APPENDIX II

Geophysical Survey Report

RPT-2013-003

GEOPHYSICAL CHARACTERIZATION OF THE SUPERIOR, AZ AREA – RESOLUTION COPPER MINE

N. Crook, Ph.D.
M. McNeill

2302 N. Forbes Blvd, Tucson, AZ 85745 USA

Date Published
March 2013

Prepared for Resolution Copper Mine

TABLE OF CONTENTS

1.0 INTRODUCTION 1-1
1.1 PROJECT DESCRIPTION 1-1
1.2 SITE LOCATION 1-1
1.3 OBJECTIVE OF INVESTIGATION 1-1
2.0 GEOPHYSICAL THEORY 2-1
2.1 P-WAVE SEISMIC REFRACTION 2-1
2.2 MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW) 2-2
3.0 METHODOLOGY 3-1
3.1 SURVEY AREA AND LOGISTICS 3-1
3.2 EQUIPMENT 3-1
3.2.1 Equipment for P-Wave Refraction Surveying 3-1
3.2.2 Equipment for MASW Surveying 3-1
3.3 DATA PROCESSING 3-2
3.3.1 Quality Control – Onsite 3-2
3.3.2 P-wave Refraction Processing 3-2
3.3.2.1 Seismic Refraction Modeling 3-3
3.3.3 MASW Processing 3-5
4.0 RESULTS & INTERPRETATION 4-1
4.1 AREA 1 4-1
4.1.1 Profile 1A 4-2
4.1.2 Profile 1B 4-3
4.1.3 Profile 1C 4-5
4.1.4 Profile 1D 4-7
4.2 AREA 2 4-8
4.2.1 Profile 2B 4-8
4.2.2 Profile 2C 4-10
4.2.3 Profile 2D 4-12
4.3 AREA 3 4-13
4.3.1 Profile 3A 4-14
4.3.2 Profile 3B 4-16
4.3.3 Profile 3C 4-17
4.4 AREA 4 4-19
4.4.1 Profile 4A 4-19
4.4.2 Profile 4B 4-21
4.4.3 Profile 4C 4-23
4.5 MASW PROFILES 4-24
5.0 SUMMARY 5-1

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

This report documents the results of a seismic survey conducted at a project site northwest of Superior, AZ in February 2013 under contract to Resolution Copper by hydroGEOPHYSICS, Inc (HGI). P-wave refraction surveying was conducted along thirteen profiles to determine bedrock topography and rippability. In addition, multi-channel analysis of surface wave (MASW) surveying was conducted along three profiles to determine shear wave velocity of the underlying bedrock.

1.2 SITE LOCATION

The survey site is located in central Arizona within Pinal County, and approximately 64 miles east of Phoeniz, AZ. The investigation targeted a number of major and minor creek beds, located on USDA Tonto National Forest land, between approximately 3.5 and 8.0 miles northwest of Superior, AZ. Figure 1-1 shows the locations of the seismic survey profiles in these areas; the survey profiles are overlaid onto the regional geology in Figure 1-2.

1.3 OBJECTIVE OF INVESTIGATION

The objectives of the P-wave seismic refraction survey were to:

- Map the top of the buried bedrock surface,
- Determine the thickness of the overlying alluvium,
- Indirectly determine the rippability of the overlying alluvium.

The objectives of the MASW survey were to:

- Determine the shear wave velocity of the underlying weathered bedrock in the top 10 meters (32 feet) of the subsurface,
- Map any variations in shear wave velocity with depth in the near surface.

The results will be used to add to baseline characterization in the general project area. The methods were selected to take advantage of physical property contrasts that are reflective of site conditions. For example, it was expected that the bedrock would be of significantly higher acoustic velocity compared to the overlying alluvium.

Figure 1-1. General Site Map with Geophysical Survey Lines; Profiles 2CS, 2DS, and 2ES Correspond to the MASW Profiles.

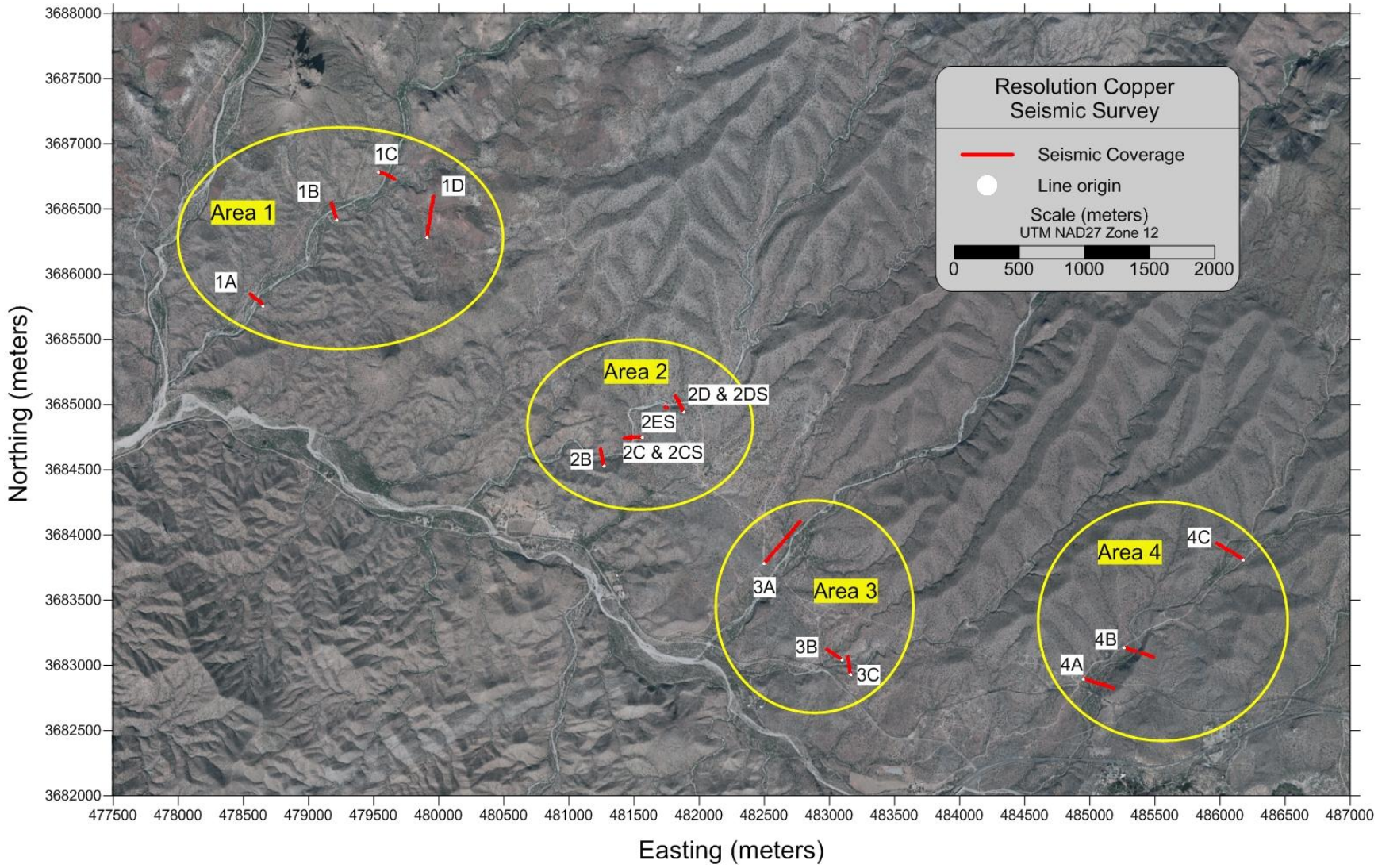
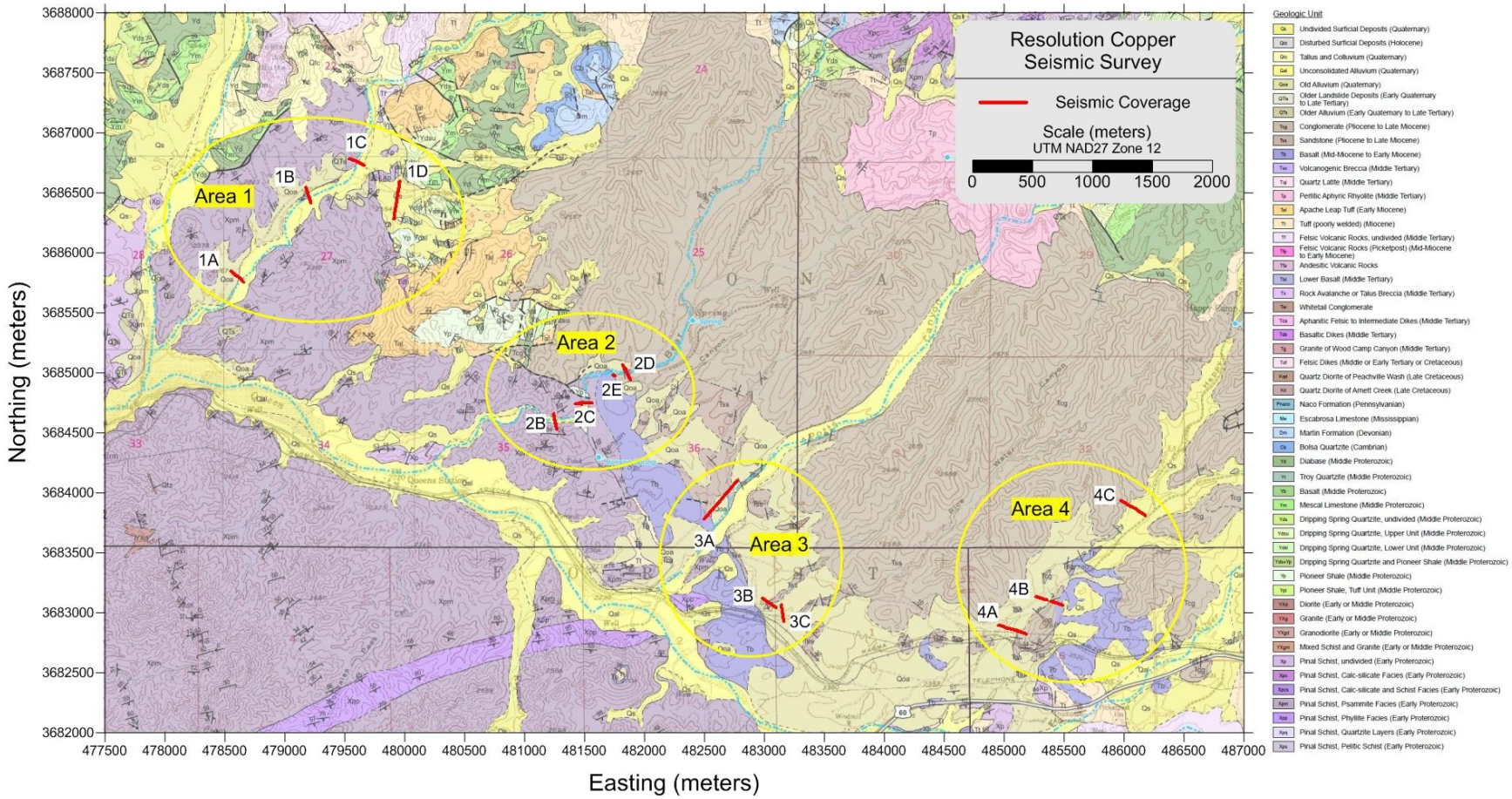


Figure 1-2. General Site Map with Geology*; Profiles 2CS, 2DS, and 2ES Correspond to the MASW Profiles.*

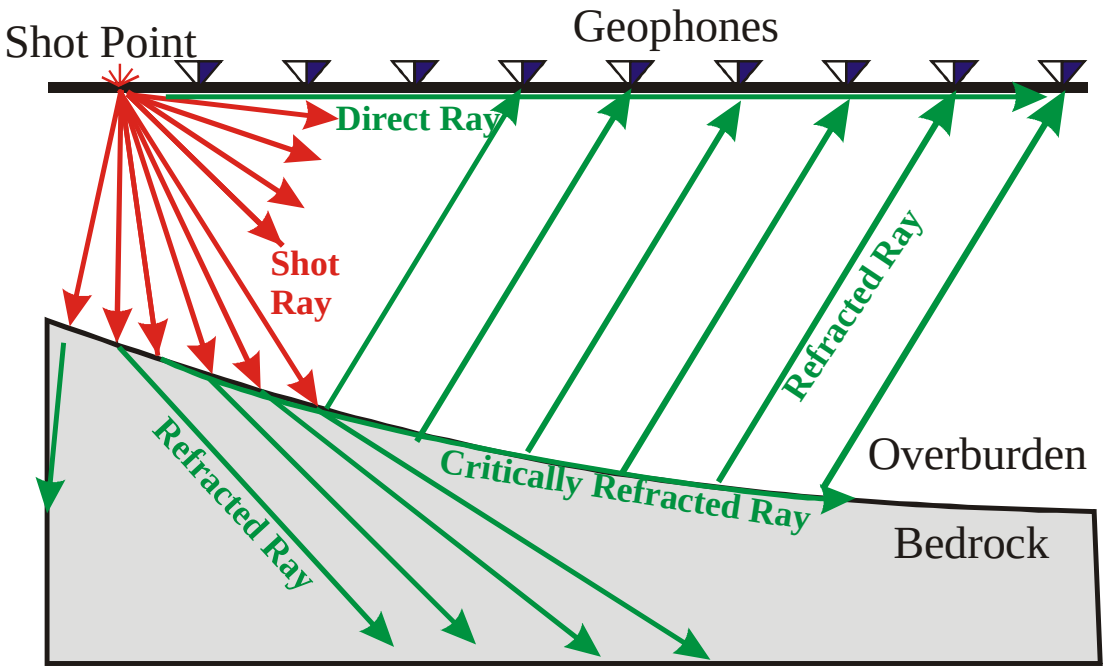


2.0 GEOPHYSICAL THEORY

2.1 P-WAVE SEISMIC REFRACTION

The P-wave seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity. Figure 2-1 shows an example of the seismic refraction method. Seismic energy is provided by a source ('shot') located on the surface. For shallow applications, the shot normally comprises a hammer and plate, weight drop, or small explosive charge (blank shotgun cartridge). Energy radiates out from the shot point, either traveling directly through the upper layer (direct arrivals), or traveling down to and then laterally along higher velocity layers (refracted arrivals) before returning to the surface. The refracted energy is detected on the surface using a linear array (or spread) of geophones spaced at regular intervals. Beyond a certain distance from the shot point, known as the cross-over distance, the refracted signal is observed as a first-arrival signal at the geophones (arriving before the direct arrival). Observation of the travel times of the direct and refracted signals provides information on the depth profile of the refractor.

