Appendix 5-G

2012 Open Pit Geotechnical Design

HARPER CREEK PROJECT

Application for an Environmental Assessment Certificate / Environmental Impact Statement

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN

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OHSAS 18001

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
(REF. NO. VA101-458/4-5)

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YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
(REF. NO. VA101-458/4-5)

EXECUTIVE SUMMARY

The Harper Creek Project is a proposed copper-gold-silver mine located approximately 150 km north by highway of Kamloops, British Columbia. The proposed open pit mine will extract approximately 700 Mt of ore, which will be processed at 70,000 tons per day over the 28 year mine life. The pit slopes will vary in height from approximately 200 to 450 m for the ultimate open pit configuration.

Knight Piésold Ltd. (KPL) was retained by Yellowhead Mining Inc. (YMI) to complete feasibility level geotechnical investigations at the proposed open pit and to develop recommendations for the maximum practical pit slopes that can be achieved. A total of 2395 m of diamond drilling has been completed in 7 holes at the Harper Creek site during the 2011 Geotechnical Site Investigation (KPL Report Ref. No. VA101-458/3-1). Detailed geomechanical logging of oriented core, in situ hydrogeological testing, rock core sampling and test pitting were performed as part of this program. The data collected by KPL staff was supplemented with detailed geological logging of core from the 2011 exploration drilling program conducted by CME Consultants Inc. (CME).

The Harper Creek deposit is an extensive volcanogenic sulphide system hosted in metamorphic rocks. Silica alteration dominates the volcanic package. The Harper Creek Fault bisects the deposit along a northeast-southwest trend, dipping sub-vertically. The predominant foliation feature of the deposit dips towards the north at flat angles ranging between 25° and 35°.

A geotechnical model was created based on lithology, alteration, rock strength, and rock mass quality within the deposit. The geotechnical model incorporates three major geotechnical domains: East Volcaniclastics, West Volcaniclastics, and Phyllite. The overburden unit is negligible in the deposit area. The intact rock strengths were found to be generally strong; however, the foliation planes that are ubiquitous throughout the rock create planes of weakness. Combining the intact rock properties and characteristics of discontinuities, the overall rock mass quality was characterized as GOOD.

The water table is typically near surface or artesian throughout the pit area.

The geotechnical database has been utilized to evaluate rock mass characteristics and develop recommendations for feasibility pit slope and pit dewatering designs. Six design sectors, namely, the Northeast, East, South, Southwest, West and Northwest, were defined based on pit wall orientations and geotechnical domains. Design methods used to determine appropriate pit slope angles for the Harper Creek pit included detailed kinematic stability assessment and evaluation of the overall rock mass stability for designated design sectors. The pit slope geometries for each

design sector have been determined based on minimum acceptable criteria for each of these design methods.

Stereographic analyses were performed to determine the potential kinematic failure modes in the rock slopes. It was determined that the northward dipping foliation and joint structure present within the pit allows for planar failures to develop in the walls of the South and Southwest Sectors. Therefore, the inter-ramp angle of the South and Southwest Sector pit slopes should be no steeper than 35° to prevent multiple bench planar failure from occurring. Kinematically possible failure modes are less significant in the other areas of the pit and an inter-ramp slope angle of 44° is considered to be achievable.

The bench geometry has been selected based on the minimum allowable bench width of 8 metres for a 12 metre high single bench configuration in accordance with the British Columbia Mines Act (2003). A bench face angle of 70° is recommended for the bedrock slopes with the exception of the northward dipping pit walls in the South and Southwest Sectors, which will be reduced to a 60° bench face angle. Bench widths in the South and Southwest Sectors will be increased to 10 m to flatten the slope to the design inter-ramp angles. Optimum bench configurations will be determined during initial open pit development.

Limit equilibrium analyses were performed to assess the stability of the rock mass and determine practical inter-ramp slope heights for the inter-ramp angles determined in the kinematic analysis. It was determined that slopes excavated in East Volcaniclastics (Northeast, East and South Sectors) should have inter-ramp slopes no greater than 200 m high. Inter-ramp slopes should not exceed a height of 150 m in all other sectors. Overall slope angles are typically 3° to 4° shallower than the inter-ramp slope angles once the haulage ramps and/or step outs are included.

The recommended pit slope design parameters are summarized below:

Design Sector	Wall Geology	Bench Face Angle	Bench Height	Bench Width	Inter-ramp Angle	Maximum Inter-ramp Height	Overall Slope Angle
		(°)	(m)	(m)	(°)	(m)	(°)
Northeast	East Volcaniclastics	70	12	8	44	200	42
East	East Volcaniclastics	70	12	8	44	200	42
South	East Volcaniclastics	60	12	10	35	200	33
Southwest	West Volcaniclastics	60	12	10	35	200	33
West	Phyllite	70	12	8	44	200	40
Northwest	West Volcaniclastics	70	12	8	44	200	40

The Harper Creek Fault is sub-vertically dipping and is not expected to adversely affect the final wall stability. However, it is recommended that the fault be mined through when encountered and not left exposed within an interim pit wall.

The recommended pit slope angles are based on the assumptions that low-damage controlled blasting techniques and effective water diversion and pit dewatering measures are implemented. The blasting patterns should be evaluated by means of trial blasts during early mining activities in order to develop the optimum hole spacing, charge weights and delay sequences for both the cushion (buffer) blast holes and perimeter trim (pre-shear) blast holes. Diversion channels should be constructed around the perimeter of the pit, and staged in construction to provide effective redirection of water at all phases of pit development. Detailed geotechnical mapping of the rock mass should be completed once bedrock is exposed during pre-production and ongoing mining. Pit face mapping should also be supplemented with continuous monitoring of the slope deformations and hydrogeological conditions in and around the pit. Data collected during pit development will be used for ongoing pit slope optimization. Pit slope monitoring must also include regular inspections of benches and pit crests in order to identify any tension cracking or other indications of potential slope instability. Appropriate movement monitoring systems will be required for any potentially unstable areas of the pit.

The currently available drilling and discontinuity mapping data and stability analyses suggest the recommended pit slope design is reasonable and appropriate. However, given the inherent risks it is possible that a portion of the overall pit slope could require flattening during later years of the operation. It will be useful to update the geological model and incorporate additional geological interpretations of the nature and extent of major structural features, as well as the alteration assemblages present. Further hydrogeological study is recommended for the detailed design of the dewatering system. The pit slope designs should be reviewed by a qualified rock slope engineer and adjusted as additional information and/or pit designs become available.

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SECTION 1.0 – INTRODUCTION

1.1 PROJECT DESCRIPTION

The Harper Creek Project is a proposed copper-gold-silver mine located approximately 12 km southwest of Vavenby, B.C, south of the North Thompson River at an elevation of approximately 1800 m, as shown on Figure 1.1.

The mineralized zone consists of chalcopyrite with accessory pyrite, magnetite and pyrrhotite, as well as significant amounts of gold and silver. The mineralization of the deposit is tabular and strikes east-west, dipping at shallow angles towards the north. The ore will be mined using open pit methods and processed at 70,000 tonnes/day for approximately 28 years. Approximately 700 Mt of ore will be extracted over the life of the mine. Ore will be taken directly from the open pit until year 22, after which backfilling of the pit with water from the tailings management facility will begin as part of the mine closure plan. Ore processed from year 22 to the end of the mine life at year 28 will be obtained from a low-grade ore stockpile that will be progressively developed during pit excavation.

1.2 PROJECT WORK HISTORY

Noranada and Quebec Cartier Mines investigated the Harper Creek property between 1966 and 1973. A pre-feasibility study, commissioned by Aurun Mines, was completed by Phillips Barratt Kaiser Engineering Ltd. in 1986. Scott Wilson Roscoe Postle Associates completed a NI43-101 Technical Report in November, 2007, and updated in March 2008. Wardrop Engineering was commissioned to produce a preliminary economic assessment, which incorporated preliminary test pitting and core logging by other consultants in 2008. Knight Piésold Ltd. (KPL) provided a TMF location alternatives assessment as part of the preliminary economic assessment, which was released in the spring of 2011.

1.3 SCOPE OF WORK

KPL completed a geotechnical site investigation program from June to October of 2011. The purpose of this program was to collect geotechnical and hydrogeological information in support of a feasibility study for the Harper Creek Project. The site investigation included geomechanical drilling, core logging and orientation, field and laboratory testing of rock and soil samples, standpipe piezometer installation, test pitting and road cut logging, hydrogeological testing (packer and falling head tests) and response testing of installed piezometers. This program was conducted simultaneously with the 2011 exploration and resource drilling program, which was overseen by CME Consultants Inc. (CME). The 2011 Geotechnical Site Investigation results are presented in a KPL data report separately (KPL Ref. No. VA101-458/3-1, February, 2012).

KPL provided preliminary pit slope recommendations to support preliminary mine planning based on partially compiled site investigation data (KPL Ref. No. VA11-01417, October, 2011). These recommendations were derived from a preliminary kinematic analysis of the available structural data collected as part of the 2011 geomechanical drilling program. A pit shell provided by Wardrop in March, 2011 was used as the basis for the preliminary pit slope recommendations, and design sectors were delineated based on the nominal pit wall dip directions.

This report presents feasibility level open pit slope designs. These designs are based on data collected during the 2011 Geotechnical Site Investigation, rock strength and soil index laboratory test results (provided November 2011), and an updated pit shell model provided by Wardrop (provided January 2012). The scope of work for this report includes:

- Characterization of the geological, geomechanical and hydrogeological data, and verification of the geotechnical parameters for the pit slope design.
- Detailed kinematic and rock mass stability analyses.
- Determination of pit slope design criteria and recommendations for the updated mine plan.
- Conceptual pit water management plan.

The available geotechnical information, including the pit geology model, rock mass structure, rock mass quality and pit hydrogeology was compiled and reviewed. The pit wall geology and pit design sectors were defined and kinematic and rock mass stability analyses completed. Slope design criteria and recommendations for feasibility pit development are provided in this report.

SECTION 2.0 – PIT SLOPE DESIGN CONCEPTS

2.1 GENERAL

The overall objective of hard rock pit slope design is to determine the steepest practical slope angles for the open pit mine, so the operator can maximize the extraction of the identified ore resource. Balanced against this is the increased likelihood that steep slopes will lead to the development of slope stability issues that could ultimately impact worker safety, productivity and mine profitability. The approach is to base the pit design on achieving an acceptable level of risk and incorporating this into the stability analyses as a factor of safety (FOS).

This section briefly introduces pit slope terminology that is used throughout this report and some of the key geotechnical and mining factors that can impact slope design. In addition, a summary of the analysis techniques utilized in this study and the adopted risk management approach are discussed.

2.2 PIT SLOPE GEOMETRIES

Figure 2.1 illustrates the inter-relationships between bench geometry, inter-ramp slope angle and the overall slope angle. The primary components of pit slope design are as follows:

- **Bench Geometry** – The height of the benches is typically determined by the size of the shovel chosen for the mining operation. The bench face angle is usually selected in such a way as to reduce, to an acceptable level, the amount of material that will likely fall from the face or crest. The bench width is sized to prevent small wedges and blocks from the bench faces falling down the slope and potentially impacting workers and equipment. The bench geometry that results from the bench face angle and bench width will ultimately dictate the inter-ramp slope angle. Double or triple benches can be used in certain circumstances to steepen inter-ramp slopes.
- **Inter-ramp Slope** – The maximum inter-ramp slope angle is typically dictated by the bench geometry. However, it is also necessary to evaluate the potential for multiple bench scale instabilities due to large-scale structural features such as faults, shear zones, bedding planes, foliation etc. In some cases, these persistent features may completely control the achievable inter-ramp angles and the slope may have to be flattened to account for their presence. It may not be economically feasible to construct inter-ramp slopes at shallow enough angles for complete stability. A slope monitoring and management plan should be developed in these cases to monitor and control slope behaviour.
- **Overall Slope** – The overall slope angle that is achieved in a pit is typically flatter than the maximum inter-ramp angle due to the inclusion of haulage ramps. Other factors that may reduce the overall slope angles are things such as rock mass strength, groundwater pressures, blasting vibration, stress conditions and mine equipment requirements.

2.3 KEY FACTORS FOR PIT SLOPE DESIGN

The stability of pit slopes in rock is typically controlled by the following key geotechnical and mining factors:

- **Lithology and Alteration** – The rock types intersected by the final pit walls and level of alteration are key factors that impact eventual stability of the pit. Geological domains are created by grouping rock masses with similar geomechanical characteristics.
- **Large-scale Structural Features –** The orientation and strength of major, continuous geological features such as faults, shear planes, weak bedding planes, structural fabric, and/or persistent planar joints will strongly influence the overall stability of the pit walls.
- **Small-scale Structural Features –** The orientation, strength, and persistence of smaller scale structural features such as joints will control the stability of individual benches and may ultimately restrict the inter-ramp slope angles.
- **Rock Mass Quality –** Rock mass strengths are typically estimated via intact rock strength and rock mass classification schemes such as the rock mass rating (RMR) system. Lower rock mass quality typically results in flatter overall slope angles.
- **Groundwater Conditions –** High groundwater pressures and water pressure in tension cracks will reduce rock mass shear strength and may adversely impact slope stability. Depressurization programs can reduce water pressure behind the pit walls and allow steeper pit slopes to be developed.
- **Blasting Practices** – Production blasting can cause considerable damage to interim and final pit walls. This increased disturbance is typically accounted for with a reduction in the effective strength of the rock mass. Controlled blasting programs near the final wall can be implemented to reduce blasting induced disturbances and allow steeper slopes. Scaling of blast induced fracturing is essential.
- **Stress Conditions –** Mining induces stress changes due to lateral unloading within the vicinity of the pit. Stress release can lead to effective reductions in the quality of the rock mass and increases in slope displacements. Localized stress decrease can reduce confinement and result in an increased incidence of ravelling type failures in the walls. Modifying the mining arrangement and sequence can sometimes manage these stress changes to enhance the integrity of the final pit walls.

2.4 METHODOLOGY FOR PIT SLOPE STABILITY ASSESSMENT

A series of design sectors were defined to group areas of the proposed mine with similar mine geometry, geology and rock mass characteristics in order to complete the slope stability analyses. A number of different types of stability analyses were undertaken to determine appropriate slope angles for a given open pit slope. Slope stability analyses undertaken in this study included the following types:

- **Kinematic Stability Analyses** – Stereographic analyses were conducted on the discontinuity orientation data to identify the kinematically possible failure modes. Appropriate bench face angles and/or inter-ramp slope angles are assigned in such a way as to reduce the potential for discontinuities to form unstable wedges or planes. Typically, it is not cost effective to eliminate all potentially unstable blocks and a certain percentage of bench face failure and/or multiple bench instabilities are acceptable. Most of the smaller unstable features will be removed during mining by scaling the bench faces.
- **Rock Mass Stability Analyses** – Limit equilibrium analyses of the rock slopes were performed to compute the overall factors of safety against large-scale, multiple-bench failures

through the rock mass. Maximum inter-ramp slope heights and overall slope angles were defined based on the results of the rock mass stability analyses.

2.5 ACCEPTANCE CRITERIA

The recommended pit slope configurations were developed based on analysis results and using data interpreted from the geological model, rock mass characteristics, and inferred groundwater conditions. All these data may be limited or variably distributed and/or of uncertain quality. The target level of confidence for this feasibility level pit slope study is typically around 50% to 70%. A general guidance to pit slope design acceptance criteria is summarized below (after Read and Stacey, 2009) and suggested FOS targets for open pit design at the Harper Creek are highlighted in **BOLD**.

Slope Scale	Consequences of Failure	Acceptance Criteria		
		FOS (min) (Static)	FOS (min) (Dynamic)	POF (max) P[FOS≤1]
Bench	Low to High	1.1	N/A	25% - 50%
Inter-ramp	Low	1.15 - 1.2	1.0	25%
	Medium	**1.2**	**1.0**	**20%**
	High	1.2 – 1.3	1.1	10%
Overall	Low	1.2 – 1.3	1.0	15% - 20%
	Medium	**1.3**	**1.05**	**5% - 10%**
	High	1.3 – 1.5	1.1	≤5%

It is noted that there are few recorded instances in which earthquakes have been shown to produce significant instability in hard rock open pits. In most cases, earthquakes have produced small shallow slides and rock falls in rock slopes, but none on a scale sufficient enough to disrupt mining operations (Read and Stacey, 2009). It is also noted that the seismicity at the project site is low. As such, slope stability under seismic (earthquake) conditions was not evaluated in this study.

SECTION 3.0 PIT GEOTECHNICAL CHARACERIZATION

3.1 GENERAL

The characterization of the pit geomechanical conditions was based on all relevant geological, geomechanical and hydrogeological information from the 2011 Geotechnical Site Investigation. Data from both geomechanical and exploration drillholes including descriptive geological and geotechnical logging, and the in-situ, field and laboratory test results were utilized to characterize the geotechnical conditions of the open pit. Seven geomechanical drill holes were completed in the open pit (HC11-GM01 to GM07) and were the primary sources of geomechanical information used in the open pit design.

This section provides a review of geological, geomechanical and hydrogeological conditions for the proposed Harper Creek Open Pit. A preliminary pit shell model provided by Merit Consultants International (Merit) in January 2012 was utilized for this geotechnical characterization work.

3.2 REGIONAL GEOLOGY

The regional geology consists of deformed and metamorphosed Lower Cambrian and Upper Devonian to Mississippian sedimentary and volcanic rocks with sills and dikes consisting of foliated granite to diorite. These rock units comprise what is known as the Eagle Bay Assemblage. This assemblage is intruded by Middle to Upper Jurassic and Cretaceous granitic plutons. Eocene-age Kamloops Group volcanic rocks overlay the Eagle Bay Assemblage rocks (Scott Wilson, 2007).

The regional structure typically consists of east-west striking, low to moderately dipping stratigraphy. Thrust faults disrupt the stratigraphic sequence by positioning Cambrian rocks overtop of younger Paleozoic strata. A series of steeply southeast-dipping normal faults are present, hosting Tertiary dikes.

3.3 TOPOGRAPHY AND GEOMORPHOLOGY

The project area is hosted in gently sloping upland ridges flanked by steepened valley slopes. These valleys include the Harper Creek Valley to the west and the Barriére River to the East, with the moderately sloped Thompson River Valley to the north. The elevations of the area range from approximately 1100 m at the floor of the Harper Creek Valley to 1830 m at the ridges overlooking the south end of the open pit. The average elevation of the open pit area and plant site is 1800 m. The area has been glaciated and mountain tops are typically rounded. The property is covered in coniferous forest, and has undergone extensive logging in the past.

3.4 DEPOSIT GEOLOGY

The Harper Creek deposit is an extensive volcanogenic sulphide system hosted in the metamorphic rocks of the Eagle Bay Assemblage, specifically within the Lower Paleozoic and Greenstone Belts. The predominant geological units in the open pit area include schist, quartz eye schist, phyllite, silica altered host, and fault zones in accordance with CME's geological interpretation. The quartz eye schist is identified by the presence of its titular quartz-eyes, and features sericite and quartz, and may also contain feldspar, chlorite and hornblende. The schist without quartz eyes features intermittent silicification, but lacks the defining quartz eye feature. The schist unit also contains feldspar, chlorite, augen and sericite. The phyllite is the second most predominant unit in the open pit area (after the schists) and is characterized by sericite-chlorite-quartz and graphitic zones. The silica altered host defines the main alteration in the pit area, demarcated by silica alteration overprinting the host rock. The fault zones are a distinct lithological unit, and are characterized by broken rock and fault gouge.

The deposit is interpreted to be a polymetallic volcanogenic sulphide deposit comprised of lenses of disseminated, banded and fracture-filling iron and copper sulphides. The mineralization consists of chalcopyrite with accessory pyrite, magnetite and pyrrhotite. There are significant amounts of Au and Ag present within the mineralized zone. The mineralization is tabular and strikes east-west, dipping at 15° to 25°, with sulphides lenses up to tens of meters thick. There is a broad lower-grade zone of Cu with Au/Ag that is linked to multi-phased stringer or feeder zones within the eastern zone of the pit area.

3.5 GEOTECHNICAL CHARACTERIZATION

3.5.1 Overburden

Overburden in the open pit area is typically comprised of orangey-brown silty sands and gravels with trace to some cobbles and boulders and trace clay. The overburden is stiff to dense, moist, and has angular to sub-angular particles. There is a topsoil veneer covering the entire pit area, consisting of moist, spongy, fibrous, dark to blackish brown silt and sand with organics. This topsoil layer varies in thickness from 0.1 m to 0.5 m.

Overburden is scarce within the southeast areas of the pit, which is covered by a thin veneer of topsoil over bedrock. The northwest region of the pit is overlain by silty sands and gravels, till and weathered bedrock, as noted through test pit and road cut logging within the area. Organic topsoil covers the overburden. Bedrock near surface or at the overburden/bedrock interface is typically rippable due to weathering of the rock mass. The depth of overburden and rippable bedrock combined is typically 6.1 m. The till identified in the open pit area is suitable for use as construction material.

Overburden is shallow to negligible in depth around the open pit area, existing as a thin veneer of topsoil to a one to three metres thick layer of till overlying weathered, rippable bedrock. The overburden and rippable bedrock will be stripped from the pit area for use as construction backfill in the tailings management facility. The stripping area will exceed the boundaries of the open pit, creating a catch bench for settled overburden material. An overburden stability analysis was not performed for this pit, as the shallow overburden depth and the layback resulting from stripping will negate the risk of overburden slope failure adversely affecting worker safety or pit operations.

3.5.2 Bedrock Units

Bedrock within the open pit area is light grey to grey green to dark grey green in colour, with occasional quartz inclusions and traces of pyrite and other sulphides. The bedrock is strongly foliated, with foliation planes dipping towards the north at approximately 25° to 35°. Numerous minor thrust faults exist throughout the deposit, dipping towards the north at shallow angles, similar to the orientation of the foliation within the rock mass. The Harper Creek Fault bisects the proposed pit location, running sub-vertically along a northeast-southwest trend.

CME created an extensive geological database by re-logging approximately 30,000 m of drill core from 128 historic exploration core holes and logging of an additional 36,000 m of core from exploration drilling programs conducted from 2006 through to 2011. Multiple lithological units were defined within the open pit by CME geologists, including phyllite, schist, quartz eye schist, silica altered host rock and zones of faulting. These lithologies are described in detail in the 2011 Geotechnical Site Investigation Factual Report (KPL Ref. No. VA101-458/3-1).

The individual lithological units are complex due to multiphase deformation and alteration sequences, and correlating lithologies across drill holes and sections is difficult and may produce an unreliable geological model. Regrouping the individual lithologies into packages of common characteristics allowed for an easier understanding of the geology and ability to correlate between drill holes across the deposit area. A series of geological rock packages were defined by CME geologists to allow for greater confidence in geological interpretation between drill holes and geological sections. The geological packages, as defined by CME geologists that were logged in the geomechanical drillholes are as follows:

- **H –** Mafic Polymictic Volcaniclastics, frequently calcareous.
    - ‘FAIR’ quality rock with a mean RMR value of 60.
    - Average RQD value of 61%.
    - ‘AVERAGE’ rock strength classification with UCS laboratory test results ranging from 29 to 60 MPa with a mean of 44 MPa for all failures. It should be noted that all lab samples tested failed along pre-existing foliation planes, which are ubiquitous throughout the open pit rock mass, and that the intact rock strength may be higher.
- **Fa –** Felsic to Intermediate Volcaniclastics.
    - ‘GOOD’ quality rock with a mean RMR value of 64.
    - Average RQD value of 84%.
    - ‘AVERAGE’ rock strength classification with UCS laboratory test results ranging from 1 to 100 MPa with a mean of 29 MPa for failures along foliation planes and 68 MPa for intact rock failures. The low-end values typically represent breaks along foliation, as opposed to through intact rock.
- **Fb -** Intermediate to Mafic Polymictic Volcaniclastics.
    - ‘GOOD’ quality rock with a mean RMR value of 63.
    - Average RQD value of 76%.
    - ‘SOFT’ rock strength classification with UCS laboratory test results ranging from 2 to 42 MPa with a mean of 20 MPa for failures along foliation planes

and 40 MPa for intact rock failures. The low-end values typically represent breaks along foliation, as opposed to through intact rock.

- **E –** Graphitic Horizon, typically comprised of Silica Altered Host and graphitic Phyllite.
  - 'GOOD' quality rock with a mean RMR value of 68.
  - Average RQD value of 77%.
  - 'AVERAGE' rock strength classification with UCS laboratory test results ranging from 10 to 75 MPa with a mean of 33 MPa for failures along foliation planes and 38 MPa for intact rock failures. The low-end values typically represent breaks along foliation, as opposed to through intact rock.
- **D –** Intermediate Volcaniclastics & Fragmentals, primarily calcareous Phyllite and fragmental Schist.
  - 'GOOD' quality rock with a mean RMR value of 64.
  - Average RQD value of 80%.
  - 'SOFT' rock strength classification with UCS laboratory test results ranging from 13 to 32 MPa with a mean of 20 MPa for failures along foliation planes. The low-end values typically represent breaks along foliation, as opposed to through intact rock.
- **B –** Sandy Sediment dominated, comprised of calcareous Phyllite, Quartz Eye Schist, and mafic sediments.
  - 'GOOD' quality rock with a mean RMR value of 68.
  - Average RQD value of 74%.
  - 'HARD' rock strength classification with UCS laboratory test results ranging from 1 to 175 MPa with a mean of 47 MPa for failures along foliation planes and 101 MPa for intact rock failures. The low-end values typically represent breaks along foliation, as opposed to through intact rock.
- **FD –** Combines elements of D and Fa packages as found on the east side of the Harper Creek Fault.
  - 'GOOD' quality rock with a mean RMR value of 64.
  - Average RQD value of 81%.
  - 'HARD' rock strength classification with UCS laboratory test results ranging from 7 to 110 MPa with a mean of 28 MPa for failures along foliation planes and 97 MPa for intact rock failures. The low-end values typically represent breaks along foliation, as opposed to through intact rock.

Geological packages were only defined within or near the open pit area. A map of the surficial geology of the open pit is illustrated on Figure 3.1. A summary of the rock mass parameters by geological package is presented in Table 3.1.

3.5.3 Rock Mass Structure

There is a dominant structural trend in the open pit area, influenced by the foliation that is ubiquitous throughout the rock mass, dipping at 25° to 35° towards the north (Dip/Dip Direction of 25°-35°/340°-360°). The only large scale structural feature in the open pit area is the Harper Creek Fault which runs sub-vertically through the open pit, bisecting the pit along a northeast-southwest trend (see Figure 3.1).

Detailed characterization of rock mass discontinuities was carried out, and the main rock mass characteristics can be summarized below:

- **Discontinuity Spacing –** Typical discontinuity spacing within the rock mass was on the order of 0.1 to 0.4 m. The foliation planes within the rock mass account for the close spacing observed in the drill core.
- **Discontinuity Persistence –** The persistence has been conservatively assumed to have a high persistence (10 to 20 m).
- **Discontinuity Roughness and Shape –** The majority of discontinuity surfaces are characterized as smooth and planar.
- **Discontinuity Infilling –** Typical types of infilling include chlorite, calcite, sericite, quartz, dolomite and gouge. Other infilling materials are present including sulphide mineralization of chalcopyrite and pyrite. Close to ground surface iron oxide infilling was observed, as well as frequent iron oxide surface staining. Rubble, crushed rock, clay and white clay infillings are common in more fractured zones of bedrock, but were identified throughout the drillholes. Occasional graphite, biotite and mica infillings were observed. The thickness of most infillings is typically 1 millimetre to 5 millimetres.
- **Discontinuity Shear Strength –** Representative samples from four drillholes were subjected to direct shear tests. Based on the results, a conservative friction angle of 30° is used in the open pit design. The results are summarized below:

Sample/Borehole	Depth (m)	Geological Package	Peak Friction Angle (°)	Residual Friction Angle (°)
HC11-GM02-S06	210.80 – 211.08	Fa	42	37
HC11-GM06-S03	70.47 – 70.79	B	37	32
HC11-GM06-S06	137.36 – 137.70	B	37	32
HC11-GM07-S04	169.48 – 169.86	Fa	36	29

3.5.4 Geotechnical Domains

Creating a geotechnical model utilizing the numerous geological packages identified by CME is impractical due to the relative similarities between units, the lack of information to delineate packages throughout the pit area, and because such a model would be too complex to be practical. The geomechanical data collected from the seven oriented core holes logged by KPL was used to define rock mass characteristics. Simplified geotechnical domains were delineated by incorporating CME's geological interpretation for slope stability analyses.

A mineralization model was provided by GeoSim Services Inc. (GeoSim) in October 2011, which illustrates three units: Phyllites, located at the northwest corner of the pit, the West Mineralized Zone, and the East Mineralized Zone. These mineralized zones are divided by the Harper Creek Fault, which bisects the pit area along a northeast-southwest strike. Figure 3.2 shows a plan view of the mineralization zones within the pit area.

Three geotechnical domains were defined for the purposes of the rock mass stability analysis. Geological packages were grouped based on their relative similarities in rock mass parameters and their distribution throughout the open pit. It was assumed that the alteration assemblages used to define the Phyllite and Western and Eastern Mineralized Zones (Figure 3.2) are related to the alteration phases that characterize the geological packages. The distribution of the mineralized zone was correlated with the distribution of geological packages with similar rock mass strength and quality parameters to delineate the geotechnical domains used in the stability analyses.

The geotechnical domains are defined as follows:

- **Phyllite –** The Phyllite unit is geological package H, and is located in the northwest corner of the pit. Phyllite is defined in the same region on both the mineralization zone block model provided by GeoSim, and the geological map provided by CME.
- **West Volcaniclastics –** Comprised of geological packages Fa, Fb, E and D. These units are located along the west side of the Harper Creek Fault and are correlated with the Western Mineralized Zone as defined in the GeoSim block model.
- **East Volcaniclastics –** Comprised of geological packages FD and B. These units are located on the east side of the Harper Creek and are correlated with the Eastern Mineralized Zone as shown on the GeoSim block model. The rock mass strength of these units are relatively higher compared to the Western Volcaniclastics, due to the silicification of the rock mass in that area, as confirmed by CME geologists.

Basic rock mass and strength parameters are summarized in Table 3.2. Figure 3.3 illustrates a projected geotechnical domain map for the final pit walls.

3.6 ROCK MASS STRENGTH PARAMETERS

The overall rock mass strength parameters were derived using the Hoek-Brown failure criterion (2002 edition). The characteristics of the rock mass are described by geological package, intact rock strength and rock mass quality. The strength properties can be adjusted to account for the expected level of rock disturbance. Rock mass disturbance is typically caused by blast damage and from strains resulting from stress changes in the pit walls due to unloading during mining.

3.6.1 Rock Mass Quality

The Rock Mass Rating (RMR) classification system (Bieniawski, 1989) was used to summarize the geomechanical characteristics of the rock masses encountered during the 2011 Geotechnical Site Investigation. It is based on five parameters describing the key rock mass characteristics, including: field estimated Unconfined Compressive Strength (UCS), Rock Quality Designation (RQD), joint spacing, joint conditions and groundwater conditions. Ratings are assigned to each of the five parameters and the sum of these ratings defines the rock mass quality as an RMR value. RMR values range from near zero, equating to VERY POOR rock, to 100, equating to VERY GOOD rock.

The RMR data for each geological package was grouped for each geotechnical domain. A statistical analysis of the RMR data collected for each geological domain was performed to determine the mean RMR and standard deviation values for each domain.

Table 3.2 summarizes the RMR values for each domain. The typical RMR values for each geological package and geotechnical domain, summarized in Tables 3.1 and 3.2, respectively, indicate that the rock mass in the Harper Creek pit area is generally FAIR to GOOD quality as the average RMR ranges from 60 to 68. The upper and lower bound RMR values were calculated for each domain, and were assumed to be one standard deviation greater or lower than the average RMR.

3.6.2 Intact Rock Strength

The rock mass within the open pit area consists primarily of schists and strongly foliated phyllites. The intact rock mass within the pit is typically “Average” to “Hard”, with unconfined compressive strengths (UCS) of 60 to 175 MPa. The foliation planes within the rock mass are planes of weakness along which several samples failed preferentially, and at a much lower UCS than failures that occurred through intact rock.

The UCS of the geotechnical domains was determined from the rock laboratory testing performed at the UBC Normal B. Keevil institute of Mining Engineering. Testing was performed on samples collected during the 2011 Geotechnical Site Investigation. The test results were grouped by geological package, and then further grouped into geotechnical domains. The test results were visually evaluated to determine which failures occurred along foliation and which occurred through intact rock. The summary of the geological packages strengths is shown on Table 3.1. Table 3.2 lists the UCS values used for the three geotechnical domains, which are based on the combined test results for the component geological packages of which the domain is comprised.

Upper and lower strength boundaries were defined for each geological domain based on the failure mode of the sample. Lower bound rock parameters were defined using rock strength test results that failed along foliation, and the lower bound RMR values (one standard deviation below the mean RMR). Upper bound rock parameters were defined using rock strength test results from failures through intact rock, and upper bound RMR values (one standard deviation above mean RMR). An average rock mass strength was calculated using strength test results from both foliation and intact rock failures, and the mean RMR.

3.6.3 Lithological Factor and Unit Weight

Following Hoek, et. al. (1995), the lithological factor (m_i) has been estimated for each domain based on typical values for that rock type. The m_i values are summarized in Table 3.2, and have average values of 10 for the Phyllite and 13 for the East and West Volcaniclastics.

The unit weight of all geological domains has been assumed at 27 kN/m^3, based on an average value of the bedrock within the Harper Creek deposit (Scott Wilson, 2007).

3.6.4 Disturbance Factor

Hoek et al., 2002 recommends that the utilized rock mass strengths be downgraded to disturbed values to account for rock mass disturbance associated with heavy production blasting and vertical stress relief. Hoek indicates that a disturbance factor of 0.7 would be appropriate for a mechanical excavation where no blasting damage is expected. KPL experience has suggested that a disturbance factor approaching the value of 0.85 may be achievable for moderate height slopes with the application of good controlled blasting practices. A value of 1.0 is assumed for conventional production blasting. It is assumed that good controlled blasting practices will be used for final pit wall development, and a disturbance factor of 0.85 has been assigned to all geotechnical domains for the open pit design.

3.6.5 Anisotropic Strength of the Rock Mass

Rock mass failure in pit slopes, excluding a rock mass with very low RMR, typically occur as a combination of sliding along discontinuities and failures through intact rock. Rock mass strength derived using Hoek-Brown Criterion represents isotropic strength. However, one of the assumptions inherent in the Hoek-Brown constitutive model is that there is no explicit structural control on failure. Cases where the theorized failure surface includes movement along lower strength discontinuities may be present depending on wall orientation and structures in the pit wall. The dominant structure of the rock mass in the Harper Creek open pit (which, within the South and Southwest Sectors, dips at a 30° to 35° angle towards the north) is considered to be one of these cases as it satisfies the requirement for large scale planar failure (structural features with a peak structural dip direction within a 020° azimuth of the pit wall orientation). As such, anisotropic rock mass strength parameters were estimated for the South and Southwest Walls.

