on the surface of the supernatant pond. To allow continuous decanting and reclamation of water during these months, a minimum depth of approximately 6 ft will be maintained beneath the ice cover. Some makeup water from Lake Superior will be required during these months to maintain a steady flow of process water to the mill.

2.0 WATER BALANCE LOGIC

2.1 Model Components and Interaction

The water balance model performs monthly calculations of the amounts of water contained in the system from defined or calculated inflows and outflows. Figure 1 presents a schematic diagram of the water flow routings in the operational water balance model. The model operates on a monthly basis by quantifying the monthly changes to inflows and outflows due to tailings production, process water requirements, mine dewatering, tailings consolidation, and precipitation and evaporation. The model uses the following governing equation:

$$V = I - Q - E$$

Where:

- V = change in pond volume
- I = inflows to the pond from direct precipitation on the TDF, water liberated from the tailings, and direct makeup for winter operation storage
- Q = outflows from the pond consisting of reclaim water to the plant and/or excess water discharges
- E = evaporation

2.2 Modeling Runs

The model computes the volume in the TDF supernatant pond, together with certain other outputs (reclaim water, discharge, etc.), for each month during the mine life. The operational mine life was modeled to be approximately 14.25 years from the start to end of tailings deposition. The water balance also accounts for 2 months of start-up, where the facility would accumulate water prior to initiating deposition, and for approximately 4 years after the end of mine operations for draining the supernatant

pond. Based on a starting point of September 1st of Year 1 and an ending point of December 31st of Year 19, each run of the water balance model has a duration of approximately 18.3 years. Using 34 years of climate data as input, a total of 34 independent model runs were computed, where the first model run placed the start of the mine life in the first year of the 34 years of precipitation data, while the second run placed it in the second year of the data, and so on. Each model run produced 220 months of output data (outcomes) covering the 18.3-year period of mine operations and closure, and when all 34 of the runs were complete, each of the 220 months was represented by 34 values of output data (pond volumes, discharge rates, etc.). Monthly average, maximum, minimum, and various other probabilistic values were then determined for the output data (outcomes) for each month of each year of the mine life.

2.3 Maximum Pond Storage Requirements

The average monthly size of the pond, throughout the mine life, was determined as the average of the 34 pond volumes predicted from each month the facility is in operation by stepping the model through the 34 years of data (see Section 2.2).

The design storm event volume considers the direct precipitation from the half-PMP storm event occurring in 72 hours that falls within the limits of the TDF. All runoff produced by precipitation beyond the TDF interior basin is assumed to be diverted away from the facility, and is therefore not included.

The average required pond storage volume is then determined by adding the average pond volume to the half-PMP storm event volume.

3.0 INPUT PARAMETERS

3.1 Climatic Conditions

An important model input component is climatic data, which consist of monthly precipitation and evaporation. The climatic data was based on 34 years of daily temperature and precipitation data (1977-2010) from the nearby Ontonagon weather station, based on Knight Piésold's experience with projects under similar conditions. The key climatic characteristics at the site can be summarized as follows:

- The average annual precipitation for the site was found to be 33.02 inches.
- The average annual pond evaporation was found to be 23.71 inches.
- The design 72-hour/one-half Probable Maximum Precipitation (half-PMP) storm event was determined to be 16.4 inches, likely to occur in August (U.S. Department of Commerce, 1978).
  - The 72-hour/half-PMP was utilized for the design of the TDF supernatant pond based on a “high-hazard potential” dam, greater than 40 ft in height, classification according to the Natural Resources and Environmental Protection Act, 1994 PA 451, Part 315, Dam Safety.

3.2 Tailings Disposal Facility

3.2.1 Operation

It was assumed that:

- The facility will be operated 24 hours per day and 365 days per year.
- Construction of the Stage 1 TDF (with storage through Year 3 of the production plan) will be completed by August of Year 1 and will start to accumulate water from direct precipitation in September of Year 1.
- The start of operations (tailings deposition) will occur in November of Year 1.
- All precipitation on the tailings beach will report directly to the supernatant pond in the month it occurs.
- Approximately 75 percent of the tailings beach area will remain wet at all times.

- The amount of water liberated from the deposited tailings was calculated as the difference between the water entering the TDF in the tailings slurry and the water remaining in the voids of the deposit after consolidation. The dry density of the consolidated tailings ranged from 0.71 t/yd³ [0.84 tonnes/cubic meter (t/m³)] in Year 1 to 1.07 t/yd³ (1.26 t/m³) after 14.25 years of production. A final dry density of 1.12 t/yd³ (1.33 t/m³) was estimated 4 years after closure. Table 2 gives the amount of water released from the tailings versus time.
- The process plant will be supplied by reclaim water from the TDF supernatant pond, moisture in the ore feed (3-percent by weight), mine dewatering, direct precipitation acting on the TDF interior basin, and makeup from Lake Superior.
- Any seepage from the TDF will be collected in a sump immediately downstream of the facility and will be pumped, along with the TDF reclaim, back to the process.

3.2.2 Water Inflows to the Tailings Disposal Facility

- Total water in the tailings slurry from the plant is estimated to be 1,138 gallons per minute (gpm) at 50 percent solids (per K D Engineering (KDE) for an ore production rate of 2,620,000 tons per year, assuming 24 hour/365 days per year operations).
- Direct precipitation within the TDF basin.
- Fresh water makeup from Lake Superior (to control the pond size for winter operation).

3.2.3 Water Outflows from the Tailings Disposal Facility

- Evaporation.
- Water retained in the tailings voids (that will be released over time due to consolidation).
- Reclaim water to the plant (including seepage from the TDF).
- Discharge water to water treatment (modeled to begin in January of Year 9.

3.3 Process Plant

3.3.1 Water Inflows to the Process Plant

- Reclaim water from the TDF.
- Water from mine dewatering.
- Moisture contained in the ore (3 percent by weight).
- Continuous miner water.
- Makeup water from Lake Superior.

3.3.2 Water Outflows from the Process Plant

- Water component of tailings slurry (varies based on production, 50 percent solids by volume).
- Water as moisture (10 percent) in concentrate.

4.0 RESULTS

4.1 General

This section summarizes the results of the process water balance analyses. The water balance model runs were carried out to provide equally-likely outcomes for each possible combination of climate and operational components. The outcomes are comprised of average, maximum, and minimum cases for the 18.3-year modeled duration. Table 1 provides summary results for:

- Maximum rate of TDF water returned to the mill (column 6)
- Maximum rate of makeup water required (column 7)
- Maximum rate of TDF water to be treated and discharged (column 8)
- Rate of mine dewatering (column 9), and
- Maximum rate of total water to be treated (column 10).