Figure 2-1. Ray Travel for Seismic Refraction Surveying



Data are recorded on a seismograph and later downloaded to a computer for analysis of the first-arrival times to the geophones from each shot position. Travel-time versus distance graphs are then constructed and velocities calculated for the overburden and refractor layers through analysis of the direct arrival and T-minus graph gradients. Depth profiles for each refractor are produced by an analytical procedure based on consideration of shot and receiver geometry and

the measured travel-times and calculated velocities. The final output comprises a depth profile of the refractor layer and a velocity model of the subsurface.

The primary applications of seismic refraction are for determining depth to bedrock and bedrock structure. Due to the dependence of seismic velocity on the elasticity and density of the material through which the energy is passing, seismic refraction surveys provide a measure of material strengths and can consequently be used as an aid in assessing rippability and rock quality. The technique has been successfully applied to mapping depth to base of backfilled quarries, depth of landfills, thickness of overburden, voids, and the topography of groundwater.

2.2 MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW)

Dispersion, or change in phase velocity with frequency, is the fundamental property utilized in surface-wave methods. Phase velocity of surface-wave is sensitive to the Shear wave velocity (Vs); phase velocity of surface-wave is typically 90-95% that of the Shear wave velocity. Surface wave dispersion can be significant in the presence of velocity layering, which is common in the near-surface environment. There are other types of surface waves, or waves that travel along a surface, but in this application we are concerned with the Rayleigh wave, which is also called "ground roll" since the Rayleigh wave is the dominant component of ground roll.

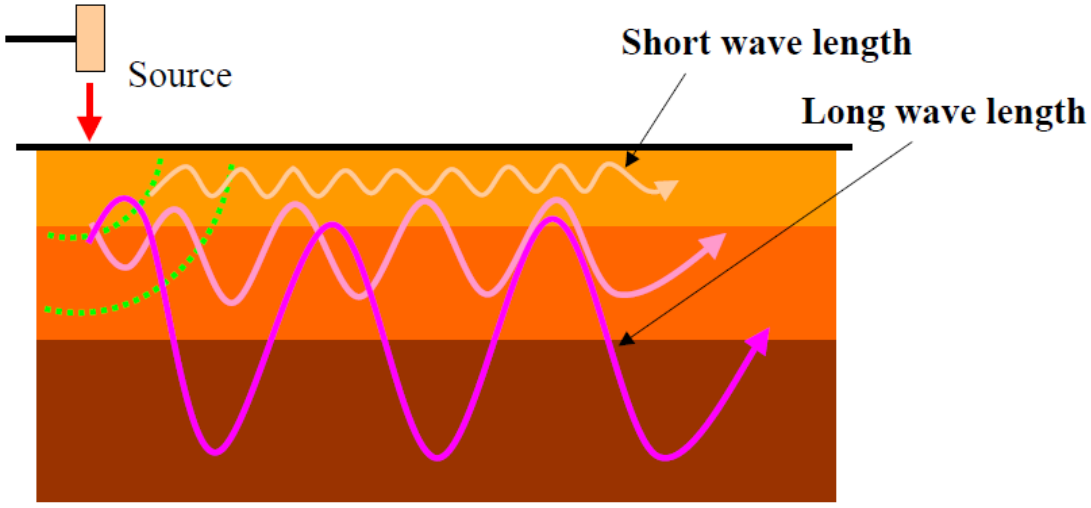
"Active source" surface-wave surveying means that seismic energy is intentionally generated at a specific location relative to the geophone spread and recording begins when the source energy is imparted into the ground. This is in contrast to "passive source" surveying, also called "microtremor" surveying, or sometimes referred to as "refraction microtremor" (or the commercial term "ReMi") surveying, where there is no time break and motion from ambient energy generated by cultural noise, wind, wave motion, etc. at various, and usually unknown, locations relative to the geophone spread is recorded.

Surface-wave energy decays exponentially with depth beneath the surface. Longer wavelength (that is, longer-period and lower-frequency) surface waves travel deeper and thus contain more information about deeper velocity structure (Figure 2-2). Shorter wavelength (that is, shorter-period and higher-frequency) surface waves travel shallower and thus contain more information about shallower velocity structure. In this context, by their nature and proximity to the geophone spread, it can be said that higher frequency active source surface waves resolve the shallower velocity structure and lower frequency passive source surface waves resolve the deeper velocity structure.

MASW surveys are conducted using the same source and seismograph equipment as the more common P-wave seismic refraction surveys, requiring only a change to lower frequency geophones (typically 4.5Hz). They are much easier to conduct than Shear wave surveys, and

benefit from increasing source power efficiency (for each sledgehammer blow 67% of the energy produced is in the form of surface-waves, 26% shear waves, and 7% P-waves) and consequently improved signal to noise. The techniques works best in soft rock geology conditions with minimal or constant topography change across the spread.

Figure 2-2 Example of Surface Wave Dispersion Produce During Multi-Channel Analysis of Surface Wave Surveying



Shear wave velocity is one of the elastic constants and closely related to Young's modulus. Under most circumstances, Shear wave velocity is a direct indicator of the ground strength (stiffness) and therefore can be used to derive load-bearing capacity.

3.0 METHODOLOGY

3.1 SURVEY AREA AND LOGISTICS

A geophysical survey, including P-wave seismic refraction and multi-channel analysis of surface waves (MASW), was conducted in the field near Superior, AZ between February 15th, 2013 and February 20th, 2013. The geophysical survey site consisted of four areas, encompassing a number of major and minor creek beds. Figure 1-1 shows a detailed line layout for the geophysical surveying.

3.2 EQUIPMENT

3.2.1 Equipment for P-Wave Refraction Surveying

Two Geode Ultra-Light Exploration 24 –Channel Seismographs (Geometrics, Inc., San Jose, CA) were used for seismic P-wave refraction surveying, providing a total of 48-channels. 28Hz geophone placement was every 10 feet, shot point spacing was 50-feet located at the midpoint of geophone positions along the spread, with off-end shots at 50-feet beyond the first and last geophones. The seismic source consisted of a 16-lb sledgehammer and hammer plate. The Geodes ran from a laptop in order to view each shot to ensure acceptable data quality, and record and process the data. Additional hammer blows forming a new "stack" of data were added until the desired data quality was achieved. The shot record (seismogram) was also saved to the computer and stored for subsequent processing. A real-time noise monitor showing all geophones was carefully scrutinized during shots to ensure that noise levels were at a minimum for each shot. This included watching for breaks in wind noise, ATV traffic, and other sources of noise.

3.2.2 Equipment for MASW Surveying

A single Geode Ultra-Light Exploration 24 –Channel Seismograph (Geometrics, Inc., San Jose, CA) was used for seismic surface-wave surveying, providing a total of 24-channels. 4.5Hz geophone placement was every 3 feet, shot point spacing was 6-feet located at the midpoint of geophone positions along the spread, with off-end shots at 14 and 28-feet beyond the first and last geophones. The seismic source consisted of a 16-lb sledgehammer and hammer plate. The Geodes ran from a laptop in order to view each shot to ensure acceptable data quality, and record and process the data. Additional hammer blows forming a new "stack" of data were added until the desired data quality was achieved. The shot record (seismogram) was also saved to the computer and stored for subsequent processing. A real-time noise monitor showing all geophones was carefully scrutinized during shots to ensure that noise levels were at a minimum for each shot. This included watching for breaks in wind noise, ATV traffic, and other sources of noise.

3.3 DATA PROCESSING

3.3.1 Quality Control – Onsite

Data for each survey method were given a preliminary assessment for quality control (QC) in the field to assure quality of data before progressing the survey. Following onsite QC, the data were transferred to the HGI server for storage and detailed data processing and analysis.

3.3.2 P-wave Refraction Processing

Data processing for the seismic refraction method consisted primarily of accounting for energy source and geophone locations, making adjustments for topographic changes along the geophone array profiles, and determining the first arrival times at the geophones. The final step was to determine subsurface acoustic properties using two different processing methods: refraction analysis, and tomographic inversion. The software incorporated all of the features necessary for accurate representation of subsurface properties, including the first break pick, inversion, and plotting.

Input Data: Data were reformatted to SEG-Y internal format while preserving trace header information. The geometry was created to define the relationship between the field file and channel numbers, and the source and receiver station numbers. Records marked in the Observer's logs as needing to be omitted were edited from the data.

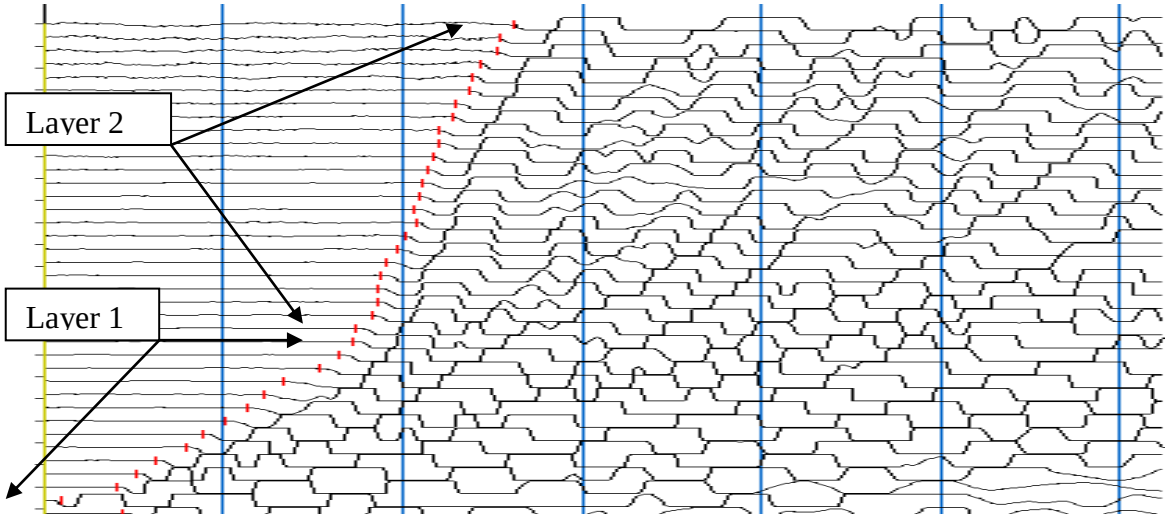
Geometry & Editing: Positional data recorded, using a Leica Geosystems RTK 1200 survey grade GPS, was merged with the trace data. The data was output as a SEG-Y formatted file for input into the refraction statics program Seisimager (Geometrics, Inc.). At this stage and within the software, edits and corrections were made to account for any errors made in the field.

First Arrival Selection: The first step for data processing was to pick the time for first arrival of energy at the geophone from each of the shot records, also known as first break picking. Each geophone had a separate first break pick for each shot. The first break picking was conducted interactively within the Seisimager's software called Pickwin Version 4.2.0.0.

Figure 3-1 shows an example shot record taken along Line L. The x-axis is time in milliseconds and the y-axis is distance between geophones. The first break picks of energy arriving at the geophones are annotated as red marks below. There is an automatic picking option that is used initially in the software and then each trace in each shot record is manually reviewed and adjusted. In total there were 273 shot records and nearly 13,500 first break picks assigned. There were two distinct velocity slopes in arrivals representing the two layers as illustrated in Figure 3-1. The first slope, which is much steeper, indicates the slower velocity alluvium layer.

The other layer is the refracted energy as it returns from the second and higher velocity layer. The second higher velocity layer was either a more consolidated alluvium or weathered bedrock.