A step function was built defining strengths based on the angle of the slice base in a trial slip surface. The function utilized in the anisotropic strength model applies a reduction factor to the strength parameters of all slip surfaces with a base angle of 30° to 35°. This reduction factor represents the decreased strength of the foliation planes relative to the intact rock mass, as demonstrated during the rock strength laboratory testing. The estimated strength parameters were represented using the Mohr-Coulomb failure criterion.

The assumption being made in this anisotropic strength model is that there are planes of weakness of unlimited length that can occur at any point within the slope. In reality, rock bridging, an estimate of the amount of failure through intact rock along a trial failure surface, depends on the persistence and spacing of the pitward dipping structure. These two parameters are difficult to obtain from drill core logging, so a sensitivity analysis utilizing 0%, 25%, 50%, and 75% rock bridging was completed by calculating the following strength parameters for the discontinuity:

$$\varphi_{\%\,bridge} = (\%bridge \times \varphi_{rock\,mass}) + ([1 - \%bridge] \times \varphi_{discontinuity})$$

$$\sigma_{\%bridge} = (\%bridge \times \sigma_{rockmass}) + ([1 - \%bridge] \times \sigma_{discontinuity})$$

The application of anisotropic strength parameters will be further discussed in Section 4.0.

3.7 HYDROGEOLOGY

Groundwater levels vary throughout the open pit, from artesian conditions observed within the south, northeast and east regions of the pit to 12 m deep in the northwest. The hydraulic conductivity of the rock varies from 1×10^{-9} to 5×10^{-6} m/sec. There is no significant correlation between hydraulic conductivity and lithology or geological package; however conductivity generally decreases with depth.

The average hydraulic conductivity of bedrock is in the order of 4×10^{-8} m/sec. This value is based on the geometric mean of the permeability values measured during the 2011 Geotechnical Site Investigation. There is no significant variation in hydraulic conductivity by depth or rock type, so a single value has been deemed appropriate for all geotechnical domains in the pit. The porosity of the rock mass is assumed to be 10%, based on the typical porosity for a dense rock mass (Freeze, Cherry, 1979).

SECTION 4.0 – PIT SLOPE STABILITY ASSESSMENT

4.1 GENERAL

A feasibility pit model provided by Merit (January, 2012) was utilized for the geotechnical pit slope stability assessment. Kinematic and rock mass stability analyses were conducted for selected critical pit walls. This section outlines the projected ultimate pit wall geology and pit design sectors along with the stability assessments for the overburden, bench and overall slopes.

4.2 PIT DESIGN SECTORS

The pit design sectors have been defined in accordance with the location of the geological domains and the orientation of the proposed pit walls. A total of six major design sectors, namely: Northeast, East, South, Southwest, West, and Northwest, were defined to group areas of the proposed mine with similar geology, geomechanical characteristics and wall orientations, as shown on Figure 4.1. In each sector, the geology and pit wall orientation are generally consistent.

The four major design sectors are described as follows:

- **Northeast Sector**
  - The north hanging wall dips at an azimuth of 180°.
  - Comprised of West Volcaniclastics geotechnical domain.
  - Pit walls approximately 270 m high.
  - Characterized by drillholes HC11-GM03 to GM05.
- **East Sector**
  - Dips towards the west at a nominal pit wall dip direction of 270°.
  - Comprised of East Volcaniclastic geotechnical domain.
  - Pit walls approximately 375 m high.
  - Characterized by drill hole HC11-GM06.
- **South Sector**
  - This sector contains the northward dipping south foot wall of the pit. The slope angle of the foot wall is influenced by the orientation of the foliation.
  - Comprised of East Volcaniclastic geotechnical domain.
  - Pit walls in this sector are approximately 445 m high.
  - Characterized by drillholes HC11-GM01 and HC11-GM07.
- **Southwest Sector**
  - This sector contains the northward dipping south foot walls of the western arm of the pit. The slope angle of this foot wall is influenced by the orientation of the foliation.
  - Comprised of West Volcaniclastics geotechnical domain.
  - Pit walls are approximately 210 m high.
  - Characterized by drill hole HC11-GM02.
- **West Sector**
  - Comprised of southeast and northeast dipping walls of the western area of the pit.
  - Both Phyllite and West Volcaniclastic geotechnical domains are present in this sector.
  - Pit walls approximately 210 m high.

- Characterized by drill hole HC11-GM02.

- **Northwest Sector**
  - Continuation of the north hanging wall which dips at an azimuth of 180°, rotates towards a 220° dip direction at the eastern end of the sector.
  - Comprised of East Volcaniclastic geotechnical domain.
  - Pit walls approximately 270 to 300 m high.
  - Characterized by drillholes HC11-GM03 to GM05.

4.3 KINEMATIC STABILITY ANALYSIS

4.3.1 Potential Modes of Failure

Kinematically possible failure modes in rock slopes typically include planar, wedge and toppling failures. These failure modes can be identified by using stereographic analysis of peak pole concentrations of the discontinuity data. These failure modes will occur if the discontinuities are continuous over the bench scale or more, if weak infilling is present along the measured discontinuities or the geometry of the discontinuities is conducive to failure. A brief introduction on each mode of failure is provided below:

- **Planar Failure** – This failure mode is kinematically possible where a discontinuity plane is inclined less than the slope face (daylights) and at an angle steeper than the friction angle.
- **Wedge Failure –** This failure mode is kinematically possible where the plunge of the intersection of two planes (sliding vector) is inclined less than the slope face (daylights) and at an angle greater than the combined friction angle which is determined from the characteristics of each plane that forms the wedge. Where kinematics are the controlling factor, the recommended pit slope angles have been adjusted to reduce the potential for large-scale, multiple bench wedge failures.
- **Toppling Failure –** this failure mode is kinematically possible due to interlayer slip along discontinuity surfaces where sub-vertical jointing dips into the slope at a steep angle β. The condition for toppling to occur is when $\beta > (\phi_j + (90 - \Psi))$, where Ψ is the slope face angle and ϕ_j is the friction angle (Goodman, 1989).

4.3.2 Stereographic Analysis

The purpose of the kinematic analyses was to identify the kinematically possible failure modes within each design sector using the stereographic technique. The rock mass structural orientation data collected from the geomechanical drillholes completed during the 2011 Geotechnical Site Investigation was utilized for kinematic stability analyses of the pit walls. The analysis results are used to define and appropriate bench geometry in order to reduce the potential for small-scale discontinuities to form instabilities.

Stereographic analyses have been carried out for each design sector and bore hole using the DIPS program (Rocscience Inc., 2001). The borehole orientation is used to convert the structural data collected in the field to produce real-space dip / dip-direction measurements of the discontinuities logged in the drill core. The azimuth and inclination of the bore hole is applied as a “traverse” to each measurement. In an un-surveyed bore hole the azimuth and dip of the collar, as measured on surface, are used as the traverse. The downhole orientation survey data is used to create additional traverses to account for deviation in the bore hole that may occur during drilling. Borehole orientation survey data from the Reflex EZ-Shot was applied to HC11-GM01A, GM02, GM04 and GM07. Inclination survey data from the Reflex ACT II RD was applied to HC11-GM03, GM05 and GM07.

The overall rock mass structural orientations at the Harper Creek deposit are illustrated in a stereographic plot in Figure 4.2. A predominant North dipping foliation feature is clearly defined. The inter-ramp angles utilized in the stereographic analysis were chosen based on the nominal dip of the pit walls from the pit model provided by Merit Consultants in March, 2011. An inter-ramp angle of 44° was used for all pit sectors excluding the South Sectors, which used a 35° angle. A bench face angle of 70° was assumed for initial trials. A joint friction angle of 30° was selected as a conservative estimate. Data was separated into the predominant discontinuity types, joints and schistosity. The foliation planes within the rock mass are the dominant structural feature, however secondary and tertiary structures were identified in the jointing. Detailed stereographic analyses for each design sector and oriented core hole are presented in Appendix A and discussed in the following sections.

4.3.3 Analysis Results by Design Sector

The data sets for each sector analyses were selected based on the drill hole locations and azimuths. Design sectors were selected based on overall pit wall orientation; however some sectors had multiple kinematic analyses performed to account for in-sector variations in the pit wall orientation. Table 4.1 shows the pit wall orientations, data sets used, and results summary for each sector.

A detailed discussion for each design sector is provided below:

- **Northeast Sector –** Analyses were performed for pit wall orientations of 180° and 220°, using data from holes HC11-GM03, GM04 and GM05. The foliation dips at 34° towards the north, primary jointing dips at approximately 30° towards the north, and secondary jointing dips at 50° towards the northwest. Kinematically controlled failure mechanisms are not present.
- **East Sector –**Analyses for the East sector were performed using data from hole HC11-GM06. The foliation and primary jointing in the east sectors dips at approximately 30° towards the northwest. There are no kinematically controlled failure mechanisms.
- **South Sector –** Analyses were performed for pit walls orientations of 000° and 320°, dipping at 35° using data from holes HC11-GM01A and GM07. Primary jointing and foliation dips at 32° and 34°, respectively, towards the northwest, and may allow for kinematically controlled planar failure. The inter-ramp slope should not exceed 35° to mitigate the formation of large scale planar failure. Wedge/planar failures are

kinematically possible; however the failure condition is at the limit of the assumed friction angle.

- **Southwest Sector –** Analyses for the Southwest Sector were performed for a pit wall Dip/Dip Direction of 35°/320°, using data from HC11-GM02. Primary jointing and foliation dips at 32° and 34°, respectively, towards the northwest, and may allow for kinematically controlled planar failure. The inter-ramp slope should not exceed 35° to mitigate the formation of large scale planar failure. Wedge failures are kinematically possible; however the failure condition is at the limit of the friction angle.
- **West Sector –** The primary wall in the West Sector slopes at an azimuth of 135°. A kinematic analysis of this sector was performed using data from hole HC11-GM02. There are no kinematically controlled failure mechanisms.
- **Northwest Sector –** The northern hanging wall dips at an azimuth of 180°, and was analyzed using data from holes HC11-GM03, GM04 and GM05. The foliation dips at 34° towards the north, primary jointing dips at approximately 30° towards the north, and secondary jointing dips at 50° towards the northwest. Kinematically controlled failure mechanisms have not been identified in this sector.

4.3.4 Analysis Results by Drillhole

An analysis of the structural data was performed using the data sets from each drill hole individually to provide an estimation of kinematic stability at the localized areas represented by the drill holes. A summary of the kinematic stability analysis for the boreholes is shown on Table 4.2

A detailed discussion for each borehole is below:

- **HC11-GM01A –** This hole intersects a proposed pit wall dipping at 35° at an azimuth of 000°. Planar failure is kinematically possible due to the northward dipping joint and foliation planes. Wedge and planar failures are possible at the bench scale.
- **HC11-GM02 –** This hole intersects the proposed pit wall which slopes at 44° towards a 135° azimuth. There are no kinematically possible failure modes shown by the discontinuity data.
- **HC11-GM03 –** This hole intersects the north wall, which dips towards the south at 44°. There are no kinematically possible failure modes indicated by the discontinuity data.
- **HC11-GM04 –** This hole intersects the southward dipping north wall. There are no kinematically possible failure modes indicated by the discontinuity data.
- **HC11-GM05 –** This hole intersects the eastern end of the north wall, which slopes at 44° towards an azimuth of 220°. Bench scale wedge failure is kinematically possible due to the intersection of two minor joint sets.
- **HC11-GM06 –** This hole intersects the west dipping east wall. There are no kinematically possible failure modes in the survey corrected data. Uncorrected data indicates the possibility for minor toppling and planar failure.
- **HC11-GM07 –** This hole intersects the eastern end of the south wall, which dips at 35° at an azimuth of 320°. Planar failure is kinematically possible due to the influence of the foliation and major jointing, and wedge failures are possible due to the intersection of a minor joint set with the schistosity.

4.3.5 Summary of Kinematic Stability Analysis

The stereographic analysis suggests that the primary cause of kinematic failure within the pit is the northward dipping foliation of the rock mass. This foliation dips at a 30° to 35° angle within the South and Southwest Sectors, which allows for planar failure to develop along the northward dipping slopes. It is recommended that the pit slopes be constructed with inter-ramp angles no steeper than 35° within these sectors. An inter-ramp angle of 44° is achievable in all other sectors and pit walls which do not dip towards the north.

A bench face angle of 70° is expected to be achievable in all sectors excluding the northward dipping walls of the South and Southwest Sectors. A single bench configuration (12 m high) is assumed for all slopes based on the size of anticipated mining equipment. A bench width of 8 m is recommended in all sectors excluding the South and Southwest.

The northward dipping walls within the South and Southwest Sectors are recommended to be excavated using 10 m wide benches and a bench face angle of 60°, allowing for an inter-ramp angle of 35°.

4.4 ROCK MASS STABILITY ANALYSIS

Rock mass stability analysis was performed using the SLOPE/W limit equilibrium computer program (GEO-SLOPE International Ltd., 2007). The limit equilibrium analyses were completed to evaluate the overall slope stability of the jointed rock mass and determine the slope depressurization requirements for the open pit. A Factor of Safety (FOS) of 1.3 has been targeted for inter-ramp pit walls under base case strength conditions. .

The purpose of the rock mass stability analysis is to confirm that the inter-ramp angles determined in the kinematic analysis are acceptable for large scale slopes, and to determine what slope depressurization requirements are necessary to achieve the target FOS.

The geotechnical domains used in the stability models are defined in Section 3.0. Intact rock strength, the Hoek-Brown constant of intact rock (m_i), Geological Strength Index (GSI, related to RMR using the equation "GSI = RMR^{89} – 5"), unit weight and blast disturbance are the primary material parameters used in limit equilibrium models. The parameters used for the SLOPE/W analyses are summarized in Table 4.3.

The overburden stability analysis was not performed for this pit, as the shallow overburden depth and the layback resulting from stripping will negate the risk of overburden slope failure adversely affecting worker safety or pit operations.

4.4.1 Analysis Model Definition

Isotropic analyses were completed for each geotechnical domain at varying slope heights, using the slope angles established in the kinematic analysis. Each section analysed was built in stages to represent inter-ramp slope heights of 50, 100, 150 and 200 m. The East Volcaniclastics model was created with additional slope heights of 270 m and 375 m to reflect the ultimate wall height within the Northeast and East pit sectors respectively. The West Volcaniclastics model was created with an additional slope height of 300 m to reflect the wall height of the Northwest sector. The upper bound, lower bound, and average rock mass strength and quality parameters were used in the model to reflect the range of rock mass conditions that may be encountered during pit development. The slope angle for these analyses was 44°, as established in the kinematic analysis.

An anisotropic analysis was conducted specially for the South and Southwest Sectors. This type of analysis was required due to the dominant northward dipping structure within the rock mass, comprised of low strength foliation planes. Models were created utilizing East and West Volcaniclastic material parameters for inter-ramp slope heights of 50, 100, 150, 200, 210 (Southwest Sector only) and 420 m (South Sector only). Each slope height model was run as a sensitivity analysis to simulate the effects of intact rock bridging through the foliation. The slope angle of the South and Southwest Sector pit walls is 35°; the shallow angle required to reduce the risk of planar failures developing within the pit. The slope models representing the highest pit wall in each geotechnical domain were used to determine appropriate overall slope angles.

Table 4.3 summarizes the Hoek-Brown model parameters used for the isotropic analyses, and the Mohr-Coulomb parameters and modification factors used in the anisotropic analysis.

The following groundwater conditions were modelled to determine the effect of groundwater depressurization on slope stability:

- **Fully saturated slope conditions –** Groundwater conditions simulating a fully saturated slope where modelled by placing the phreatic surface along the surface of the pit face.
- **Simulated drawdown of groundwater –** A seepage analysis was conducted for each slope case to model the natural drawdown of groundwater occurring due to the excavation of the pit.

4.4.2 Seepage analysis

A seepage analysis was conducted using the SEEP/W software (GeoStudios, 2007) in order to establish the piezometric surface within the pit wall. Each inter-ramp slope height model had a seepage analysis performed prior to the stability analysis. The groundwater source for the seepage analysis was specified at a distance from the pit crest equal to the slope height (e.g. a slope height of 150 m will have a groundwater point source 150 m laterally from the pit crest). The ground was assumed to be fully saturated at the source point, and allowed to drop through the rock to simulate drawdown.

The hydraulic conductivity of the rock mass within the open pit area ranges between $9x10^{-9}$ to $2x10^{-6}$ m/sec. The geometric mean of the hydraulic conductivities is $4x10^{-8}$ m/sec, and this value was assumed for the pit rock for use in the seepage and stability analyses. A porosity of the 10% was assumed for the rock mass (Freeze & Cherry, 1979).

The drawdown depth was measured from a reference point of 10 m back from the crest of the pit. The modelling predicted that the drawdown depths vary from 20 m in a 50 m high pit slope, to approximately 110 m in a 300 m high pit slope. The results of the seepage analysis are summarized in Tables 4.4 to 4.7.

4.4.3 Isotropic Stability Analysis

Tables 4.4 to 4.7 summarize the results of the isotropic rock mass stability analyses. Inter-ramp height, groundwater depressurization, and FOS are shown in these tables. The groundwater pressure was defined using a piezometric line.

Excavation of the pit will reduce confining stress from within the pit wall and cause the slope to relax. It is assumed that the relaxation will cause the rock mass to lose cohesion along the foliation planes and reduce the overall rock mass strength and quality. Therefore, using average rock mass strength parameters will produce a representative base-case scenario for the North, East and West Walls.

Slopes in each of these models were laid back until a FOS greater than 1.2 was achieved in a fully saturated slope. This FOS is considered appropriate for an overall slope analysis because the model conservatively assumes a fully disturbed rock mass. The fully disturbed scenario is considered appropriate to determine inter-ramp slope stability, but is overly conservative when determining overall slope stability. A typical rock mass stability analysis result for the base case high wall is presented on Figure 4.3. Detailed sensitivity analysis results are included in Appendix B.

East Volcaniclastics

The results of the analysis show that a fully saturated pit wall within East Volcaniclastic rock achieves a FOS of 1.3 up to heights of 200 m. The inter-ramp slope achieves the requisite FOS for all inter-ramp slope heights due to the natural depressurization of the pit slopes from groundwater drawdown. The drawdown is expected to drop the phreatic surface by 20 m in a 50 m high slope, to 110 m for a 375 m high slope.

The base case stability analysis (using average rock mass strength) indicates that an overall slope of 44° is achievable up to a height of 375 m in the East Volcaniclastic unit. However, it is recommended that haul ramps and/or step-outs be incorporated into the pit wall design to limit the maximum inter-ramp slope height to 200 m. Limiting the inter-ramp slope height will reduce the risk of shallow multi-bench failure occurring, provide a safer working environment on the slopes below, and allow flexibility for pit access by introducing wider benches or ramps at regular intervals.

West Volcaniclastics

Fully saturated West Volcaniclastic rock achieves a FOS of 1.3 up to heights of 150 m. The inter-ramp slope achieves the requisite FOS for all inter-ramp slope heights due to the natural depressurization of the pit slopes from groundwater drawdown. The drawdown is expected to drop the phreatic surface by 20 m in a 50 m high slope, to 110 m for a 300 m high slope.

The base case stability analysis indicates that an overall slope of 44° is achievable up to a height of 300 m in West Volcaniclastic unit. However, it is recommended that the maximum inter-ramp slope height not exceed 200 m mainly for operational considerations.

Phyllite

Fully saturated Phyllite rock achieves a FOS of 1.3 up to heights of 150 m. The inter-ramp slope achieves the requisite FOS for all inter-ramp slope heights due to the natural depressurization of the pit slopes from groundwater drawdown. The drawdown is expected to drop the phreatic surface by 20 m in a 50 m high slope, to 85 m for a 235 m high slope.

The base case stability analysis indicates that an overall slope of 44° is achievable up to a height of 235 m in the Phyllite unit. A haul ramp or wide catch bench (step-out) is also recommended to limit the maximum inter-ramp slope height to 200 m in this rock unit.

4.4.4 Anisotropic Stability Analysis

The anisotropic rock mass stability analysis of the South and Southwest Walls was set up to simulate planes of weakness along the foliation of the rock mass. Mohr-Coulomb parameters were derived for the foliation structure within the South Sector, which dips at a 30° to 35° angle. The failure surfaces dipping within that range had a reduction factor applied to their cohesion and friction angle. A sensitivity analysis was performed using these modified parameters to simulate intact rock bridging through the foliation planes. The amount of rock bridging was specified as 0%, 25%, 50%, 75% and 100%.

The South Sector is comprised of East Volcaniclastics, and the Southwest Sector is comprised of West Volcaniclastics. Both geotechnical domains were modelled at inter-ramp slopes heights of 50, 100, and 150 m. Two additional cases were modelled at 200 and 420 m for the South Sector, and one additional case with a slope height of 210 m was created for the Southwest Sector.

The results of the stability analyses for the South and Southwest Sector pit walls are presented in Table 4.7. Base case modelling results are presented in Figure 4.4. Detailed sensitivity analyses results are included in Appendix B. The most conservative scenario, at 0% rock bridging, does not achieve the requisite FOS for any slope height, even under completely drained slope conditions. However, this scenario assumes an uninterrupted plane of weakness persisting through the entire slope, which is a very conservative, unrealistic, scenario.

Analysis results for rock bridging scenarios of 25% to 75% show that the drawdown of groundwater caused by the open pit provides adequate depressurization to allow for the requisite FOS of 1.3 to be achieved for all slope heights. It is recommended that the inter-ramp slopes in the South Sector do not exceed 200 m to reduce the risk of shallow multi-bench planar failures forming. An overall slope angle of 35° is considered reasonable for the pit slopes in both sectors.

SECTION 5.0 – PIT WATER MANAGEMENT

5.1 GENERAL

Open pit development will have a significant impact on the local hydrogeologic regime, as the open pit will become a groundwater discharge area. The existing groundwater table is at or near surface, and progressive development of the pit will result in a gradual lowering of the groundwater table in the vicinity of the excavation.

Pit water management systems are typically comprised of a combination of surface water diversion ditches, vertical pumping wells, horizontal wall drains and seepage collection and pit dewatering pumping systems. These measures will be implemented as a staged observational approach during pit development, involving the installation of depressurization measures and associated monitoring of groundwater pressures. This will enable an assessment of the pit slope drainage capability and the requirements for additional installations.

A conceptual water management plan has been developed for controlled removal of both groundwater inflows and precipitation runoff from within the pit, which include allowances for:

- Diversion ditches to collect surface runoff, snowmelt and seepage along the pit crest.
- A series of pumps and collection systems which transfer water from the pit excavation to the TMF for recycle to the milling process.

Each of these depressurization/dewatering features is discussed in more detail in the following sub-sections, along with the estimates of pit inflows.

5.2 SURFACE DIVERSION DITCHES

Diversion ditches along the pit crest are required to divert the surface runoff away from the pit during operations. It is recommended that a staged sequence of diversion ditches be utilized to minimize surface water inflows during all phases of pit development. These surface runoff ditches will capture and divert the majority of all runoff and snowmelt before the water reaches the pit and will reduce power requirements for pumping water from the deeper levels of the open pit. It may be necessary to include a low permeability liner along sections of these ditches in order to reduce seepage losses.

5.3 PIT DEWATERING SYSTEM

The estimates for water inflow volumes into the Harper Creek open pit were developed from groundwater monitoring and permeability testing conducted during the 2011 Geotechnical Site Investigation and summarized in the 2011 Geotechnical Site Investigation data report and Hydrometeorology Report. Potential sources of pit inflows include the following:

- Dewatering of fissures and fractures in the rock mass
- Infiltration of precipitation into the ground water system
- Direct precipitation into the pit, and
- Surface runoff.

5.3.1 Pit Inflow Estimates

The simplified Dupuit approximation equation for steady radial flow (Freeze and Cherry, 1979) was used in order to provide an estimate of pit inflows.

The pit inflows were calculated for five stages of pit development to provide a basis for infrastructure requirements and cost estimation.

A simplified estimate of groundwater inflow into an open pit can be made using the Dupuit approximation equation for steady radial flow in an unconfined aquifer. This approach assumes that flow is horizontal and the hydraulic gradient is equal to the slope of the groundwater table at the seepage face and does not vary with depth. Groundwater inflow estimates using this approach are reported to be in good agreement with more detailed analytical methods when the water table gradient is low and the depth of the unconfined flow is shallow. The radius inflow (Q) to the pit can be calculated as follows:

$$Q = \frac{\pi k H^2}{\ln(R/r)}$$

Where:

- *k* is the average hydraulic conductivity of the rock mass. A k value of 4×10^{-8} m/sec has been assumed for the open pit, which is based on the geometric mean of test results from the 2011 Geotechnical Site Investigation program.
- *H* is the head drop in the pit, and the maximum drop of 352 m has been assumed for the final pit by estimating an average slope height of 352 m and an average groundwater level of 0 m (i.e. ground surface).
- *r* is the equivalent radius of pit excavation and is calculated as the square root of the total pit surface area divided by π.
- *R* is the radius of influence and it is estimated as the equivalent radius of excavation plus 500m.

Estimates of pit inflows during staged pit development are summarized in Table 5.1. The maximum seepage inflow into the final pit has been estimated as 39 l/s (618 gpm) by using the Dupuit Approximation equation. By including the inflows from direct precipitation of 102 l/s (based on the long term average annual precipitation for the site of 1050 mm), a total pit average annual inflow rate of 141 l/s (2235 gpm) has been estimated for the final pit layout.

5.3.2 Inflows From a Storm Event

The pit inflows occurring during a peak storm event have been calculated in order to determine the maximum pumping requirements that the dewatering system should consider. The 1 in 10 year storm event was utilized, with an estimated 53 mm of precipitation expected in a 24 hour period.

The following assumptions are used when calculating pit inflows from the 1 in 10 year 24-hour storm event:

- The ground is fully saturated and no precipitation infiltrates the groundwater system.
- All surface runoff is intercepted and prevented from entering the open pit by runoff and snowmelt diversion ditches.
- Evaporation is negligible.
- The water is removed from the pit before any significant groundwater infiltration or evaporation can occur.
- Seepage and normal base flow based on annual average precipitation continues during the dewatering of the pit.

Approximately 162,000 m^3 of water will flow into the pit during the 1 in 10 year storm event.

5.3.3 Conceptual Pit Dewatering Plan

The dewatering system for the open pit is designed to pump all seepage and precipitation inflows to the pit. The system is designed to keep the pit bottom dry during normal operating conditions. Water removed from the open pit will be pumped into the TMF to allow for sediment settling before being used for mill process water. A general arrangement of the mine site is shown on Figure 5.1, which illustrates a conceptual layout for the dewatering pump system in the final pit phase.

The design capacity for the dewatering system is controlled by the pit inflows during the 1 in 10 year 24-hour storm event. It has been assumed that the water will be removed over a ten-day period, during which time mining operations can continue in other active areas of the pit. The maximum pumping capacity is designed to be greater than the estimated storm pit inflow + 20%. The peak operational design capacity of the pumping system ranges from 100 l/s during the first phase of the pit, to 400 l/s for the final pit. The storm inflows and design pump flows are summarized in Table 5.1.

The pump system will use 18” HDPE DR9 pipe to convey the water from the bottom of the pit to the TMF. A pit pump station will be installed in the pit bottom sump. A series of four identical booster pump stations have been uniformly sized for staged installation as the pit depths and pit areas, and consequently design flows increase annually. Water will be pumped from the pit via a direct route along the South Wall of the pit, with booster pumps placed approximately every 100 m of vertical rise. The pipeline length and pump power requirements are summarized in Table 5.2. One option would be to design the pump system for peak flow capacity during the third stage of pit development. Allowances for identical standby pumps may be added in later years, to operate in parallel with the main pumps for handling increased storm runoff, or the existing system could be maintained with the necessary time for pit dewatering somewhat increased.

5.4 ALLOWANCE FOR PIT SLOPE DEPRESSURIZATION

Groundwater conditions must be monitored throughout the mine life and water management systems must be flexible as new data acquired from the monitoring programs may necessitate a change in the dewatering systems. Additional water management measures are present at many open pit operations which may be considered during future phases of mine development. Vertical pumping wells placed around the perimeter of the open pit can be used to draw down the groundwater level and lower the hydraulic pressure within the pit walls. Horizontal wall drains allow for slope depressurization. Slope stability analyses results indicated that slope depressurization measures are not required. However, the potential benefits for these pit dewatering measures should be continually assessed during mining operations. Therefore it is recommended that an allowance for implementing and maintaining these measures be included in the contingency fund for mine development.

SECTION 6.0 – PIT SLOPE DESIGN CRITERIA

6.1 GENERAL

The proposed Harper Creek open pit varies in pit wall height from 210 m to 420 m. This feasibility pit slope design has considered site-specific geotechnical and hydrogeological information collected from the 2011 Geotechnical Site Investigation program and utilized that data for slope stability analyses. Recommended pit slope geometries are summarized in this section, and some operational considerations related to the recommended slopes are considered, along with a discussion of the experiences encountered at other large open pit operations.

6.2 RECOMMENDED PIT SLOPE ANGLES

6.2.1 Bench Geometries

The bench design was developed based on bench geometry specifications provided by YMI and adjusted based the geology, geomechanical and geometrical characteristics of each main design sector. The bench face angles derived from the kinematic analyses are as steep as reasonably can be expected given the characteristics of the rock masses and mine requirements. As such, the potential for planar or wedge failures still exists within some design sectors, but the majority of these are expected to be manifested as small bench-scale ravelling type failures that will be removed during initial excavation or controlled through a normal bench maintenance program.

Optimum bench configurations will be determined during initial open pit development. However, recommendations for bench design will be provided for design and costing. Recommended bench geometries are summarized in Table 6.1 based on the kinematic assessment of the inter-ramp slope angles achievable in the open pit. Bench face angles of 60° are required in all northward dipping slopes within the South and Southwest Sectors to allow the requisite inter-ramp angle of 35° to be achieved. A 70° bench face angle is considered appropriate in all other sectors of the pit.

6.2.2 Inter-ramp Slopes

The inter-ramp slope angle is typically dictated by the bench geometry and controlled by large-scale structural features. It is assumed that a 12 m high single bench configuration will be used for pit development. The recommended inter-ramp slope angles for each of the design sectors are summarized in Table 6.1.

The critical wall of the open pit is the foot wall within the South Sector of the pit. This wall is oriented parallel to the foliation and primary jointing of the rock mass. Therefore, it is recommended that the inter-ramp angle of the South sector be 35° or less to mitigate the risk of multiple-bench planar failures. This is achievable by developing 12 m high single benches, with a minimum width of 10 m and a bench face angle of 60°. The Southwest Sector inter-ramp slopes should utilize the same geometry to reduce the risk of multiple-bench planar failures.

The remaining design sectors contain no significant kinematic controls, and slope angles are therefore primarily determined by bench geometry. The Northeast, East, West and Northwest sectors of the open pit will utilize 12 m high single benches, 8 m bench widths, and a maximum bench face angle of 70°, such that an inter-ramp angle of 44° is attainable.

6.2.3 Overall Slopes

Maximum inter-ramp slope heights of 150 m in Phyllite and West Volcaniclastic domains, and 200 m in East Volcaniclastic domains are recommended to maintain slope stability during wet periods. The inclusion of haul ramps and/or step-outs into the pit wall will reduce the overall slope angles and enhance the rock mass stability of the final pit walls.

A summary of the maximum overall slope angles for each design sector is shown in Table 6.1. Maximum overall slopes of 42° are expected to be achievable in the East Volcaniclastic geotechnical domains. Maximum overall slopes of 40° are expected to be achievable in slopes comprised of West Volcaniclastics and Phyllite.

The design basis for these maximum overall slope angles requires the implementation of careful controlled blasting practices along with monitoring of groundwater conditions to evaluate pore pressures in the pit walls.

6.3 OPERATIONAL CONSIDERATIONS

6.3.1 Controlled Blasting

Blasting disturbance is one of the controlling factors for rock mass strength and overall slope stability. Slope instabilities are often triggered by the progressive deterioration (ravelling) of the wall face and this process often initiates with the detachment of small rock blocks (key blocks) bounded by the rock mass discontinuities. The preservation of rock mass integrity during mining is critical to prevent these progressive failures and is required to achieve the steepest bench face angles possible.

Controlled blasting methods will facilitate steeper final pit slopes by reducing face damage from blasting. Typical controlled blasting strategies utilize small diameter blast holes detonated as a pre-shear line in harder massive rock or as a post-shear (cushion) line in weak or heavily fractured rock. In all cases, it is important that blast hole lengths be staggered so the bottom of the hole does not intercept the crest of the bench below. Otherwise, highly fragmented bench crests will develop. A typical controlled production blasting, or buffer blasting, pattern is illustrated on Figure 6.1.

Interim pit slopes must also incorporate some “controlled blasting” to maintain safety, but the requirements in this situation are less rigorous, due to the shorter operating life of these walls. In addition, steeper walls are less critical on interim faces, since the stripping ratio is typically controlled by the final overall pit slopes. The initial pit can be developed with variable slopes and blast patterns to develop the optimal blast design for the final pit walls. Trial blasts are also recommended wherever there is a substantial change in rock mass characteristics, in order to evaluate and optimize blast performance.

6.3.2 Bench Scaling

It is important that the benches be kept clear and that the bench faces be maintained regularly so that they remain functional during mining operations. Scaling will be an important part of the bench maintenance program and may be conducted after blasting in areas where access is still available. Routine scaling may allow the bench widths to be optimized, due to a reduction in the volume of material to be controlled.

6.3.3 Fault Zone Control

The Harper Creek Fault runs sub-vertically through the open pit along a northeast-southwest strike. The sub-vertical orientation of this fault prevents it from having an adverse effect on final wall stability. However, it is recommended that the fault be mined through when encountered and not left exposed within an interim pit wall.

6.3.4 Water Control

Surfaces ditches will direct water around the pit perimeter and prevent ingress of surface water into the pit. A pit dewatering system will be implemented to remove direct precipitation and seepage flow from the pit.

Horizontal wall drains in the pit and vertical pumping wells around the pit perimeter are not required for stability purposes in the Harper Creek open pit due to the natural drawdown of groundwater that is expected to occur during mining. However, water management schemes must be flexible to account for changes in conditions that occur throughout the mine life and it is recommended that a suitable allowance be included in the operating budget for the installation of these additional measures.