4.2 Tailings Disposal Facility

The water balance has been developed to maintain the depth of water contained in the supernatant pond at about 10 feet during operations, which is sufficient to allow decanting of reclaim water during winter operations without accumulating excessive water over the project life. The TDF will start to accumulate water from direct precipitation in September of Year 1 to provide water for the start of operations.

The average operational pond volume will most likely fluctuate between 13,000,000 cubic feet (ft^3) and 48,000,000 ft^3, from the start to the end of the project (Year 16). Figure 2 shows operational pond fluctuations over the life of the project.

Figure 3 shows the reclaim water from the TDF supernatant pond that will be sent to the process plant under average, maximum, and minimum conditions. As seen on this figure the reclaim flows may reach 920 gpm, with a minimum flow less than 270 gpm at the start of operations.

The effect of the design 72-hr/half-PMP storm event on the pond volume is shown on Figure 4. This figure shows that the estimated maximum pond volume (average volume plus half-PMP storm event) could be contained in the conceptual pond configuration.

At start-up, the supernatant pond area will cover 100 percent of the tailings surface area, but will decrease slightly with time and eventually occupy, on average, approximately 82 percent of the surface area. Figure 5 reflects the percent of the tailings surface covered by the supernatant pond over time.

At the start of operations the supernatant pond depth may reach a maximum of 31 ft. The pond depth should then decrease rapidly over the next 6 months and then remain relatively stable, fluctuating between about 8 ft and 13 ft until the end of operations. Figure 6 shows the predicted supernatant pond depth over time.

Figure 7 shows the area of the TDF in ft^2 that will be covered by the pond. The average pond area will gradually increase to about 7,800,000 ft^2 from September of Year 1 through January Year 8, and then remain relatively stable until August of Year 16.

4.3 Treatment and Makeup Water Requirements

The current operating strategy requires excess water from the TDF to be pumped to the water treatment plant beginning in January of Year 9 to maintain the supernatant pond at a relatively constant depth. The estimated flows to be pumped from the TDF are shown on Figure 8. From January of Year 9 through February of Year 16, an estimated flow of 330 gpm for several months of each year will be required to control the size of the TDF pond. Beginning in March of Year 16, this flow would need to be increased to

660 gpm and continued until the remaining water in the pond is drawn down for final reclamation and closure.

The total amount of flow to the treatment plant will be the sum of:

- The excess water from the TDF to be released.
- Flows from mine dewatering.
- The amounts of TDF reclaim water (liberated from separation and consolidation) requiring treatment.
- Sewage flows from the plant.
- Other sources of wastewater from the facility (truck wash, contact storm water, etc.)

This memorandum only estimates treatment requirements for the excess water from the TDF, above and beyond what is required to be returned to the process, and the flows from mine dewatering. The estimated maximum amounts of these flows are shown in Table 1 (column 10).

Additional makeup water requirements are shown on Figure 9. Three equally possible levels of additional makeup water requirements are shown (average, maximum, and minimum) depending on climatic conditions during operations. Under the current strategy, maximum makeup water requirements were predicted to range from 0 to 216 gpm during Year 2. From Year 3 through Year 6, a continuous makeup flow of 374 gpm (maximum requirement) is predicted to be required. From Year 7 through Year 14, maximum required makeup flows are predicted to range from 351 to 374 gpm for several months each year. As noted in Section 4.2, the model assumes the TDF will begin filling with direct precipitation in September of Year 1, and will accumulate water prior to the start of operations in November of the same year. If desired, the construction of the Stage 1 TDF could be scheduled such that it would be completed earlier to allow more water to be accumulated from precipitation for start-up.

We look forward to discussing this water balance, and would be happy to answer any questions you might have.

Sincerely,
Knight Piésold and Co.

Thomas F. Kerr, P.E.
President

Jason Reiss for
John Dwyer, P.E.
Senior Project Engineer

cc: Jim Jacques (Orvana)
Dave Anderson (Orvana)

Enclosure: Tables 1 and 2, and Figures 1 - 9

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Tables

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Table 1
Orvana Resources U.S. Corporation
Copperwood Project
Pre-Feasibility Study
Process Water Balance, Revision 1

Production Schedule, Process Water Requirements, and Treatment Requirements

1	2	3	4	5	6	7	8	9	10	11
Year	Ore Production (Mt/yr)	Cumulative Ore Production (Mt)	Tailings Solids to TDF (Mt/yr)	Estimated Process Water Required (gpm)	Maximum Rate of TDF Water to Mill (gpm)	Maximum Rate of Fresh Makeup Water Required (gpm)	Maximum Rate of TDF Water to be Treated and Discharged (gpm)	Mine Dewatering to Treatment and Mill (gpm)	Maximum Rate of Total Water to Treatment(4) (gpm)	Average Annual Volume of TDF Water to be Treated and Discharged(5) (gal)
1	0.08	0.08	0.08	33.2	0-183	0	0	15	15	0
2	0.77	0.85	0.72	293.1	133-266	0-266	0	15	15	0
3	1.97	2.81	1.84	770.0	86-360	374	0	37	37	0
5	2.62	7.58	2.49	1030.2	921	374	0	60	60	0
6	2.62	10.20	2.47	1030.2	810	374	0	121	121	0
7	2.62	12.82	2.49	1030.2	722	0-361	0	225	225	0
8	2.62	15.44	2.48	1030.2	709	0-355	0	320	320	0
9	2.62	18.06	2.49	1030.2	704	0-352	330	329	329-659	113,269,184
10	2.62	20.68	2.49	1030.2	702	0-351	0-330	341	341-671	43,159,489
11	2.62	23.30	2.47	1030.2	865	0-374	0-330	342	342-672	43,579,056
12	2.62	25.92	2.53	1030.2	889	0-374	0-330	170	170-500	43,425,215
13	2.62	28.54	2.53	1030.2	892	0-374	0-330	170	170-500	6,391,408
14	2.62	31.16	2.53	1030.2	891	0-374	0-330	170	170-500	13,943,620
15	2.62	33.78	2.53	1030.2	891	0	0-330	170	170-500	15,677,831
16	0.13	33.90	0.12	49.0	0-54	0	330-660	8	338-668	292,270,578
17	0	0	0	0	0	0	660	0	660	348,073,027
18	0	0	0	0	0	0	660	0	660	284,986,668
19	0	0	0	0	0	0	257-660	0	257-660	165,387,227