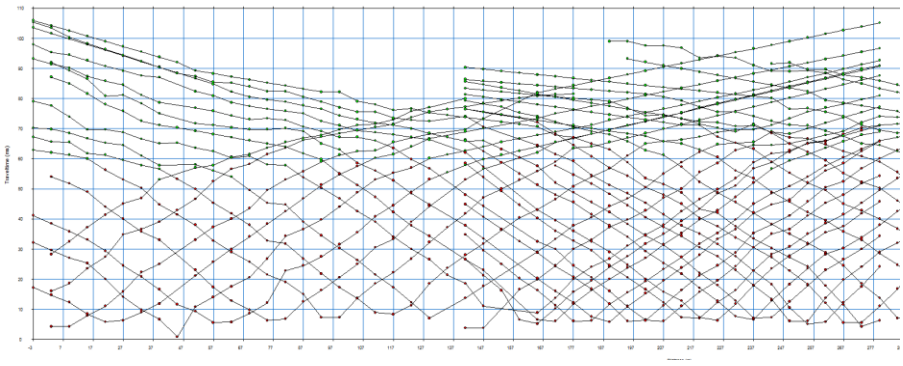
Figure 3-1. Example shot record showing first break picks.



3.3.2.1 Seismic Refraction Modeling

Layer Assignment: Once the first breaks were assigned for all of the seismic lines, the next step in the process was layer assignment, where the user chose the slopes that best fit the two-layer model. Three-layer models were attempted, but only a few first arrivals indicated a third layer. In order to be an effective model, most of the first arrivals would have needed to show a third layer. Figure 3-2 shows an example of the layer assignment chosen. The x-axis now shows distance and the y-axis shows the time in milliseconds. The red circles represent Layer 1 and the green circles represent Layer 2.

Figure 3-2. Example of layer assignments (Line A).



Distance (ft)

Refraction Analysis: Upon completion of the first break picks and the layer assignments, the refraction analysis was completed using the Seisimager software. Refraction analysis was completed for all 13 lines using the time-term inversion modeling assuming a two layer model. An initial model was used for geometry verification. The refraction statics program compared the predicted pick times with the actual pick times producing numerous statistical displays used for finding and correcting shot/patch position errors. A two layer depth model was created using algorithms based on the generalized reciprocal method. This method assumed that layer velocity was constant and that the layer extended throughout the modeled section. For flat-layered geology this method is reliable and accurate, but tends to poorly represent variable horizontal velocity material and complex topographic changes within the layer.

Tomographic Inversion: Tomographic velocity inversion was completed using the Seisimager software. This method starts with an initial velocity model (generated manually or by the above mentioned time-term inversion and iteratively traces rays through the numerical model) with the goal of minimizing the root-mean squared (RMS) error between the observed and calculated travel times. Tomographic inversion is generally best used when velocity contrasts are known to be more gradational than discrete. In cases where strong horizontal velocity variations are known to exist, and in extreme topography, processing can lead to erroneous results with time-term least squares and delay-time inversion, depending on the severity of variations. Thus, tomographic inversion was chosen for the profiles here. The final output of the inversion modeling is a profile (X and Z dimensions) of acoustic velocity beneath each geophone spread. Generally tomographic inversion requires a larger quantity and higher quality of data to produce viable results.

The results on time-term inversions have been posted as a layer on top of the tomographic inversion results. These similarities and variations, within and between areas respectively are most likely a consequence of the difference in surficial and bedrock geology across the site (Figure 1-2).

Table 3-1 shows the velocities of the layers as calculated by the time-term inversions. Each area tends to demonstrate differing properties for the calculated velocities for the two layers. For example, with the exception of Profile 1D, Area 1 profiles display an average first layer velocity of 1,311 ft/s with an average second layer velocity of 11,208 ft/s. Profile 1D displays the highest first layer velocity of 4042 ft/s but a relatively low second layer velocity of 9,003 ft/s, compared to the site wide average. Area 2 profiles display an average first layer velocity of 1,128 ft/s, with an average second layer velocity of 10,024 ft/s. The average first layer velocity for Area 3 profiles is faster at 2,298 ft/s, while the second layer average velocity is slower at 8,155 ft/s, when compared to the site wide average. Area 4 profile display an average first layer velocity of 1,998 ft/s, with an average second layer velocity of 9,075 ft/s. These similarities and variations,

within and between areas respectively are most likely a consequence of the difference in surficial and bedrock geology across the site (Figure 1-2).

Table 3-1. Layer velocities from seismic inversions

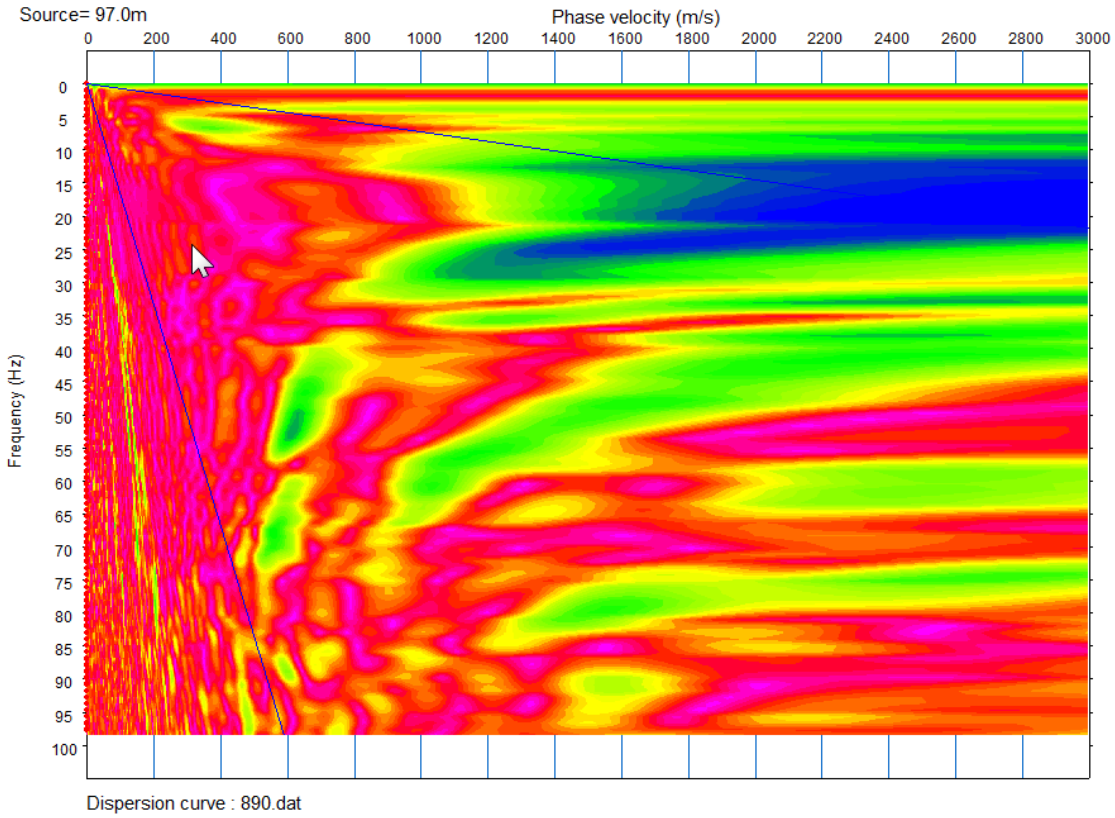
Profile	Length (ft)	Layer 1 Velocity (ft/s)	Layer 2 Velocity (ft/s)
1A	470	1540	10791
1B	470	1088	12415
1C	470	1306	10419
1D	1070	4042	9003
2B	470	821	9856
2C	470	945	9577
2D	470	1618	10638
3A	1430	2266	9293
3B	470	2370	7737
3C	470	2259	7435
4A	830	1688	8364
4B	830	2843	9160
4C	830	1462	9700
Total	**8750**		

3.3.3 MASW Processing

The data processing flow for the MASW follows the first two steps reported above for the P-wave seismic refraction processing. Any geometry changes were made in these two steps to correct for errors made during the field acquisition within Seisimager's software called Pickwin Version 4.2.0.0. Topography variations across all the MASW profiles collected were minimal (<1 foot).

Seisimager's Pickwin was then used to calculate the Common Mid-Point (CMP) cross-correlation gathers, a bin size of 6 feet was used for the three profiles. Seisimager's WaveEq was used to generate the dispersion curves and run the inversion to produce the shear wave velocity profile. A multichannel field record is first decomposed via Fast Fourier Transformation (FFT) into individual frequency component, and then amplitude normalization is applied to the each component. Then, for a given testing phase velocity in a certain range necessary amount of phase shifts are calculated to compensate for the time delay corresponding to a specific offset, applied to individual component, and all of them are summed together. This is repeated for different frequency components. Display of all summed energy in frequency-phase velocity space will show patter of energy accumulation that represents the dispersion curve as shown in Figure 3-3.

Figure 3-3 Example Dispersion Curve taken from Profile 2DS.



The inversion is then performed within Seisimager's WaveEq using a non-linear least square method to iteratively seek the 2D shear wave velocity profile, with the goal of minimizing the root-mean squared (RMS) error between the observed and calculated velocity curves.

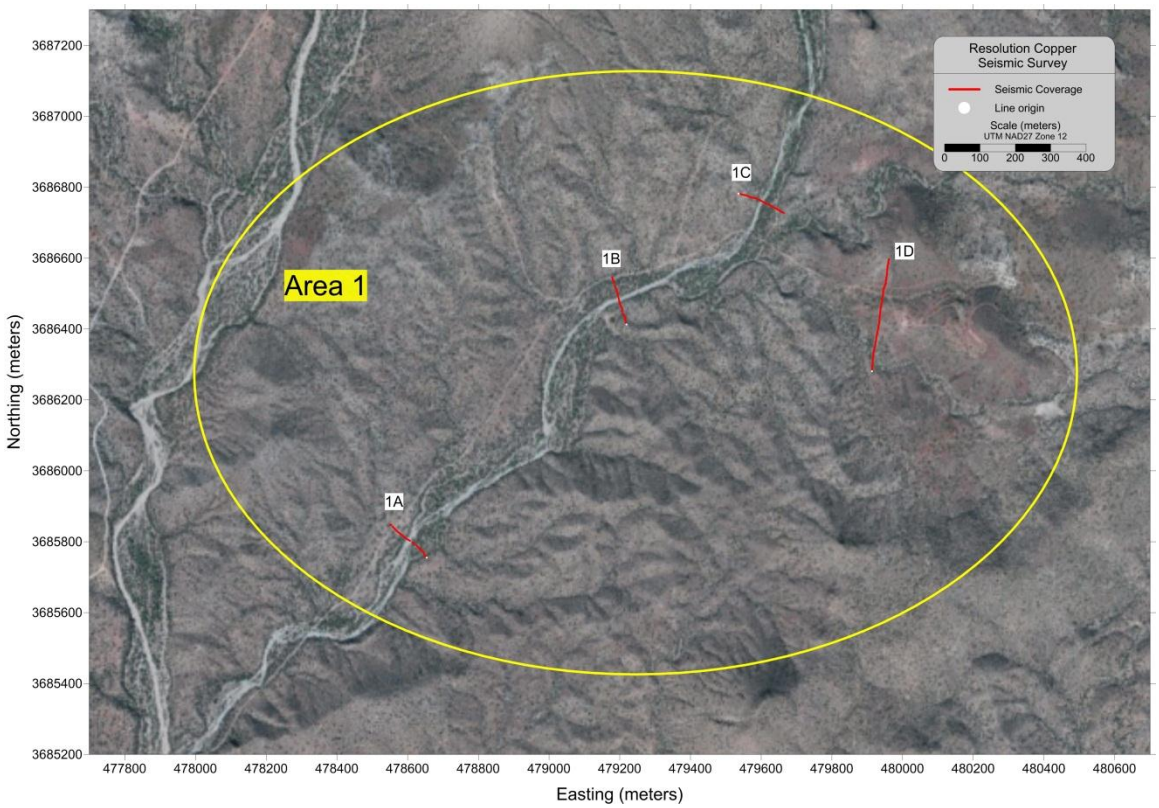
4.0 RESULTS & INTERPRETATION

Figure 1-1 and Figure 1-2 show the location of the survey, and each of the 13 individual P-wave seismic refraction and 3 MASW profiles are presented below with an interpretation. The results for each of the P-wave seismic refraction profiles include 1) a velocity tomogram, with the two layered model overlaid and 2) a layered earth model calculated from the tomographic inversion results.

4.1 AREA 1

Area 1 consisted of four profiles, A though D (Figure 4-1). Profiles 1A, 1B, and 1C, all 470 feet in length, were orientated perpendicular to the direction of the major creek bed they were targeting, with the center point of the spread located approximately in the middle of the channel. Thirteen shot locations were acquired along each of these profiles. Profile 1D, 1070 feet in length, was orientated perpendicular to a separate minor creek bed located at approximately 700 feet along the spread. Thirty-seven shot locations were acquired along this profile.