6.3.5 Geotechnical Monitoring

Pro-active geotechnical monitoring is recommended for all stages of pit development. The monitoring program should be implemented as a staged approach and include detailed geotechnical and tension crack mapping, as well as a suitable combination of surface displacement monitoring (surface prisms and wire line extensometers) and piezometers. Sufficient staffing resources should be allocated to collect, process and interpret the geotechnical monitoring data on a weekly basis or as frequently as required. The timely identification of accelerated movements from surface displacement monitoring and tension cracks will be critical. Up-to-date reports on the status of highwall stability should be compiled and discussed regularly with operations personnel. These reports will also assist mine engineering staff with their efforts to optimize final pit slopes and improve the effectiveness of the controlled blasting program. All seeps and springs should be inspected, mapped and photographed. Large-scale structures should be characterized and monitored as they have the potential to develop into tension cracks. A typical geotechnical monitoring schedule is presented in Table 6.2. Detailed monitoring requirements are discussed as follows:

- **Geotechnical Mapping –** Detailed geotechnical mapping should be carried out along newly formed benches along the pit highwalls. Detailed information to be noted includes the orientation of the main fracture sets, the type, thickness, extent (persistence) and frequency of any infilling (clay, gouge, chlorite, sericite, etc.), the distribution of joint spacings, the nature of the fracture surfaces (smooth, planar, polished, slickensided etc.) and any observations of seepage. Detailed maps for each bench face and a complete database should be compiled to include all the recorded geotechnical data. All relevant (and particularly adverse) geotechnical information should be updated on weekly mine plans to ensure that mine planners and operations personnel are aware of the current geotechnical conditions. The geotechnical mapping will also provide the quantitative and qualitative information needed to conduct ongoing highwall stability assessments during mining activities.
- **Tension Crack Mapping –** Detailed tension crack mapping should be carried out along all newly formed benches. Detailed information to be noted should include the surveyed location, orientation, aperture and both vertical and lateral extents of all tension cracks. The development of all tension cracks should be very carefully observed. The frequency of mapping and observations should be commensurate with the rate of development of individual tension cracks. Initial mapping and inspections should be carried out on a weekly basis. Simple extensometers should be installed across any significant tension cracks to confirm the rate and overall extent of movement. A detailed map and database should be compiled to include all the recorded data. The occurrence of tension cracks should be highlighted and presented on mine plans on a weekly basis so that mine planners and operations personnel are aware of the current ground conditions along the pit highwalls. Areas of slope movement that are associated with the development of tension cracks should also be monitored with surface displacement prisms as discussed below.
- **Surface Prism Monitoring –** Surface displacement monitoring survey prisms should be established along the highwalls to detect the onset of any possible movement/sliding at various locations within the vertical sequence of mining development of the open pit. An initial series of surface displacement monitoring prisms should be established along the crest of the highwalls as early in the mine-sequence as possible so that baseline information can be obtained. A subsequent series of surface displacement monitoring prisms should be established along all newly exposed benches. It is estimated that a total of 90 surface prisms will be required during the mine development. Prism surveying should be undertaken at regular intervals to develop a comprehensive record of highwall deformation. Data should be evaluated on an ongoing basis to enable the early detection of instability and allow for safe mining operations.
- **Piezometer Installation** – The groundwater level within the pit walls should be monitored to evaluate pore pressure reduction due to the natural drawdown of groundwater. It is recommended that piezometers be installed to allow long-term monitoring of groundwater depressurization over the life of the mine. It is estimated

that 30 to 40 piezometer installations will be required over the life of the mine. These piezometers will be progressively installed during operations and locations for new piezometers should be reviewed on an annual basis.

6.4 PRECEDENT PRACTICE

Pit slope stability depends on a variety of site-specific factors (geological structure, alteration rock strength, groundwater conditions, discontinuity characteristics and orientation, pit geometry, blasting practices, stress conditions, climatic conditions, and time), which make it difficult to provide direct comparisons with other operations. However, it is still quite useful to review the successes and problems encountered at other open pit operations in order to recognize opportunities and potential constraints for the proposed open pit development.

A summary plot of pit depth vs. slope angles achieved in various operations around the world is illustrated on Figure 6.2.

The proposed slope angles for the Harper Creek Pit are generally comparable to the slope angles achieved in other deep pits. This comparison highlights the importance of developing and maintaining good controlled blasting practices, effective groundwater depressurization measures and geotechnical data collection. It is also noted in these case studies, that adverse structural conditions have had a major impact on pit slope stability.

In addition, it is important to note that almost all of these large open pit operations have encountered slope stability problems in some area of the mine. The experiences at most of the large open pits suggest that there is a significant possibility that some area of the pit slope will require flattening during operations in response to slope movement. Therefore, the mine plans should remain flexible so that extra laybacks, step-outs, or buttresses can be incorporated in critical areas of the pit.

SECTION 7.0 – CONCLUSIONS AND RECOMMENDATIONS

The fundamental considerations for design of the Harper Creek pit slopes at the feasibility stage are related to the determination of allowable inter-ramp and overall slope angles, as these will affect the stripping ratio and the amount of ore that can be economically removed from the mineralized zone.

The South Sector pit walls dip in the same direction as the dominant structural features in the deposit, a series of foliation planes, joints, and thrust faults which dip towards the north. It is recommended that the inter-ramp slopes in all northward dipping walls be no greater than 35° to prevent the formation of planar failure along these structures. It has been shown that inter-ramp slope angles of 44° are achievable in all other sectors. A 12 m high, single bench configuration can be adopted in all sectors with 8 m wide benches and 70° bench face angles, excluding the South Sector. A 10 m wide bench and 60° bench face angle can be utilized in the South Sector to achieve the target inter-ramp slope of 35°. This design has a number of operational constraints including requirements for careful controlled blasting and continual monitoring of groundwater pressures during mining. Extensive monitoring and ongoing commitment to data collection will be necessary throughout the operational life of the mine. It is possible that double benching may be viable for southerly dipping slopes and should be evaluated when additional data is obtained during operations. The use of double benches may also allow these pit slopes to be developed at a slightly steeper inter-ramp angle.

Surface water diversion channels will be utilized to direct the majority of surface runoff around the pit. A conceptual pit dewatering system has been designed which utilizes a primary pumping station placed in the pit sump, used in conjunction with a series of booster pumps to remove water from the pit and convey it to the TMF for sediment settling and re-use/storage as required.

Additional studies are recommended to increase confidence of the geomechanical database. It will be helpful to update the current geological/structural model based on the on-going surface mapping and monitoring data during the early stages of pit operations. These data will be used to enhance the current database and to optimize the pit slope design. In addition, further hydrogeological studies are recommended to refine the estimate of pit inflows and adjust the pit water management plan. The pit slope designs should be reviewed by a qualified rock slope engineer as additional information becomes available and when the pit designs are modified.

SECTION 8.0 – REFERENCES

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SECTION 9.0 – CERTIFICATION

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

Prepared by: April 30, 2012

Greg Magoon, P.Eng.
Project Engineer

Reviewed by:

Daniel Y. Yang, P.Eng.
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Approved by:

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Managing Director

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TABLE 3.1

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
SUMMARY OF ROCK MASS PROPERTIES BY GEOLOGICAL PACKAGE

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Package Codes		H	FD			Fa			Fb			E			D	B		
RQD (%)	Number of Runs Measured	108	229			263			188			62			142	295		
	RQD Mean	61	81			84			76			77			80	74		
	RQD Median	68	93			92			88			86			86	84		
	RQD Std. Dev.	29	25			19			27			22			20	27		
RMR^{89}	Numbers of Discontinuities Measured	513	613			779			624			199			440	124		
	RMR89 Mean	60	64			64			63			68			64	68		
	RMR^{89} Median	59	65			65			64			69			64	67		
	RMR^{89} Std. Dev.	7	10			9			9			8			8	11		
	RMR^{89} Description	FAIR	GOOD			GOOD			GOOD			GOOD			GOOD	GOOD		
Rock Strength (MPa)	Failure Type[1]	Foliation Break	Foliation Break	Intact	All	Foliation Break	Intact	All	Foliation Break	Intact	All	Foliation Break	Intact	All	Foliation Break	Foliation Break	Intact	All
	Number of Samples	3	2	4	6	13	5	18	8	1	9	4	1	5	6	14	2	16
	Mean[2]	44	28	97	74	29	68	40	20	40	23	33	38	42	20	47	101	54
	Median	43	28	100	86	29	83	33	20	-	24	23	-	37	17	44		44
	Std. Dev.	15	30	15	40	23	31	31	13	-	14	31	-	33	8	33		45
	Maxium	60	49	110	110	76	100	100	42	-	42	75	-	75	32	113	175	175
	Minimum	29	7	76	7	1	33	1	2	-	2	10	-	10	13	1	27	1
	Classification	R3 - Average Rock	R3 - Average Rock	R4 - Hard Rock	R4 - Hard Rock	R3 - Average Rock	R4 - Hard Rock	R3 - Average Rock	R2 - Soft Rock	R3 - Average Rock	R2 - Soft Rock	R3 - Average Rock	R3 - Average Rock	R3 - Average Rock	R2 - Soft Rock	R3 - Average Rock	R5 - Very Hard Rock	R4 - Hard Rock
Direct Shear	Peak Friction	-	-			39			-			-			-	37		
	Residual Friction	-	-			33			-			-			-	32		
Young's Modulus (GPa)	Mean	-	67			44			43			-			-	91		
Poisson's Ratio	Mean	-	0.28			0.29			0.32			-			-	0.20		

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 3.1 - Rock Mass Properties by Geo Package -sg.xlsx]Table 3.1 - Geo. Pack. Prop.

NOTES:

1. TWO ROCK STRENGTHS REQUIRED FOR ANISOTROPIC STABILITY ANALYSES DUE TO DOMINANT STRUCTURAL FEATURES WITHIN THE ROCK MASS.
2. MEAN UCS IS AN UNWEIGHTED COMBINATION OF UCS AND PLT DATA .
3. INTACT ROCK CONSTANT IS ASSUMED BASED ON TYPICAL VALUES FOR PHYLLITES AND SCHISTS (HOEK-BROWN, 2007)

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REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3.2

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
SUMMARY OF GEOTECHNICAL DOMAIN ROCK MASS PARAMETERS

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Rock Mass Properties		Phyllite			West Volcaniclastics			East Volcaniclastics		
Package Codes		H			Fb, Fa, E, D			FD, B		
RQD (%)	Number of Runs Measured	108			897			567		
	RQD Mean	80			76			81		
	RQD Median	93			85			92		
	RQD Std. Dev.	27			25			24		
RMR^{89}	Numbers of Discontinuities Measured	513			2766			1430		
	RMR89 Mean	63			63			64		
	RMR^{89} Median	63			63			65		
	RMR^{89} Std. Dev.	8			9			10		
	RMR^{89} Description	GOOD			GOOD			GOOD		
Rock Strength (MPa)	Failure Type[1]	Foliation Break	Intact	All	Foliation Break	Intact	All	Foliation Break	Intact	All
	Number of Samples	3	-	3	29	7	36	15	6	21
	Mean[2]	44	-	44	26	65	34	45	98	60
	Median	43	-	43	20	100	29	42	100	53
	Std. Dev.	15	-	15	20	48	27	34	48	45
	Maxium	60	-	60	76	175	100	113	175	175
	Minimum	29	-	29	1	27	1	1	27	1
	Classification	R3 - Average Rock	-	R3 - Average Rock	R3 - Average Rock	R4 - Hard Rock	R3 - Average Rock	R3 - Average Rock	R4 - Hard Rock	R4 - Hard Rock
Direct Shear	Peak Friction	-			39			37		
	Residual Friction	-			33			32		
Young's Modulus (GPa)	Mean	45			38			75		
Poisson's Ratio	Mean	0.17			0.23			0.25		
Intact Rock Constant (mi)[3]		7			10			10		

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 3.2 - Rock Mass Properties by Geo Domain.xlsx]Table 3.2 - Geotech Domains

NOTES:

1. TWO ROCK STRENGTHS REQUIRED FOR ANISOTROPIC STABILITY ANALYSES DUE TO DOMINANT STRUCTURAL FEATURES WITHIN THE ROCK MASS.
2. MEAN UCS IS AN UNWEIGHTED COMBINATION OF UCS AND PLT DATA .
3. INTACT ROCK CONSTANT IS ASSUMED BASED ON TYPICAL VALUES FOR PHYLLITES AND SCHISTS (HOEK-BROWN, 2007)

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REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 4.1

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HARPER CREEK

2012 OPEN PIT GEOTECHNICAL DESIGN
SUMMARY OF STRUCTURE AND KINEMATICALLY POSSIBLE FAILURE MODES (BY SECTOR)

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SECTOR	BORE HOLES	JOINTS	FOLIATION	WALL ORIENTATION	IRA PLANAR	IRA WEDGE	IRA TOPPLE	BFA PLANAR	BFA WEDGE	BFA TOPPLE	COMMENT
Northeast	HC11-GM03, HC11-GM04, HC11-GM05	J1 (27/011) J2 (52/323) J3 (82/217)	S1 (25/355)	180°							No possible kinematically controlled failure mechanisms.
				220°							No possible kinematically controlled failure mechanisms.
East	HC11-GM06	J1 (34/338) J2 (86/115)	S1 (33/344)	270°							No possible kinematically controlled failure mechanisms.
South	HC11-GM01, HC11-GM07	J1 (32/341) J2 (75/053) J3 (74/245)	S1 (34/342)	000°	J1 (35°) S1 (35°)			J1 S1			Kinematically possible planar failure for walls dipping steeper than 35°.
				320°	J1 (35°) S1 (35°)	J1/J2 J1/J3		J1 S1	J1/J2 J1/J3		Kinematically possible planar failure for walls dipping steeper tha 35°. Wedges formed with J1/S2 and J2 or J3 at limit of friction angle.
Southwest	HC11-GM02	J1 (34/356) J2 (61/094) J3 (11/273) J4 (53/040) J5 (80/265)	S1 (34/350)	320°	J1 (35°) S1 (35°)			J1 S1	J1/J4		Some planar failure possible to due scatter and variation in the structural set. Wedges formed with J1 and J4 at the limit of the friction angle.
West	HC11-GM02	J1 (34/356) J2 (61/094) J3 (11/273) J4 (53/040) J5 (80/265)	S1 (34/350)	135°							No possible kinematically controlled failure mechanisms.
Northwest	HC11-GM03, HC11-GM04, HC11-GM05	J1 (27/011) J2 (52/323) J3 (82/217)	S1 (25/355)	180°							No possible kinematically controlled failure mechanisms.

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 4.1 - Kinematic Analysis Results by Sector.xlsx]Table 4.1

NOTES:

1. POOR AND VERY POOR QUALITY ORIENTATION DATA REVMOED FROM DATA SET. DATA ADJUSTED FOR QUANTITY OF MEASUREMENTS.
2. IRA = INTER-RAMP ANGLE, BFA = BENCH FACE ANGLE.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	24FEB'12	ISSUED WITH REPORT VA101-458/4-5	MF	GM	KJB

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TABLE 4.2

YELLOWHEAD MINING INC.
HARPER CREEK

2012 OPEN PIT GEOTECHNICAL DESIGN
SUMMARY OF STRUCTURE AND KINEMATICALLY POSSIBLE FAILURE MODES (BY DRILLHOLE)

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DRILLHOLE	JOINTS	FOLIATION	WALL ORIENTATION	IRA PLANAR	IRA WEDGE	IRA TOPPLE	BFA PLANAR	BFA WEDGE	BFA TOPPLE	COMMENT
GM01	J1 (33/346) J2 (74/245) J3 (59/212) J4 (72/061)	S1 (35/355)	000°	J1 (35°) S1 (35°)			J1 S1	J1/J4		Kinematically possible planar failure for walls dipping steeper than 35°. Planar and wedge failures expected in benches.
GM02	J1 (34/356) J2 (61/094) J3 (11/273) J4 (53/040) J5 (80/265)	S1 (35/350)	135°							No possible kinematically controlled failure mechanisms.
GM03	J1 (29/257) J2 (44/297) J3 (83/189)	S1 (29/345)	180°							No possible kinematically controlled failure mechanisms.
GM04	J1 (26/012) J2 (87/219) J3 (55/323)	S1 (26/359)	180°							No possible kinematically controlled failure mechanisms.
GM05	J1 (28/016) J2 (78/180) J3 (62/276) J4 (78/223) J5 (46/118)	S1 (20/002)	220°					J2/J3		Lots of scatter in the data, particularly schistosity. J2/J3 forms wedges for Bench only.
GM06	J1 (34/338) J2 (86/115)	S1 (33/344)	270°							No possible kinematically controlled failure mechanisms.
GM07	J1 (30/339) J2 (75/057) JJ3 (89/169)	S1 (34/337)	320°	S1 (35°)	J1(S1) / J2		J1 S1			Kinematically possible planar failure for walls dipping steeper than 35°, with increased likelihood of failures as wall turns towards the north. J1 dips at same angle as assumed friction angle. Some planar failure may form due to scatter and variation within the structural set.

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 4.2 - Kinematic Analysis Results by Drillhole.xlsx]Table 4.2

NOTES:

1. POOR AND VERY POOR QUALITY ORIENTATION DATA REVMOED FROM DATA SET. DATA ADJUSTED FOR QUANTITY OF MEASUREMENTS.
2. IRA = INTER-RAMP ANGLE, BFA = BENCH FACE ANGLE.

0	24FEB'11	ISSUED WITH REPORT VA101-458/4-5	MF	GM	KJB
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TABLE 4.3

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ROCK MASS PARAMETERS

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ISOTROPIC ANALYSIS

Geological Domain	East Volcaniclastics			West Volcanicastics			Phyllite		
Material Parameter	Lower Bound	Average	Upper Bound	Lower Bound	Average	Upper Bound	Lower Bound	Average	Upper Bound
UCS (MPa)	45	60	98	26	34	65	44	44	44
mi	10			10			7		
GSI	49	59	69	50	59	68	48	55	62
Max Confining Stress (kPa)	48			48			48		
Uni Weight (kN/m^3)	27			27			27		
Disturbance Factor	0.85			0.85			0.85		
Hydraulic Conductivity, k (m/sec)	4.E-08			4.E-08			4.E-08		

ANISOTROPIC ANALYSIS

Inter-ramp Slope Height (m)	**East Volcaniclastics**									
	Cohesion					**Phi**				
	(kPa)	**Modification Factor by % Rock Bridging**				**(°)**	**Modification Factor by % Rock Bridging**			
		0					**0**			
50	480.0	0.000	0.250	0.500	0.750	44.0	0.841	0.881	0.920	0.960
100	515.0	0.000	0.250	0.500	0.750	44.5	0.831	0.874	0.916	0.958
150	530.0	0.000	0.250	0.500	0.750	45.0	0.822	0.867	0.911	0.956
200	540.0	0.000	0.250	0.500	0.750	45.5	0.813	0.860	0.907	0.953
445	555.0	0.000	0.250	0.500	0.750	45.5	0.813	0.860	0.907	0.953

Inter-ramp Slope Height (m)	**West Volcaniclastics**									
	Cohesion					**Phi**				
	(kPa)	**Modification Factor by % Rock Bridging**				**(°)**	**Modification Factor by % Rock Bridging**			
		0%	**25%**	**50%**	**75%**		**0%**	**25%**	**50%**	**75%**
50	330	0.00	0.25	0.50	0.75	38.0	0.974	0.980	0.987	0.993
100	365	0.00	0.25	0.50	0.75	39.0	0.949	0.962	0.974	0.987
150	385	0.00	0.25	0.50	0.75	40.0	0.925	0.944	0.963	0.981
210	385	0.00	0.25	0.50	0.75	41.0	0.902	0.927	0.951	0.976

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NOTES:

1. ISOTROPIC ANALYSIS PERFORMED UTILIZING HOEK-BROWN PARAMETERS TO ESTABLISH FAILURE CRITERION.
2. ANISOTROPIC ANALYSIS PERFORMED UTILIZING MOHR-COULOMB PARAMETERS.

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TABLE 4.4

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS RESULTS FOR EAST VOLCANICLASTICS

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EAST VOLCANICLASTICS			
Inter-ramp Height (m)	Parameters		
	Lower Bound	Average	Upper Bound
Saturated Slope			
50	1.6	3.1	7.2
100	1.1	2.0	4.4
150	0.9	1.6	3.4
200	0.8	1.4	2.8
270[1]	0.7	1.2	2.3
375[2]	0.6	1.0	1.9
Slope with Groundwater Drawdown			
50	2.3 20V	3.9 20V	8.0 20V
100	1.6 42V	2.6 42V	5.1 42V
150	1.4 62V	2.2 62V	4.0 62V
200	1.2 82V	1.9 82V	3.4 82V
270[1]	1.1 104V	1.7 104V	3.0 104V
375[2]	0.9 110V	1.5 110V	2.5 110V

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LEGEND

1.3	Factor of Safety
100V	Vertical Drawdown (m)[4]

(green)	FOS ≥ 1.3
(yellow)	1.0 ≤ FOS < 1.2
(orange)	FOS < 1.0

NOTES:

1. MAXIMUM SLOPE HEIGHT OF THE NORTHEAST SECTOR PIT WALL.
2. MAXIMUM SLOPE HEIGHT OF THE EAST SECTOR PIT WALL.
3. THE FAILURE SURFACE SLIP CIRCLE IS IN DRY ROCK AND THE FACTOR OF SAFETY CANNOT BE INCREASED BY FURTHER DEPRESSURIZATION OF THE SLOPE.
4. VERTICAL DRAWDOWN VALUE MEASURED FROM A REFERENCE POINT 10m AWAY FROM SLOPE CREST

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TABLE 4.5

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS RESULTS FOR WEST VOLCANICLASTICS

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WEST VOLCANICLASTICS			
Inter-ramp Height (m)	Parameters		
	Lower Bound	Average	Upper Bound
	Static	Static	Static
Saturated Slope			
50	1.2	2.2	5.2
100	0.9	1.5	3.2
150	0.7	1.2	2.5
200	0.6	1.0	2.1
300(1)	0.1	0.9	1.7
Slope with Groundwater Drawdown			
50	1.8 20V	2.8 20V	5.7 20V
100	1.3 42V	2.0 42V	3.9 42V
150	1.1 60V	1.7 60V	3.1 60V
200	1.0 80V	1.5 80V	2.7 80V
300(1)	0.8 114V	1.3 114V	2.2 114V

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LEGEND

1.3	Factor of Safety
100V	Vertical Drawdown (m)(4)

(green)	FOS ≥ 1.3
(yellow)	1.0 ≤ FOS < 1.2
(orange)	FOS < 1.0

NOTES:

1. MAXIMUM SLOPE HEIGHT OF THE NORTHWEST SECTOR PIT WALL.
2. THE FAILURE SURFACE SLIP CIRCLE IS IN DRY ROCK AND THE FACTOR OF SAFETY CANNOT BE INCREASED BY FURTHER DEPRESSURIZATION OF THE SLOPE.

4. VERTICAL DRAWDOWN VALUE MEASURED FROM A REFERENCE POINT 10m AWAY FROM SLOPE CREST

0	24FEB'12	ISSUED WITH REPORT VA101-458/4-5	GM	DAY	KJB
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TABLE 4.6

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS RESULTS FOR PHYLLITE

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PHYLLITE			
Inter-ramp Height (m)	Parameters		
	Lower Bound	Average	Upper Bound
	Static	Static	Static
Saturated Slope			
50	1.6	2.2	3.0
100	1.1	1.5	2.0
150	0.8	1.2	1.5
200	0.7	1.0	1.3
235(1)	0.7	0.9	1.3
Slope with Groundwater Drawdown			
50	1.4 20V	1.9 20V	2.5 20V
100	1.4 43V	1.6 43V	2.5 43V
150	1.1 65V	1.6 65V	2.1 65V
200	1.0 80V	1.4 80V	1.9 80V
235(1)	0.9 85V	1.3 85V	1.7 85V

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LEGEND

1.3	Factor of Safety
100V	Vertical Drawdown (m)(4)

(green)	FOS ≥ 1.3
(yellow)	1.0 ≤ FOS < 1.2
(orange)	FOS < 1.0

NOTES:

1. MAXIMUM SLOPE HEIGHT OF THE WEST SECTOR PIT WALL BASED ON OCTOBER 2011 PIT SHELL.
2. THE FAILURE SURFACE SLIP CIRCLE IS IN DRY ROCK AND THE FACTOR OF SAFETY CANNOT BE INCREASED BY FURTHER DEPRESSURIZATION OF THE SLOPE.
4. VERTICAL DRAWDOWN VALUE MEASURED FROM A REFERENCE POINT 10m AWAY FROM SLOPE CREST

0	24FEB'12	ISSUED WITH REPORT VA101-458/4-5	GM	DAY	KJB
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TABLE 4.7

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ANISOTROPIC STABILITY ANALYSIS RESULTS

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SOUTH SECTOR

Inter-ramp Height (m)	% Rock Bridging 0	25	50	75	Isotropic
Saturated Slope					
50	0.6	3.1	3.3	3.5	3.7
100	0.5	2.0	2.2	2.3	2.5
150	0.5	1.7	1.8	1.9	2.0
200	0.6	1.3	1.6	1.7	1.8
445	0.5	0.9	1.1	1.2	1.3
Slope with Groundwater Drawdown					
50	1.1 18V	3.3 18V	3.6 18V	3.8 18V	4.2 18V
100	1.1 33V	2.4 33V	2.5 33V	2.7 33V	3.0 33V
150	1.0 49V	2.0 49V	2.1 49V	2.2 49V	2.5 49V
200	1.1 55V	1.7 55V	1.8 55V	2.0 55V	2.2 55V
445	1.1 110V	1.3 110V	1.4 110V	1.5 110V	1.6 110V

SOUTHWEST SECTOR

Inter-ramp Height (m)	% Rock Bridging 0	25	50	75	Isotropic
Saturated Slope					
50	0.6	2.3	2.5	2.6	2.7
100	0.5	1.6	1.7	1.8	1.9
150	0.5	1.4	1.4	1.5	1.6
210	0.5	1.0	1.2	1.3	1.4
Slope with Groundwater Drawdown					
50	1.1 18V	2.5 18V	2.6 18V	2.8 18V	3.2 18V
100	1.1 33V	1.9 33V	2.0 33V	2.1 33V	2.3 33V
150	1.0 49V	1.6 49V	1.7 49V	1.8 49V	2.0 49V
210	0.9 53V	1.4 53V	1.5 53V	1.6 53V	1.7 53V

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LEGEND

1.3	Factor of Safety
100V	Vertical Drawdown (m)[(4)]

(green)	FOS ≥ 1.3
(yellow)	1.0 ≤ FOS < 1.2
(orange)	FOS < 1.0

NOTES:

1. 0% ROCK BRIDGING IS A THIN, TYPICALLY VERY SHALLOW, PLANAR FAILURE
2. AVERAGE ROCK MASS STRENGTH PARAMETERS USED.
3. 25% IS PLANAR FAILURE, 50% SIMILAR TO CIRCULAR FAILURE, DEWATERING BEHAVES DIFFERENTLY
4. THE FAILURE SURFACE SLIP CIRCLE IS IN DRY ROCK AND THE FACTOR OF SAFETY CANNOT BE INCREASED BY FURTHER DEPRESSURIZATION OF THE SLOPE
5. VERTICAL DRAWDOWN VALUE MEASURED FROM A REFERENCE POINT 10m AWAY FROM SLOPE CREST

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TABLE 5.1

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
STAGED DEVELOPMENT OF PIT INFLOWS

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Year	Open Pit Surface Area (m2)	Open Pit Plan Area (m2)	Avg. Ground Elevation (m)	Pit Bottom Elevation (m)	Avg. Depth of Pit (m)	Equivalent radius of excavation (m)	Radius of influence (m)	Overall Average K (m/s)	Estimate of pit seepage inflow (l/s)[1]	Inflow from average annual precipitation (l/s)	**Total pumping requirement (l/s)[2]**	Inflow from 1 in 10 yr. 24 hours storm event (l/s)[4]	**Design Pump Flow (l/s)[5]**
Pre-Production	841,032	779,000	1,700	1480	220	517	1,017	4.E-08	9	26	**35**	48	**99**
1	841,032	779,000	1,700	1480	220	517	1,017	4.E-08	9	26	**35**	48	**99**
2	841,032	779,000	1,700	1480	220	517	1,017	4.E-08	9	26	**35**	48	**99**
3	841,032	779,000	1,700	1480	220	517	1,017	4.E-08	9	26	**35**	48	**99**
4	841,032	779,000	1,700	1480	220	517	1,017	4.E-08	9	26	**35**	48	**99**
5	910,489	779,000	1,700	1420	280	538	1,038	4.E-08	15	26	**41**	48	**106**
6	1,296,280	1,181,000	1,700	1420	280	642	1,142	4.E-08	17	39	**56**	72	**155**
7	1,296,280	1,181,000	1,700	1420	280	642	1,142	4.E-08	17	39	**56**	72	**155**
8	1,296,280	1,181,000	1,700	1420	280	642	1,142	4.E-08	17	39	**56**	72	**155**
9	1,308,917	1,181,000	1,700	1410	290	645	1,145	4.E-08	18	39	**58**	72	**156**
10	1,308,917	1,181,000	1,700	1410	290	645	1,145	4.E-08	18	39	**58**	72	**156**
11	1,914,259	1,843,000	1,700	1410	290	781	1,281	4.E-08	21	61	**83**	113	**235**
12	1,914,259	1,843,000	1,700	1410	290	781	1,281	4.E-08	21	61	**83**	113	**235**
13	1,914,259	1,843,000	1,700	1410	290	781	1,281	4.E-08	21	61	**83**	113	**235**
14	1,914,259	1,843,000	1,700	1410	290	781	1,281	4.E-08	21	61	**83**	113	**235**
15	1,929,019	1,843,000	1,700	1400	300	784	1,284	4.E-08	23	61	**84**	113	**237**
16	2,657,927	2,539,000	1,700	1400	300	920	1,420	4.E-08	26	85	**111**	156	**320**
17	2,657,927	2,539,000	1,700	1400	300	920	1,420	4.E-08	26	85	**111**	156	**320**
18	2,657,927	2,539,000	1,700	1400	300	920	1,420	4.E-08	26	85	**111**	156	**320**
19	2,726,573	2,539,000	1,700	1348	352	932	1,432	4.E-08	36	85	**121**	156	**332**
20	3,239,787	3,054,000	1,700	1348	352	1,016	1,516	4.E-08	39	102	**141**	187	**393**
21	3,239,787	3,054,000	1,700	1348	352	1,016	1,516	4.E-08	39	102	**141**	187	**393**
22	3,239,787	3,054,000	1,700	1348	352	1,016	1,516	4.E-08	39	102	**141**	187	**393**
23	3,239,787	3,054,000	1,700	1348	352	1,016	1,516	4.E-08	39	102	**141**	187	**393**

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 5.1 - Pit Inflows.xls]Table 5.1

NOTES:

1. ESTIMATED PIT SEEPAGE INFLOWS ARE CALCULATED USING THE DUPIT APPROXIMATION EQUATION FOR STEADY RADIAL FLOWS IN UNCONFINED AQUIFERS.
2. THE CAPACITY OF PIT PUMPING SYSTEM SHOULD COVER THE SUM OF SEEPAGE INFLOWS AND DIRECT ANNUAL AVERAGE PRECIPITATION.
3. GROUNDWATER LEVEL IS ASSUMED TO BE NEAR SURFACE.
4. INFLOW FROM A 24-HOUR STORM IS REMOVED OVER 10 DAYS.
5. DESIGN PUMP FLOW BASED ON 120% BASE PUMPING + 24-HOUR STORM RUNOFF REMOVED OVER 10 DAYS.

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TABLE 5.2

YELLOWHEAD MINING INC.
HARPER CREEK

2012 OPEN PIT GEOTECHNICAL DESIGN
PIT DEWATERING SYSTEM SUMMARY

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Phase	Pipeline Costs, Pump Costs, & Energy Usage							
	Parameters		Piping			Pump		Annual Power Consumption
	Peak Flow	Static Head	Diameter	Length	Material	Power		
	(m^3/s)	(m)	(in)	(m)	(type)	(HP)	(kW)	(MWh)
Phase 1	0.10	360	18	2,000	HDPE DR9	635	474	**1447**
Phase 2	0.16	420	18	2,100	HDPE DR9	1180	880	**2708**
Phase 3	0.24	444	18	2,200	HDPE DR9	1968	1468	**4265**
Phase 4	0.32	444	18	2,300	HDPE DR9	2852	2128	**5751**
Phase 5	0.39	490	18	2,400	HDPE DR9	4069	3036	**8134**

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 5.2 - Pipeline Pit Dewatering Annual Peak.xlsx]Table 5.2

NOTES:

1. PEAK PIT INFLOWS BASED ON ESTIMATED 1 IN 10-YEAR 24-HOUR PRECIPITATION EVENT IN ADDITION TO AVERAGE ANNUAL INFLOWS.
2. PEAK FLOWS BASED ON PIT DEWATERING IN 10 DAYS.
3. PUMP SELECTION BASED ON ADDITIONAL 20% FOR SURGE CAPACITY.
4. ANNUAL POWER CONSUMPTION BASED ON LONGTERM AVERAGE ANNUAL PRECIPITATION (1.05 m) FOR THE SITE (FLOWS NOT SHOWN).

0	24FEB'12	ISSUED FOR WITH REPORT VA101-458/4-3	VM	DDF	KJB
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TABLE 6.1

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
RECOMMENDED PIT SLOPE ANGLES

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Pit Design Sector	Total Slope Height[1]	Geotechnical Domain	Pit Wall Dip Direction	Kinematic Stability Analyses [2]			Rock Mass Stability Analyses [3]			Recommended Slope Design [4], [5]						Comments
				Bench Face Angle	Inter-ramp Angle	Potential Instability Mechanism	Inter-ramp Angle	Groundwater Drawdown	Factor of Safety[6]	**Overall Slope Angle**	**Maximum Inter-ramp Slope Height**	**Inter-ramp Angle**	**Bench Face Angle**	**Bench Height**	**Bench Width**	
	m			degrees	degrees	-	degrees	m		**degrees**	**m**	**degrees**	**degrees**	**m**	**m**	
Northeast	270	East Volcaniclastics	180°	70	44	-	44	104	1.7	**44**	**200**	**44**	**70**	**12**	**8**	Step-out will be required to reduce inter-ramp slope heights and reduce overall slope angle.
			220°	70	44	-				**44**	**200**	**44**	**70**	**12**	**8**	
East	375	East Volcaniclastics	270°	70	44	-	44	110	1.4	**44**	**200**	**44**	**70**	**12**	**8**	Step-out will be required to reduce inter-ramp slope heights and reduce overall slope angle.
South	445	East Volcaniclastics	000°	60	35	Planar, Wedge	35	110	1.5	**35**	**200**	**35**	**60**	**12**	**10**	Step-out will be required to reduce inter-ramp slope heights and reduce overall slope angle.
			320°	60	35	Planar, Wedge	35	110	1.5	**35**	**200**	**35**	**60**	**12**	**10**	
Southwest	210	West Volcaniclastics	320°	60	35	Planar	35	53	1.5	**35**	**200**	**35**	**60**	**12**	**10**	
West	235	Phyllite	135°	70	44	-	44	90	1.3	**44**	**200**	**44**	**70**	**12**	**8**	Step-out will be required to reduce inter-ramp slope heights and reduce overall slope angle.
Northwest	300	West Volcaniclastics	180°	70	44	-	44	114	1.3	**44**	**200**	**44**	**70**	**12**	**8**	Step-out will be required to reduce inter-ramp slope heights and reduce overall slope angle.