Notes:
1) Production schedule from Marston and Marston (April 19, 2011)
2) Process Water Requirements estimated from previous production schedule
3) Mine dewatering estimate from AECOM
4) Total Treatment estimate includes only discharge water from TDF and mine dewatering flows
5) These values do not include mine dewatering

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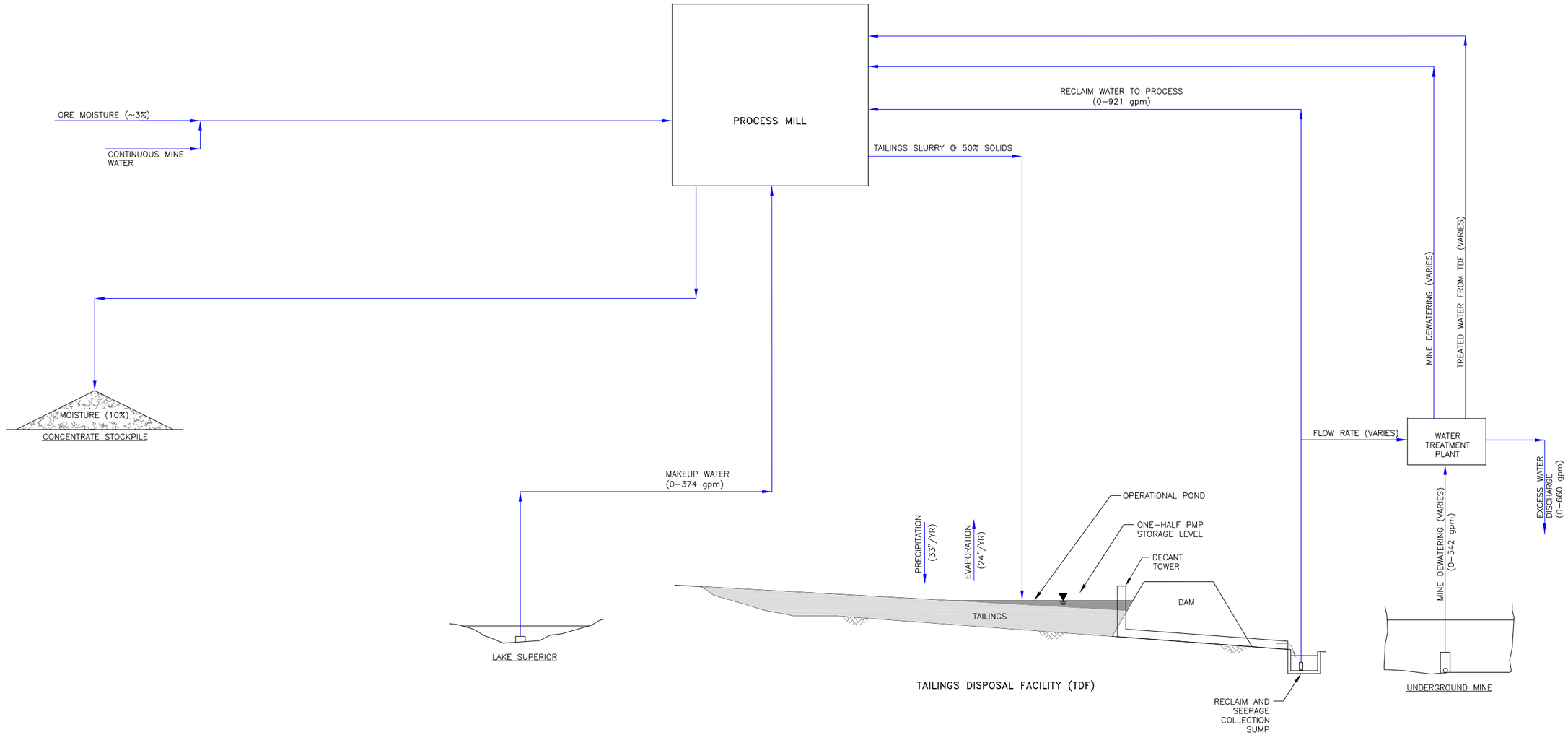
Table 2
Orvana Resources U.S. Corporation
Copperwood Project
Pre-Feasibility Study
Process Water Balance, Revision 1

Consolidation and Water Released from Tailings

1	2	3	4	5	6	7	8	9
Year	Incremental Tailings Solids to TDF (tons)	Cumulative Tailings Solids to TDF (tons)	Incremental Slurry Volume to TDF (ft^3)	Incremental H2O in Slurry before Consolidation (tons)	Incremental H2O in Slurry before Consolidation (ft^3)	Cumulative Consolidated Tailings Volume (ft^3)	Approximate Dry Density ($tons/yd^3$)	Incremental Water Released from Tailings (ft^3)
1	75,299	75,299	3,324,289	75,299	2,413,434	2,884,292	0.705	439,997
2	720,896	796,195	31,825,956	720,896	23,105,644	25,345,452	0.848	9,364,795
4	2,025,300	4,656,506	89,412,467	2,025,300	64,913,451	136,612,531	0.920	32,386,669
5	2,486,380	7,142,886	109,768,136	2,486,380	79,691,667	202,099,596	0.954	44,281,071
6	2,467,015	9,609,901	108,913,205	2,467,015	79,070,987	267,055,502	0.972	43,957,299
7	2,487,348	12,097,249	109,810,882	2,487,348	79,722,701	330,276,620	0.989	46,589,765
8	2,477,666	14,574,915	109,383,417	2,477,666	79,412,361	392,505,868	1.003	47,154,168
9	2,494,126	17,069,041	110,110,108	2,494,126	79,939,939	454,731,781	1.013	47,884,196
10	2,492,190	19,561,230	110,024,615	2,492,190	79,877,871	515,587,281	1.024	49,169,115
11	2,469,920	22,031,150	109,041,444	2,469,920	79,164,089	574,636,085	1.035	49,992,640
12	2,526,079	24,557,228	111,520,745	2,526,079	80,964,061	635,251,647	1.044	50,905,183
13	2,531,888	27,089,117	111,777,224	2,531,888	81,150,265	696,263,514	1.050	50,765,357
14	2,529,952	29,619,068	111,691,731	2,529,952	81,088,197	756,453,826	1.057	51,501,419
15	2,530,920	32,149,988	111,734,478	2,530,920	81,119,231	815,906,819	1.064	52,281,484
16	120,380	32,270,369	5,314,528	120,380	3,858,347	806,679,150	1.086	14,542,197
17	0	32,270,369	0			794,642,366	1.108	12,036,784
18	0	32,270,369	0			792,442,366	1.114	2,200,000
19	0	32,270,369	0			788,946,581	1.118	3,495,785