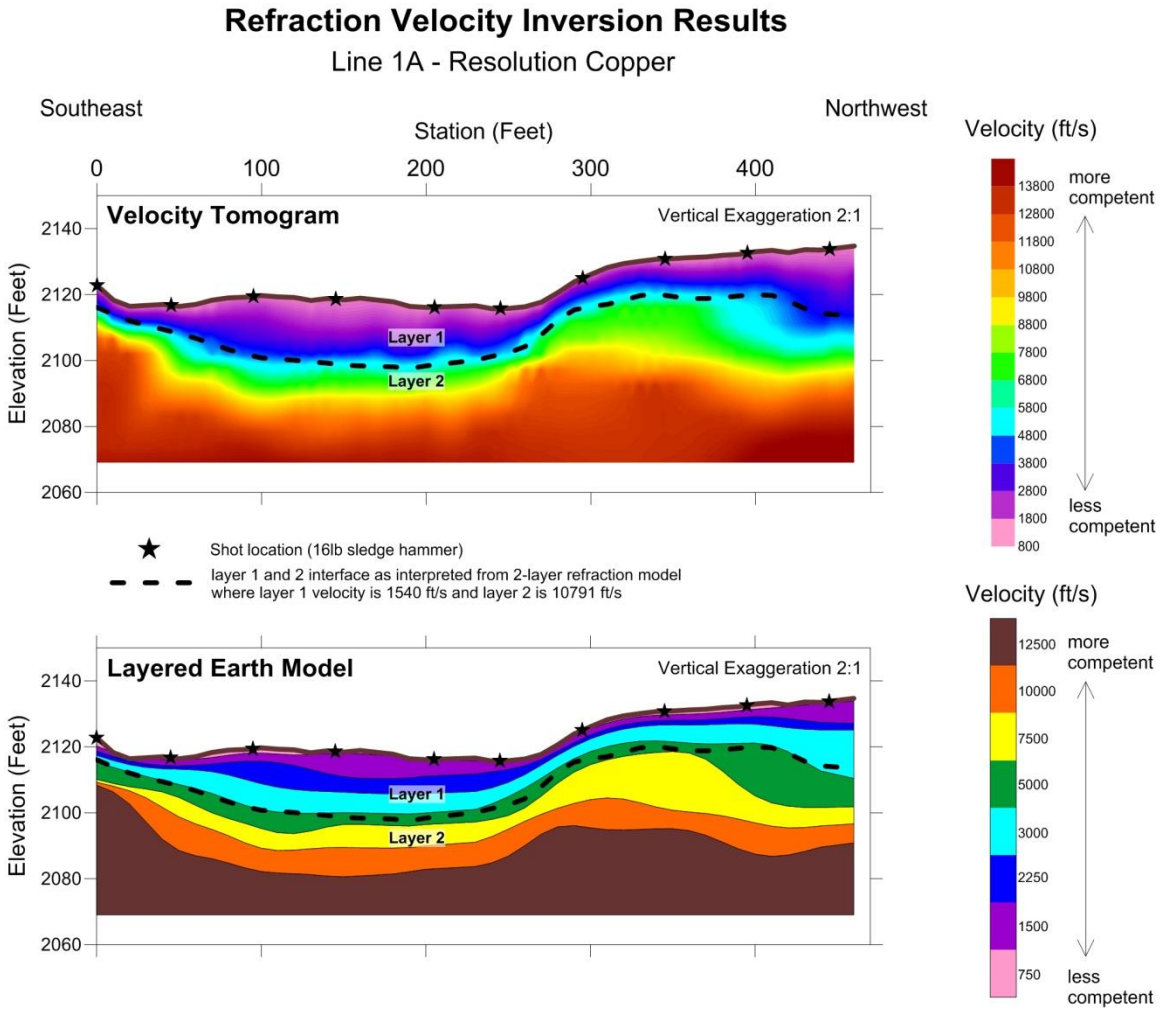
Figure 4-1 Area 1 Profile Locations.



4.1.1 Profile 1A

Figure 4-2 displays the results from Profile 1A, which was acquired in a southeast to northwest direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 1540 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 4 to 21 feet, with an average of 14 feet. Maximum thicknesses of Layer 1 are observed at approximately 160 and 460 feet along the spread. Layer 2 has an average apparent velocity of 10,791 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 1A, Layer 2 could represent a weathered layer of the Pinal Schist unit.

Figure 4-2 Profile 1A Results.



The tomographic inversion results, upper portion of Figure 4-2, displays low apparent seismic velocities as cool shades (purple and blue) and high apparent seismic velocities as warm shades

(orange and red). In general, the two layer model shows good agreement with the contoured velocity values. Towards the northwest, around 400 feet along the profile and above, we observe a divergence between the two models where a sharp gradient is apparent in the tomographic model. The apparent seismic velocities reported by the tomographic inversion and the time-term inversion differ. This is a result of the time-term inversion calculating a constant value for each layer, that best fits the distance-time plots. Typically, seismic velocity increases with depth as the geological units become more competent and the tomographic inversion can capture these subtle variations with depth. Hence, while the general trends in the interfaces between velocity contrast should be similar the apparent seismic velocities tend not to match between these models. This will generally be the case for all the profiles acquired, therefore we will only draw attention to significant anomalies from this point on.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. These velocity ranges are constant for each for the thirteen P-wave refraction profiles and are outlined in the table below in Table 4-1. The layered earth model, lower portion of Figure 4-2, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth to competent bedrock varies between 12 to 47 feet below ground surface (bgs). The shallowest depths occur towards the southeast of the profile, with a sharp increase in depth between 10 and 60 feet along the profile. Depth to the competent bedrock then remains reasonably constant across the profiles, apart from a slight ridge between 240 and 320 feet along the profile.

Table 4-1. Assigned Apparent Seismic Velocities and Color Shades for the Layered Earth Model

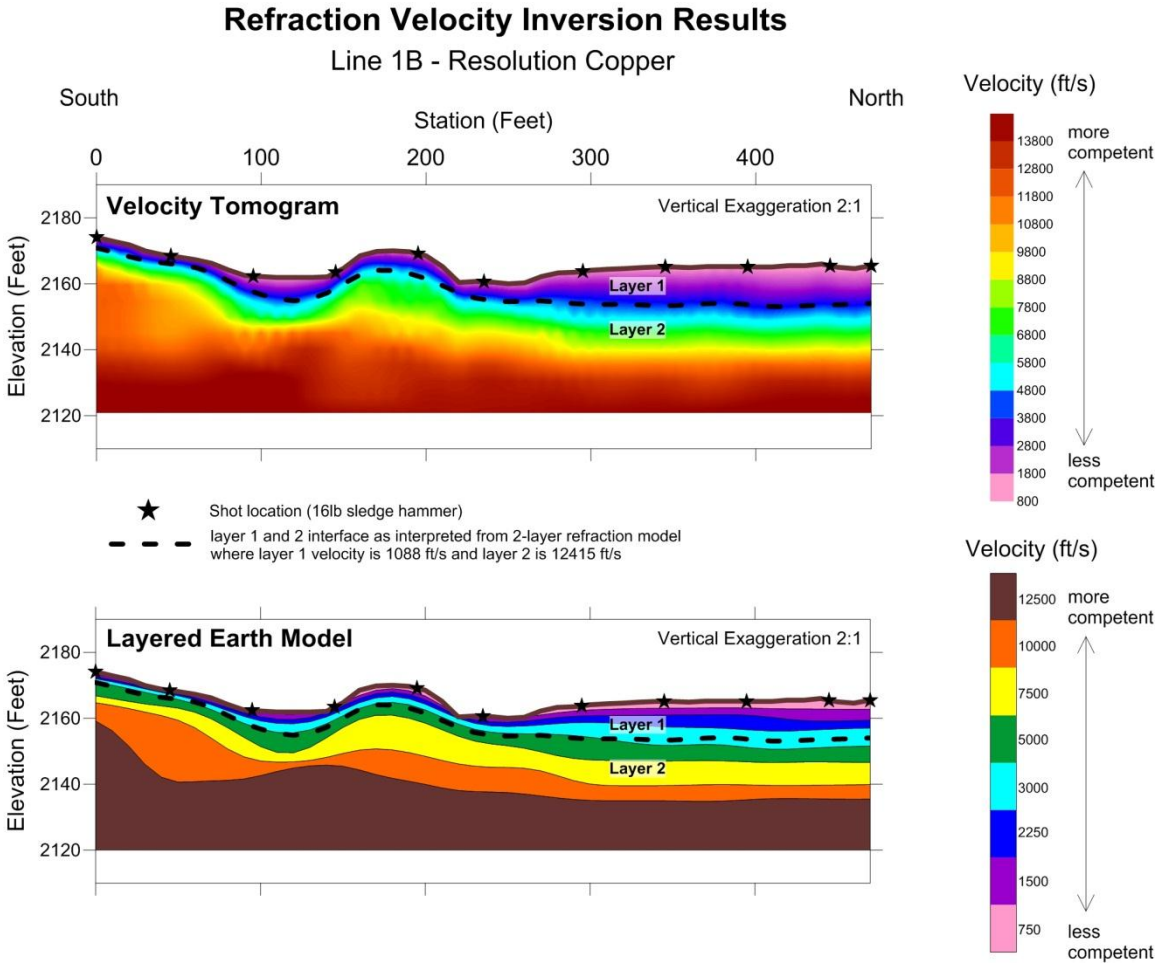
Apparent Seismic Velocity (ft/s)	Assigned Color
750 – 1500	
1500 – 2250	
2250 – 3000	
3000 – 5000	
5000 – 7500	
7500 - 10000	
10000 - 12500	
>12500	

4.1.2 Profile 1B

Figure 4-3 displays the results from Profile 1B, which was acquired in a south to north direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 1,088 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged

from 2.4 to 12.4 feet, with an average of 7.5 feet. Maximum thicknesses of Layer 1 are observed approximately between 420 and 440 feet along the spread. Layer 2 has an average apparent velocity of 12,415 ft/s, which is at the lower limit for competent bedrock based on estimates for this site. Based on the geology in the vicinity of Profile 1B, Layer 2 could represent a the Pinal Schist unit. However, since the 12,500 ft/s value is based on a conservative lower limit for the entire site, it is a slow value for competent schist and therefore Layer 2 likely represent a weathered layer of this material.

Figure 4-3 Profile 1B Results.



The low apparent seismic velocity contours of the tomographic inversion results, upper portion of Figure 4-2, display a good agreement with the two layer model. Topographic variations in the velocity structure of the near surface vary smoothly allowing for the good agreement between the two models. The tomographic results indicate that the apparent seismic velocity of Layer 2 for the time-term inversion may have been an overestimate based on the calculated depth for the Layer 1 and 2 interface. This potentially demonstrates that a 2 layer model was not adequate for

the subsurface along this profile. However, it can be problematic to identify distinct interfaces between layers in the distance–time plots (Figure 3-2), especially when weathered layers are present or additional information about the subsurface is absent.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-3, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth to competent bedrock varies between 14.9 to 30.5 feet below ground surface (bgs), with an average depth of 25.6 feet (bgs). The shallowest depths occur towards the south of the profile, with a sharp increase in depth between 10 and 40 feet along the profile. Depth to the competent bedrock then remains reasonably constant across the profiles, apart from a slight rise between 120 and 140 feet along the profile. As mentioned previous, there is a significant difference in the depth to this competent bedrock from the tomographic inversion and the top of Layer 2 from the time-term inversion. This illustrates the importance of acquiring good quality data necessary for the tomographic inversion which can provide increased resolution in the velocity models in areas where additional subsurface information is limited.