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 6.1 - Pit Slope Angles.xls]Pit Slope Angle

NOTES:

1. BASED ON THE PIT SHELL MODEL PROVIDED BY MERIT, JANUARY 2012.
2. STRONG PLANAR AND WEDGE FEATURES TO BE STEEPER THAN THE INTER-RAMP ANGLE. A MINIMUM BENCH WIDTH OF 8 m IS ASSUMED.
3. A MINIMUM FACTOR OF SAFETY (FOS) OF 1.3 IS TARGETED.
4. THE RECOMMENDED SLOPE ANGLES WERE DETERMINED BY THE LOWEST VALUE OF THE KINEMATIC AND ROCK MASS STABILITY ANALYSES.
5. A SINGLE BENCH HEIGHT OF 15 m IS ASSUMED FOR THE PIT WALL DEVELOPMENT.
6. FACTOR OF SAFETY IS TAKEN FOR AVERAGE PARAMETERS FOR ALL SECTORS EXCEPT SOUTH. THE SOUTH SECTOR FACTOR OF SAFETY SHOWN IS FOR 50% ROCK BRIDGING.
7. RECOMMENDED OVERALL SLOPE ANGLES ASSUME A FULLY SATURATED SLOPE CONDITION.

0	24FEB'12	ISSUED WITH REPORT VA101-458/4-5	MF	GM	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

Knight Piésold CONSULTING

TABLE 6.2

YELLOWHEAD MINING INC.
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
RECOMMENDED PIT GEOTECHNICAL MONITORING PRACTICES

Print Apr/25/12 10:07:29

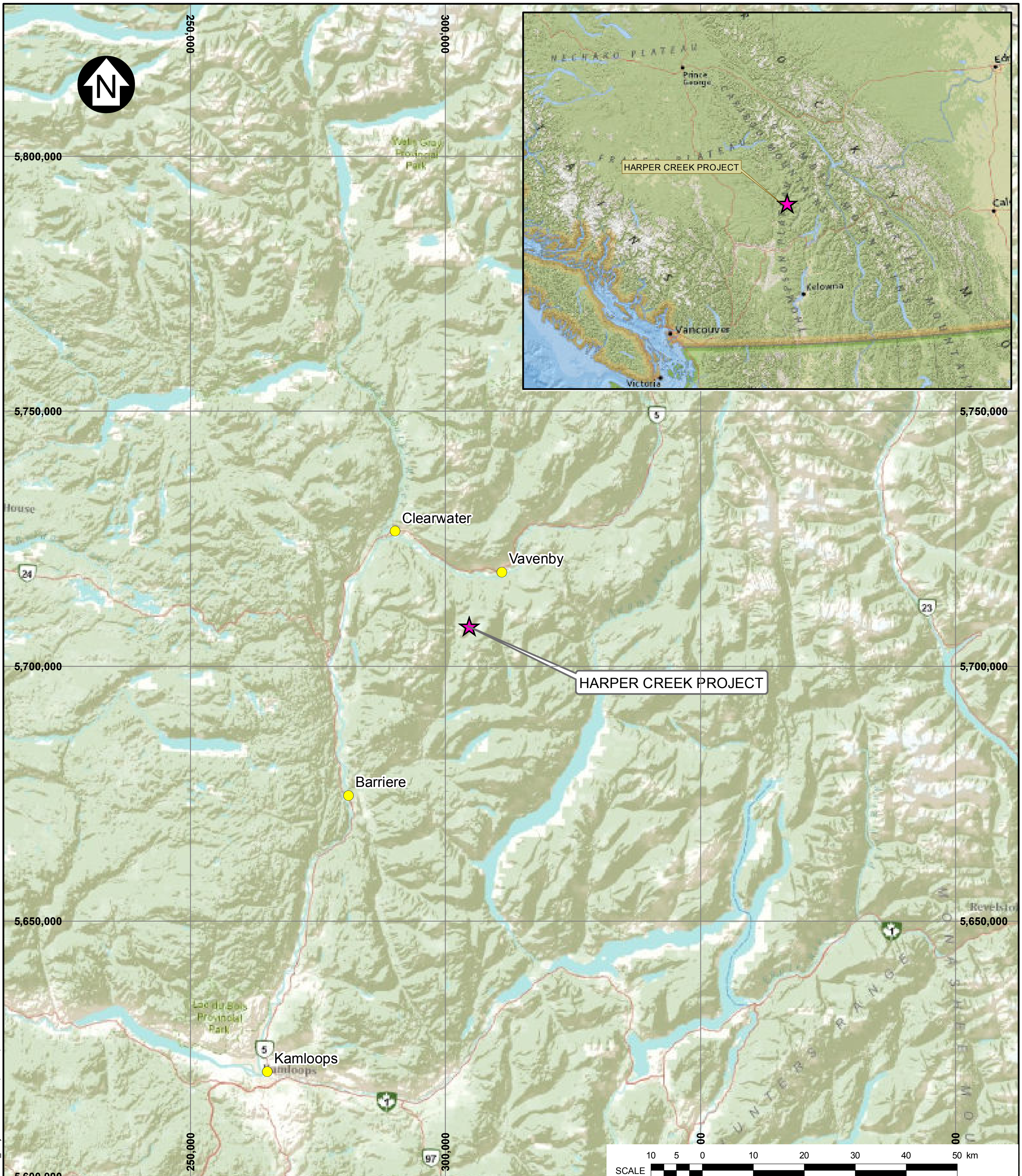
Monitoring Items	Estimated Quantity	Suggested Monitoring Schedule	
		Active Mining Area	Inactive Mining Area
General Visual Inspection	N/A	Daily	Weekly
Geotechnical Mapping	All new bench faces	Monthly	Twice monthly
Tension Crack Mapping	As required	Weekly	Twice monthly
Surface Prism Monitoring	90	Bi-weekly to Daily - Depends on the rate of displacement and location	Weekly
Piezometer Monitoring	40	Twice monthly	Monthly

M:\1\01\00458\04\A\Report\5 -Open Pit Geotechnical Design\Rev A\Tables\[Table 6.2 - Pit Monitoring.xls]Table 6.2

NOTES:

1. VISUAL INSPECTIONS OF ALL FACES MAY BE REQUIRED AT THE BEGINNING OF EACH SHIFT AND WEEKLY INSPECTIONS OF THE HIGHWALL SHOULD BE COMPLETED.
2. ADDITIONAL CRACK MAPPING AND PRISM SURVEY MONITORING SHOULD BE CONDUCTED FOLLOWING SIGNIFICANT RAINFALL OR HEAVY BLASTING IN THE AREA.
3. SENSITIVE FACILITIES, WHERE SMALL DISPLACEMENTS WOULD RESULT IN DAMAGE TO THE FACILITY MAY REQUIRE MORE PRECISE MONITORING METHODS AND MORE FREQUENT MEASUREMENTS.

0	24FEB'12	ISSUED WITH REPORT VA101-458/4-5	GM	DAY	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'	APP'D



LEGEND:

- ★ PROJECT LOCATION
- ● CITY/TOWN

NOTES:

1. BASE MAP: ARCGIS ONLINE TOPOGRAPHIC MAPS.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:1,000,000 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	16JAN'12	ISSUED WITH REPORT	AMD	AMD	GM	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

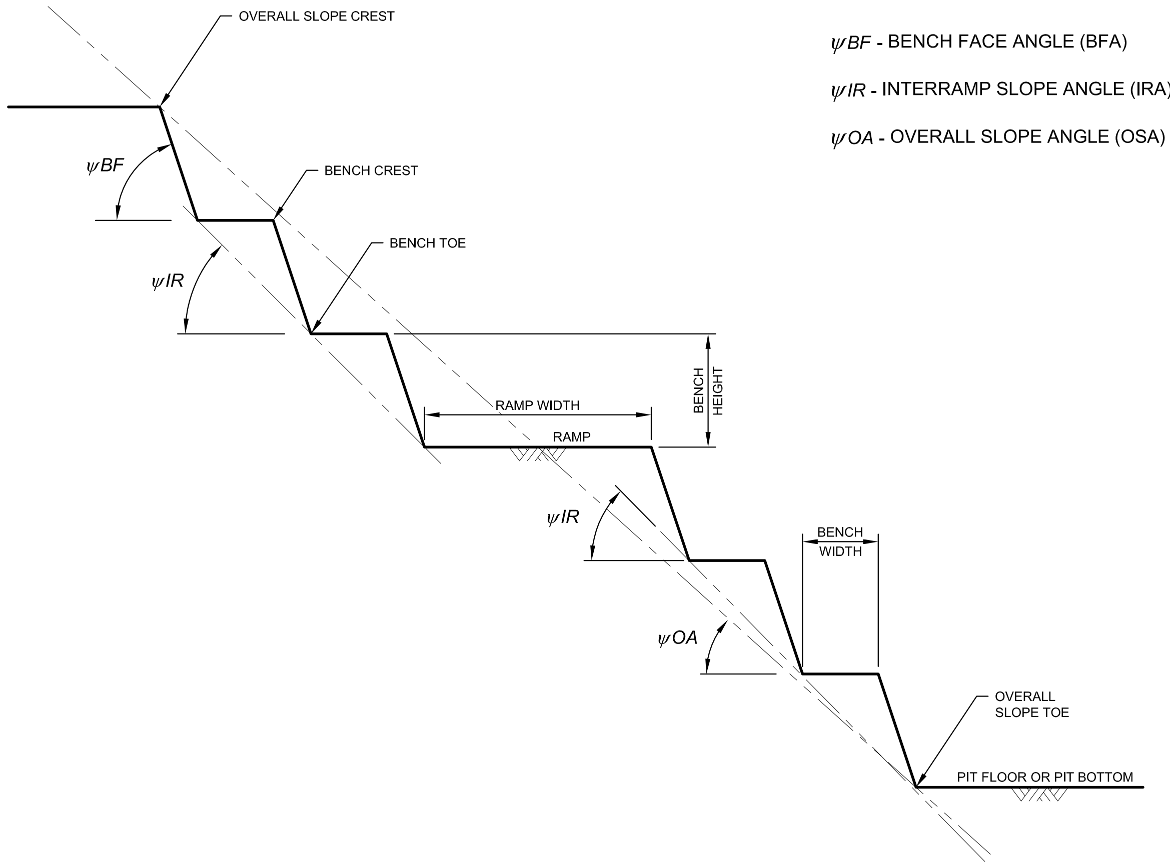
2012 OPEN PIT GEOTECHNICAL DESIGN
PROJECT LOCATION

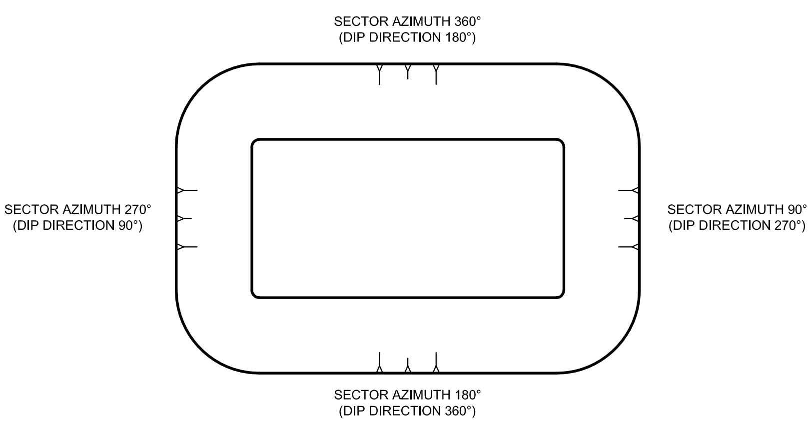
Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF NO. 5

FIGURE 1.1 | REV 0

KP FIGURE SAVED: M:\1\01\00458\04\A\GIS\Figs\HARP_ProjectLocation.mxd; Jan 30, 2012 10:47:07 AM adinca





WALL SECTOR AZIMUTH AND DIP DIRECTION
NTS

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0	26APR'12	ISSUED WITH REPORT	GM	DP	DAY	KJB

YELLOWHEAD MINING INC.

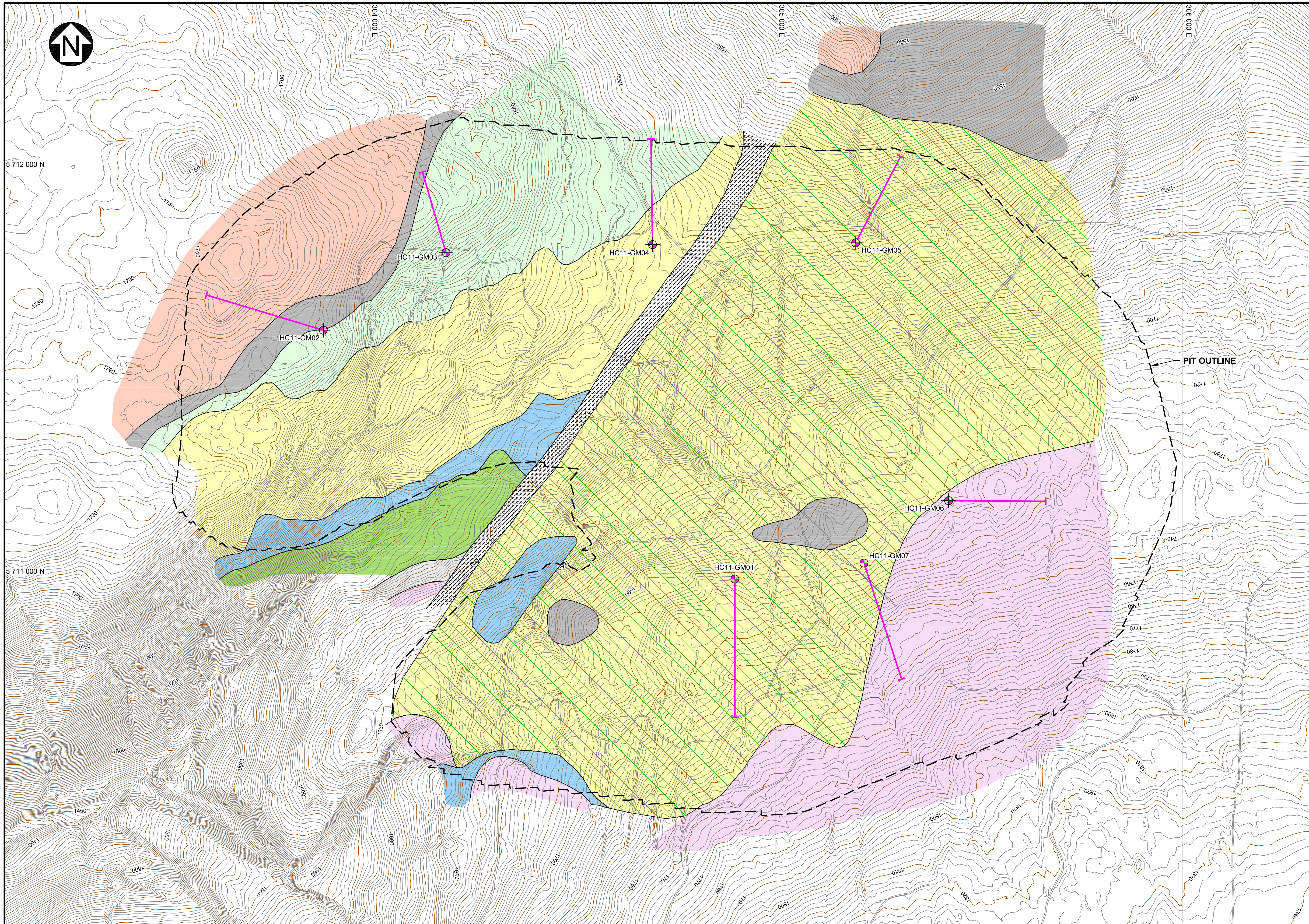
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
TYPICAL OPEN PIT SLOPE CONFIGURATIONS

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF NO. 5

FIGURE 2.1 | REV 0



LEGEND:

- H: MAFIC POLYMICTIC VOLCANICLASTICS
- G: GRAPHITIC HORIZON, SOMEWHAT CALCAREOUS
- FD: UNDIVIDED F & D
- Fb: INTERMEDIATE TO MAFIC POLYMICITIC VOLCANICLASTICS
- Fa: FELSIC TO INTERMEDIATE VOLCANICLASTICS
- E: MIXED SILICIFIED AND GRAPHITIC HORIZON
- D: INTERMEDIATE VOLCANICLASTICS AND FRAGMENTALS
- C: GRAPHITIC HORIZON
- B: SANDY SEDIMENT DOMINATED
- HARPER CREEK FAULT
- GEOMECHANICAL DRILLHOLES

NOTES:

1. COORDINATE GRID IS UTM NAD 83 ZONE 11
2. CONTOUR INTERVAL IS 2 METRES.
3. GEOLOGICAL PACKAGE INFORMATION PROVIDED BY CME, OCTOBER 2011

SCALE A 100 50 0 100 200 300 400 500 m

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
SURFICIAL BEDROCK GEOLOGY
OPEN PIT AREA

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF NO. 5

FIGURE 3.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	26APR'12	ISSUED WITH REPORT	HS	WAL	GM	KJB

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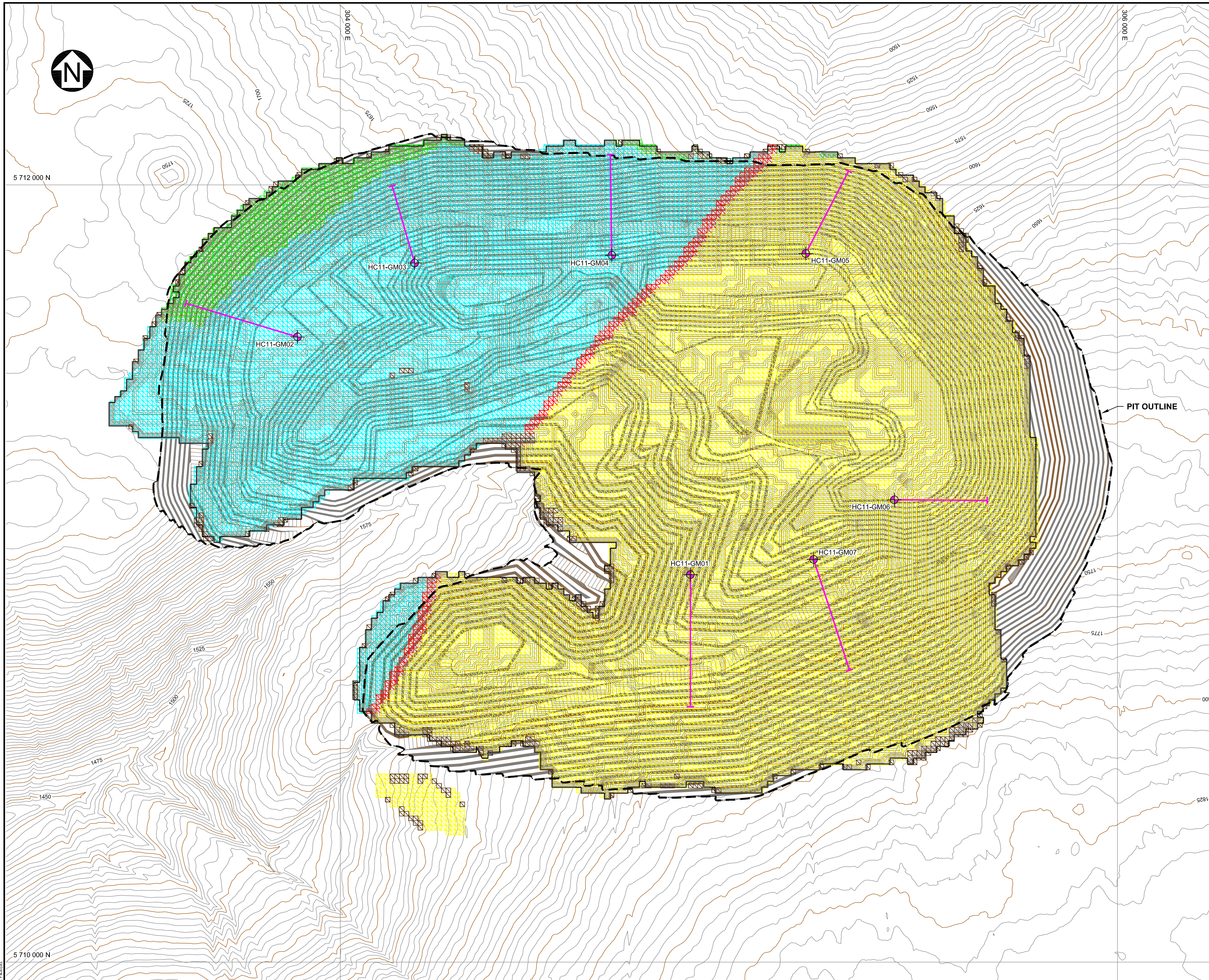

PLAN
SCALE A

LEGEND:

- EAST MINERALIZED ZONE
- WEST MINERALIZED ZONE
- PHYLLITE ZONE
- GEOMECHANICAL DRILLHOLES

NOTES:

1. COORDINATE GRID IS UTM NAD83, ZONE 10 (m).
2. PIT SHELL MODEL PROVIDED BY MERIT CONSULTANTS, JANUARY 2012.
3. MINERALIZED DOMAIN BLOCK MODEL PROVIDED BY GEOSIM SERVICES INC., OCTOBER 2011.
4. CONTOUR INTERVAL IS 5 METRES.
5. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 100 50 0 100 200 300 400 500 m

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
PIT SHELL MODEL
WITH MINERALIZED DOMAIN SEQUENCES

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/4	5

FIGURE 3.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	26APR'12	ISSUED WITH REPORT	GM	VG/WAL	DAY	KJB

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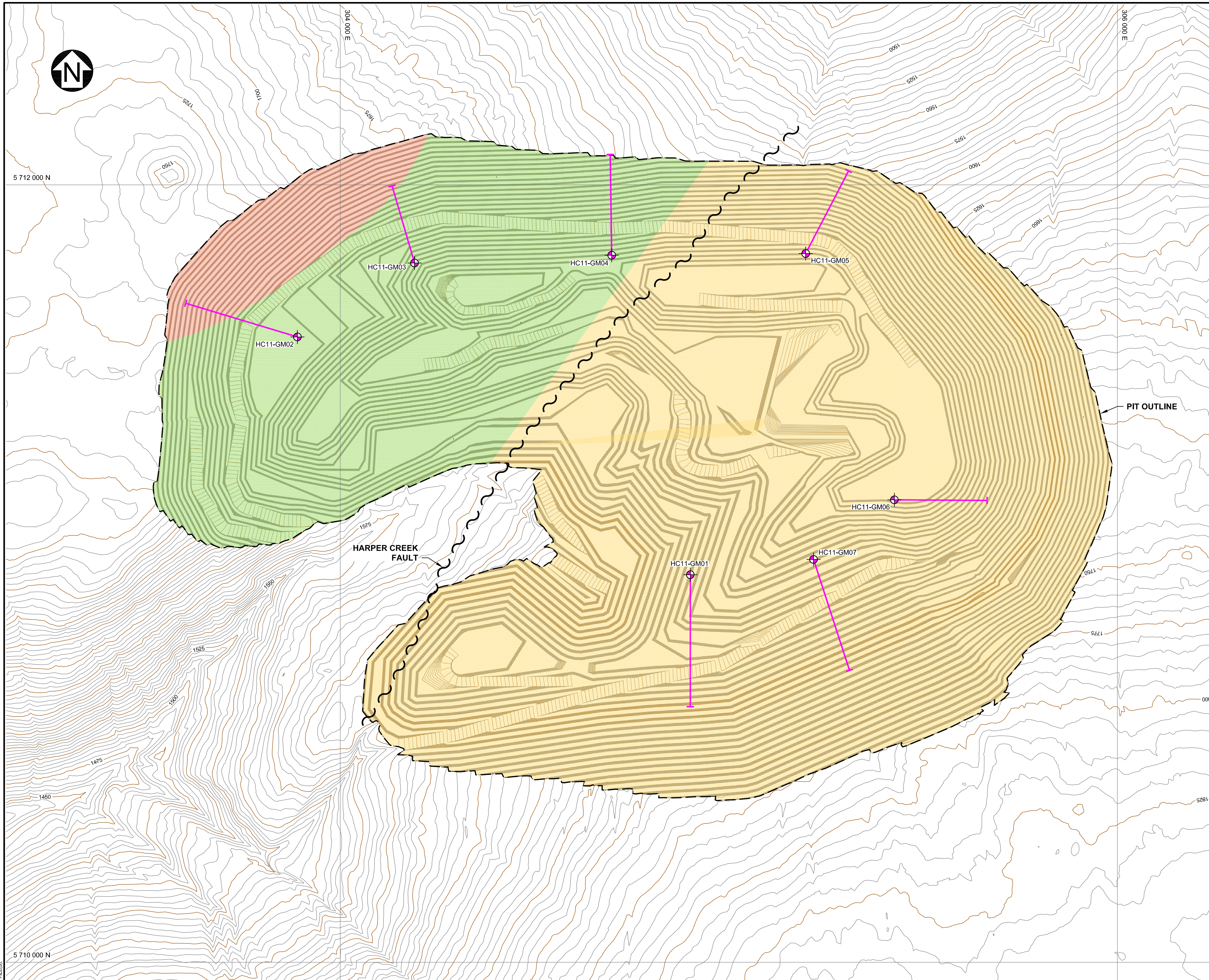

PLAN
SCALE A

LEGEND:

- EAST VOLCANICLASTICS
- WEST VOLCANICLASTICS
- PHYLLITE
- HARPER CREEK FAULT
- GEOMECHANICAL DRILLHOLES

NOTES:

1. COORDINATE GRID IS UTM NAD83, ZONE 10 (m).
2. PIT SHELL MODEL PROVIDED BY MERIT CONSULTANTS, JANUARY 2012.
3. CONTOUR INTERVAL IS 5 METRES.
4. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 100 50 0 100 200 300 400 500 m

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN PIT SHELL MODEL WITH GEOTECHNICAL DOMAINS

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/4	5

FIGURE 3.3 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	26APR'12	ISSUED WITH REPORT	GM	VG/WAL	DAY	KJB

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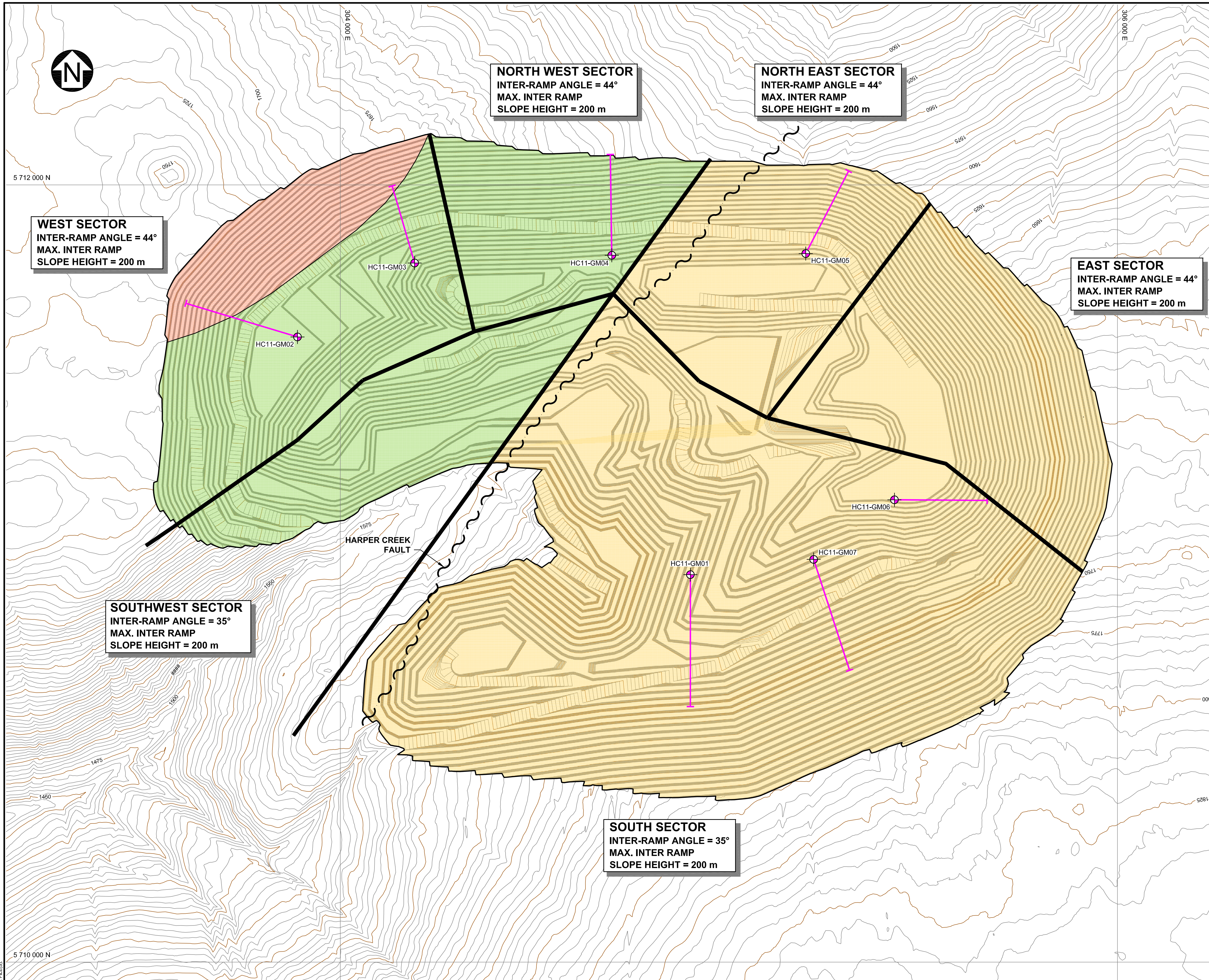

PLAN
SCALE A

LEGEND:

- EAST VOLCANICLASTICS
- WEST VOLCANICLASTICS
- PHYLLITE
- HARPER CREEK FAULT
- GEOMECHANICAL DRILLHOLES

NOTES:

1. COORDINATE GRID IS UTM NAD83, ZONE 10 (m).
2. PIT SHELL MODEL PROVIDED BY MERIT CONSULTANTS, JANUARY 2012.
3. CONTOUR INTERVAL IS 5 METRES.
4. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 100 50 0 100 200 300 400 500 m

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
PIT SHELL MODEL
WITH PIT DESIGN SECTORS

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF NO. 5

FIGURE 4.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	26APR'12	ISSUED WITH REPORT	GM	VG/WAL	DAY	KJB

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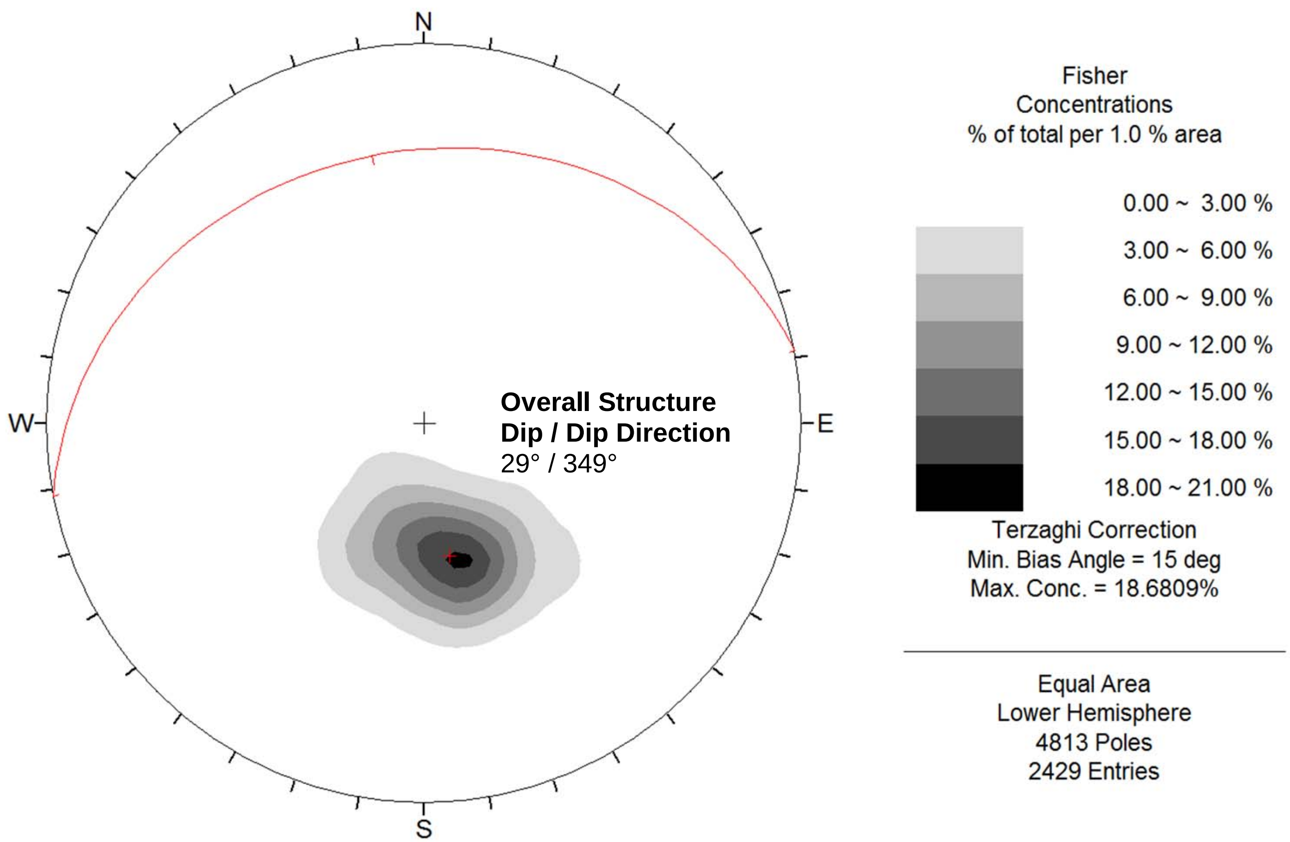


NOTES:
1. OVERALL PIT STRUCTURE DATA FROM DRILL HOLES HC11-GM01A TO HC11-GM07.
2. POOR QUALITY ORIENTATION MEASUREMENTS REMOVED FROM DATA SET.