Notes:
1) Assumes slurry is 50 percent solids by weight and SG of slurry = 1.452 (KD Engineering)
2) Consolidated tailings in slurry based on laboratory testing of flocculated tailings by Knight Piésold

Figures



PROJECT	COPPERWOOD PROJECT
TITLE	PROCESS WATER BALANCE SCHEMATIC
CLIENT	ORVANA RESOURCES U.S. CORPORATION

Knight Piésold CONSULTING

DESIGNED BY	JC	LOCATION	PROJECT NUMBER	FIGURE NUMBER	REVISION
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Figure 2
Orvana Resources U.S. Corporation - Copperwood Project
TDF Operational Pond Volume without Storm Event

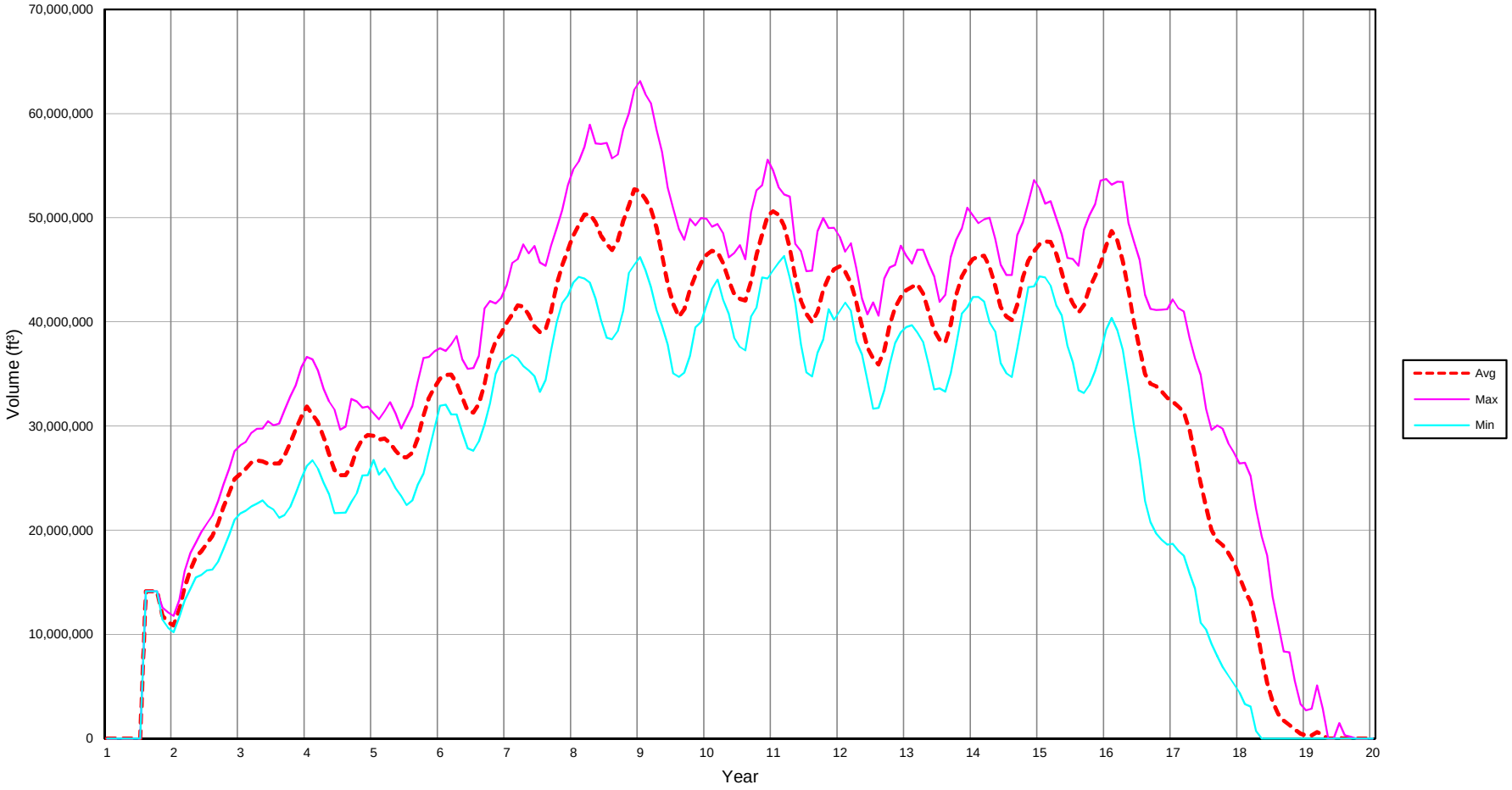

Figure 3
Orvana Resources U.S. Corporation - Copperwood Project
Flow from the TDF to the Plant