4.1.3 Profile 1C

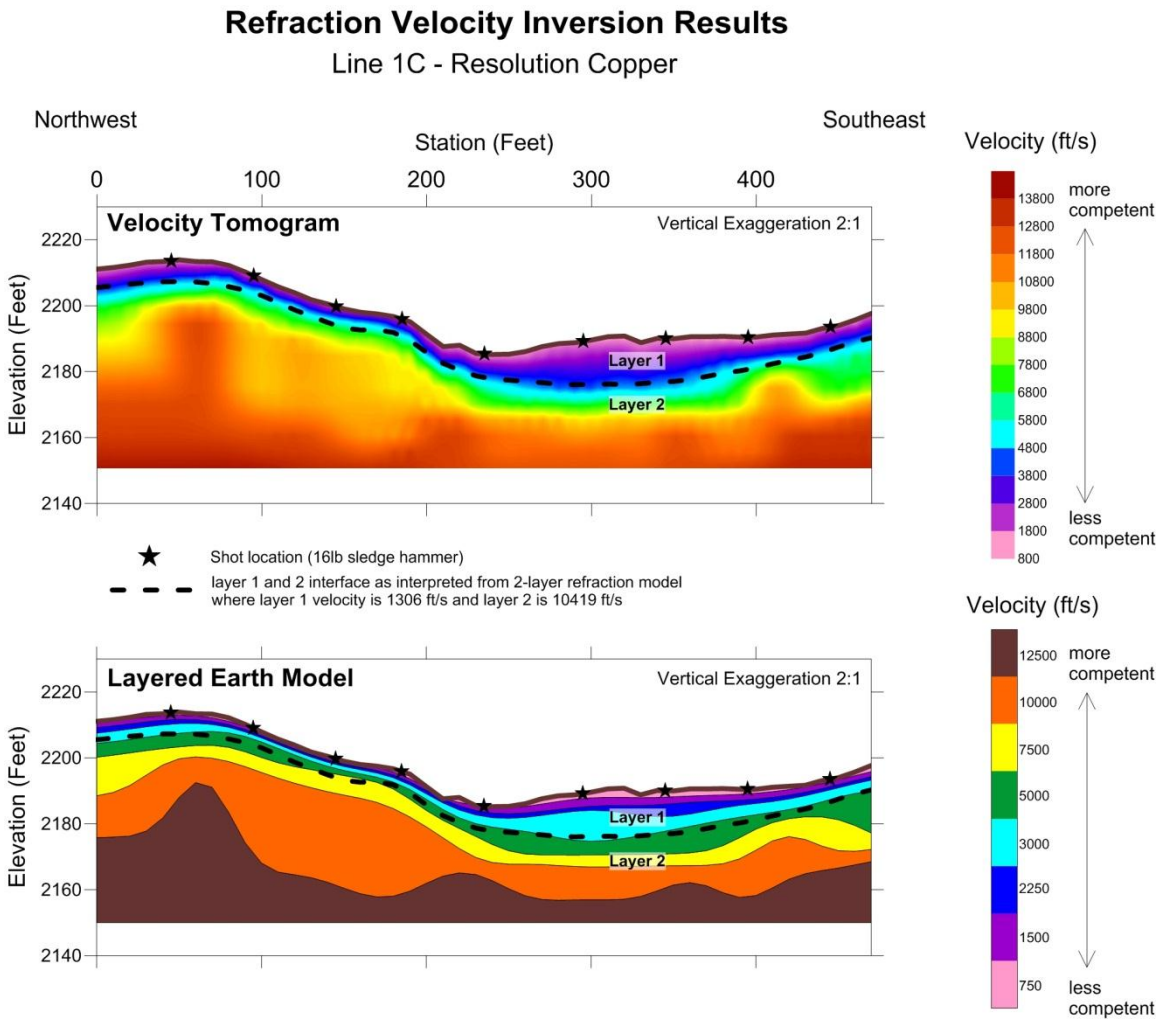
Figure 4-4 displays the results from Profile 1C, which was acquired in a northwest to southeast direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 1,306 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 4.8 to 14.7 feet, with an average of 8.1 feet. Maximum thicknesses of Layer 1 are observed approximately between 280 and 370 feet along the spread. Layer 2 has an average apparent velocity of 10,419 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 1C, Layer 2 could represent a weathered layer of the Pinal Schist unit.

Again a good agreement is observed between the low apparent seismic velocity contours of the tomographic inversion results, upper portion of Figure 4-4, and the two layer model. A thin near surface low velocity layer is observed in the first half of the profile, this increases in thickness as we approach and cross the creek bed, thinning again once topography increases. The near surface velocity contours vary smoothly across the length of the profile, allowing for the good agreement between the two models.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-4, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent

seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth to competent bedrock varies between 20.9 to 40.3 feet below ground surface (bgs), with an average depth of 31.3 feet (bgs). The shallowest depths occur towards the northwest of the profile, with a ridge displaying a sharp decrease in depth occurring between 60 and 70 feet along the profile. Depth to the competent bedrock then drops off and remains reasonably constant across the profile, with two slight rises at around 230 and 360 feet along the profile, before decreasing again beyond 430 feet.

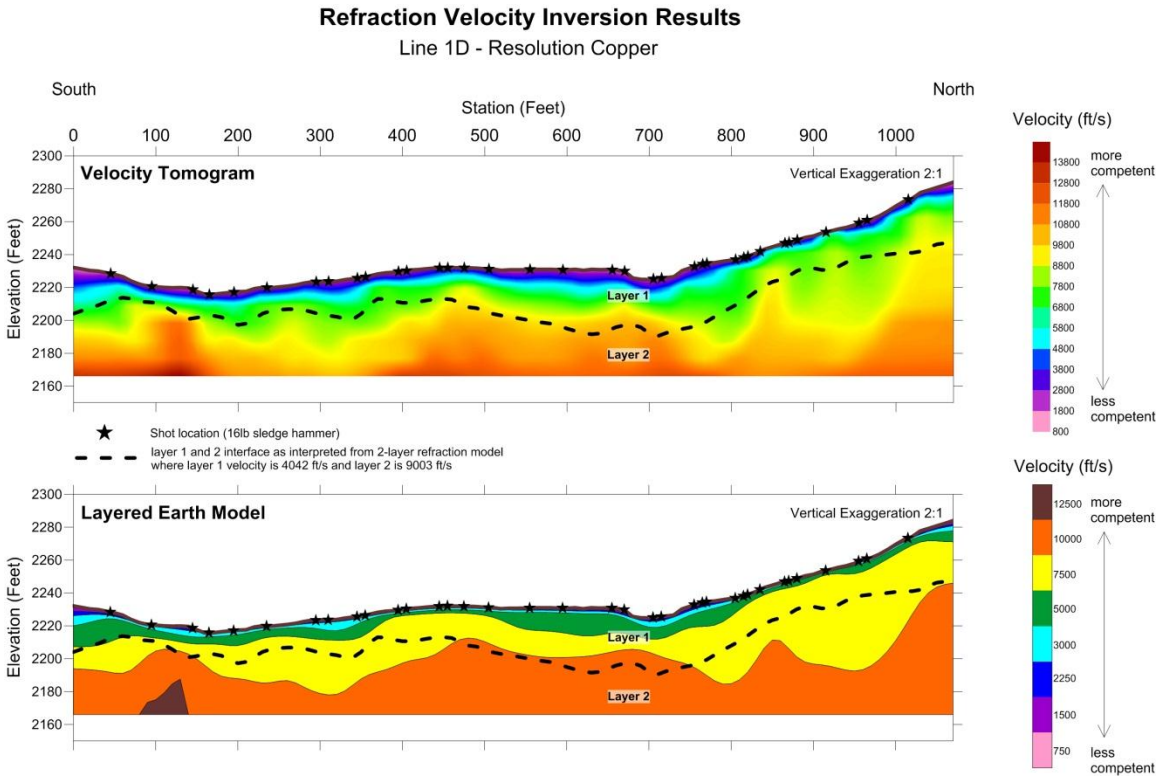
Figure 4-4 Profile 1C Results.



4.1.4 Profile 1D

Figure 4-5 displays the results from Profile 1D, which was acquired in a south to north direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 4,042 ft/s, which based on typical reported literature values is high for unsaturated alluvium but is slow for weathered bedrock, and might be indicative of more consolidated unsaturated alluvium or increased weathering of the underlying bedrock. Thickness of Layer 1 ranged from 9.7 to 39.5 feet, with an average of 24.0 feet. The thicknesses of Layer 1 varies across the profile, the most consistent thickening of this layer is associated with the creek bed, observed approximately between 600 and 770 feet along the spread. Layer 2 has an average apparent velocity of 9,003 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. The geology in the vicinity of Profile 1D is more complex and Layer 2 could represent a weathered layer of either the Pinal Schist, Mescal Limestone, or Dripping Spring Quartzite. Based on the previous profiles in the area the apparent seismic velocities appear low to be weathered Pinal Schist.

Figure 4-5 Profile 1D Results.



The tomographic inversion results, upper portion of Figure 4-5, and the two layer model do not display a good agreement for this profile. A major difference in the tomographic results is the thinner near-surface low velocity layer compared to the other profiles. This corresponds well with observations in the field, where good geophone placement was more difficult along this line due to hard compacted surface and bedrock was observed outcropping in multiple locations along the spread. Therefore, with the increase in velocity calculated for Layer 1 it may be representing a weathered bedrock player. In addition, the tomographic model displays sharp horizontal gradients in velocity in the vicinity of the two layer interface which the time-term inversion has difficulty coping with in the model.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-5, provides a visual aid to indirectly determining the ease of rippability of the material with depth. In general this profile displays more competent material in the near surface than the previous profiles in this area. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, only a small portion of the tomographic model appears to indicate depth to competent bedrock has been reached. This region is located between 90 to 130 feet along the profile. This may indicate that the seismic velocity of the underlying bedrock is much lower, typically limestones possess lower velocities than igneous and other hard rock materials. Alternatively, the weathered layer could be much thicker across this profile and the model represents varying degrees of weathered bedrock.

4.2 AREA 2

Area 2 consisted of three profiles, B though D (Figure 4-6). Profile 2A was omitted due to access problems. All three profiles were 470 feet in length, and were orientated perpendicular to the direction of the major creek bed they were targeting, with the center point of the spread located approximately in the middle of the channel. Thirteen shot locations were acquired along each of these profiles.

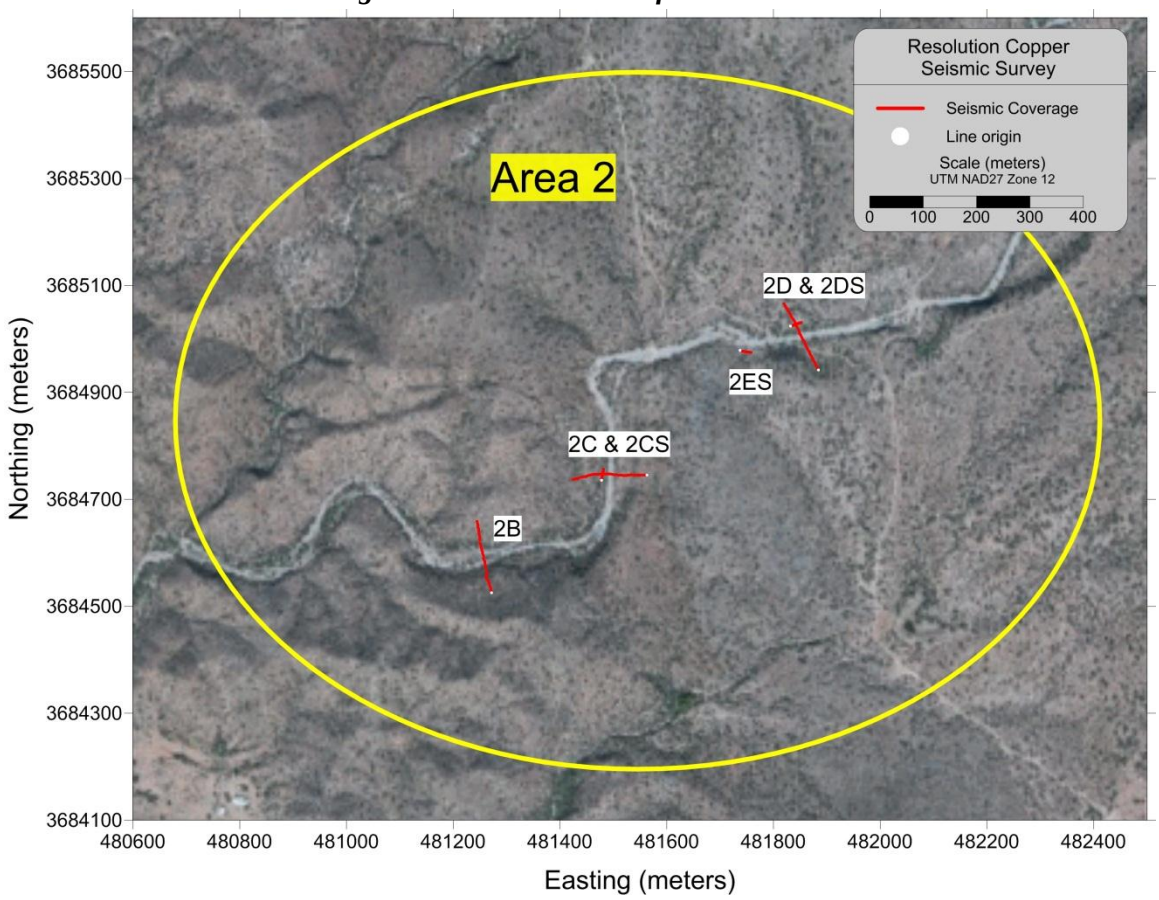
4.2.1 Profile 2B

Figure 4-7 displays the results from Profile 2B, which was acquired in a south to north direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 821 ft/s, which based on typical reported literature values would be indicative of unsaturated loose alluvium or surficial deposits. Thickness of Layer 1 ranged from 4.4 to 10.5 feet, with an average of 7.1 feet. The thickness of Layer 1 is fairly constant across the spread, it thins around the break in slope at 130 feet along the profile and beyond the break in slope at 330 feet along the profile. Layer 2 has an average apparent velocity of 9855 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or

more competent alluvial deposits. Based on the geology in the vicinity of Profile 2B, Layer 2 could represent a weathered layer of the Pinal Schist unit.