0	29FEB'12	ISSUED WITH REPORT	GM	DAY	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
OVERALL PIT STRUCTURE

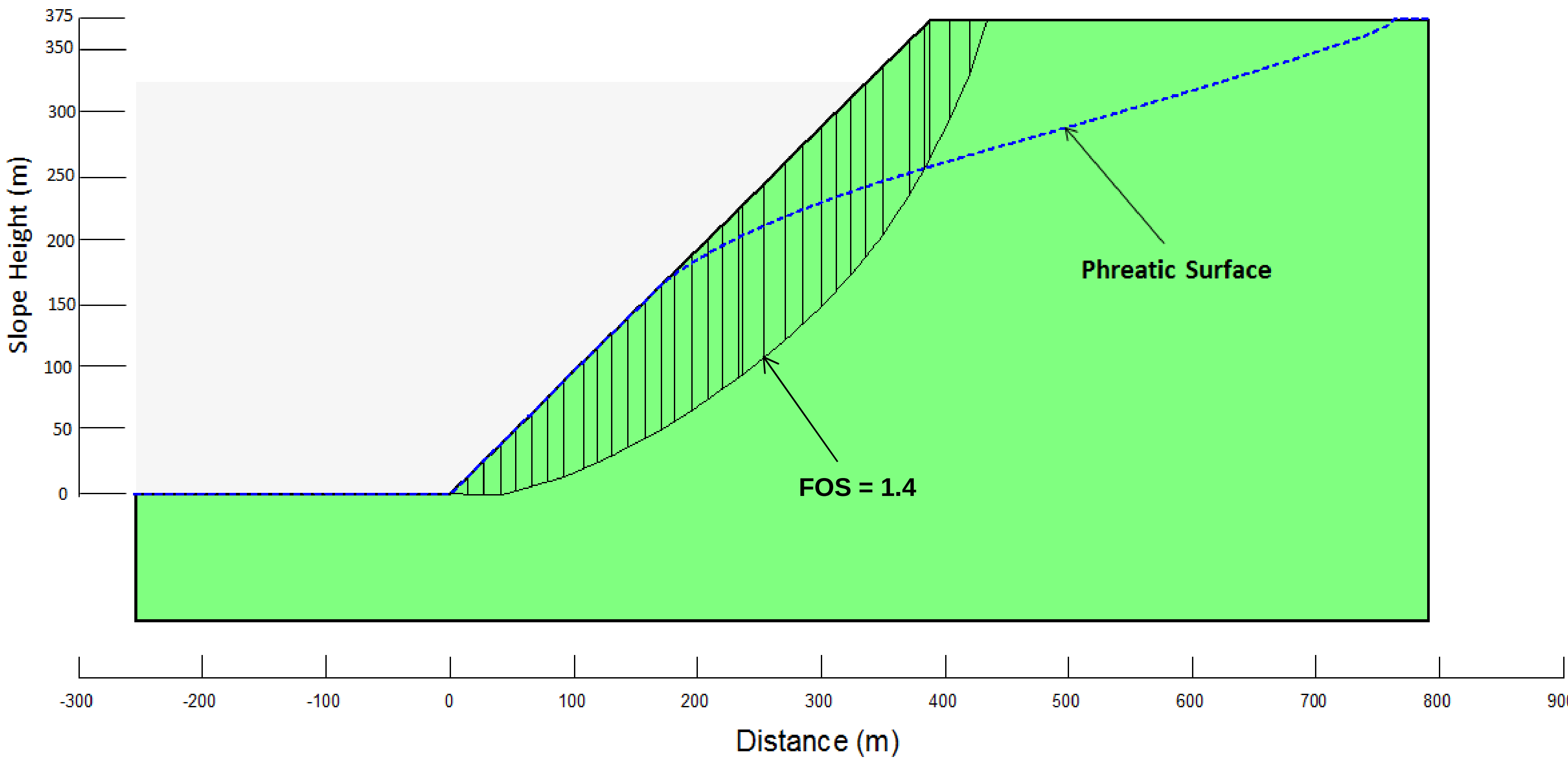
Knight Piésold CONSULTING

P/A NO. VA101-458/4

REF. NO. 5

FIGURE 4.2

REV 0



NOTES:
1. SLOPE MODELED USING AVERAGE QUALITY EAST VOLCANICLASTIC ROCK.
2. PHREATIC SURFACE MODELED TO SIMULATE GROUNDWATER DRAW DOWN.

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

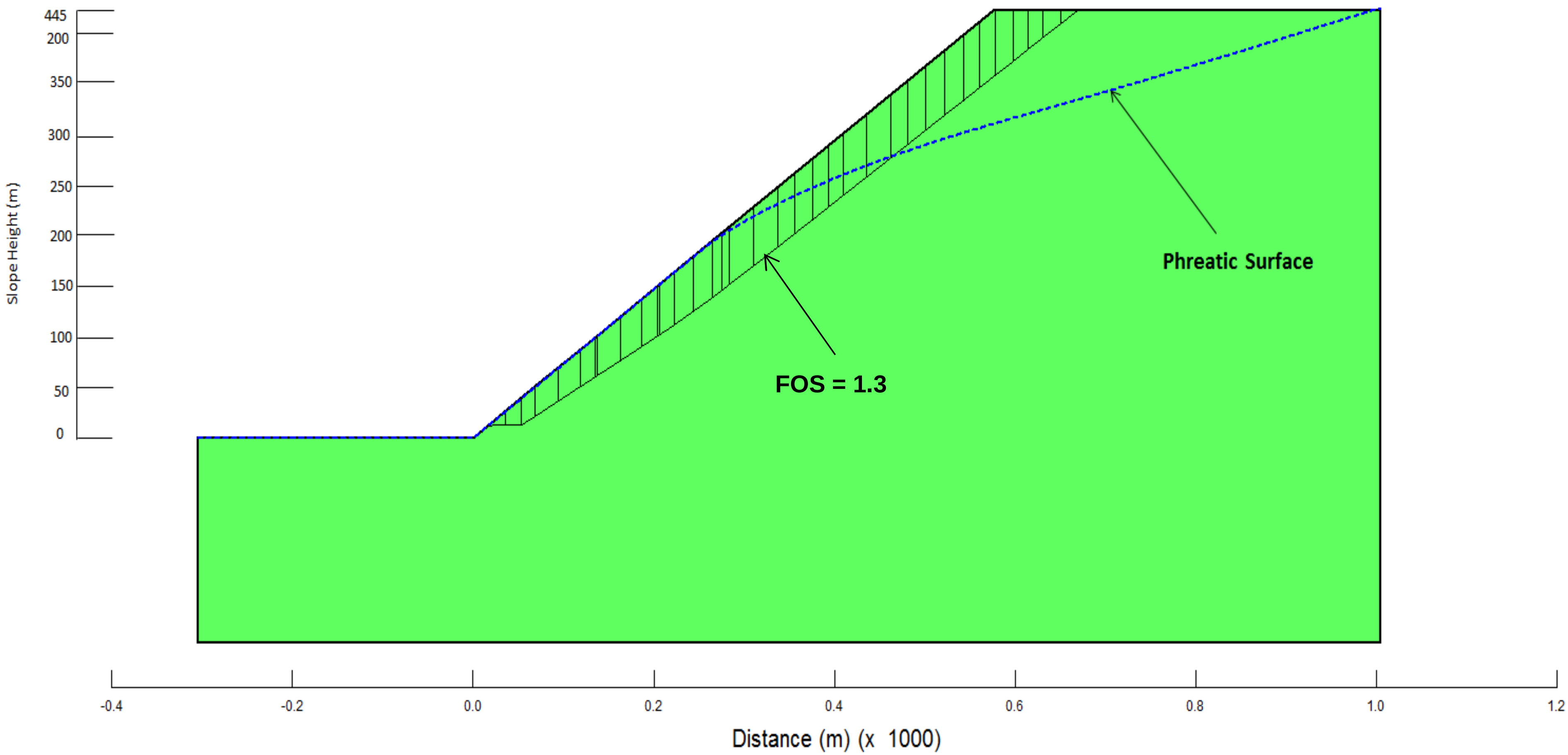
2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS
BASE CASE RESULT

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-458/4	5

FIGURE 4.3 REV A

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	29FEB'12	ISSUED WITH REPORT	GM	DAY	KJB



NOTES:

1. SLOPE MODELED USING EAST VOLCANICLASTIC ROCK WITH 25% ROCK BRIDGING.
2. PHREATIC SURFACE MODELED TO SIMULATE GROUNDWATER DRAW DOWN.

0	29FEB'12	ISSUED WITH REPORT	GM	DAY	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ANISOTROPIC STABILITY ANALYSIS
BASE CASE RESULT

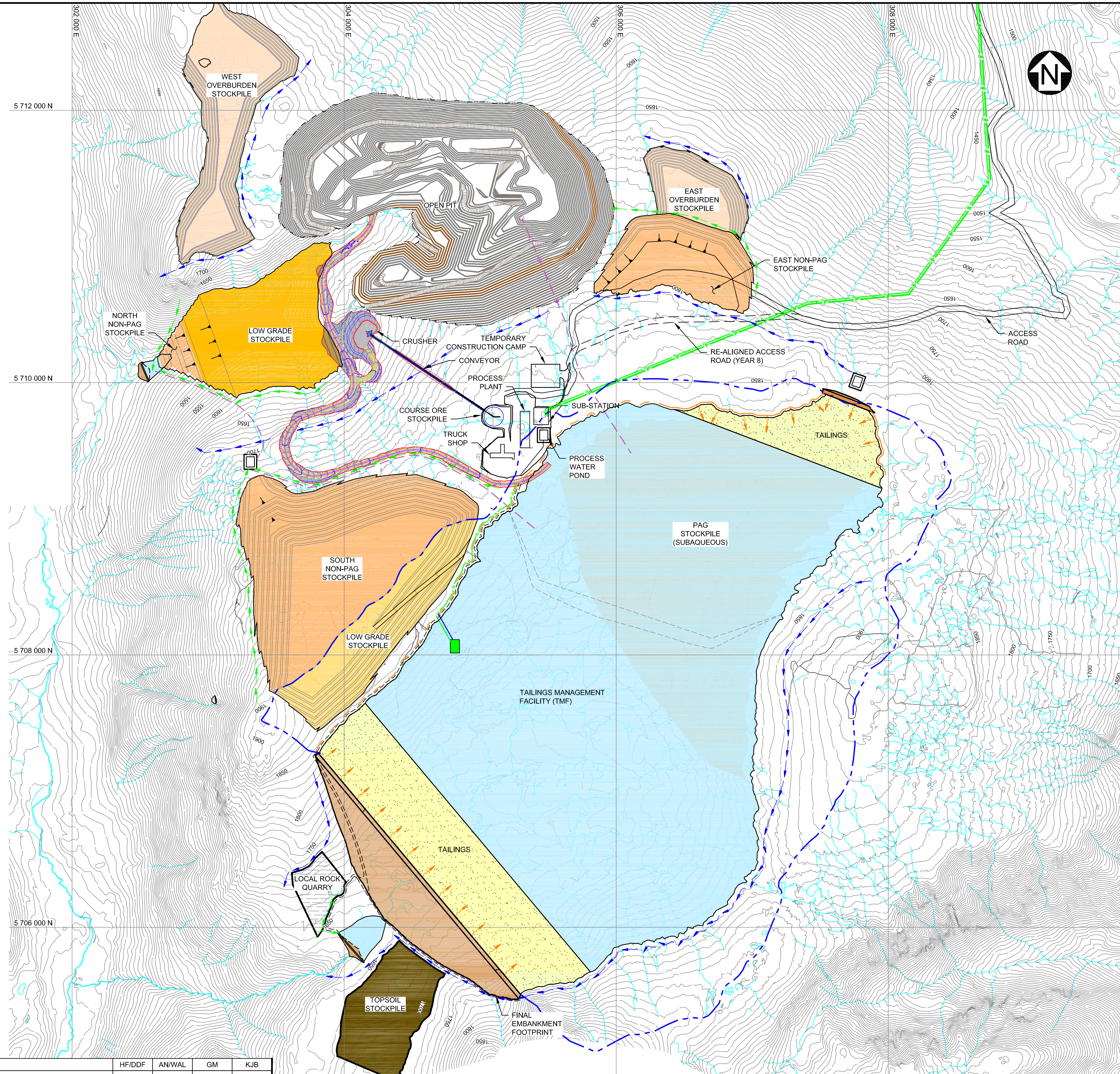
Knight Piésold CONSULTING

P/A NO. VA101-458/4

REF. NO. 5

FIGURE 4.4

REV A



LEGEND:

- SUPERNATANT POND
- TAILINGS BEACH
- TMF EMBANKMENT
- TOPSOIL STOCKPILE
- ROCK QUARRY
- LOW GRADE STOCKPILE
- LOW GRADE STOCKPILE
- NON-PAG STOCKPILE
- OVERBURDEN STOCKPILE
- NATURAL CATCHMENTS BOUNDARY
- RECLAIM BARGE
- RECLAIM PIPELINE
- BULK TAILINGS PIPELINE
- CLEANER TAILINGS PIPELINE
- WATER MANAGEMENT PIPELINES
- 138 kV TRANSMISSION LINE
- CONTACT WATER
- NON-CONTACT WATER

NOTES:

1. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A 300 150 0 500 1000 1500 m

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

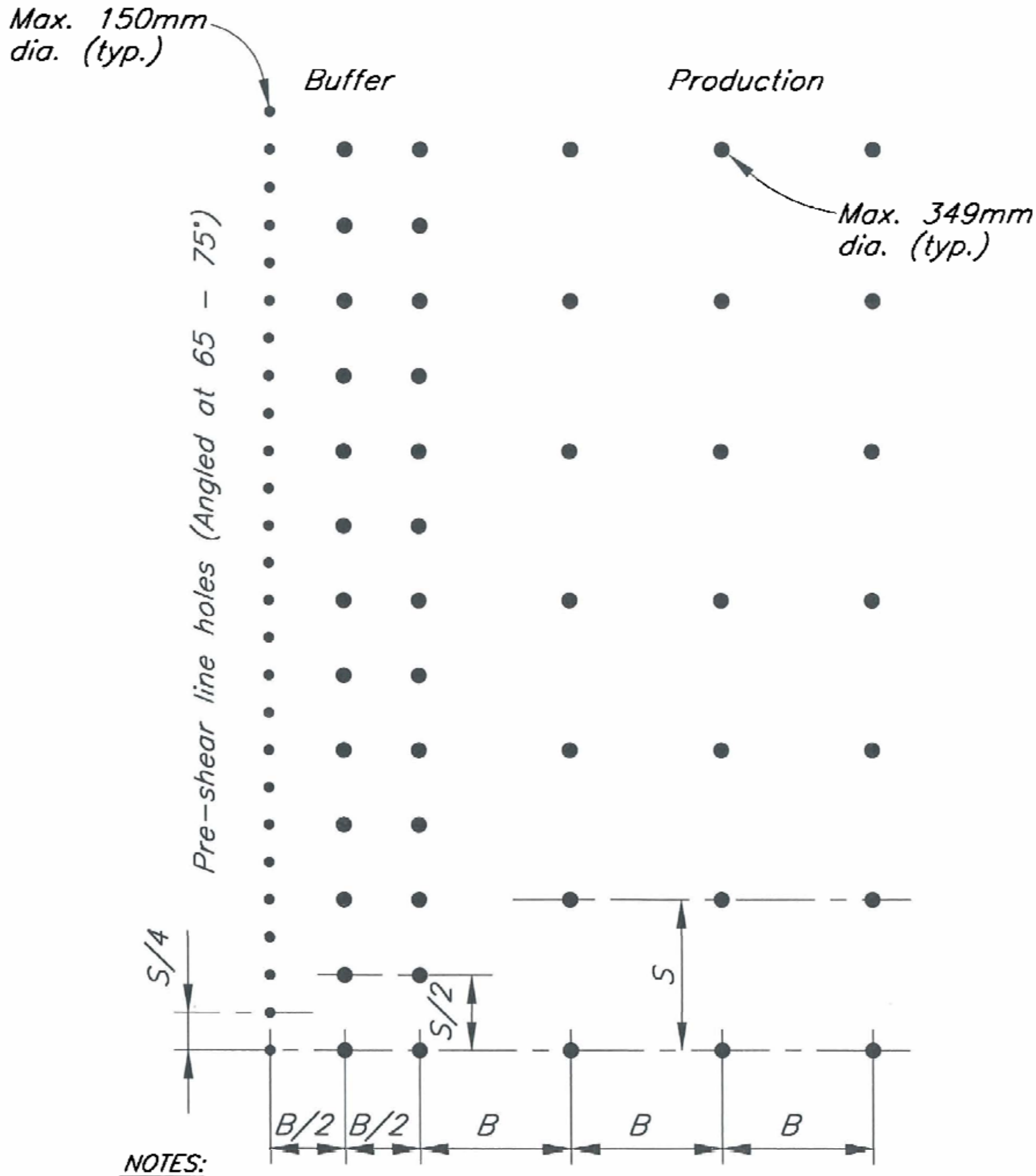
2012 OPEN PIT GEOTECHNICAL DESIGN GENERAL ARRANGEMENT WITH PIT DEWATERING SYSTEM

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/4	5

FIGURE 5.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	26APR'12	ISSUED WITH REPORT	HF/DDF	AN/WAL	GM	KJB



NOTES:

- B = 9.0m above gypsum line, B = 8.50m below gypsum line.
- S = 11.25m above gypsum line, S = 10.75m below gypsum line.
- Trial 1, Blast line holes as preshear line (first) – 6 holes/delay
- Trial 2, Blast line holes as cushion line (last) – 6 holes/delay
- Adjust kg. of explosive per hole in buffer and line holes based on results
- Test and adjust blast pattern at working faces for use at final faces

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
A	26APR'12	ISSUED WITH REPORT	HS	WAL	GM	KJB

YELLOWHEAD MINING INC.

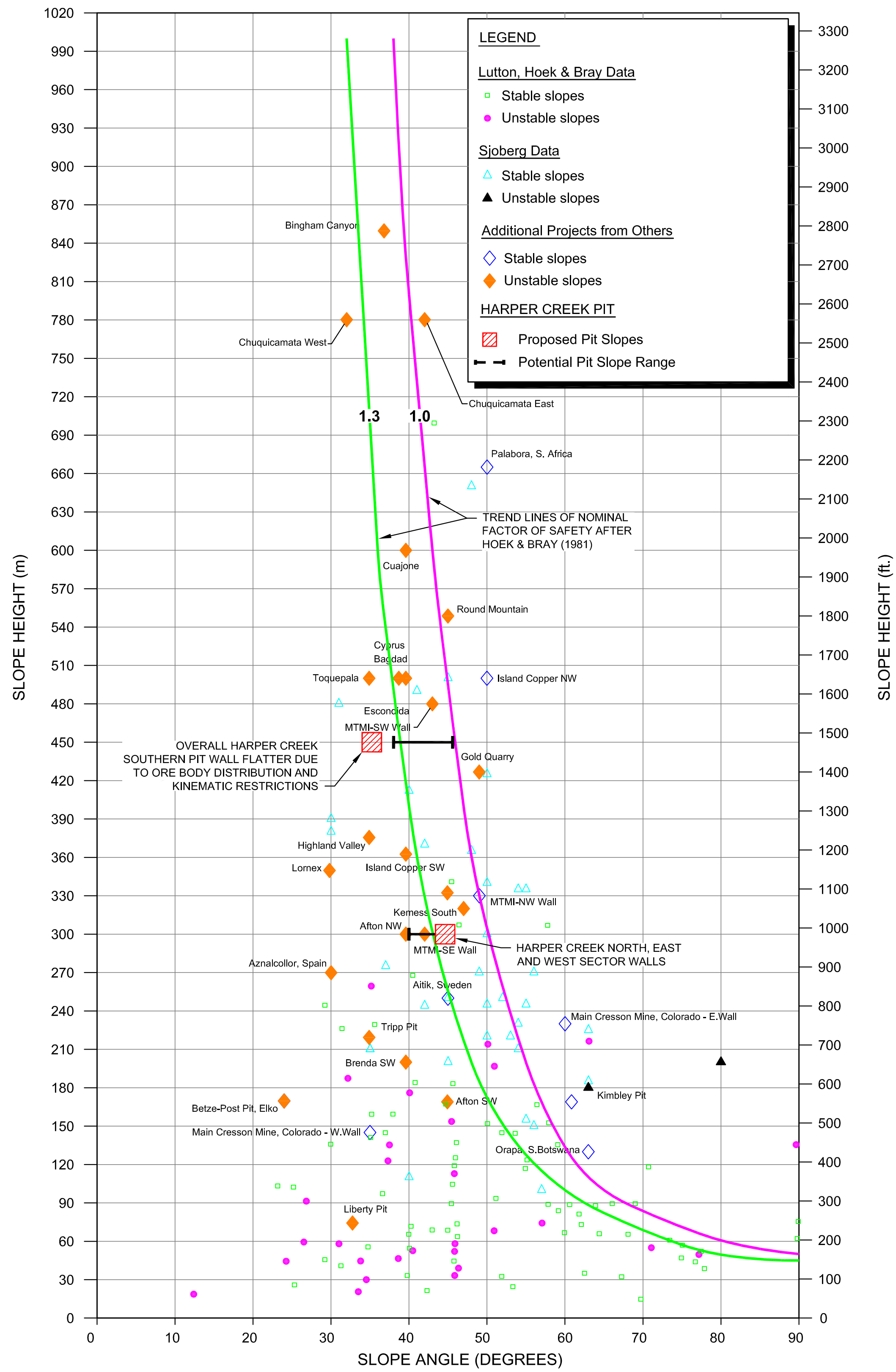
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
TYPICAL BLAST PATTERN FOR FINAL WALLS

Knight Piésold CONSULTING

P/A NO. 101-458/4 | REF NO. 5

FIGURE 6.1 | REV 0



NOTES:

1. ORIGINAL DATA POINTS AFTER LUTTON 1970, HOEK AND BRAY 1981, AND SJOBERG 1996
2. ADDITIONAL DATA FROM KNIGHT PIESOLD PROJECTS AND OTHERS.

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN SLOPE HEIGHT VERSUS SLOPE ANGLE PRECEDENT FOR HARD ROCK SLOPES

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF NO. 5

FIGURE 6.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	26APR'12	ISSUED WITH REPORT	GM	NSD	DAY	KJB

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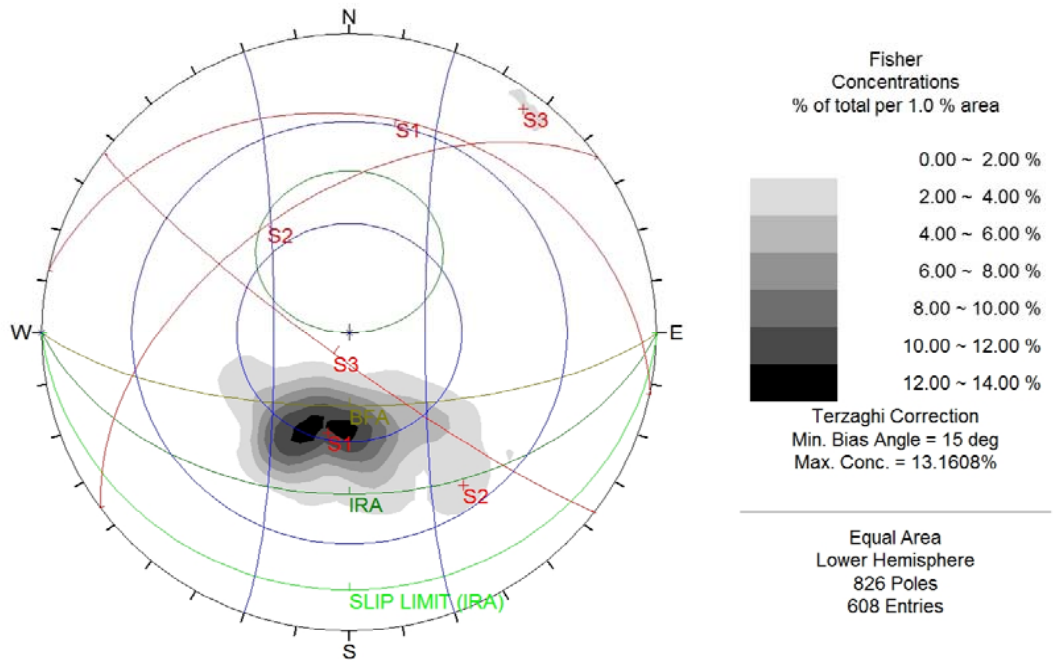
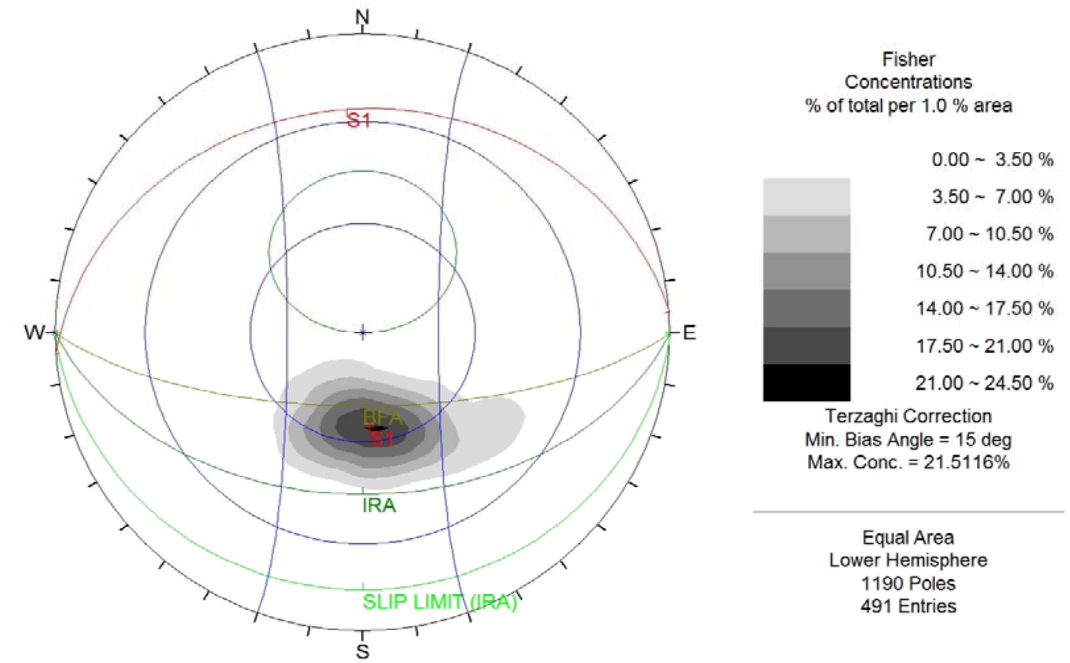
CONSULTING

APPENDIX A

KINEMATIC STABILITY ANALYSIS RESULTS

(Pages A-1 to A-14)





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	28 / 012	13.2	109
J2	53 / 324	3.0	25
J3	83 / 217	2.0	17

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	34 / 350	28.8	141

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM03, HC11-GM04 AND HC11-GM05.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.
4. NORTHWEST AND NORTHEAST SECTORS SHARE 180° DIP DIRECTION.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
NORTHEAST/NORTHWEST SECTOR - 180° WALL ORIENTATION

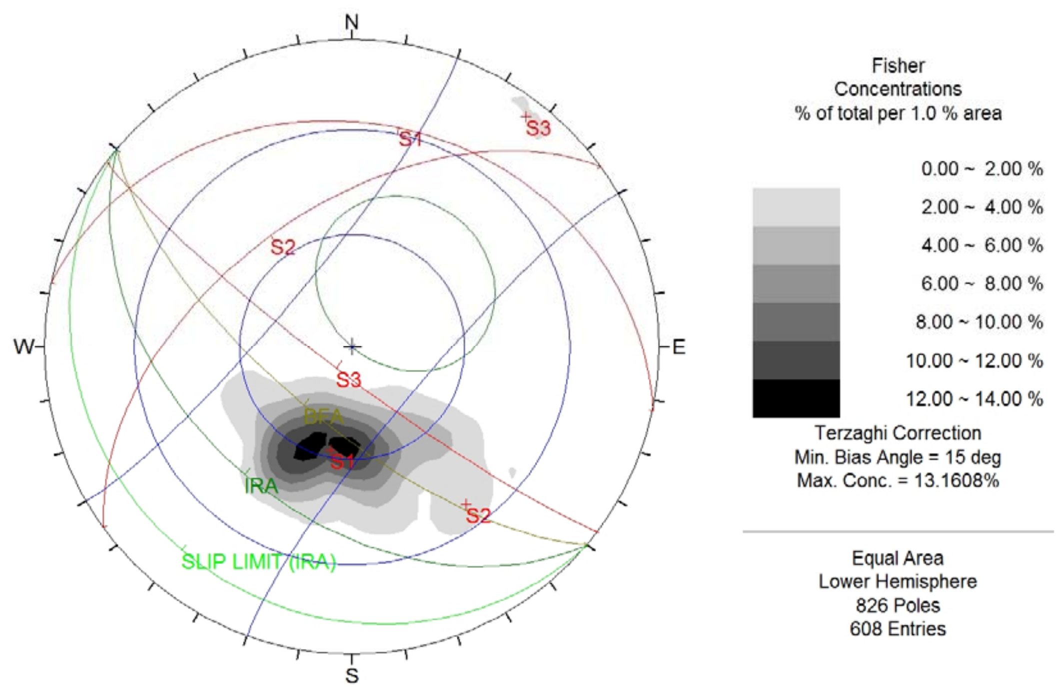
Knight Piésold CONSULTING

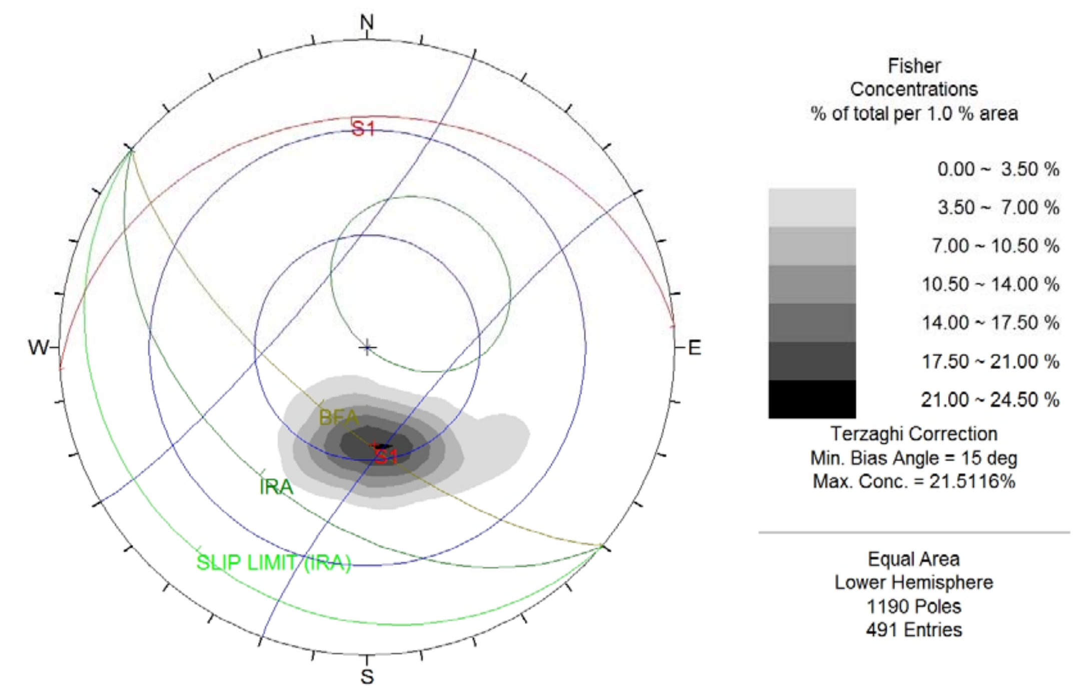
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A1

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	28 / 012	13.2	109
J2	53 / 324	3.0	25
J3	83 / 217	2.0	17

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	26 / 356	21.5	256

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM03, HC11-GM04 AND HC11-GM05.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
NORTHEAST SECTOR - 220° WALL ORIENTATION