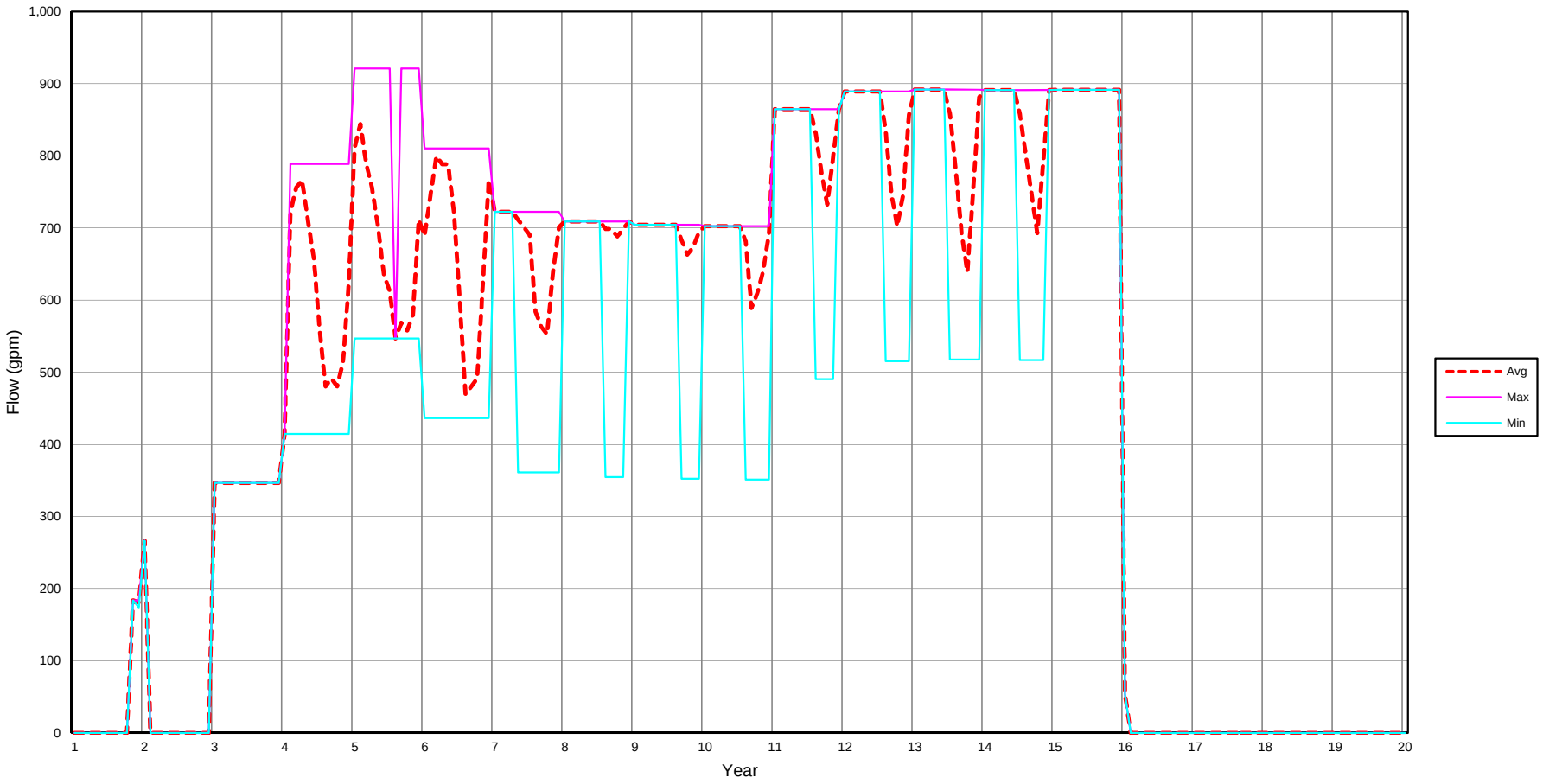

Figure 4
Orvana Resources U.S. Corporation - Copperwood Project
TDF Operational Pond Volume with Storm Event

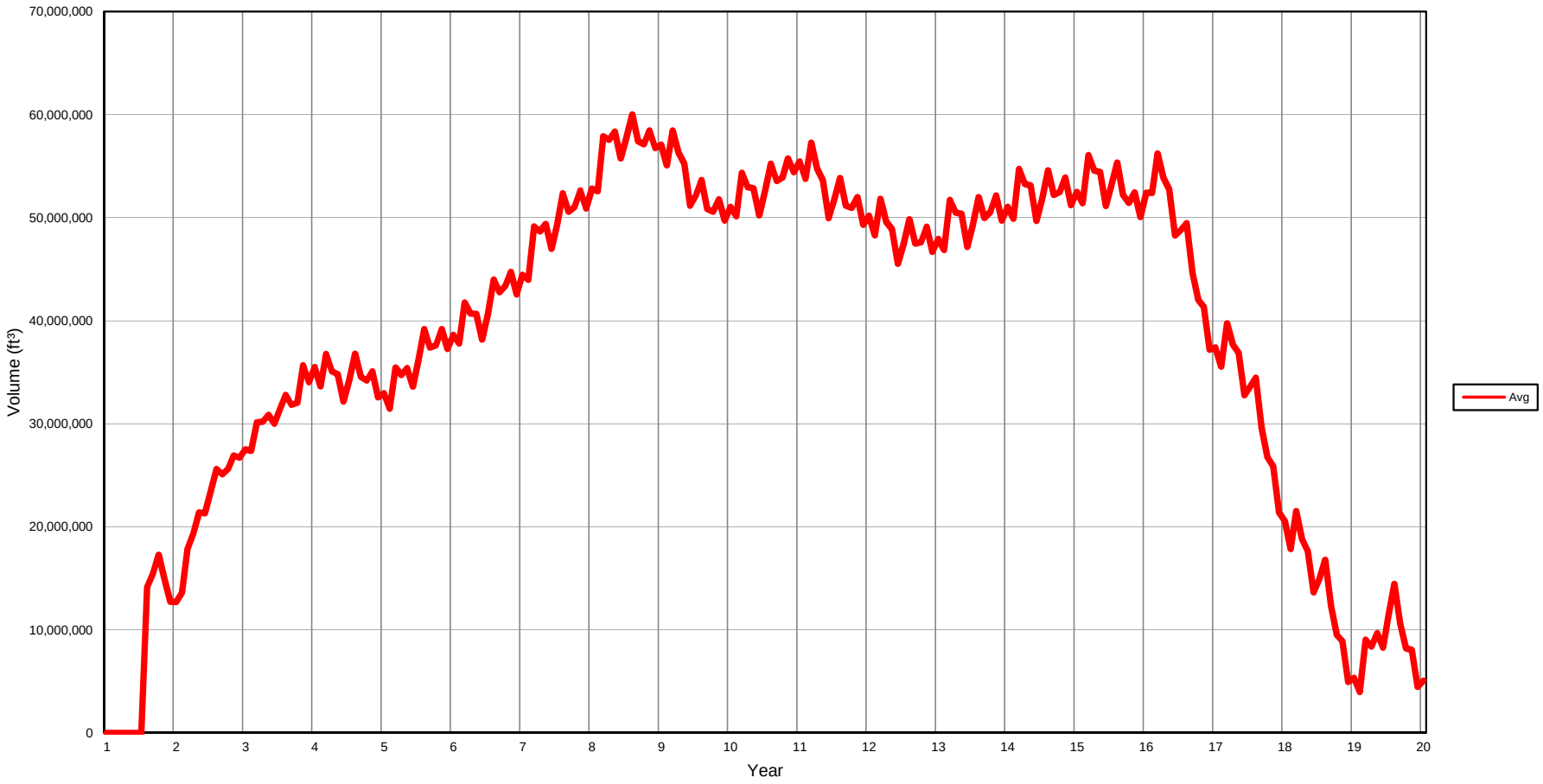

Figure 5
Orvana Resources U.S. Corporation - Copperwood Project
Percent of TDF Pond Area over Tailing Surface