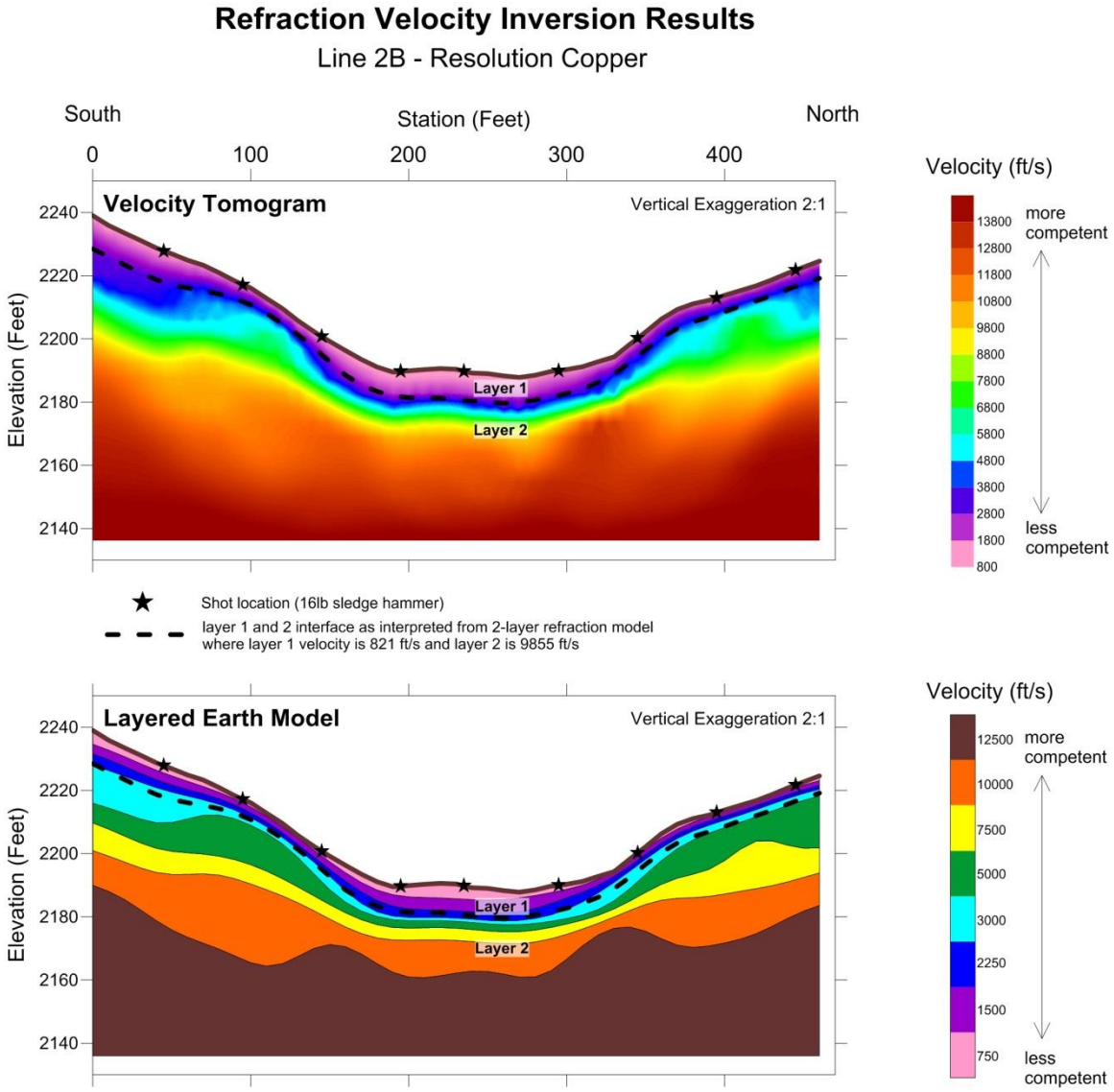
In general, the two layer model shows good agreement with the contoured velocity values, upper portion of Figure 4-7. At the southern end of the profile we observe a divergence between the two models where a sharp gradient is apparent in the tomographic model.

Figure 4-6 Area 2 Profile Locations.



Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-7, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth to competent bedrock varies between 17.9 to 51.7 feet below ground surface (bgs), with an average depth of 36.1 feet (bgs). Depth to the competent bedrock loosely mirrors the surface topography, with two slight rises located at 170 and 330 feet along the profile, which coincide with the break in slope from hill slope to creek bed.

Figure 4-7 Profile 2B Results.

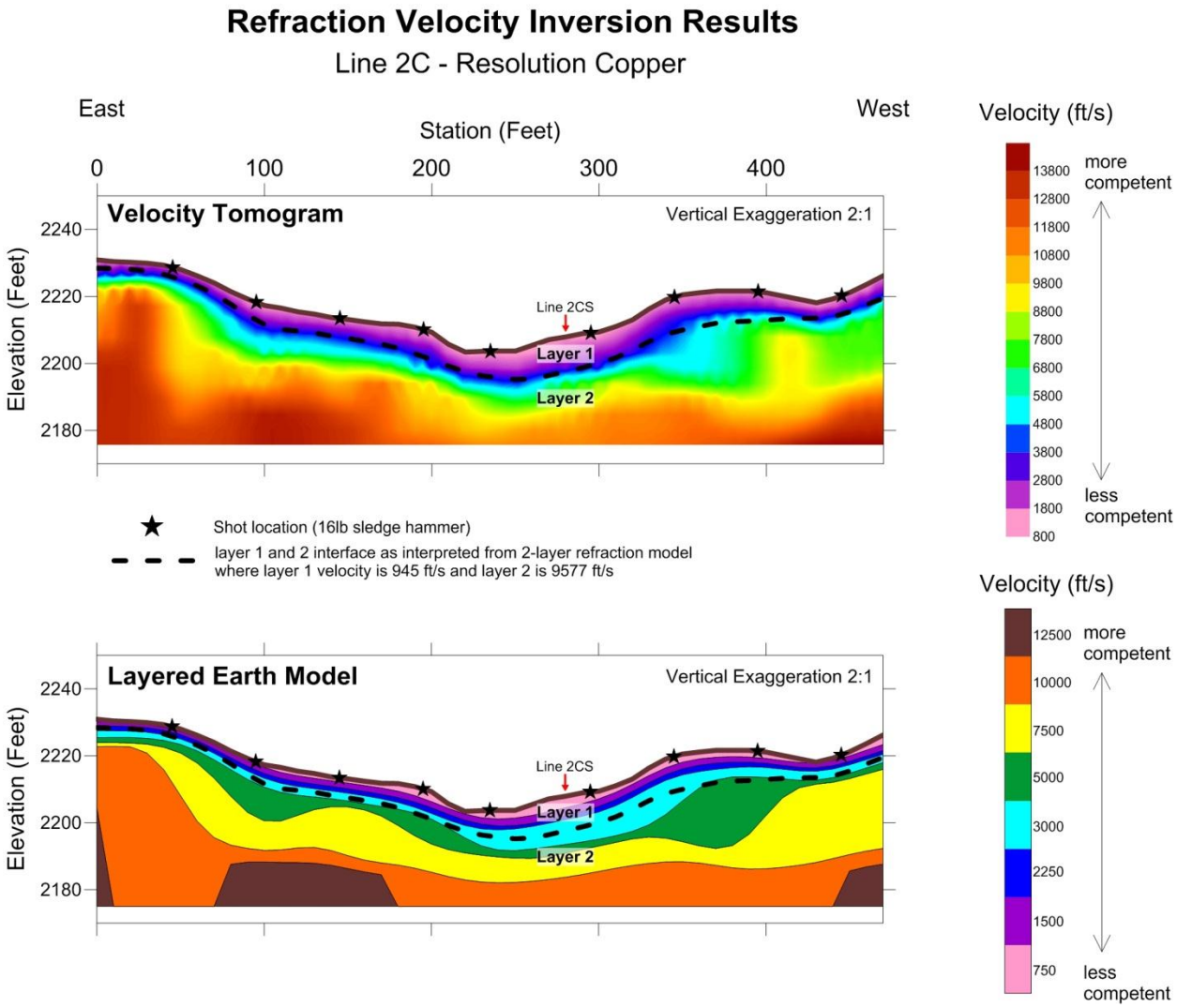


4.2.2 Profile 2C

Figure 4-8 displays the results from Profile 2C, which was acquired in an east to west direction, the intersection of the MASW Profile 2CS is displayed for comparison. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 945 ft/s, which based on typical reported literature values would be indicative of unsaturated loose alluvium or surficial deposits. Thickness of Layer 1 ranged from 2.1 to 10.7 feet, with an average of 6.7 feet. The thickness of Layer 1 is fairly constant across the spread, it thins towards the east end of the spread at distances <100 feet along the profile. Layer 2 has an

average apparent velocity of 9577 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 2C, Layer 2 could represent a weathered layer of the Pinal Schist unit.

Figure 4-8 Profile 2C Results.



The low apparent seismic velocity contours of the tomographic inversion results, upper portion of Figure 4-2, display a good agreement with the two layer model. Topographic variations in the velocity structure of the near surface vary smoothly allowing for the good agreement between the two models.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-7, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent

seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, only a few small portions of the tomographic model appear to indicate depth to competent bedrock has been reached. These regions are located between 0 to 10, 80 to 170, and 450 to 470 feet along the profile, where the average depth to the competent bedrock is 37.9 feet (bgs). This may indicate we have not imaged down to the competent bedrock along this profile, and the depth of penetration for this model is reduced compared to the previous results. This could be the result of increased noise along this profile (it was raining on the day of acquisition, which increases background noise), subsurface seismic velocity structure affecting ray paths, or surface conditions affecting the propagation of the sledgehammer blows reducing energy input into the ground.

4.2.3 Profile 2D

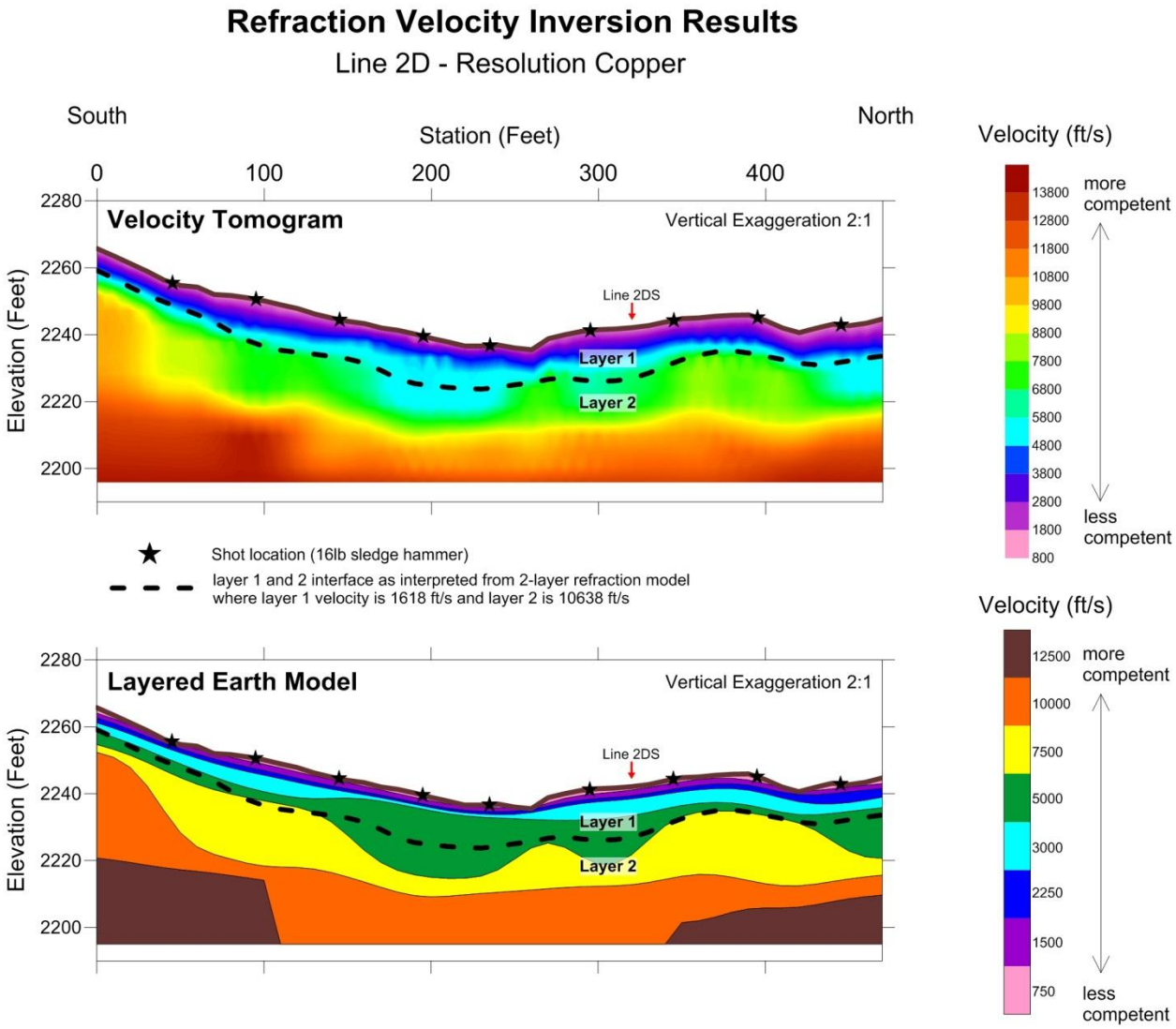
Figure 4-9 displays the results from Profile 2D, which was acquired in an south to north direction, the intersection of the MASW Profile 2DS is displayed for comparison. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 1,618 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 6.5 to 15.5 feet, with an average of 11.5 feet. The thickness of Layer 1 is fairly constant across the spread, it thins towards the east end of the spread at distances <100 feet along the profile. Layer 2 has an average apparent velocity of 10,638 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 2D, Layer 2 could represent either a weathered or competent layer of the Conglomerate unit.