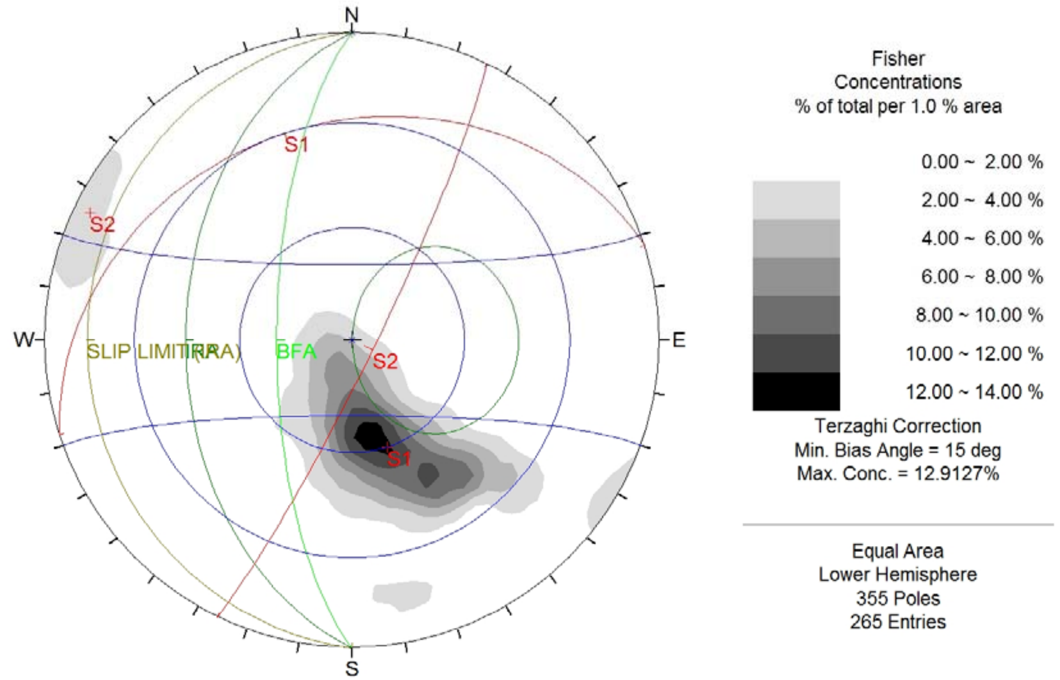
Knight Piésold CONSULTING

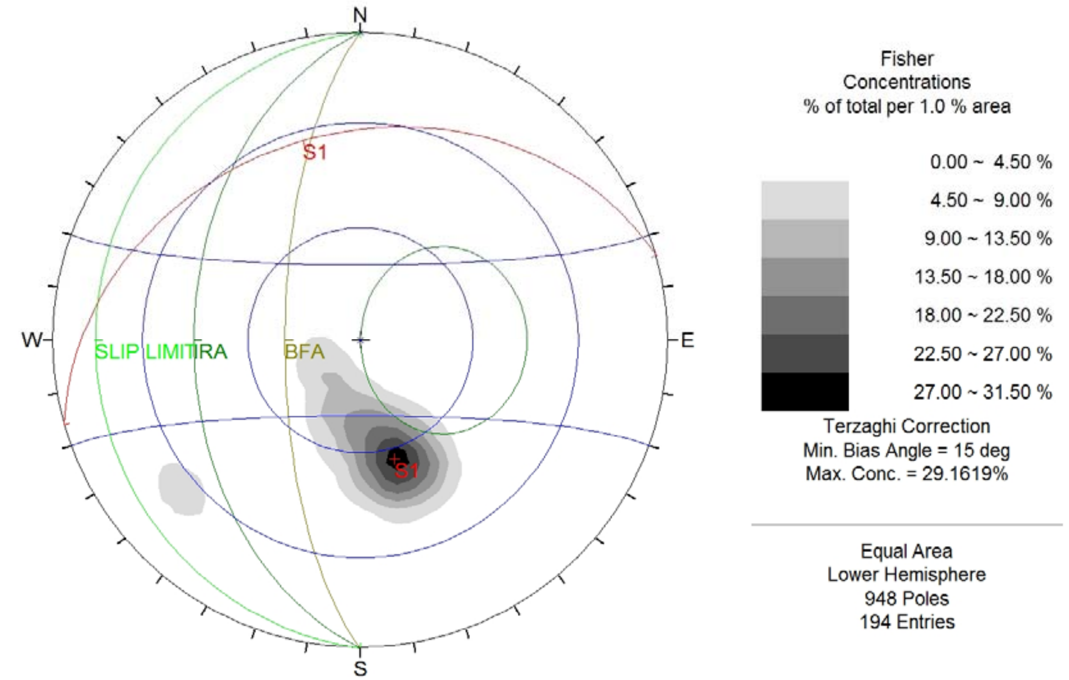
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A2

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	34 / 338	12.9	46
J2	86 / 115	3.0	11

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	33 / 344	29.2	277

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM06.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

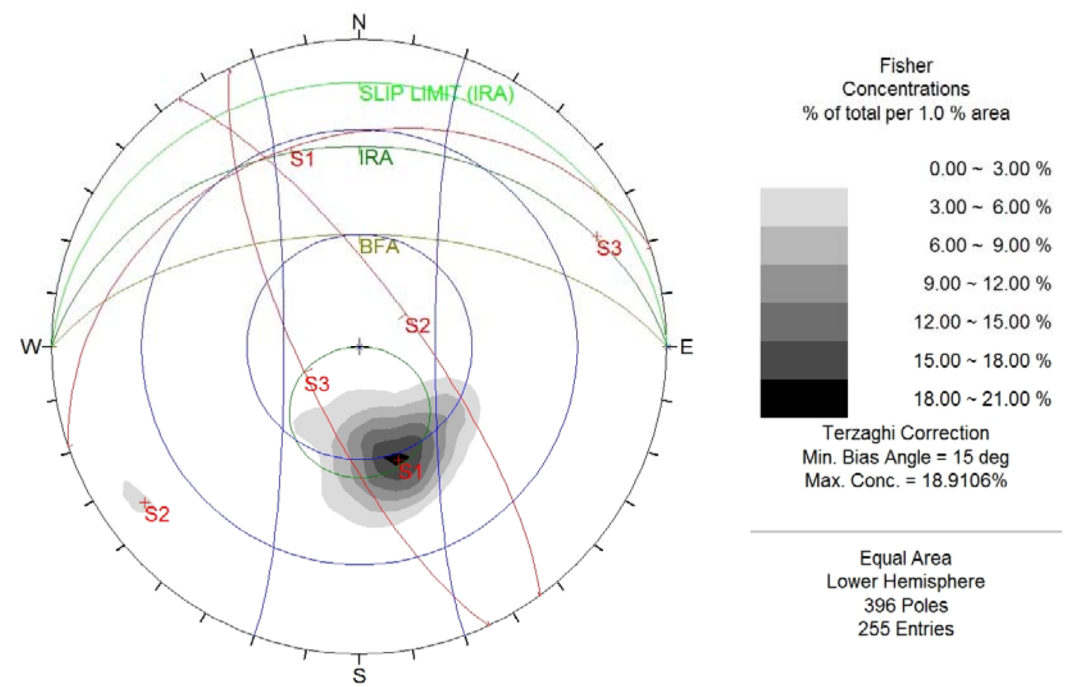
HARPER CREEK PROJECT

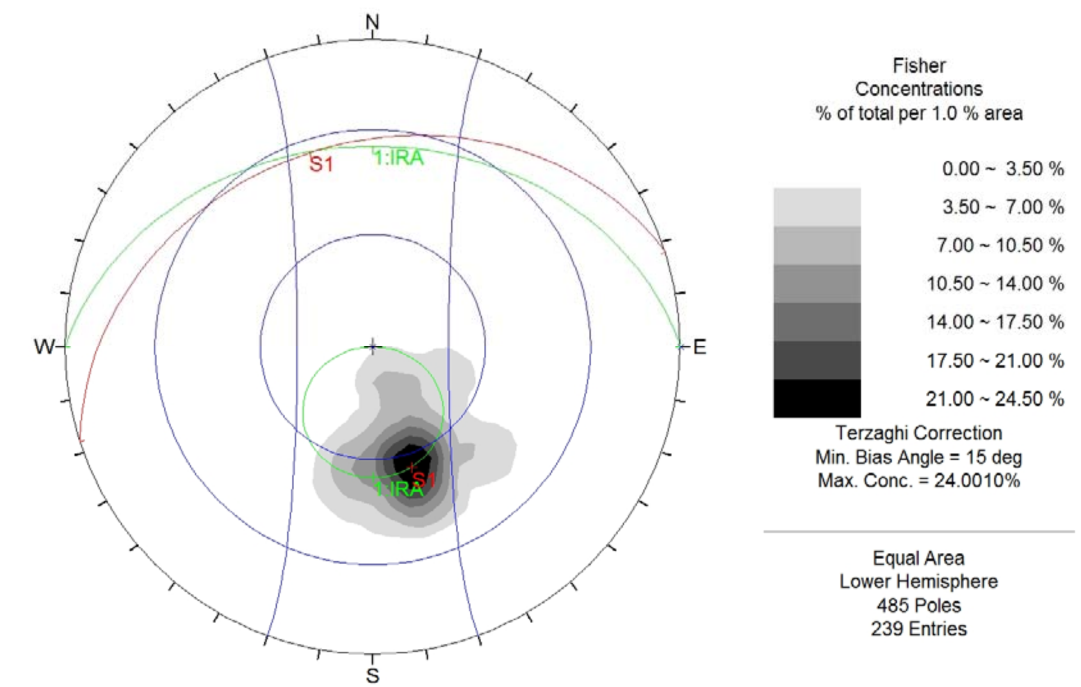
2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
EAST SECTOR - 270° WALL ORIENTATION

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF. NO. 5

FIGURE A3 REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	32 / 341	18.9	75
J2	75 / 053	3.0	12
J3	74 / 245	1.0	3

PLANAR	WEDGE	TOPPLE
J1	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	34 / 342	24.0	116

PLANAR	WEDGE	TOPPLE
S1	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM01A AND HC11-GM07.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

YELLOWHEAD MINING INC.

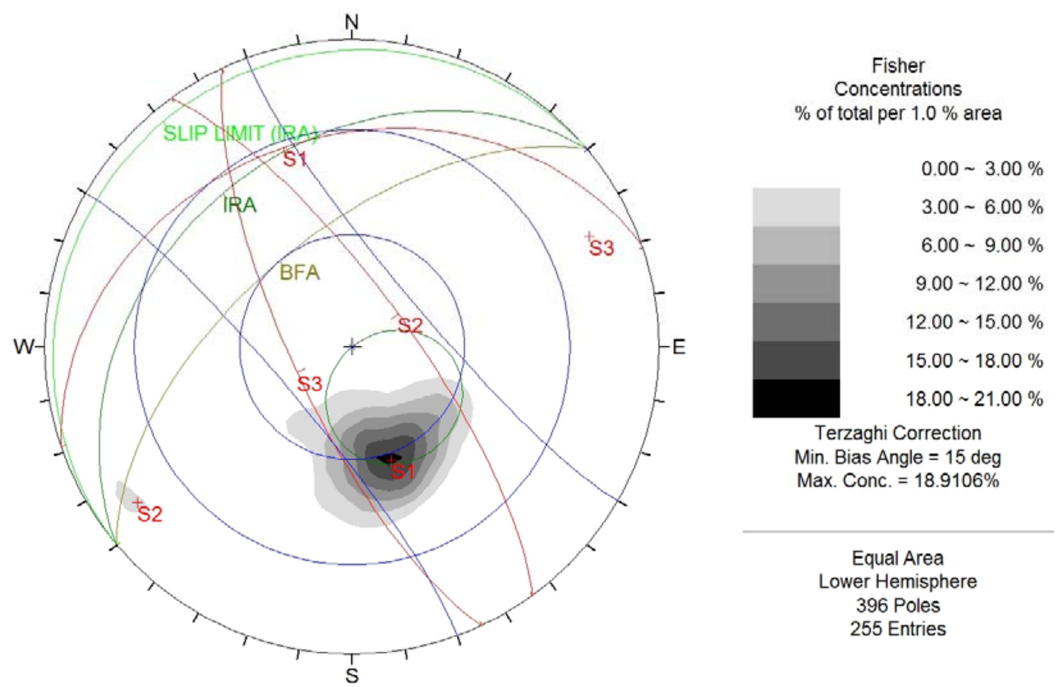
HARPER CREEK PROJECT

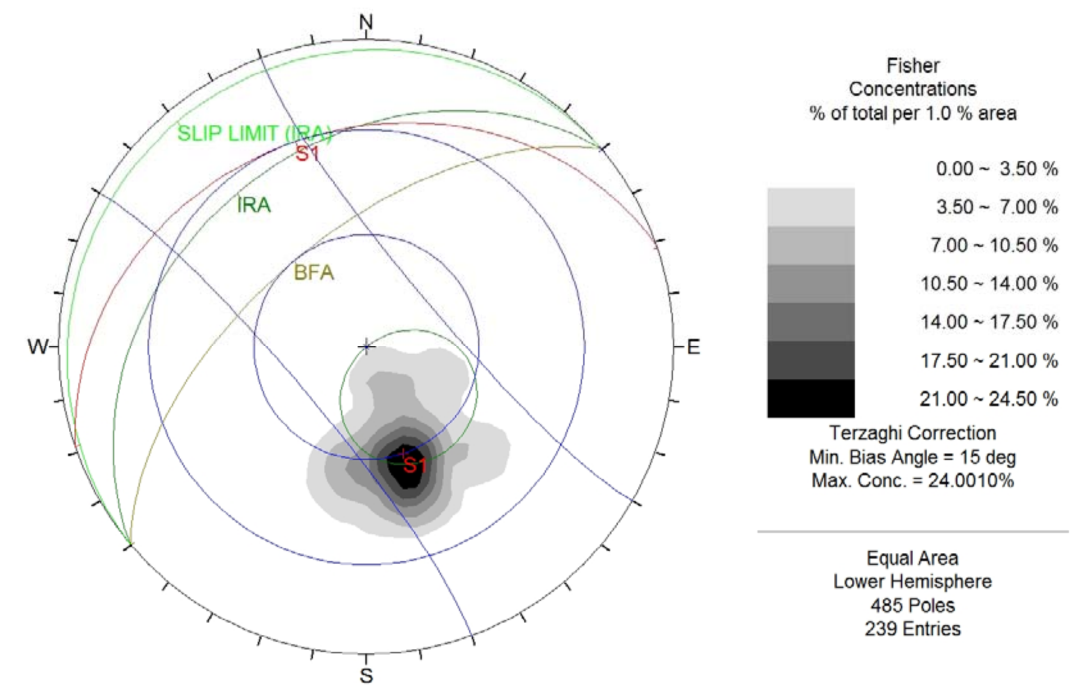
2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
SOUTH SECTOR - 000° WALL ORIENTATION

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF. NO. 5

FIGURE A4 | REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	32 / 341	18.9	75
J2	75 / 054	3.0	12
J3	74 / 245	1.0	3

PLANAR	WEDGE	TOPPLE
J1 (IRA)	J1/J2 (IRA)	None
J1/J2 (BFA)	J1/J3 (IRA)	
J1/J3 (BFA)		

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	34 / 342	24.0	116

PLANAR	WEDGE	TOPPLE
S1 (IRA)	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM01A AND HC11-GM07.
2. IRA = INTER-RAMP ANGLE, BFA = BENCH FACE ANGLE.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

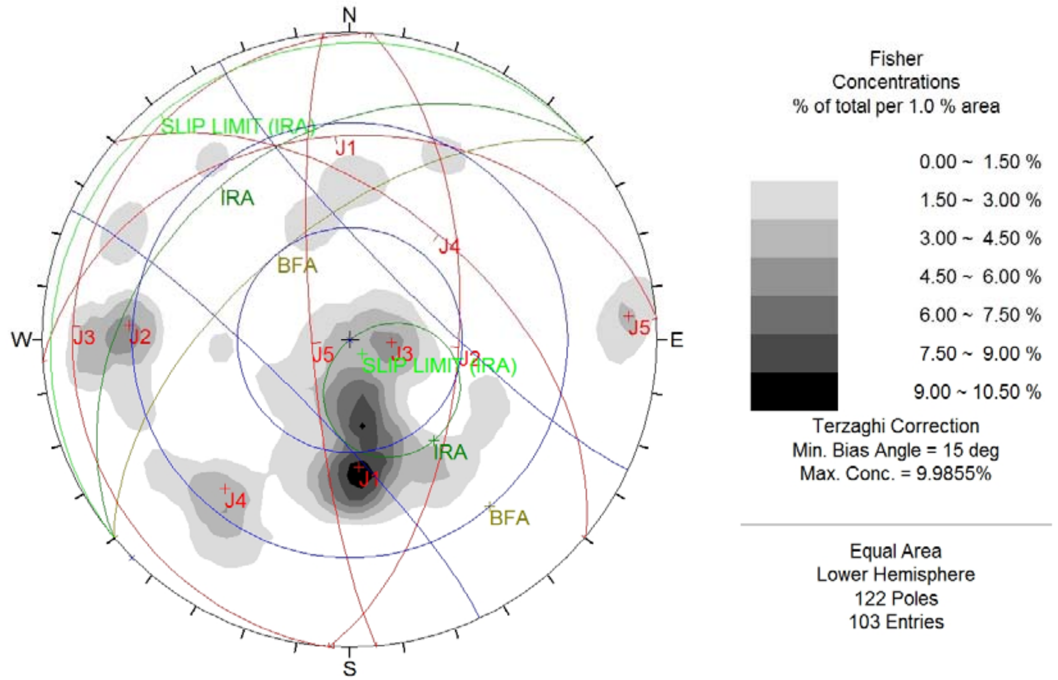
HARPER CREEK PROJECT

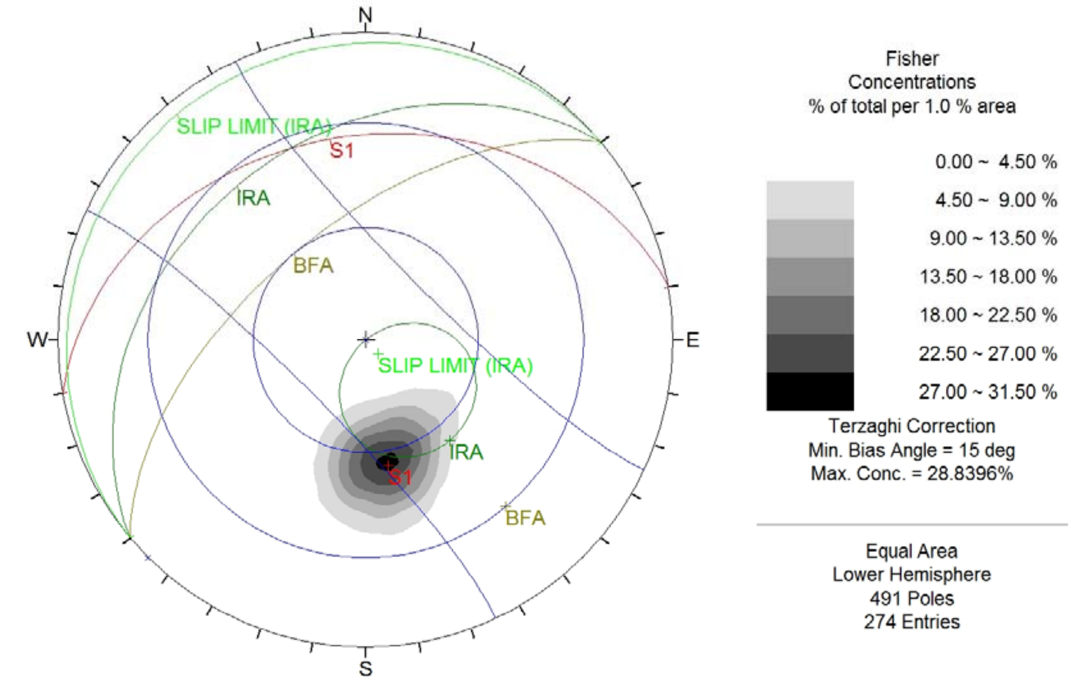
2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
SOUTH SECTOR - 320° WALL ORIENTATION

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF. NO. 5

FIGURE A5 REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	34 / 356	10.0	12
J2	61 / 094	5.0	6
J3	11 / 273	5.0	6
J4	53 / 040	3.5	4
J5	80 / 265	3.5	4

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	34 / 350	28.8	141

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM02.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

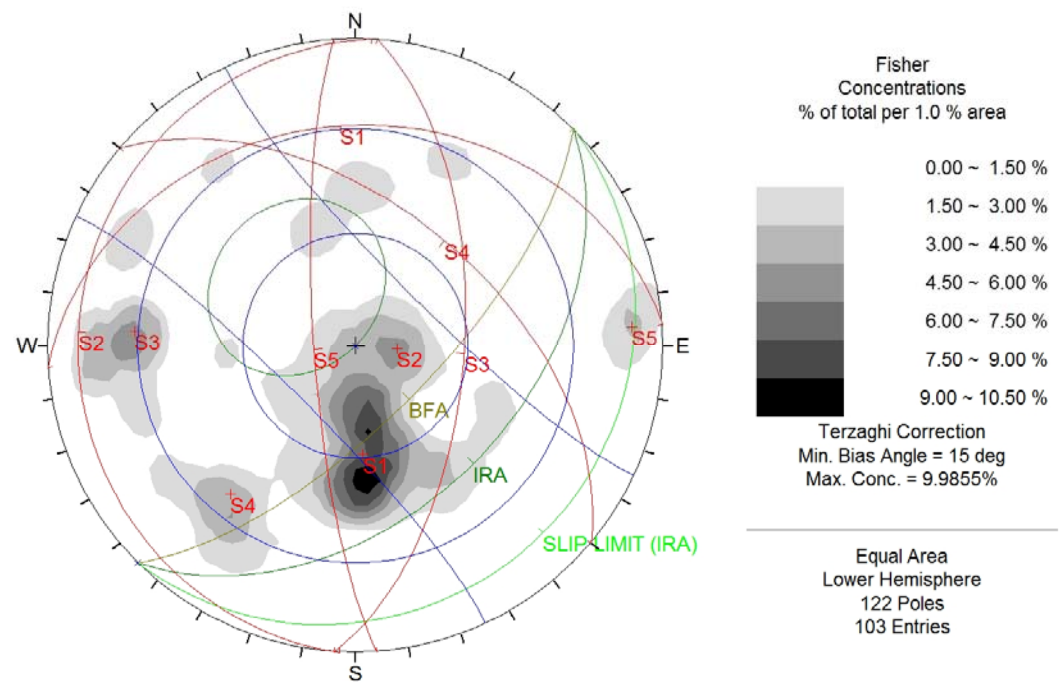
HARPER CREEK PROJECT

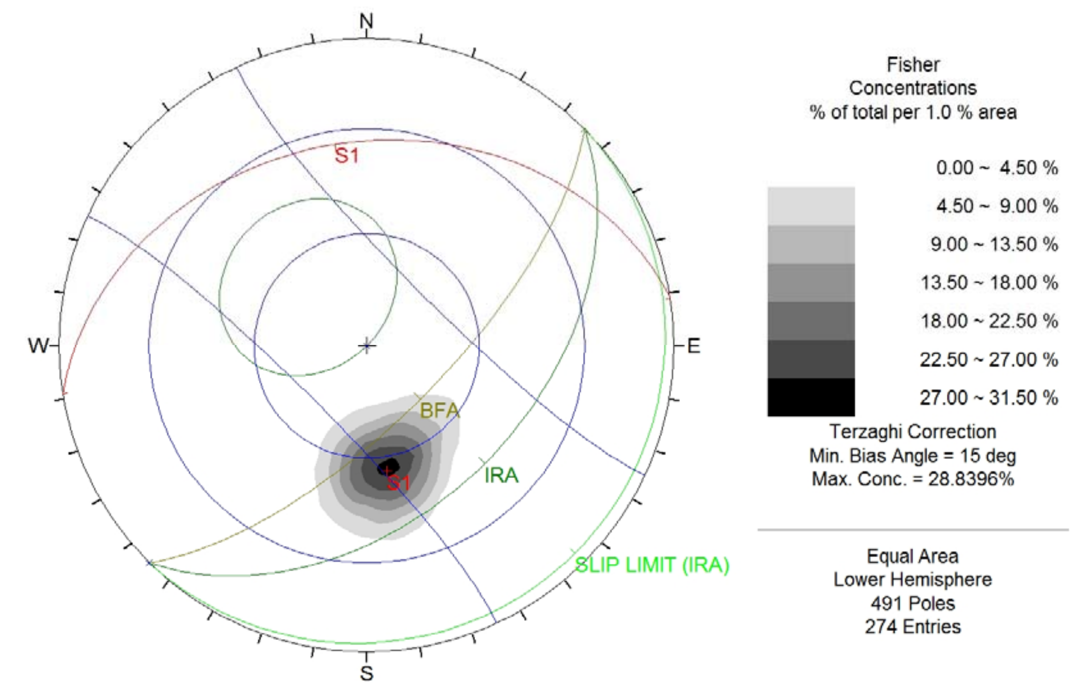
2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
SOUTHWEST SECTOR - 320° WALL ORIENTATION

Knight Piésold CONSULTING

P/A NO. VA101-458/4 | REF. NO. 5

FIGURE A6 | REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	34 / 356	10.0	12
J2	61 / 094	5.0	6
J3	11 / 273	5.0	6
J4	53 / 040	3.5	4
J5	80 / 265	3.5	4

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	34 / 350	28.8	141

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM02.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
WEST SECTOR - 135° WALL ORIENTATION

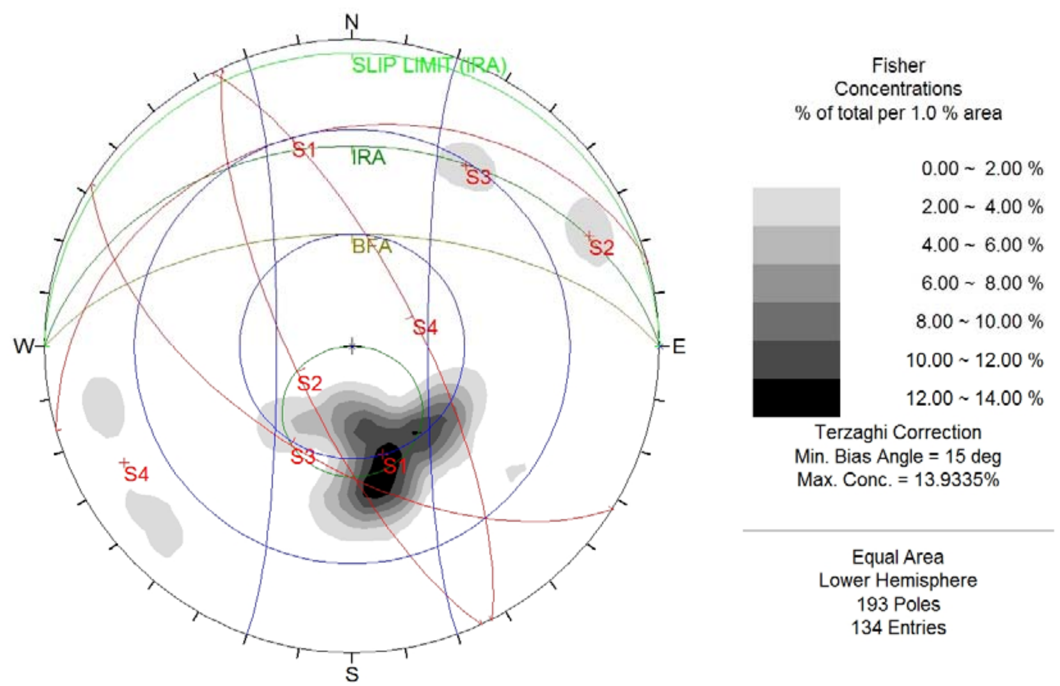
Knight Piésold CONSULTING

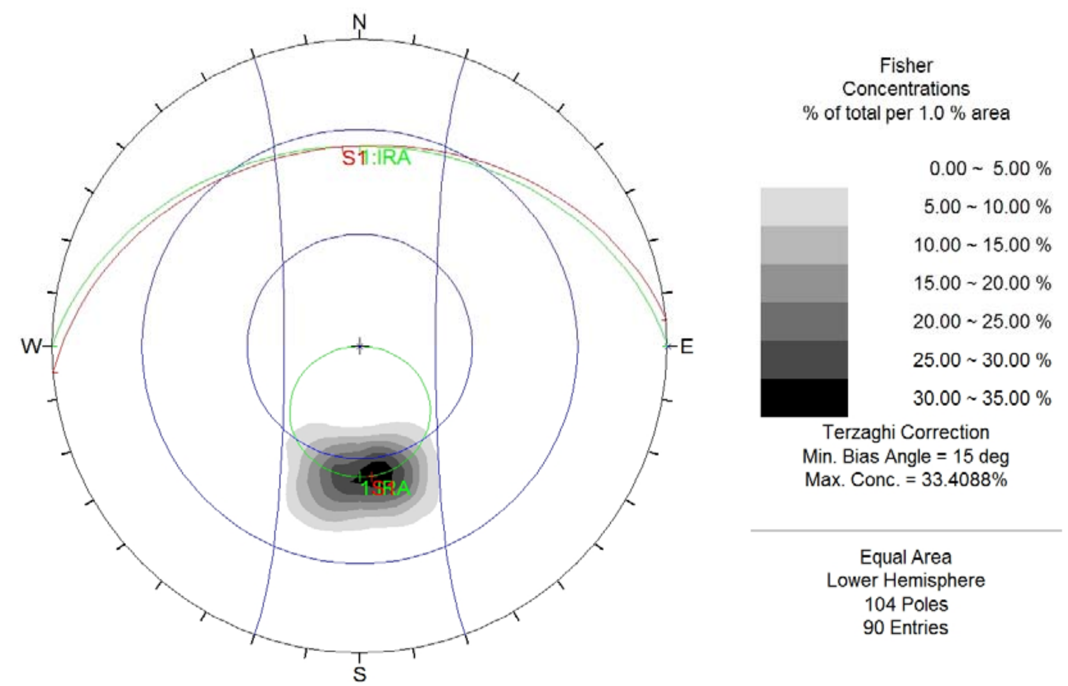
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A7

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	30 / 346	13.9	27
J2	74 / 245	3.0	6
J3	59 / 212	3.0	6
J4	72 / 063	2.0	4

PLANAR	WEDGE	TOPPLE
J1	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	35 / 355	33.4	35

PLANAR	WEDGE	TOPPLE
S1	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM01A.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICALDESIGN
INTER-RAMP KINEMATICS
HC11-GM01A - 000° WALL ORIENTATION

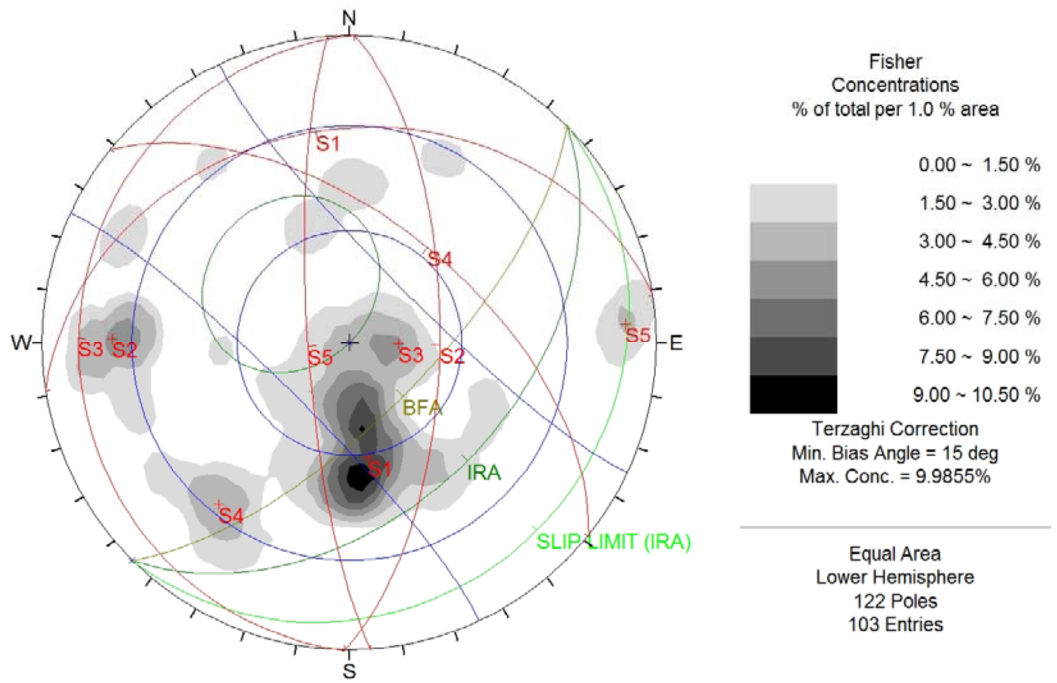
Knight Piésold CONSULTING

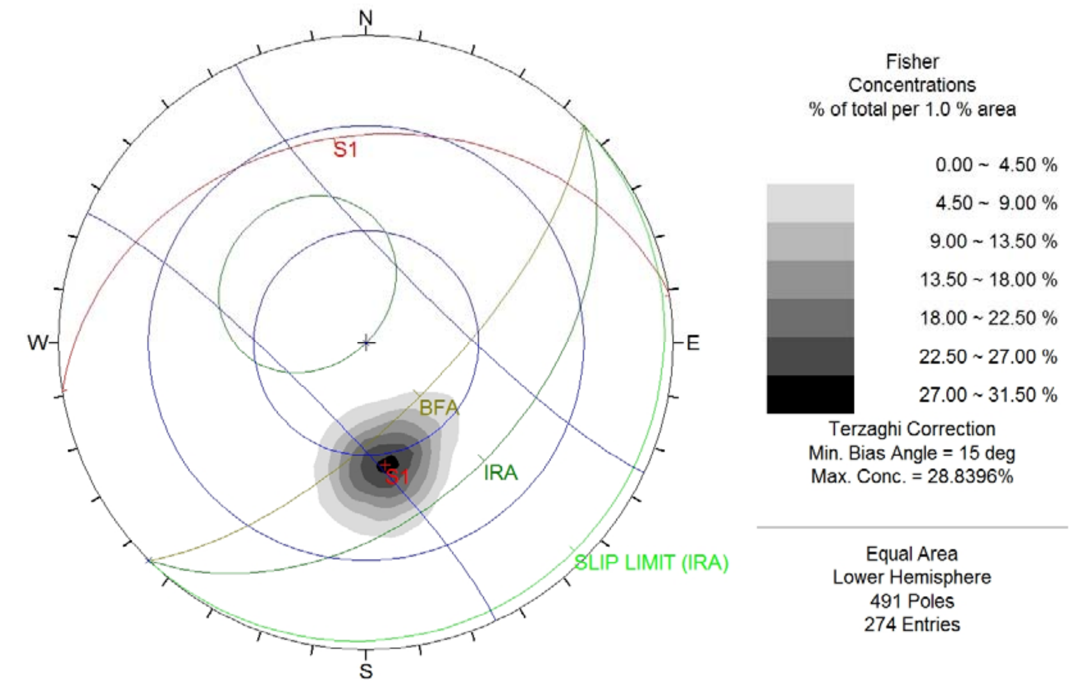
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A8

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	34 / 356	10.0	12
J2	61 / 094	5.0	6
J3	11 / 273	5.0	6
J4	53 / 040	3.5	4
J5	80 / 265	3.5	4

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	35 / 355	28.8	141

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM02.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
HC11-GM02 - 135° WALL ORIENTATION