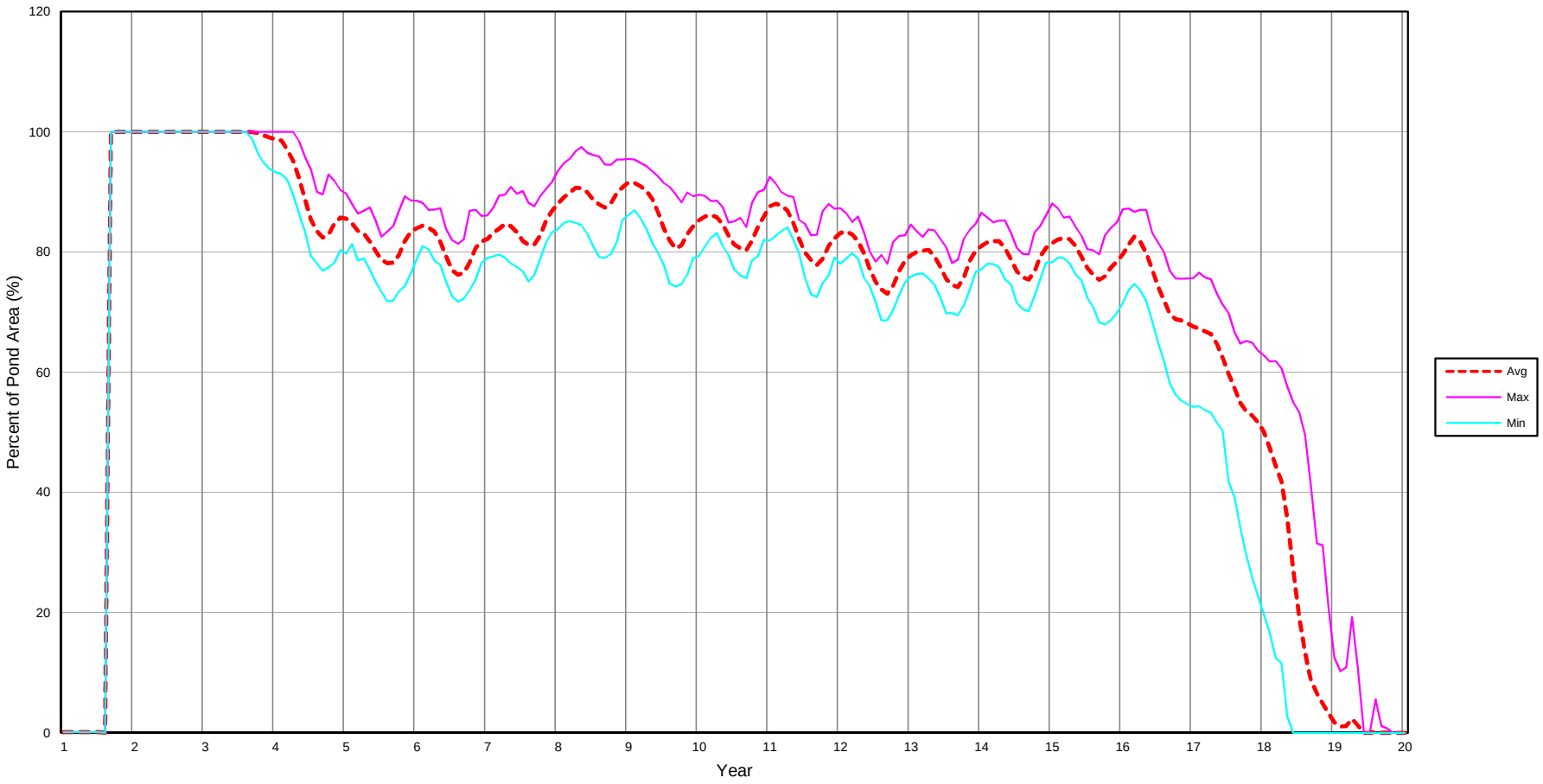

Figure 6
Orvana Resources U.S. Corporation - Copperwood Project
TDF Pond Depth at the TDF Pond