In general, the two layer model shows good agreement with the contoured velocity values, upper portion of Figure 4-9. We observe a slight divergence between the two models between 150 and 250 feet along the profile. In this region a sharp gradient is apparent in the tomographic contours, with low velocity material appearing deeper in the model space.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-7, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, only a few small portions at each end of the tomographic model appear to indicate depth to competent bedrock has been reached. These regions extend between 0 to 100 and 350 to 470 feet along the profile, where the average depth to the competent bedrock is 38.4 feet (bgs). This may indicate we have not imaged down to the competent bedrock along this profile. However, the underlying

geology could be conglomerate in this area which has a much lower value to the range of possible seismic velocities, 6,500 – 14,700 ft/s. Therefore the average value of 12,500 ft/s used to determine competent bedrock may be too high in this case and the actual boundary could be taken as the 7,500 (yellow shade) or 10,000 (orange shade) ft/s layered earth model contour. Without further information on the in-situ weathered and competent conglomerate seismic velocities it is difficult to provide an true assessment.

Figure 4-9 Profile 2D Results.

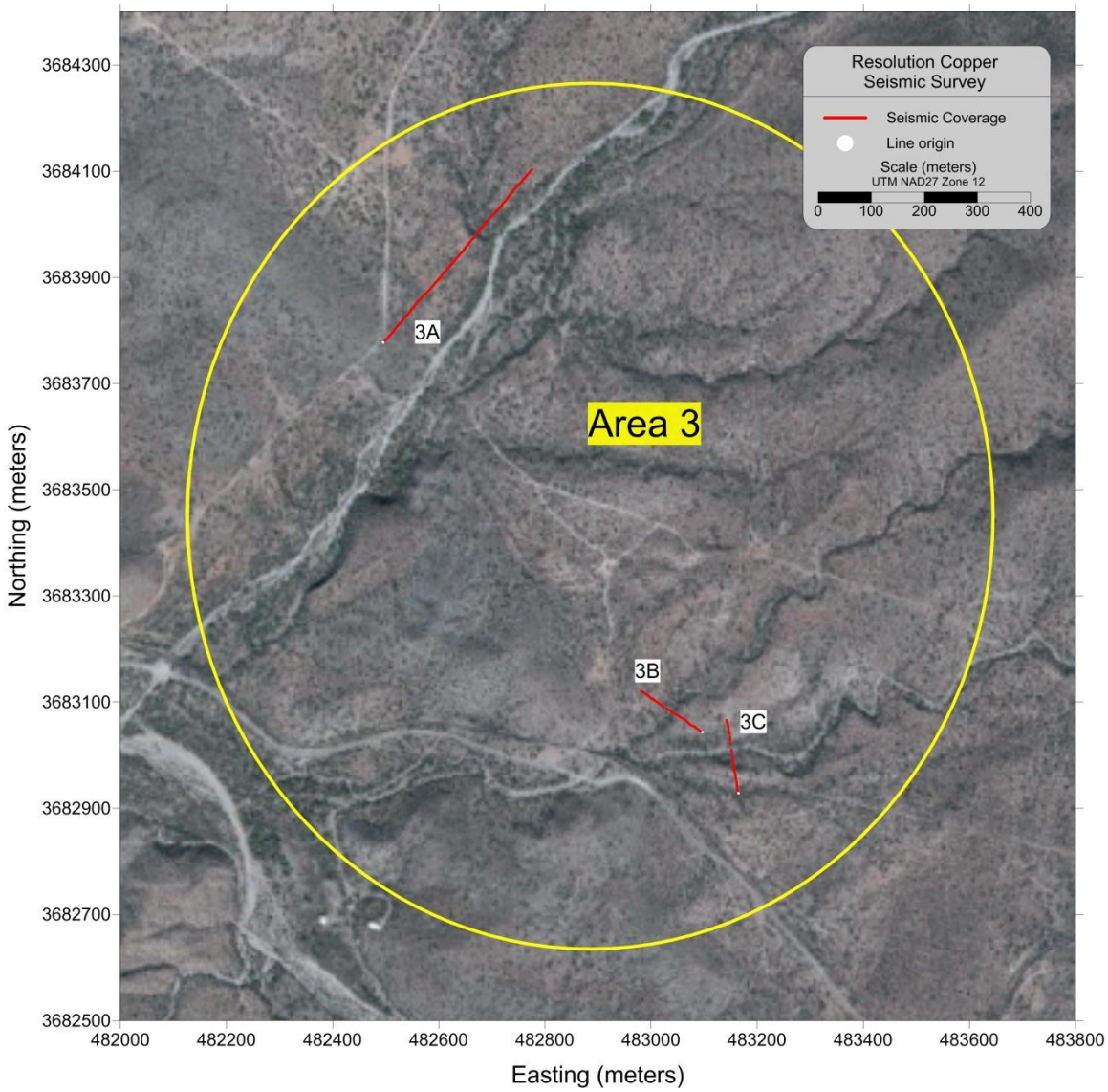


4.3 AREA 3

Area 3 consisted of three profiles, A though C (Figure 4-10). Profile 3A was 1,430 feet in length, and profiles 3B and 3C were both 470 feet in length. All three profiles were orientated perpendicular to the direction of the minor creek beds they were targeting, with the center point

of the spread located approximately in the middle of the channel for profiles 3B and 3C and approximately 60% along the length of the profile for Profile 3A. Fifty-one shot points were acquired along Profile 3A and thirteen shot locations were acquired along each Profiles 3B and 3C.

Figure 4-10 Area 3 Profile Locations.

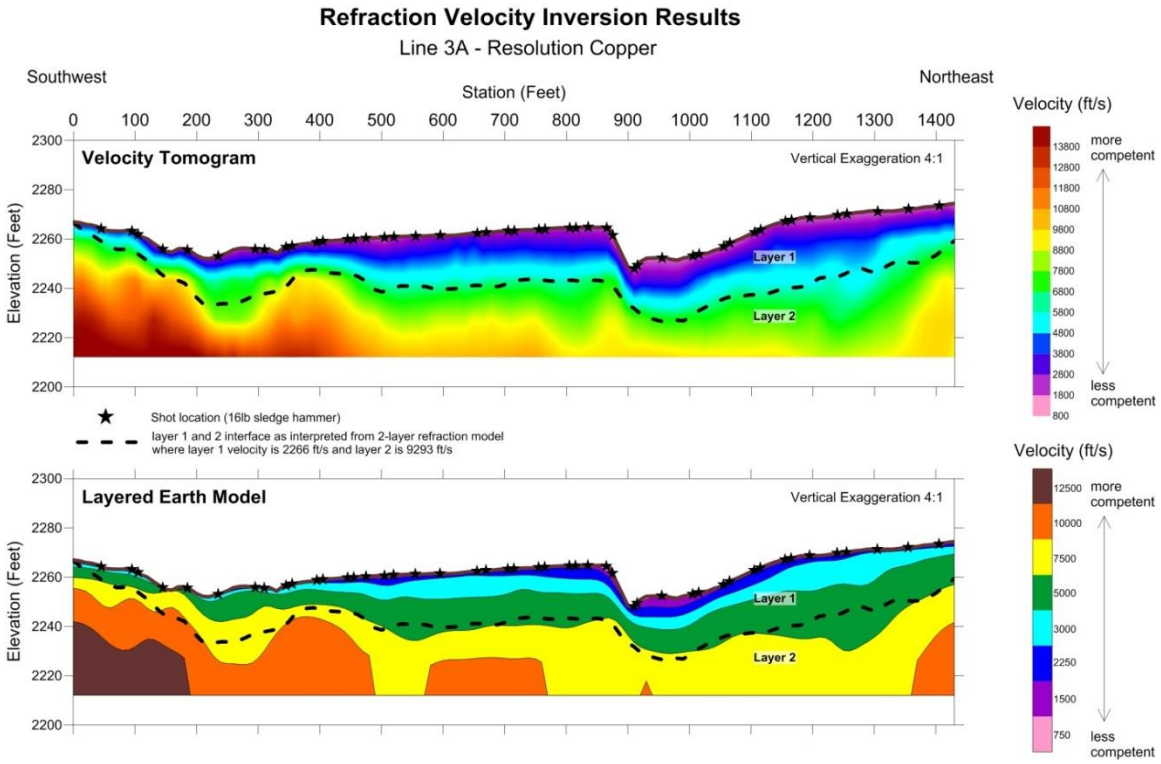


4.3.1 Profile 3A

Figure 4-11 displays the results from Profile 3A, which was acquired in an southwest to northeast direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 2,266 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of

Layer 1 ranged from 0.3 to 28.1 feet, with an average of 19.1 feet. The thickness of Layer 1 varies across the spread, it is practically non-existent at the beginning of the profile, with maximum thicknesses at 950 and 1170 feet along the profile. Layer 2 has an average apparent velocity of 9.293 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 3A, Layer 2 could represent either a weathered or competent layer of the Conglomerate unit, or a weathered layer of the Basalt unit.

Figure 4-11 Profile 3A Results.



In general, the two layer model shows good agreement with the contoured velocity values, upper portion of Figure 4-11. We observe a slight divergence between the two models between 100 and 400 feet along the profile. In this region several sharp gradients are apparent in the tomographic contours, with low velocity material appearing deeper in the model space, which are difficult for the time-term inversion to model. The southwest portion of the velocity tomogram indicates higher seismic velocities at depth (between 0 and 180 feet along the profile) than the rest of the model, which could indicate the contact between the higher velocity basalt and lower velocity conglomerate units.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-11, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent

seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, only the southwest end of the tomographic model appears to indicate depth to competent bedrock has been reached. This region extends between 0 to 180 feet along the profile, where the average depth to the competent bedrock is 27.4 feet (bgs). This may be indicative that the underlying bedrock in this region of the model is basalt, while the remaining region is competent conglomerate. As we have mentioned previously, conglomerate has a much lower value to the range of possible seismic velocities, 6,500 – 14,700 ft/s. Therefore the average value of 12,500 ft/s used to determine competent bedrock may be too high in this case and the actual boundary could be taken as the 7,500 (yellow shade) or 10,000 (orange shade) ft/s layered earth model contour. Without further information on the in-situ weathered and competent conglomerate seismic velocities it is difficult to provide an true assessment.

4.3.2 Profile 3B

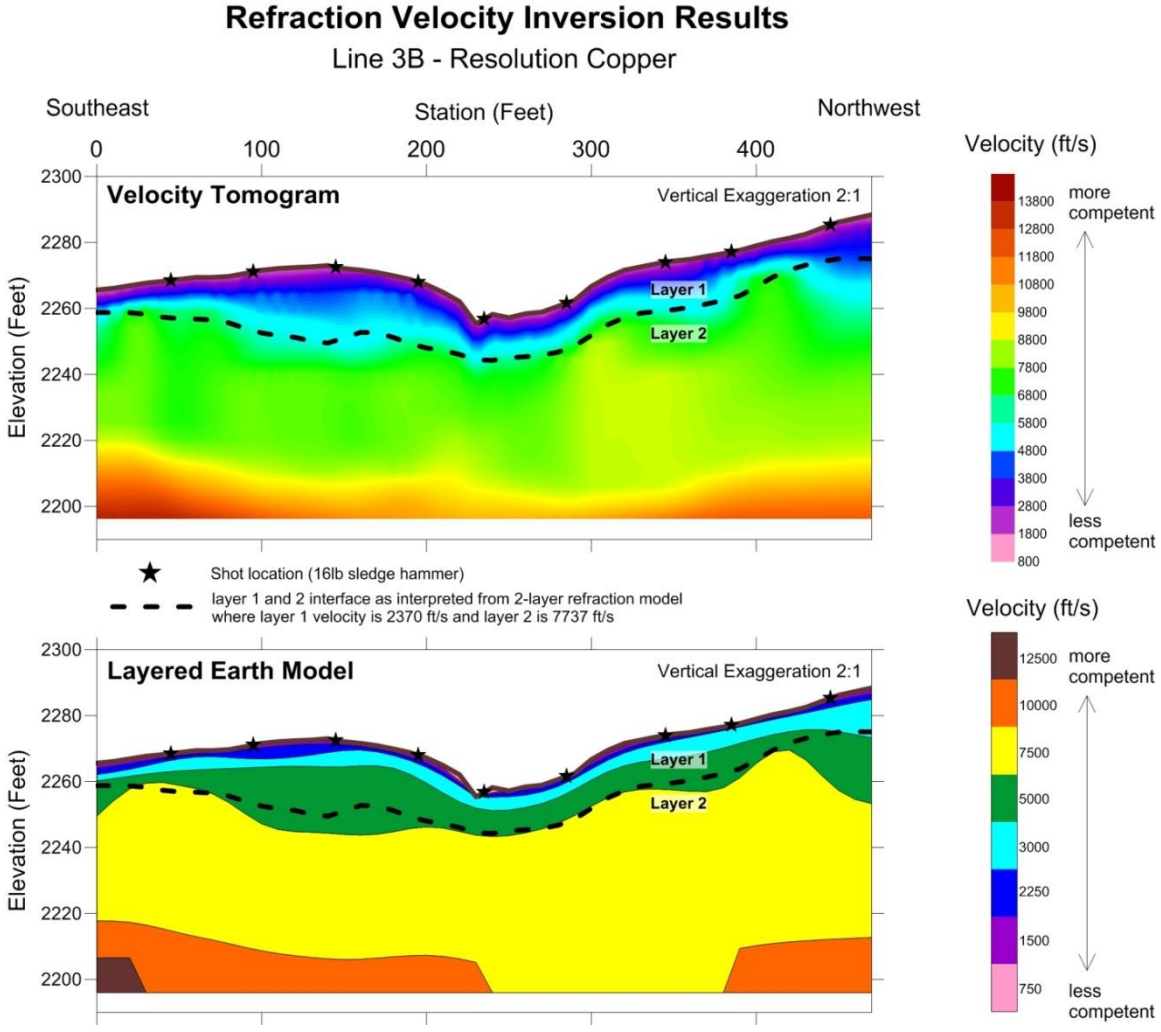
Figure 4-12 displays the results from Profile 3B, which was acquired in an southeast to northwest direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 2,370 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 6.8 to 23.5 feet, with an average of 14.4 feet. The thickness of Layer 1 varies across the spread, it is thinnest at the beginning of the profile, thickening to a maximum thicknesses at 140 feet along the profile, before thinning out and becoming relatively constant thickness at 240 feet along the profile. Layer 2 has an average apparent velocity of 7,737 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 3B, Layer 2 could represent either a weathered or competent layer of the Conglomerate unit.