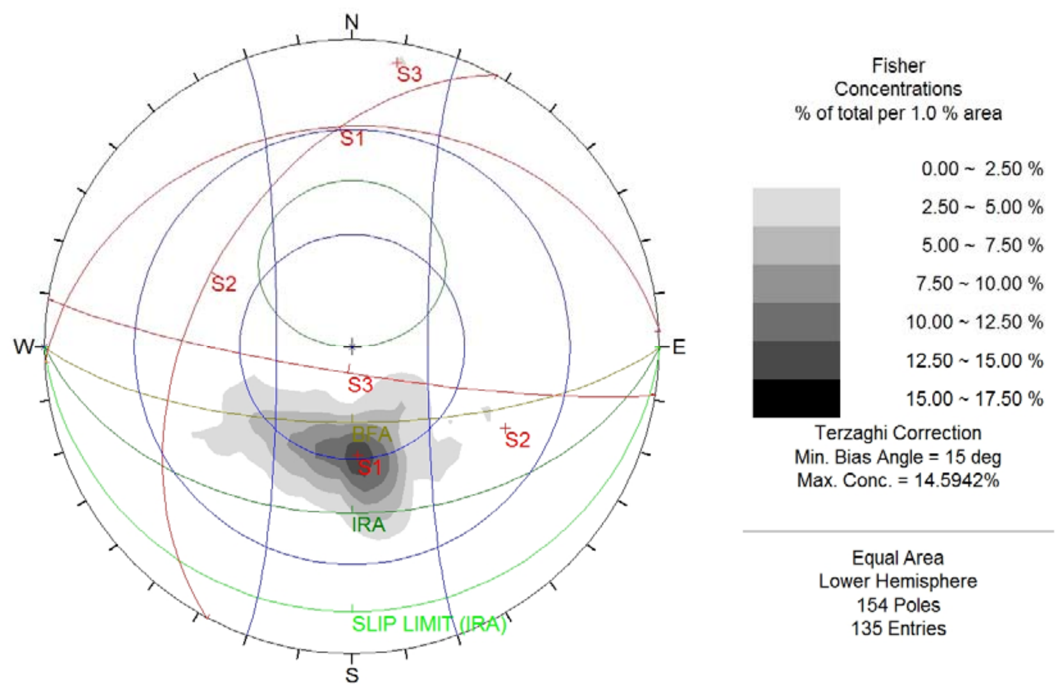
Knight Piésold CONSULTING

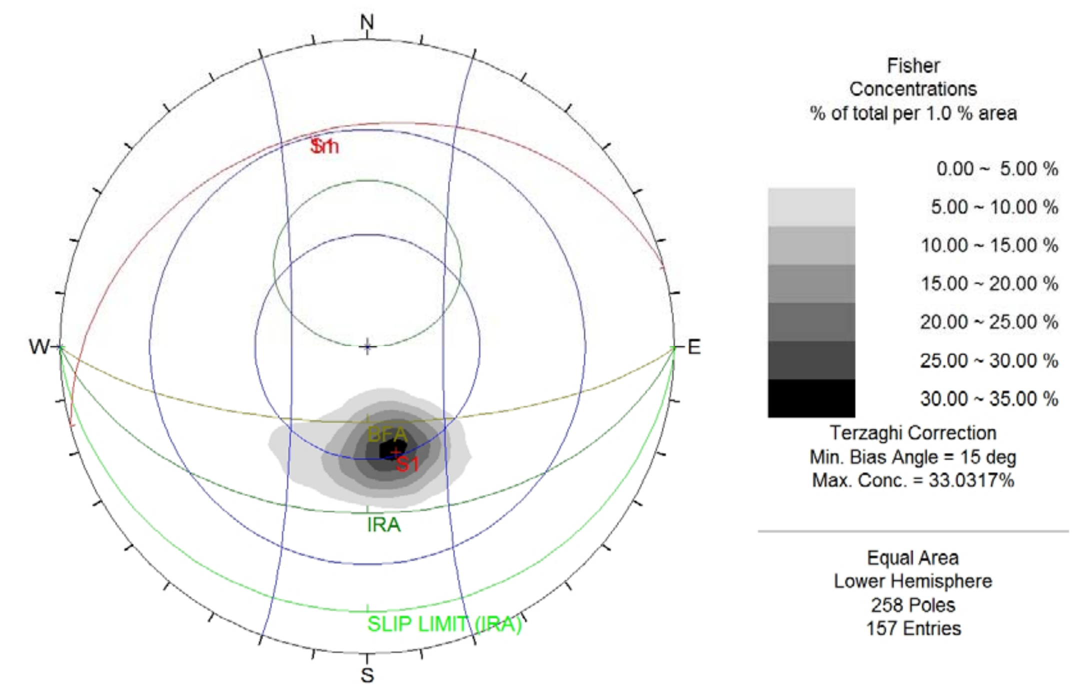
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A9

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	29 / 357	14.5	22
J2	44 / 297	2.5	4
J3	83 / 189	2.5	4

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	29 / 345	33.0	85

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM03.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
HC11-GM03 - 180° WALL ORIENTATION

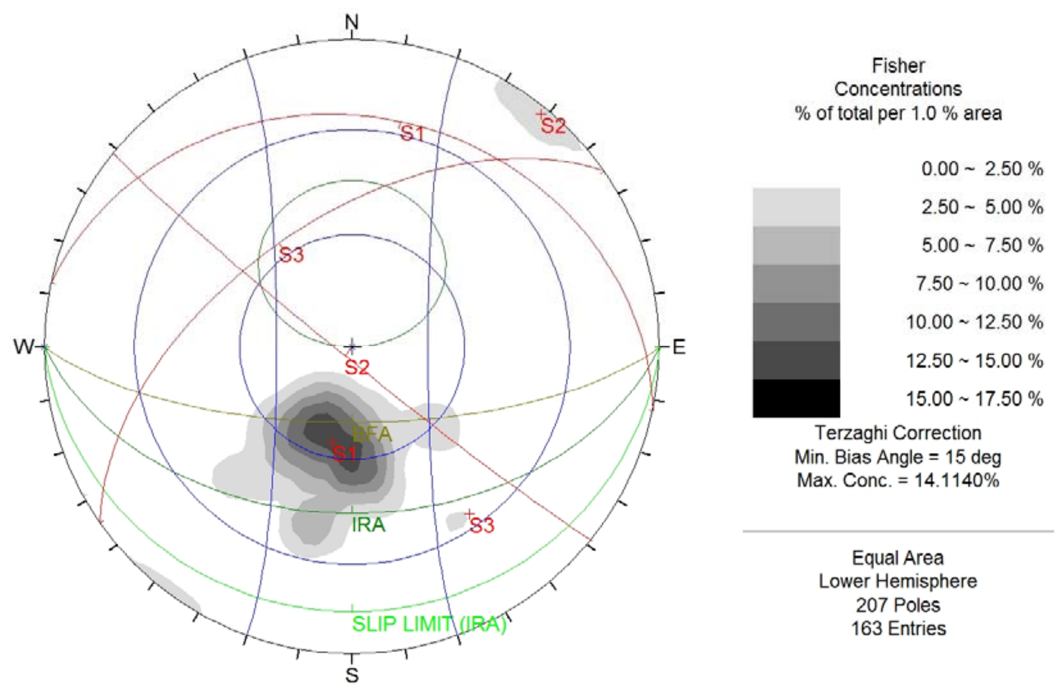
Knight Piésold CONSULTING

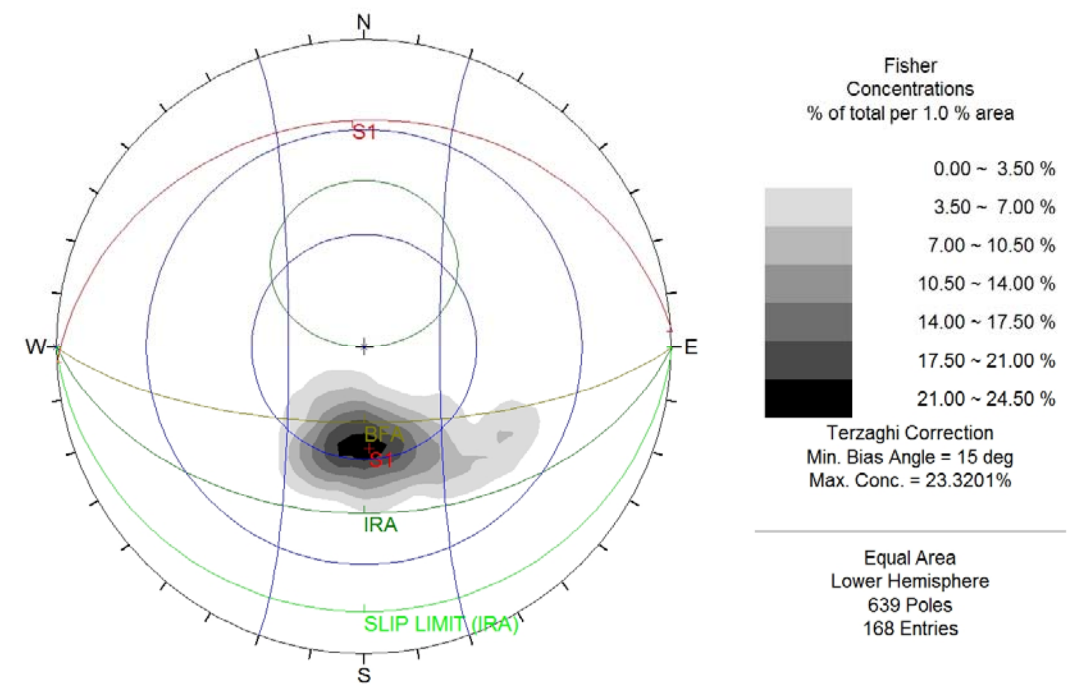
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A10

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	26 / 012	14.1	29
J2	87 / 219	4.0	8
J3	55 / 323	2.5	5

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	26 / 359	23.3	149

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM04.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
HC11-GM04 - 180° WALL ORIENTATION

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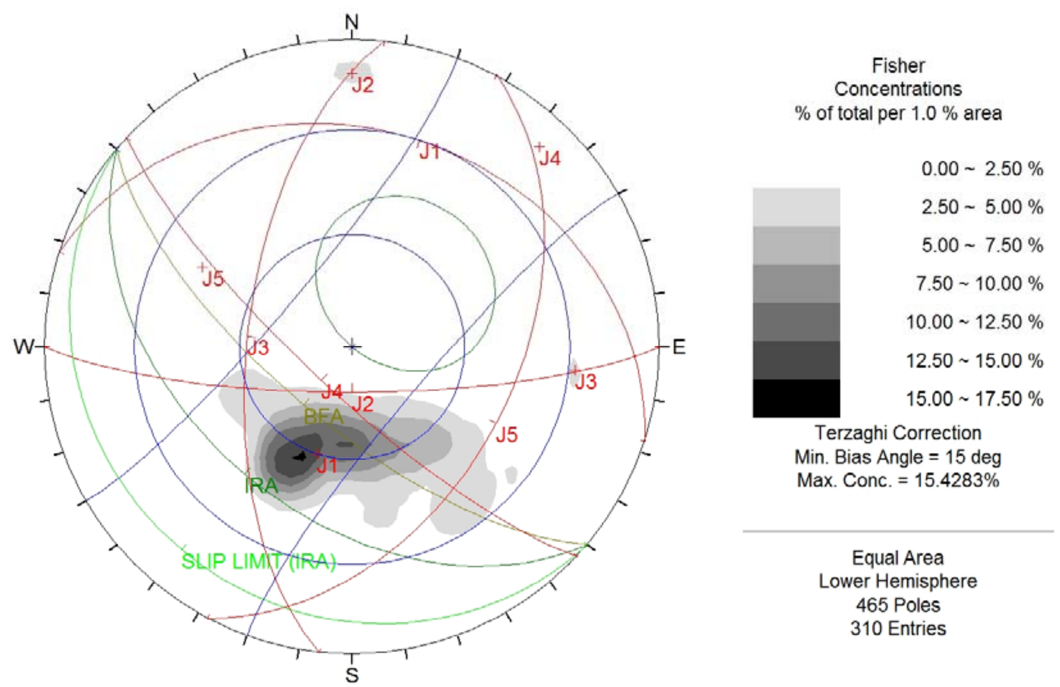
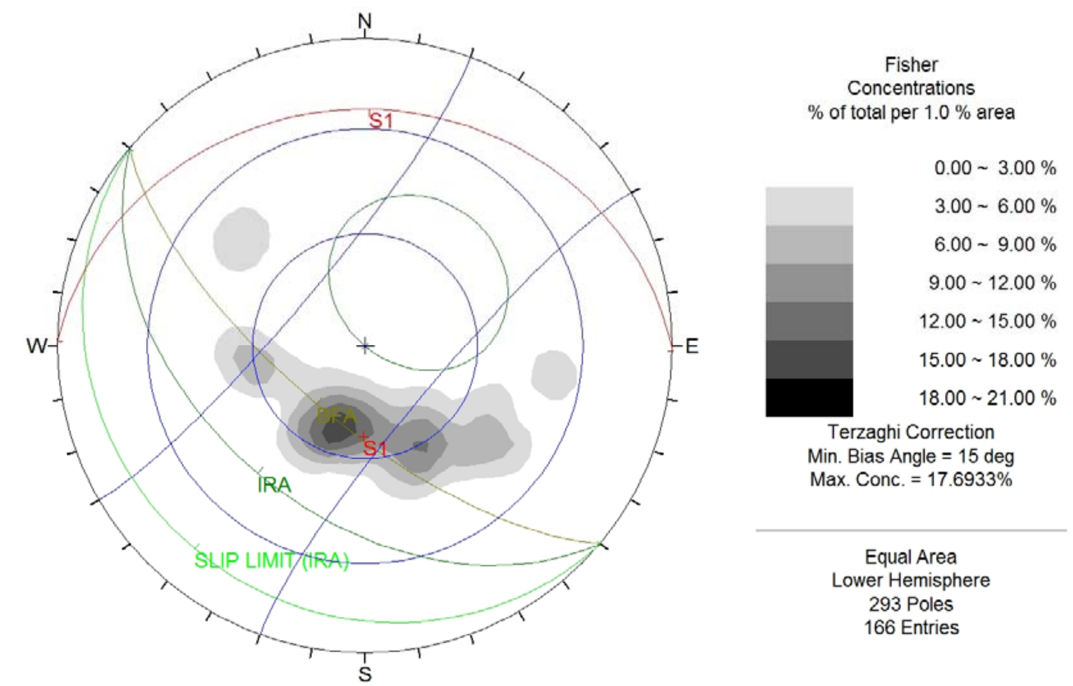
P/A NO.	REF. NO.
VA101-458/4	5

FIGURE A11 REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	28 / 016	15.4	29
J2	78 / 180	2.0	9
J3	62 / 276	2.0	9
J4	78 / 223	2.0	9
J5	46 / 118	2.0	9

PLANAR	WEDGE	TOPPLE
None	J2/J3 (Bench)	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	20 / 002	17.7	52

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM04.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
HC11-GM04 - 220° WALL ORIENTATION

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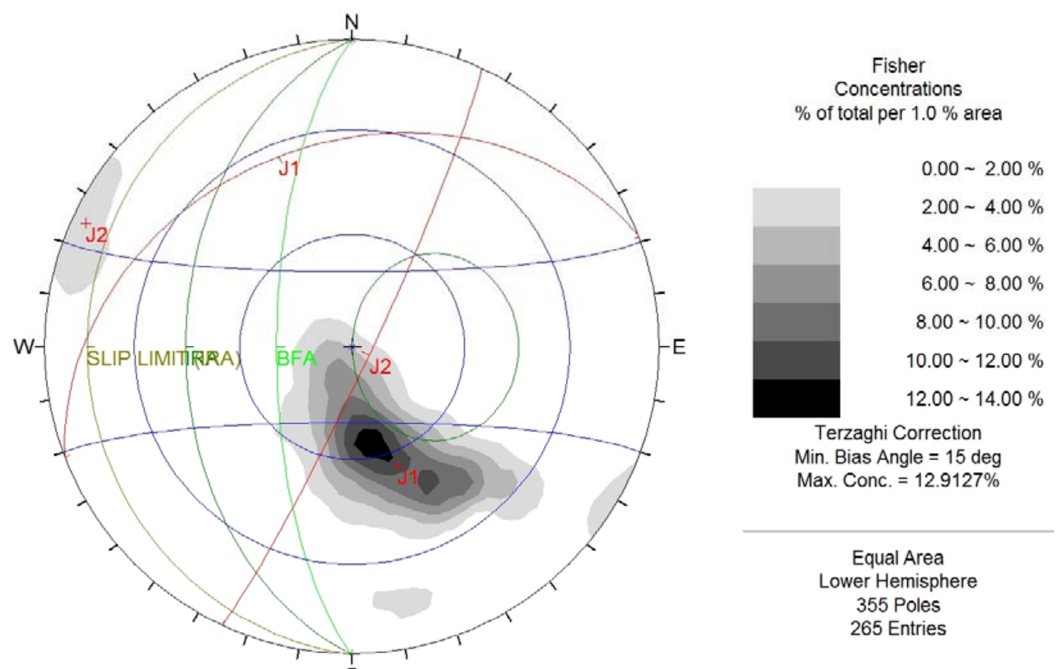
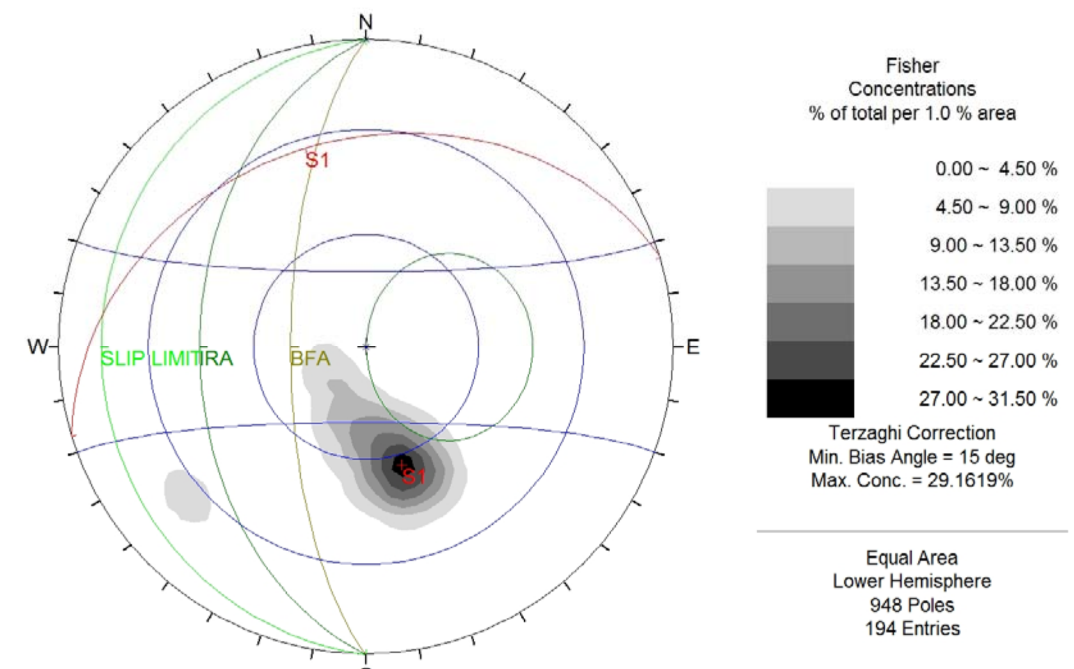
P/A NO. VA101-458/4

REF. NO. 5

FIGURE A12

REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	34 / 338	12.9	46
J2	86 / 115	3.0	11

PLANAR	WEDGE	TOPPLE
None	None	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	33 / 344	29.2	276

PLANAR	WEDGE	TOPPLE
None	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM06.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
HC11-GM02 - 270° WALL ORIENTATION

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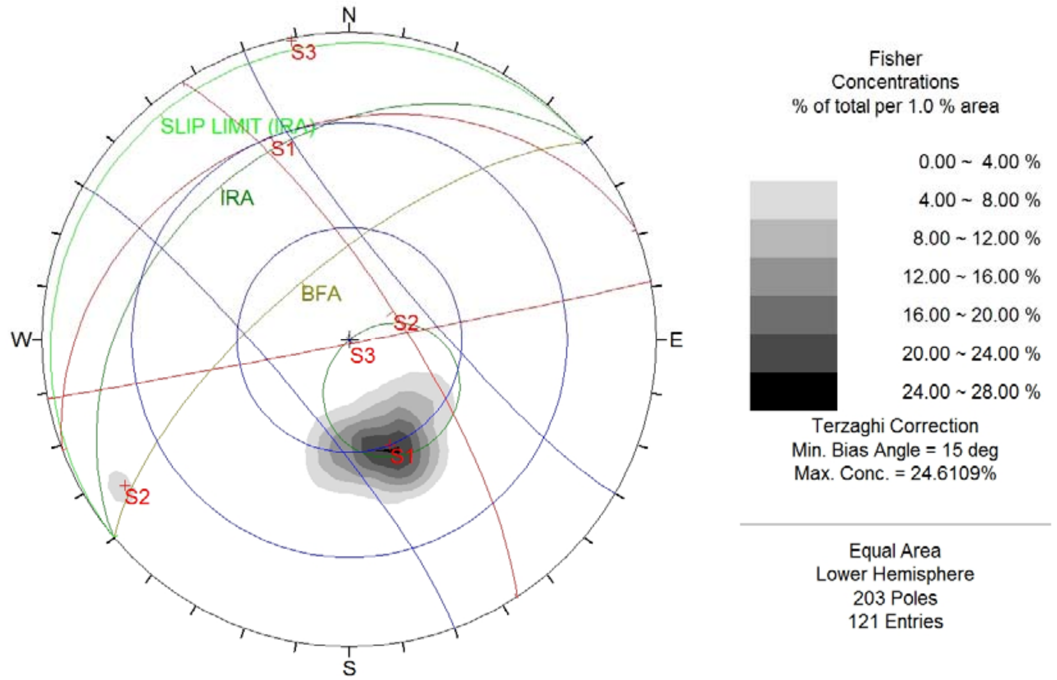
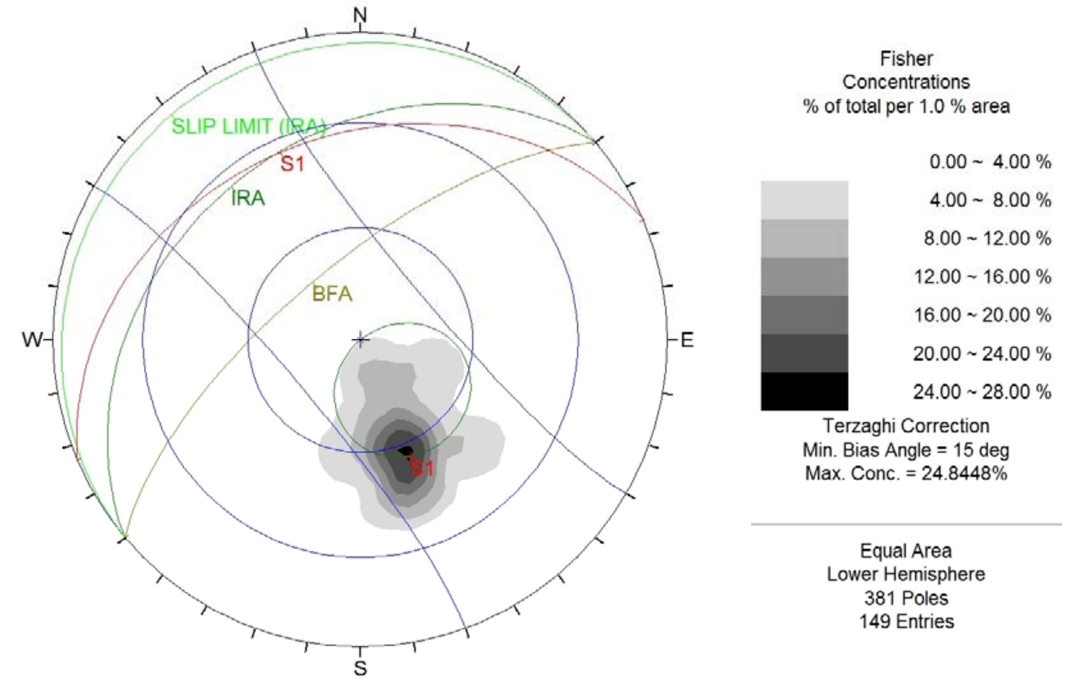
P/A NO.	REF. NO.
VA101-458/4	5

FIGURE A13 REV 0





JOINTS

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
J1	30 / 339	24.6	50
J2	75 / 057	4.0	8
J3	89 / 169	2.0	4

PLANAR	WEDGE	TOPPLE
J1	J1(S1)/J2	None

FOLIATION

NAME	DIP / DIP DIRECTION	% Conc.	# POLES
S1	34 / 337	24.8	94

PLANAR	WEDGE	TOPPLE
S1	None	None

NOTES:
1. ORIENTED CORE DATA FROM HC11-GM07.
2. DIP / DIP DIRECTION IS REPRESENTED IN DEGREES.
3. "% CONC." AND "# POLES" REPRESENTS APPROXIMATE TERZAGHI WEIGHTED CONTOUR AND EQUIVALENT TERZAGHI NUMBER OF POLES DEFINING THE CONTOUR.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	31JAN'12	ISSUED WITH REPORT	GM	DAY	KJB

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
INTER-RAMP KINEMATICS
HC11-GM07 - 320° WALL ORIENTATION

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FIGURE A14 REV 0

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APPENDIX B

LIMIT EQUILIBRIUM STABILITY ANALYSIS RESULTS

(Pages B-1 to B-5)

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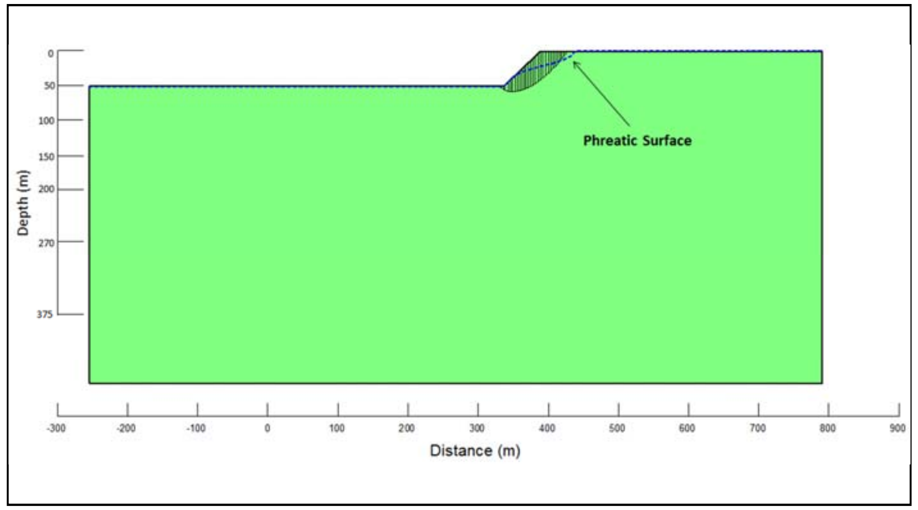
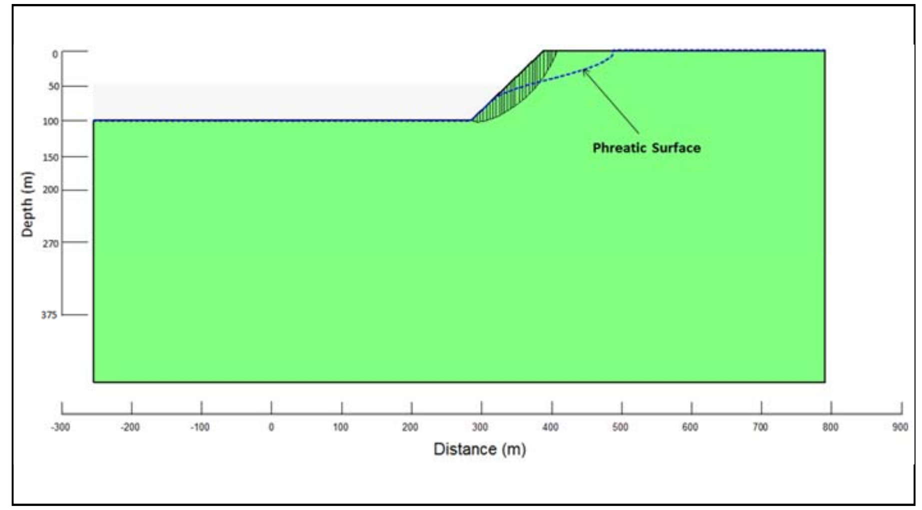


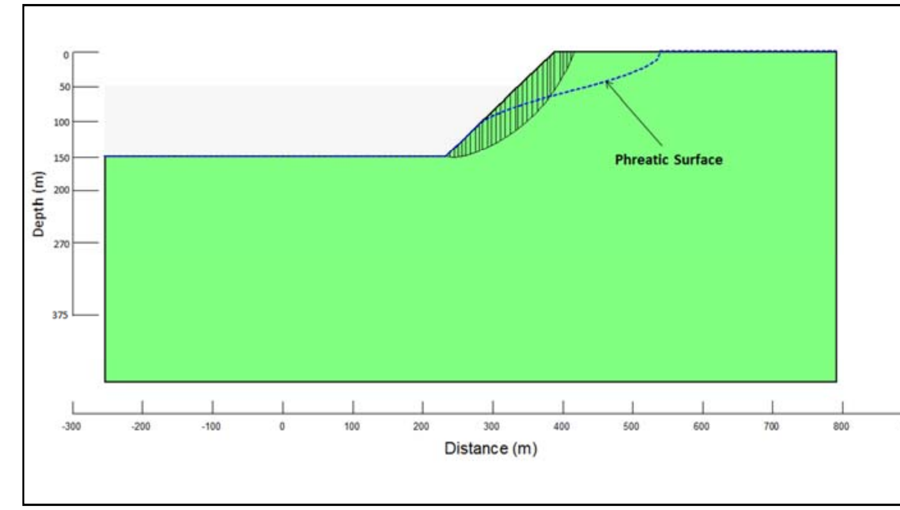
50 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	1.6	3.1	7.2
Depressurized FOS	2.2	3.9	8.0
Drawdown (m)	20V	20V	20V



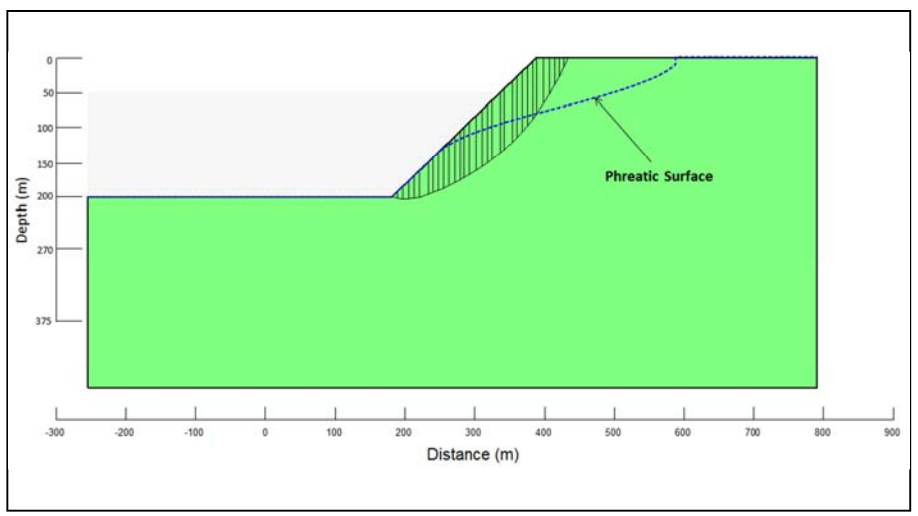
100 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	1.1	2.0	4.4
Depressurized FOS	1.6	2.6	5.1
Drawdown (m)	42V	42V	42V



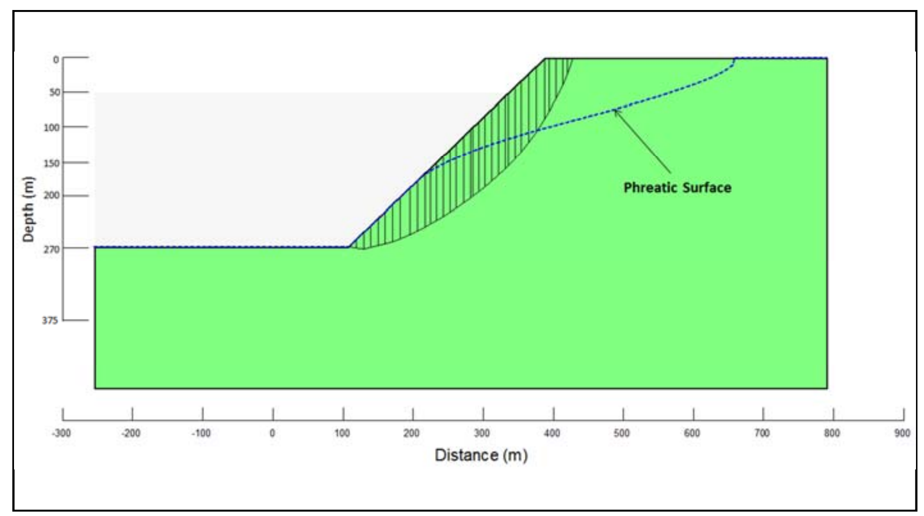
150 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.9	1.6	3.4
Depressurized FOS	1.4	2.2	4.0
Drawdown (m)	62V	62V	62V



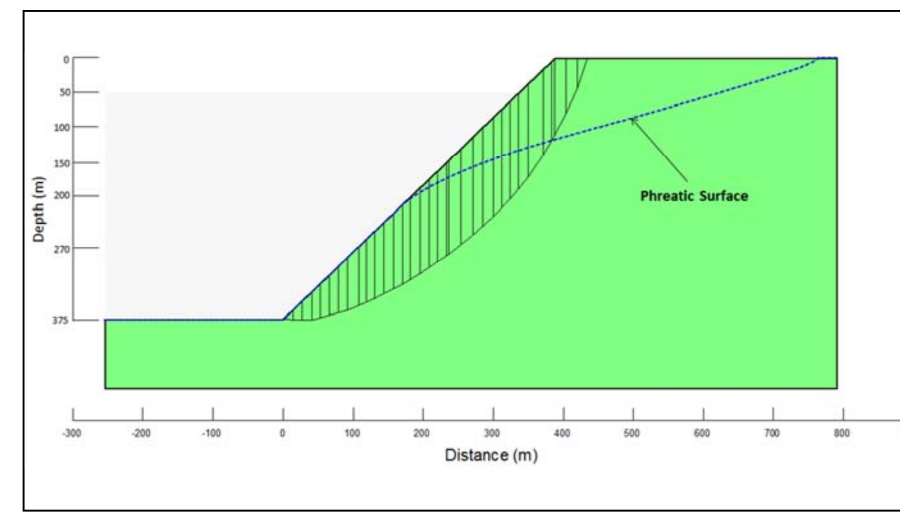
200 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.8	1.4	2.8
Depressurized FOS	1.2	1.9	3.4
Drawdown (m)	82V	82V	82V



270 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.7	1.2	2.3
Depressurized FOS	1.1	1.7	3.0
Drawdown (m)	104V	104V	104V



375 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.6	1.0	1.9
Depressurized FOS	0.9	1.5	2.5
Drawdown (m)	110V	110V	110V

NOTES:

1. Drawdown depth is the vertical distance from the pit crest that the water table naturally falls to during pit excavation.
2. Failure slip surface for depressurized slope shown for average rock mass. Rock mass assumed to be average quality.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	2FEB'12	ISSUED WITH REPORT VA101-458/4-5	AL	GM	KJB

YELLOWHEAD MINING INC.