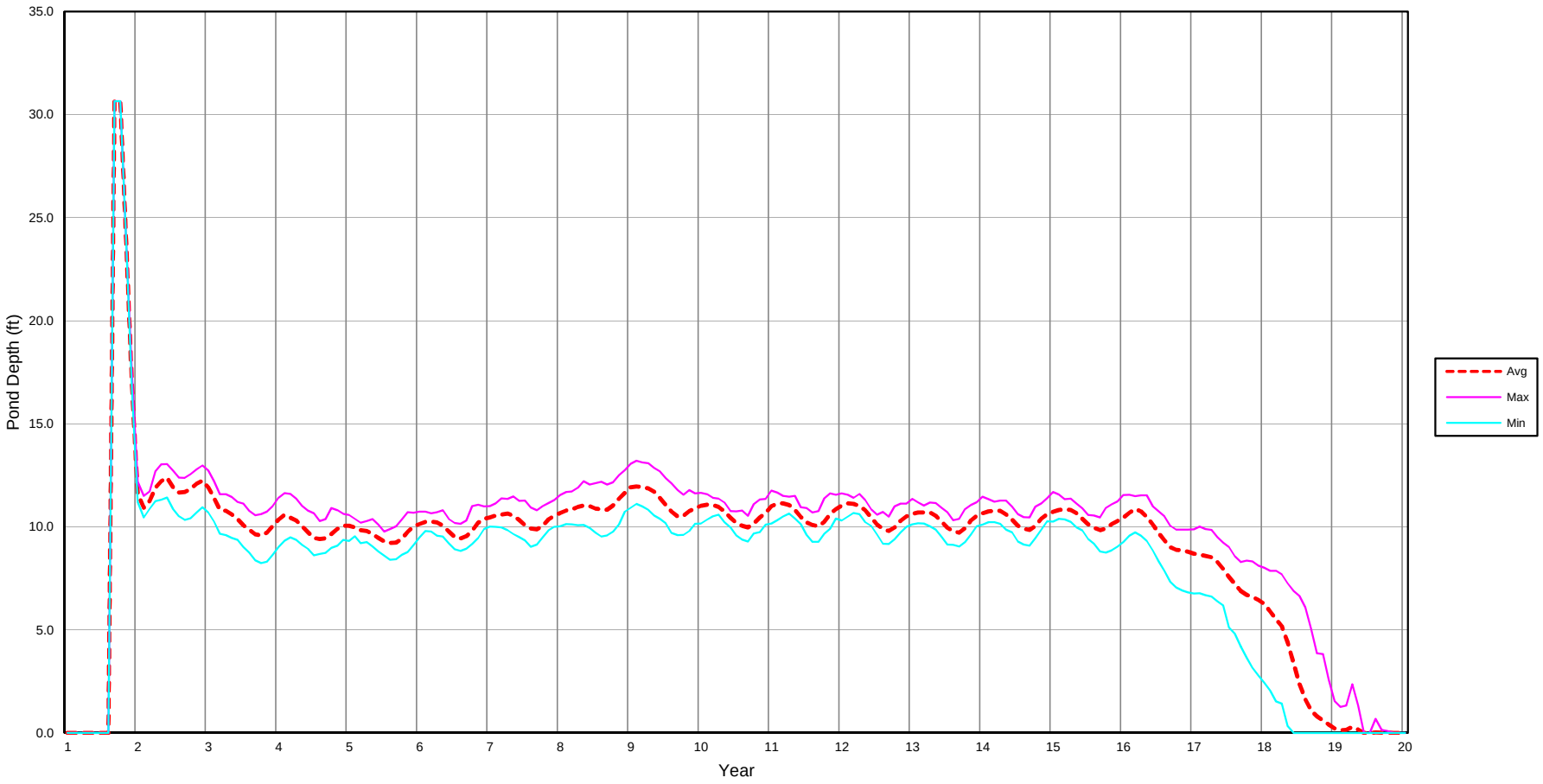

Figure 7
Orvana Resources U.S. Corporation - Copperwood Project
TDF Pond Area

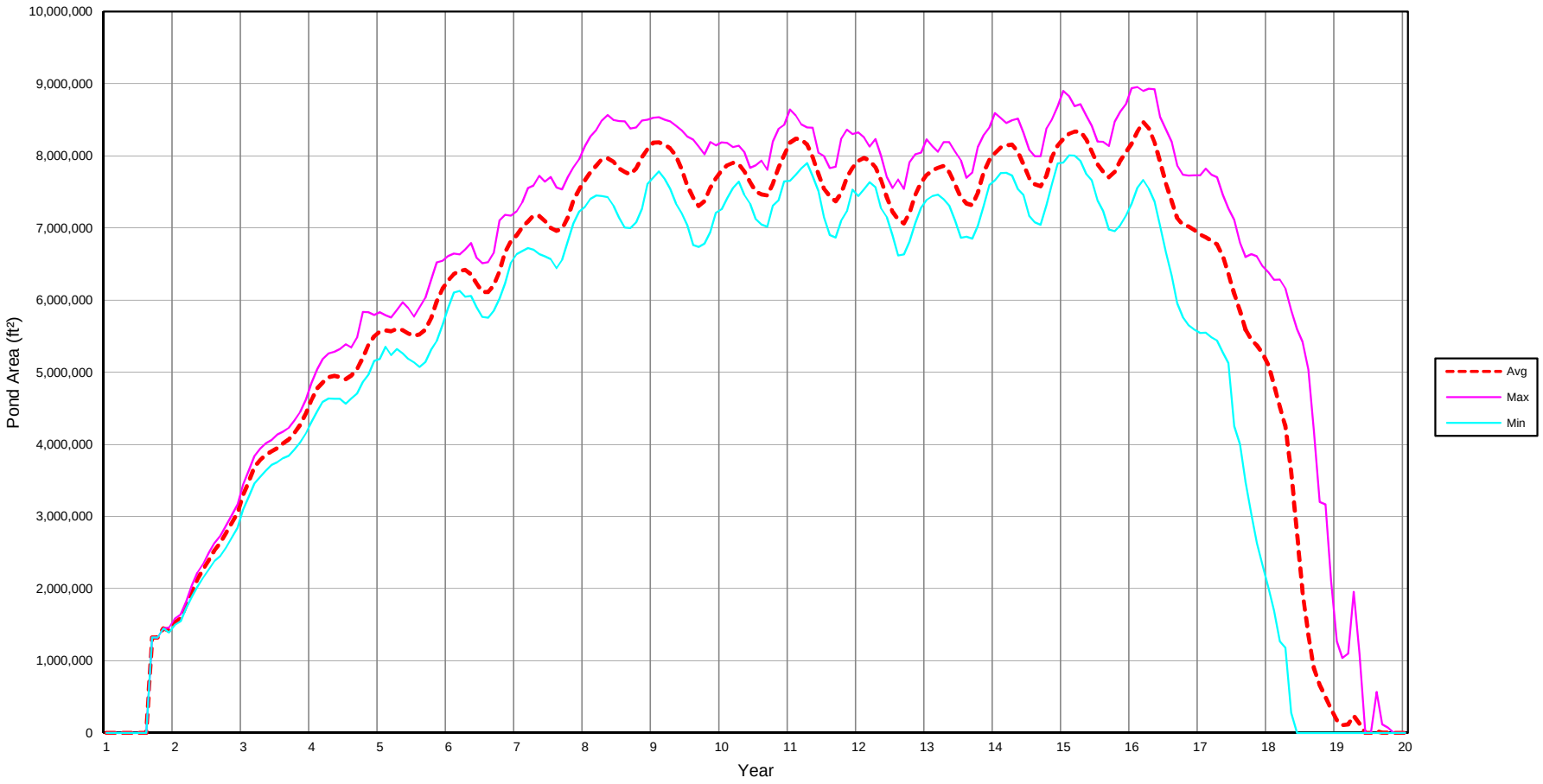

Figure 8
Orvana Resources U.S. Corporation - Copperwood Project