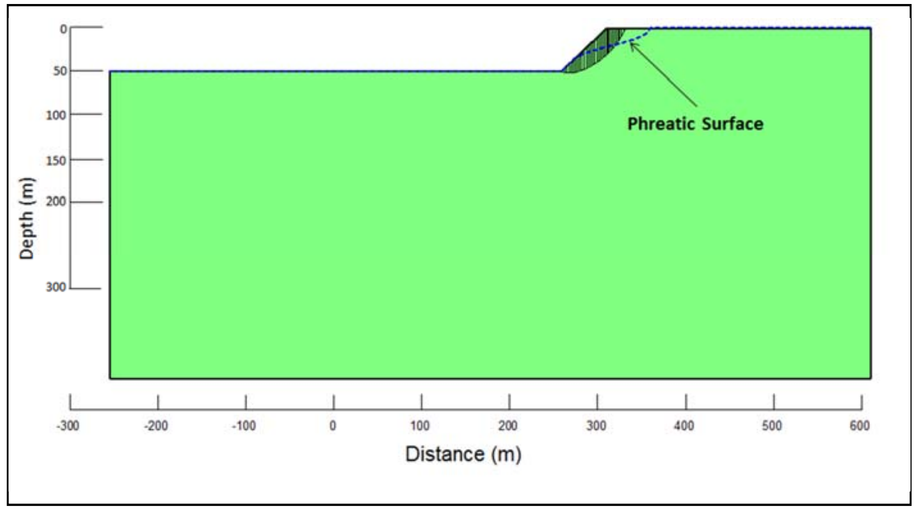
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS
RESULTS FOR EAST VOLCANICLASTICS

Knight Piésold CONSULTING

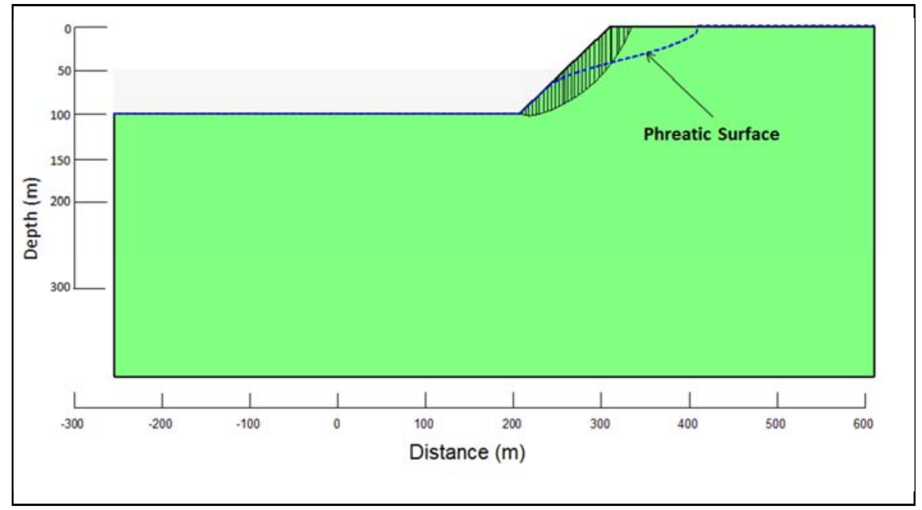
P/A NO. VA101-458/4 | REF. NO. 5

FIGURE B1 | REV 0



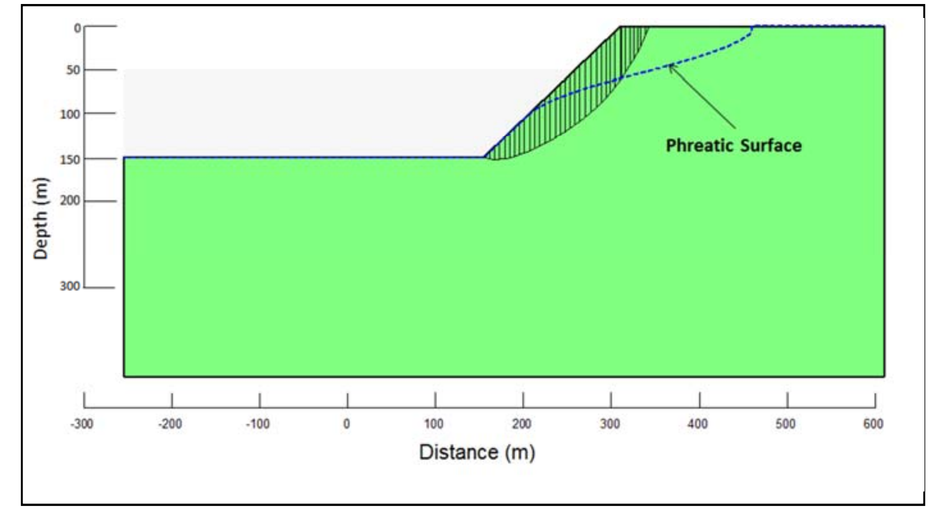
50 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	1.2	2.2	5.2
Depressurized FOS	1.8	2.8	5.7
Drawdown (m)	20V	20V	20V



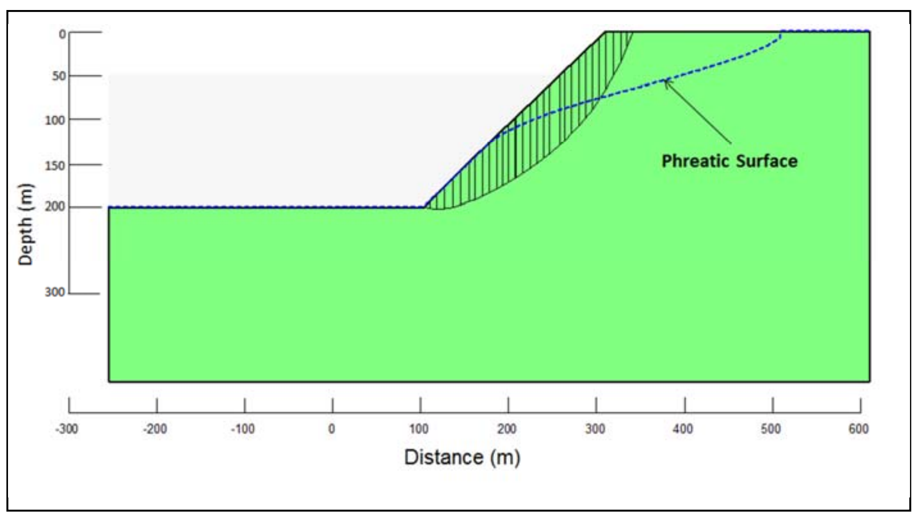
100 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.9	1.5	3.2
Depressurized FOS	1.3	2.0	3.9
Drawdown (m)	42V	42V	42V



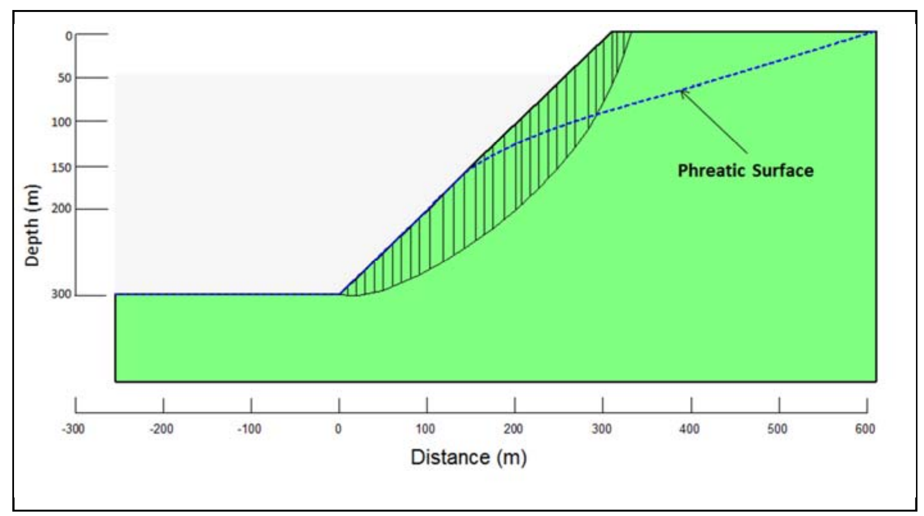
150 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.7	1.2	2.5
Depressurized FOS	1.1	1.7	3.1
Drawdown (m)	60V	60V	60V



200 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.6	1.0	2.1
Depressurized FOS	1.0	1.5	2.7
Drawdown (m)	80V	80V	80V



300 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.1	0.9	1.7
Depressurized FOS	0.8	1.3	2.2
Drawdown (m)	114V	114V	114V

NOTES:

1. Drawdown depth is the vertical distance from the pit crest that the water table naturally falls to during pit excavation.
2. Failure slip surface for depressurized slope shown. Rock mass assumed to be average quality.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30APR'12	ISSUED WITH REPORT VA101-458/4-5	AL	GM	KJB

YELLOWHEAD MINING INC.

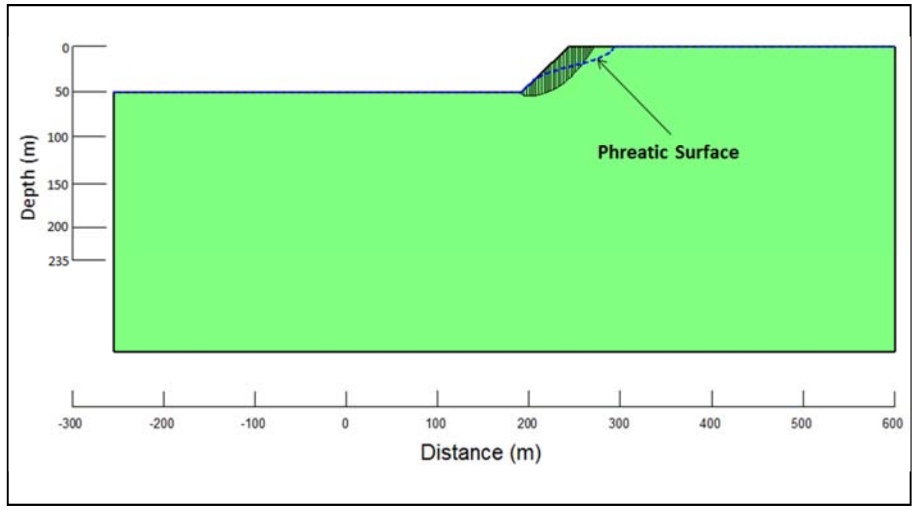
HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS
RESULTS FOR WEST VOLCANICLASTICS

Knight Piésold CONSULTING

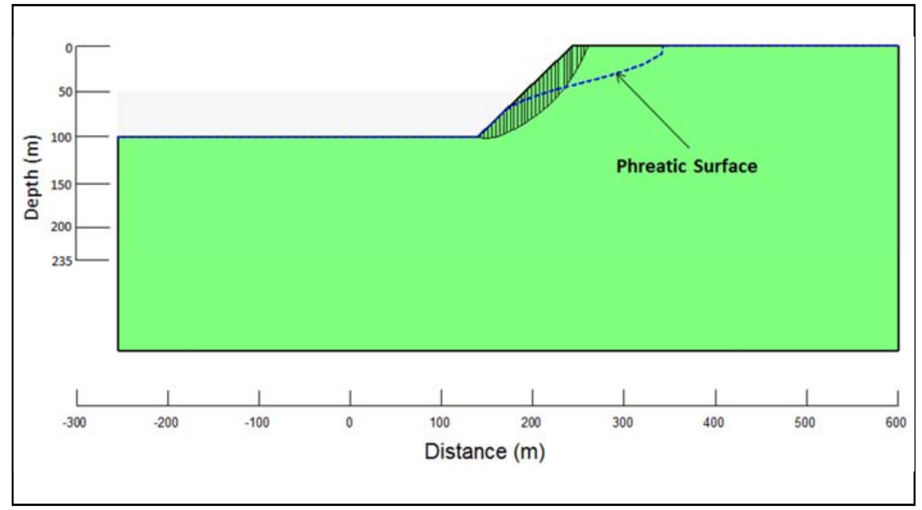
P/A NO. VA101-458/4 | REF. NO. 5

FIGURE B2 | REV 0



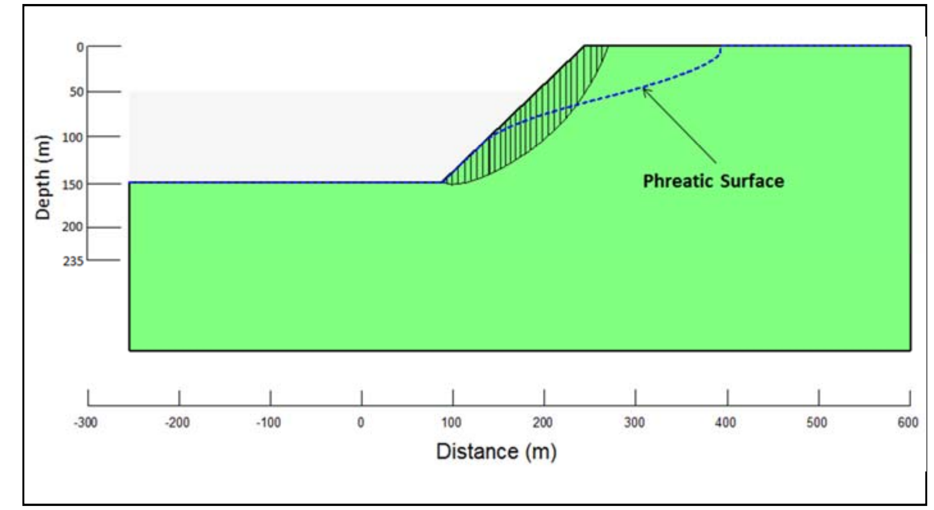
50 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	1.6	2.2	3.0
Depressurized FOS	21.4	1.9	2.5
Drawdown (m)	20V	20V	20V



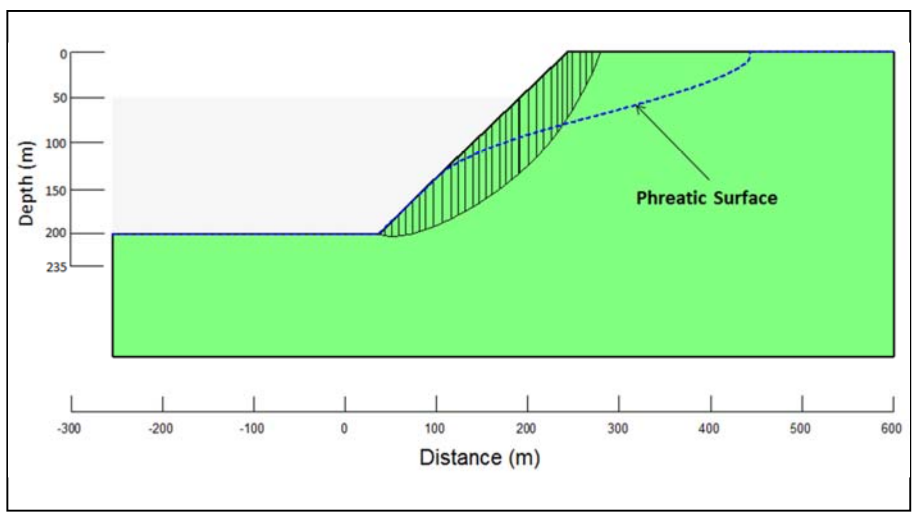
100 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	1.1	1.5	2.0
Depressurized FOS	1.4	1.6	2.5
Drawdown (m)	43V	43V	43V



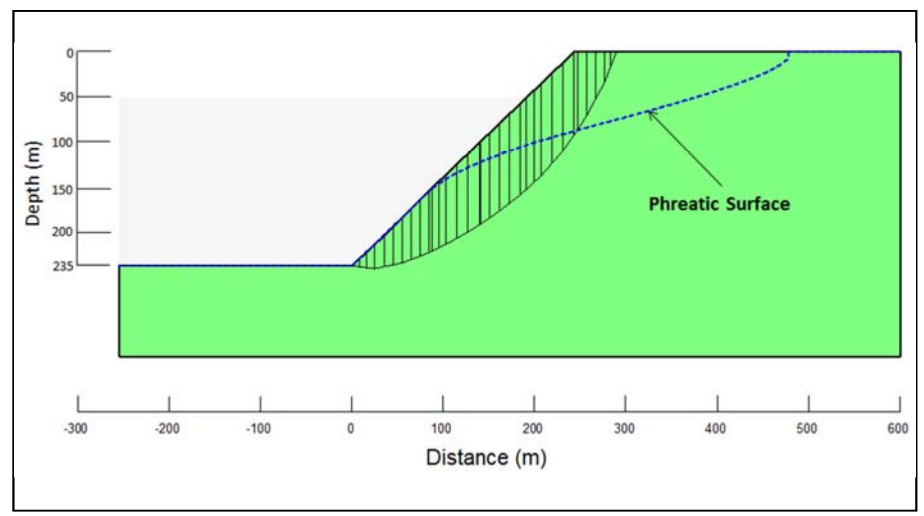
150 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.8	1.1	1.5
Depressurized FOS	1.1	1.6	2.1
Drawdown (m)	65V	65V	65V



200 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.7	1.0	1.3
Depressurized FOS	1.0	1.4	1.9
Drawdown (m)	80V	80V	80V



235 m Inter-ramp

	Lower Bound	Average	Upper Bound
Saturated FOS	0.7	0.9	1.3
Depressurized FOS	0.9	1.3	1.7
Drawdown (m)	85V	85V	85V

NOTES:

1. Drawdown depth is the vertical distance from the pit crest that the water table naturally falls to during pit excavation.
2. Failure slip surface for depressurized slope shown. Rock mass assumed to be average quality.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	30APR'12	ISSUED WITH REPORT VA101-458/4-5	AL	GM	KJB

YELLOWHEAD MINING INC.

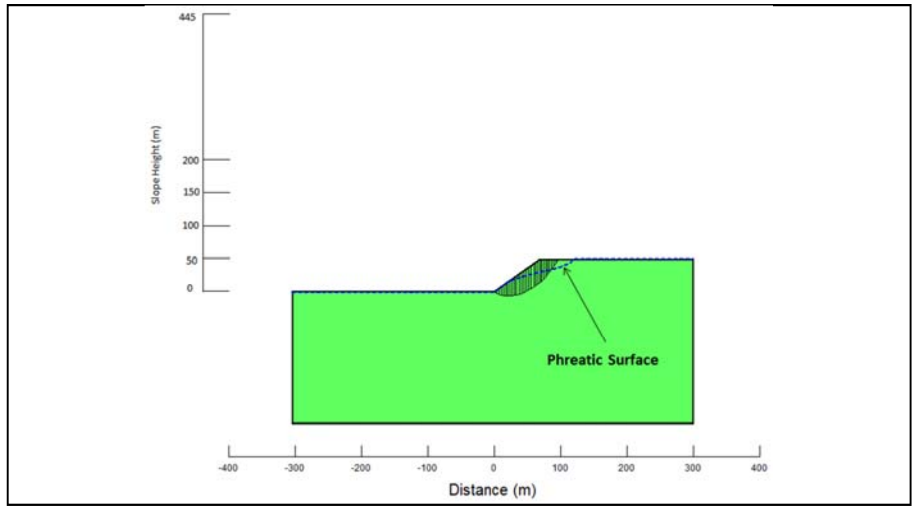
HARPER CREEK PROJECT

**2012 OPEN PIT GEOTECHNICAL DESIGN
ISOTROPIC STABILITY ANALYSIS
RESULTS FOR PHYLLITE**

Knight Piésold CONSULTING

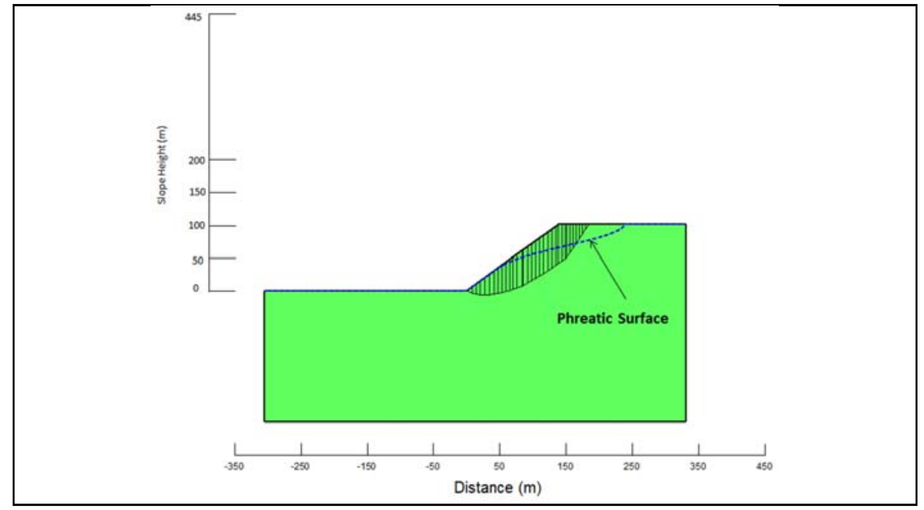
P/A NO. VA101-458/4 | REF. NO. 5

FIGURE B3 | REV 0



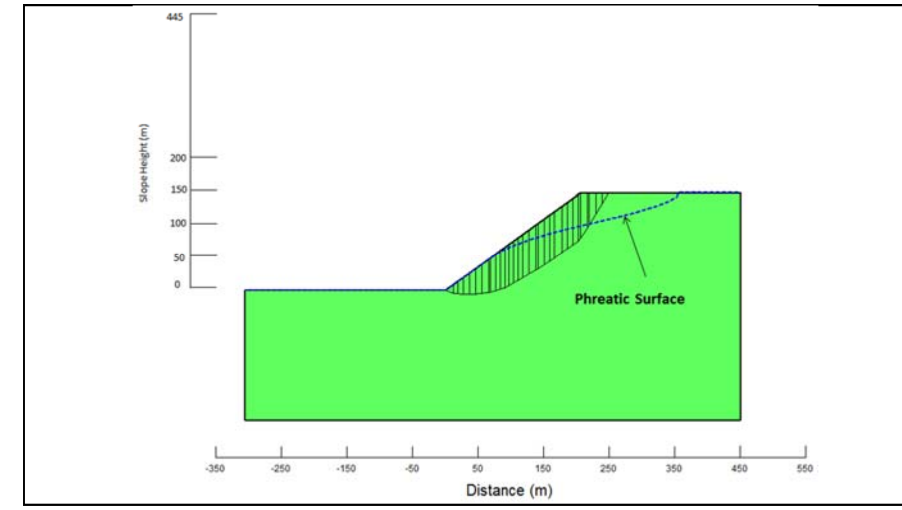
50 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.6	3.1	3.3	3.5	3.7
Depressurized FOS	1.1	3.3	3.6	3.8	4.2
Drawdown (m)	18V	18V	18V	18V	18V



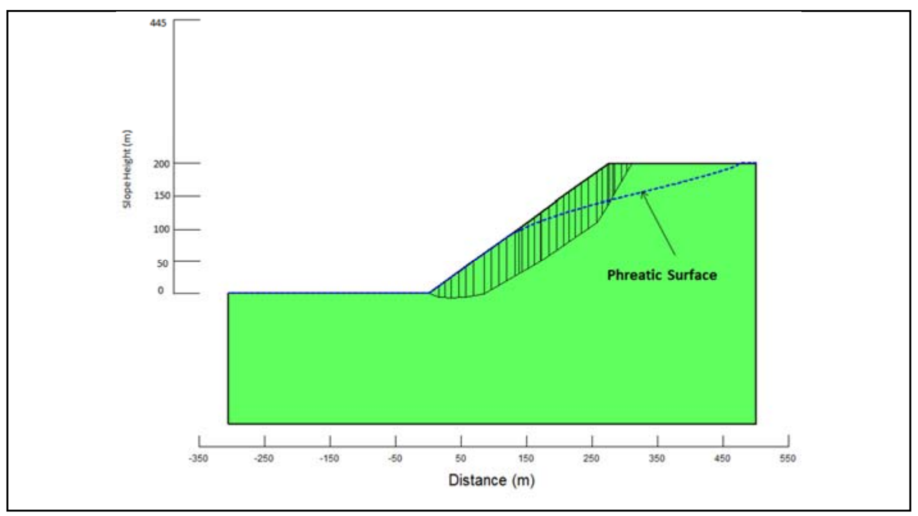
100 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.5	2.0	2.2	2.3	2.5
Depressurized FOS	1.1	2.4	2.5	2.7	3.0
Drawdown (m)	33V	33V	33V	33V	33V



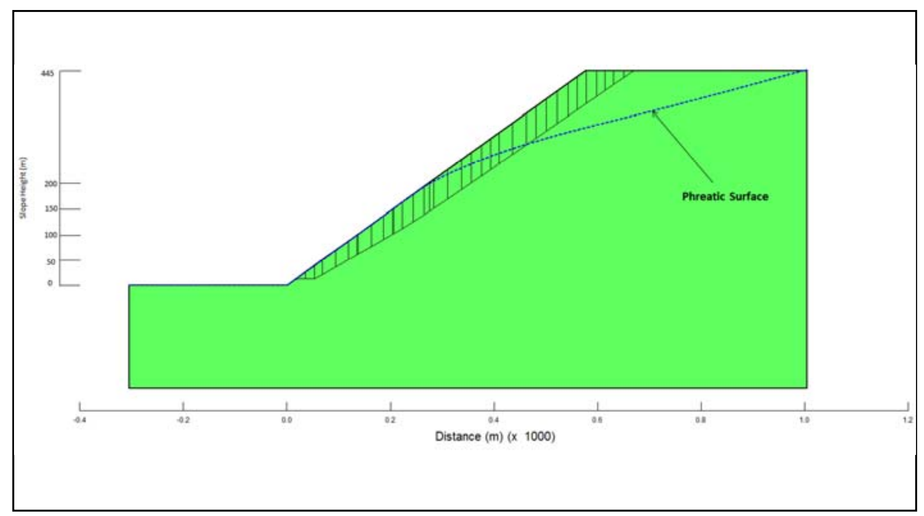
150 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.5	1.7	1.8	1.9	2.0
Depressurized FOS	1.0	2.0	2.1	2.2	2.5
Drawdown (m)	49V	49V	49V	49V	49V



200 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.6	1.3	1.6	1.7	1.8
Depressurized FOS	1.1	1.7	1.8	2.0	2.2
Drawdown (m)	55V	55V	55V	55V	55V



445 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.5	0.9	1.1	1.2	1.3
Depressurized FOS	1.1	1.3	1.4	1.5	1.6
Drawdown (m)	110V	110V	110V	110V	110V

NOTES:

1. Drawdown depth is the vertical distance from the pit crest that the water table naturally falls to during pit excavation.
2. Failure slip surface for depressurized slope shown. Rock mass assumed to be 25% anisotropic.

0	30APR'12	ISSUED WITH REPORT VA101-458/4-5	AL	GM	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ANISOTROPIC STABILITY ANALYSIS - SOUTH SECTOR
RESULTS FOR EAST VOLCANICLASTICS

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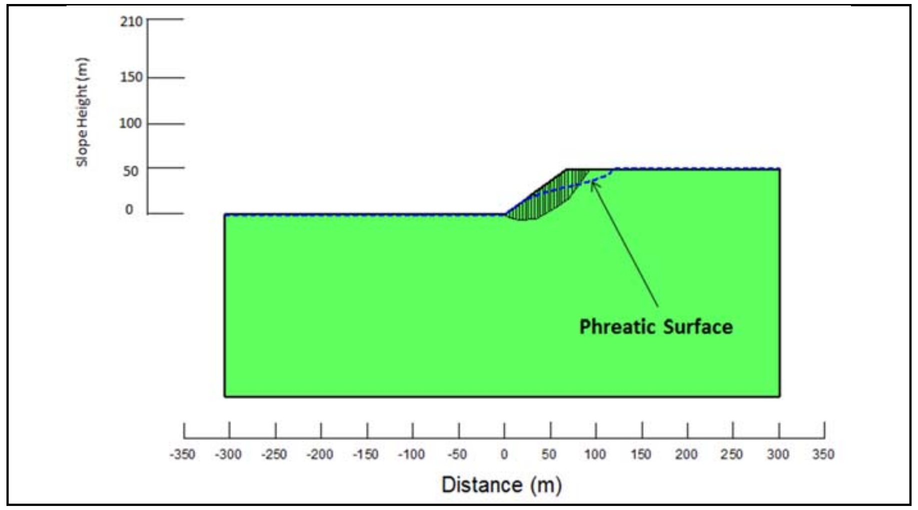
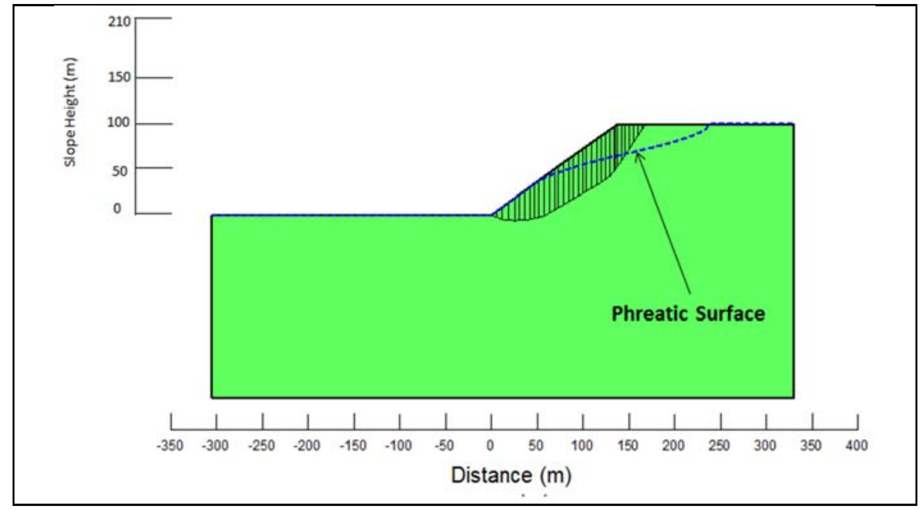
FIGURE B4 | REV 0



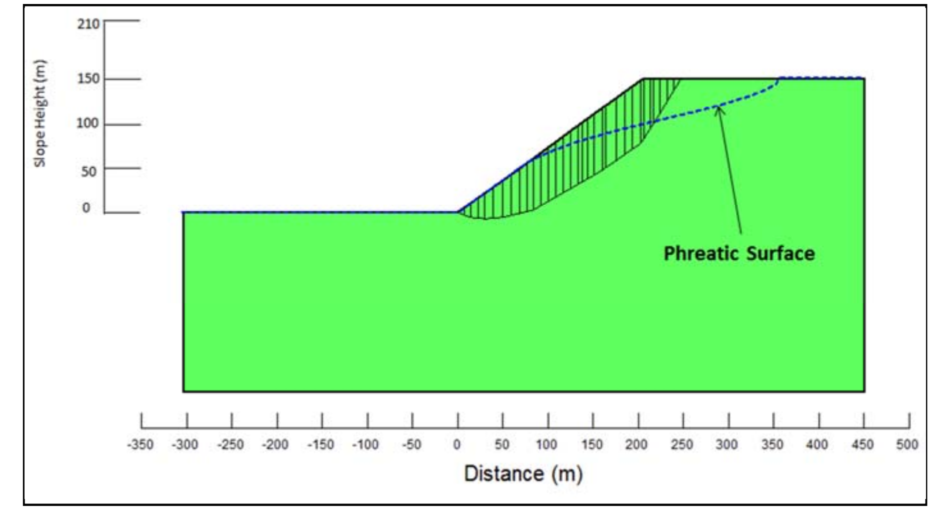
50 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.6	2.3	2.5	2.6	2.7
Depressurized FOS	1.1	2.5	2.6	2.8	3.2
Drawdown (m)	18V	18V	18V	18V	18V



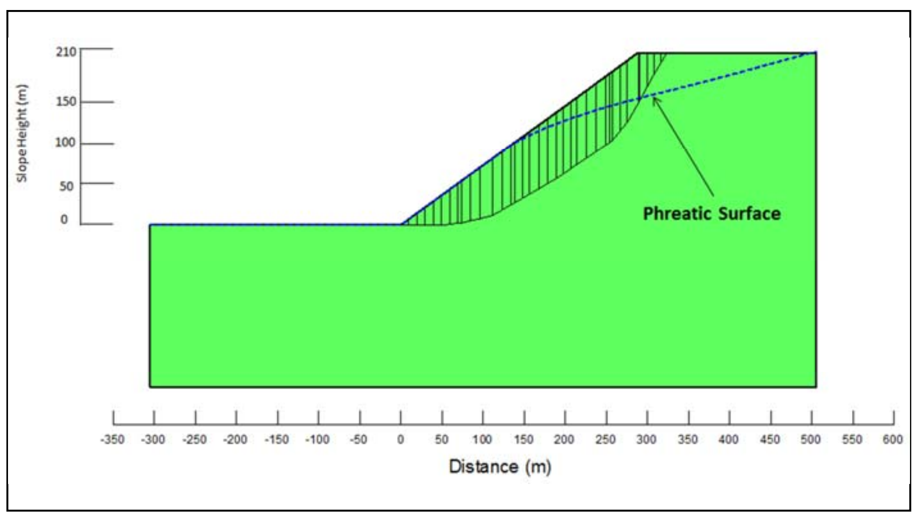
100 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.5	1.6	1.7	1.8	1.9
Depressurized FOS	1.1	1.9	2.0	2.1	2.3
Drawdown (m)	33V	33V	33V	33V	33V



150 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.5	1.4	1.4	1.5	1.6
Depressurized FOS	1.0	1.6	1.7	1.8	2.0
Drawdown (m)	49V	49V	49V	49V	49V



210 m Inter-ramp

	0%	25%	50%	75%	ISO
Saturated FOS	0.5	1.0	1.2	1.3	1.4
Depressurized FOS	0.9	1.4	1.5	1.6	1.7
Drawdown (m)	53V	53V	53V	53V	53V

NOTES:

1. Drawdown depth is the vertical distance from the pit crest that the water table naturally falls to during pit excavation.
2. Failure slip surface for depressurized slope shown. Rock mass assumed to be 25% anisotropic.

0	30APR'12	ISSUED WITH REPORT VA101-458/4-5	AL	GM	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

YELLOWHEAD MINING INC.

HARPER CREEK PROJECT

2012 OPEN PIT GEOTECHNICAL DESIGN
ANISOTROPIC STABILITY ANALYSIS - SOUTH SECTOR
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FIGURE B5 | REV 0