Water Treatment

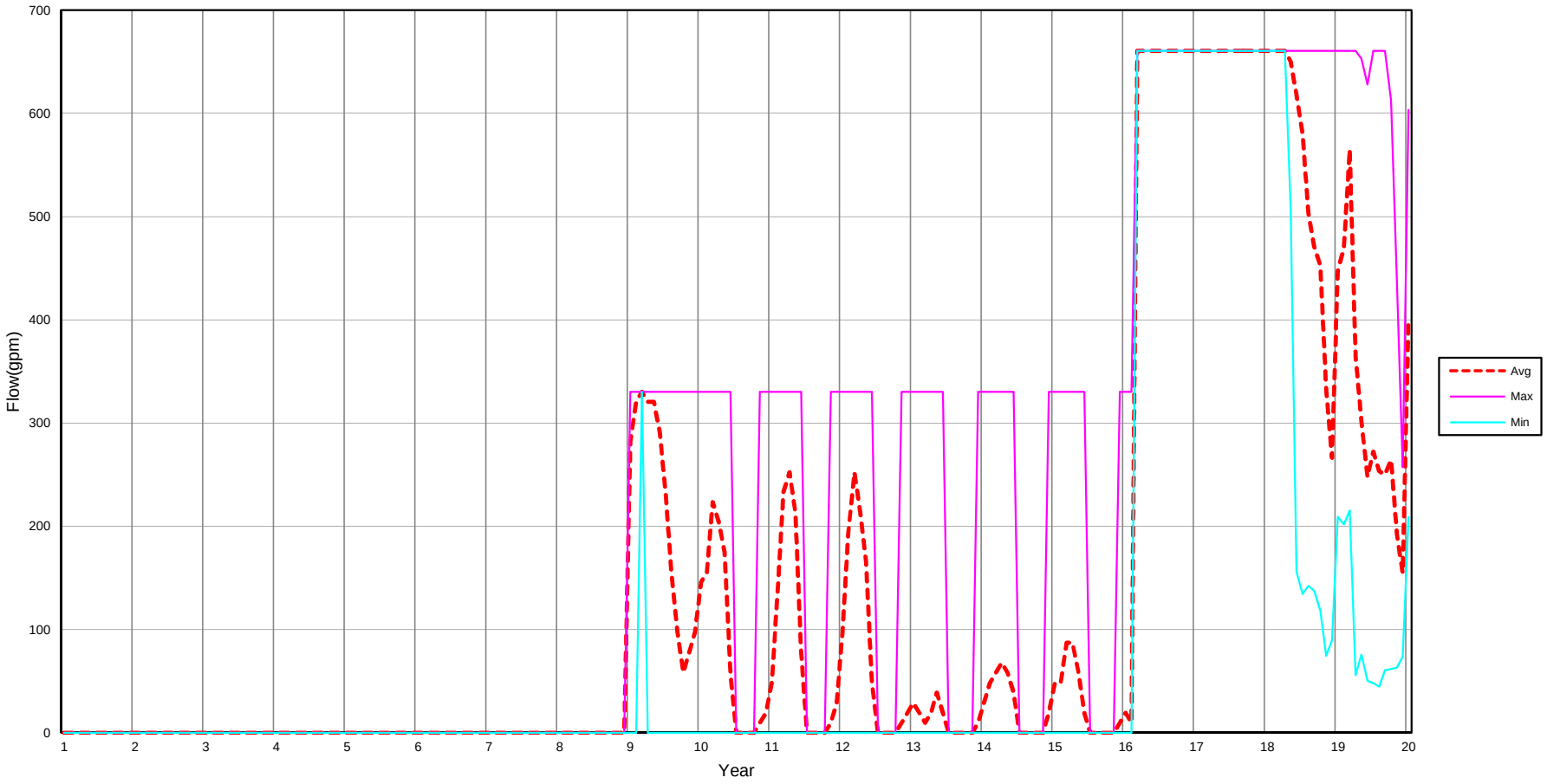
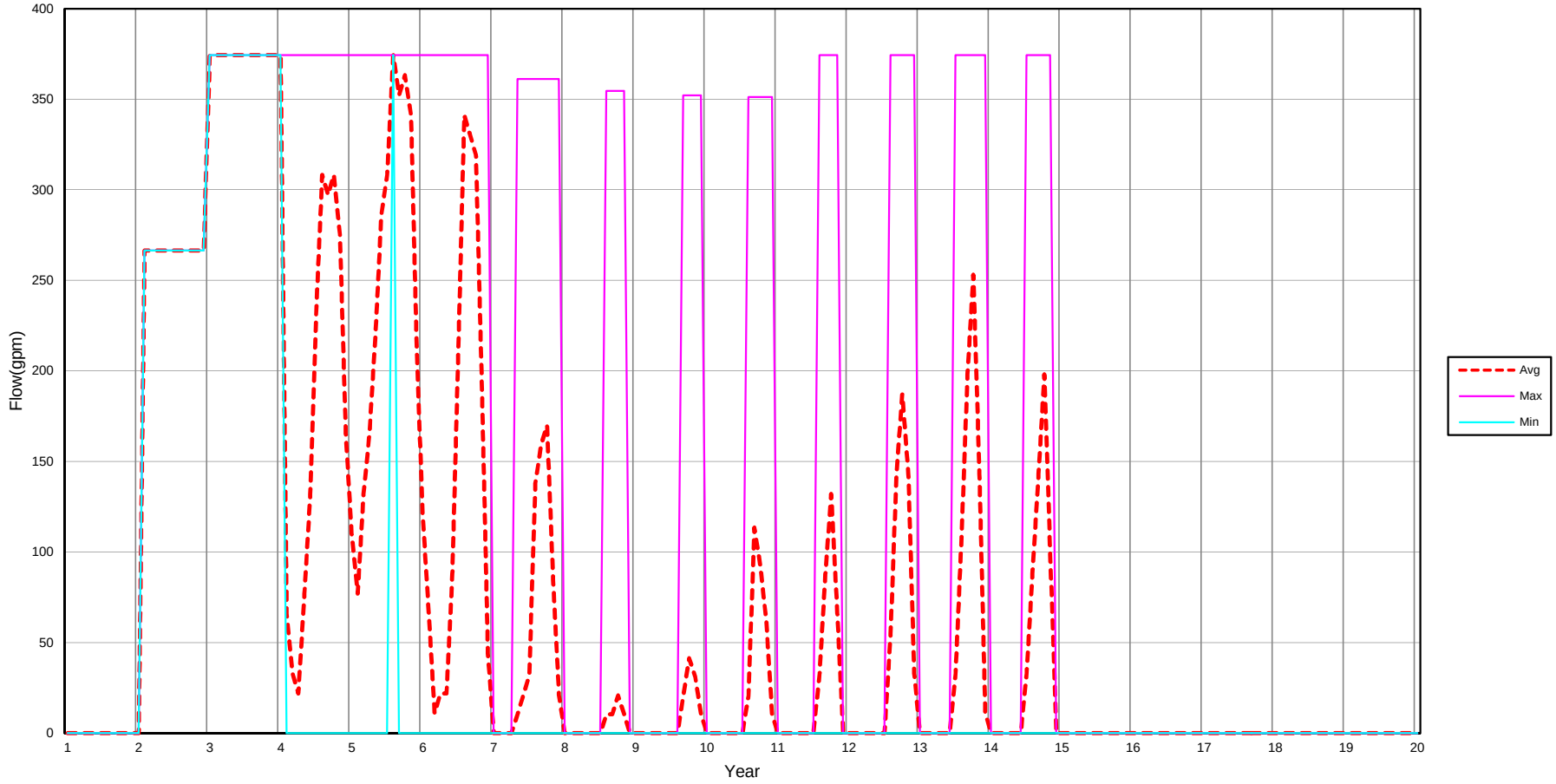
Figure 9
Orvana Resources U.S. Corporation - Copperwood Project
Required Additional Makeup Water