In general, the two layer model shows good agreement with the contoured velocity values, upper portion of Figure 4-12. We observe a slight divergence between the two models between 50 and 200 feet along the profile, coincident with several sharp gradients are apparent in the tomographic contours. Beneath the cooler low velocity shades the model displays relatively constant velocity before increasing slightly at the penetration depth limit of the model.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-12, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, only the southeast end of the tomographic model appears to indicate depth to competent bedrock has been reached. This region extends between 0 to 20 feet along the profile, where the average

depth to the competent bedrock is 59.6 feet (bgs). As we have mentioned previously, if the underlying bedrock is conglomerate, it has a much lower value to the range of possible seismic velocities, 6,500 – 14,700 ft/s. Therefore the average value of 12,500 ft/s used to determine competent bedrock may be too high in this case and the actual boundary could be taken as the 7,500 (yellow shade) or 10,000 (orange shade) ft/s layered earth model contour. Without further information on the in-situ weathered and competent conglomerate seismic velocities it is difficult to provide an true assessment.

Figure 4-12 Profile 3B Results.



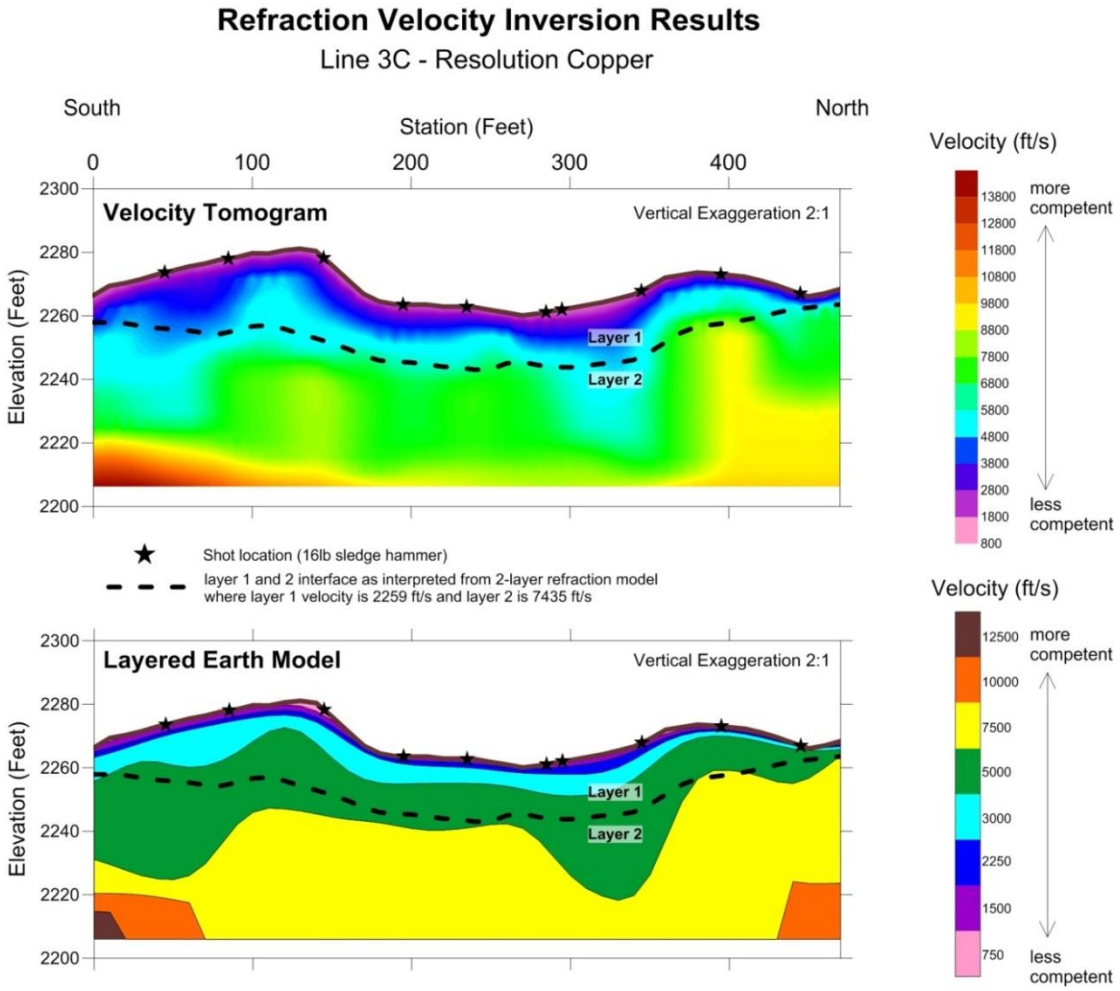
4.3.3 Profile 3C

Figure 4-13 displays the results from Profile 3C, which was acquired in an south to north direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 2,259 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1

ranged from 3.6 to 27.5 feet, with an average of 17.4 feet. The thickness of Layer 1 varies across the spread, it is thinnest at the beginning and end of the profile, with a maximum thicknesses at 140 feet along the profile coinciding with the topographic high of the profile. The thickness is relatively constant (average 18.5 feet) through the creek bed, between 200 and 350 feet along the profile. Layer 2 has an average apparent velocity of 7,435 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 3C, Layer 2 could represent either a weathered or competent layer of the Conglomerate unit.

The tomographic inversion results, upper portion of Figure 4-13, and the two layer model do not display a good agreement for this profile. We observe divergence between the two models between 90 and 450 feet along the profile. There are several sharp gradient in the tomographic contours associated with the cooler low velocity shades in the near-surface. Again, beneath the cooler low velocity shades the model displays relatively constant velocity before increasing slightly at the penetration depth limit of the model.

Figure 4-13 Profile 3C Results.



Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-13, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, only the southeast end of the tomographic model appears to indicate depth to competent bedrock has been reached. This region extends between 0 to 10 feet along the profile, where the average depth to the competent bedrock is 53.3 feet (bgs). As we have mentioned previously, if the underlying bedrock is conglomerate, it has a much lower value to the range of possible seismic velocities, 6,500 – 14,700 ft/s. Therefore the average value of 12,500 ft/s used to determine competent bedrock may be too high in this case and the actual boundary could be taken as the 7,500 (yellow shade) or 10,000 (orange shade) ft/s layered earth model contour. Without further information on the in-situ weathered and competent conglomerate seismic velocities it is difficult to provide an true assessment.

4.4 AREA 4

Area 4 consisted of three profiles, A though C, all three profiles were 830 feet in length (Figure 4-14). They were orientated perpendicular to the direction of the major creek bed they were targeting, with the center point of the spread located approximately in the middle of the channel. Twenty-six shot locations were acquired along each of these profiles.

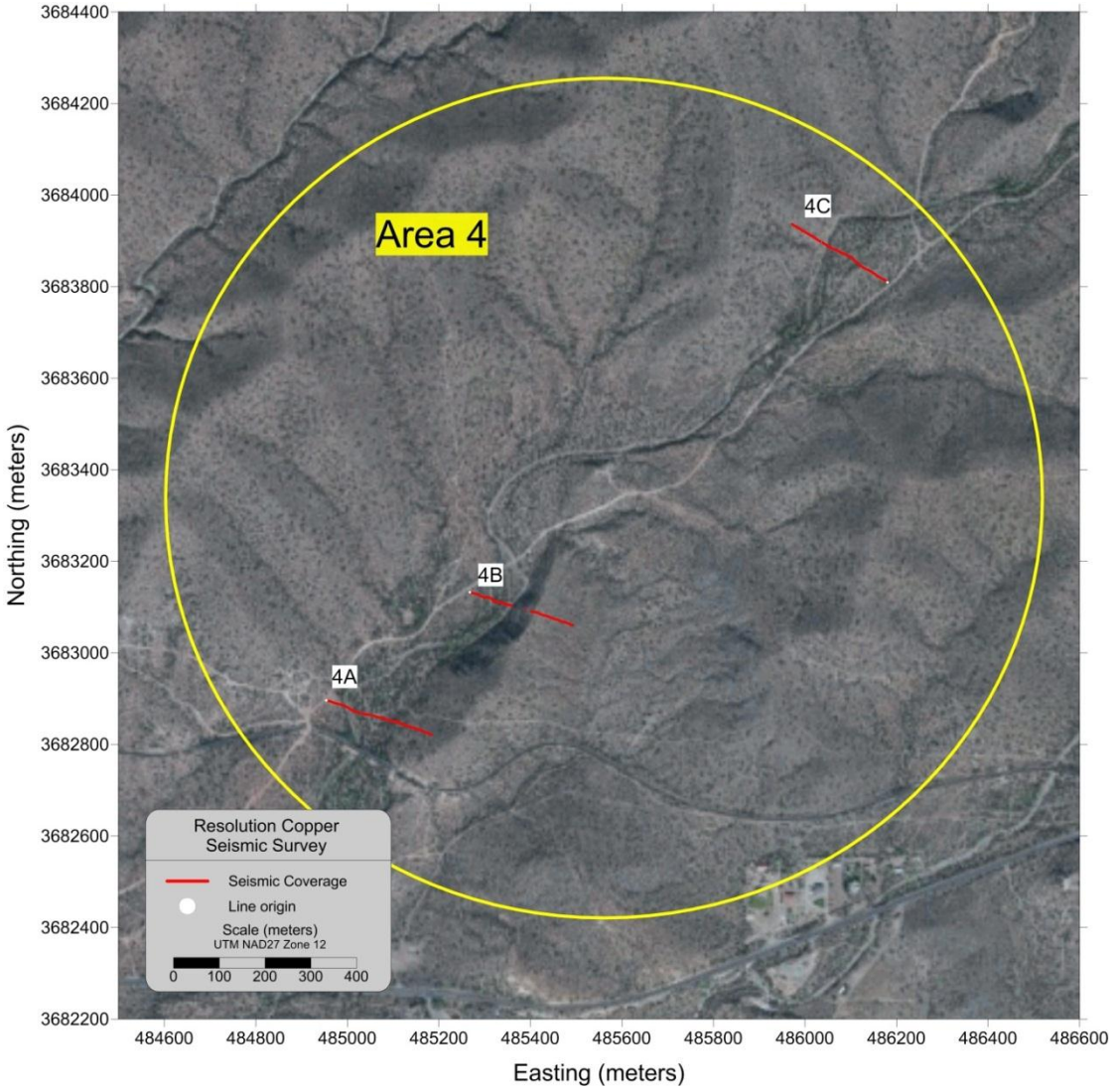
4.4.1 Profile 4A

Figure 4-15 displays the results from Profile 4A, which was acquired in a west to east direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 1,688 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 5.5 to 19.9 feet, with an average of 11.9 feet. The thickness of Layer 1 is relatively constant across the spread, thinning towards the east end of the profile between 700 and 830 feet along the profile. Layer 2 has an average apparent velocity of 8.364 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 3C, Layer 2 could represent either a weathered or competent layer of the Conglomerate unit.

The low apparent seismic velocity contours of the tomographic inversion results, upper portion of Figure 4-15, display a good agreement with the two layer model. Topographic variations in the velocity structure of the near surface vary smoothly allowing for the good agreement between the two models.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-15, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth to competent bedrock varies between 29.1 to 65.5 feet below ground surface (bgs), with an average depth of 43.8 feet (bgs). The shallowest depths occur towards the middle of the profile, around the location of the creek bed. There is a sharp increase in depth between 230 and 290 feet along the profile, where it increases to beyond the penetration depth of the model. Due to the sharp increase in topography towards the east end of the profile, beyond 500 feet along the profile, the information on the 12,500 ft/s layer interface is unreliable due to the lack of resolution at this depth.

Figure 4-14 Area 4 Profile Locations.



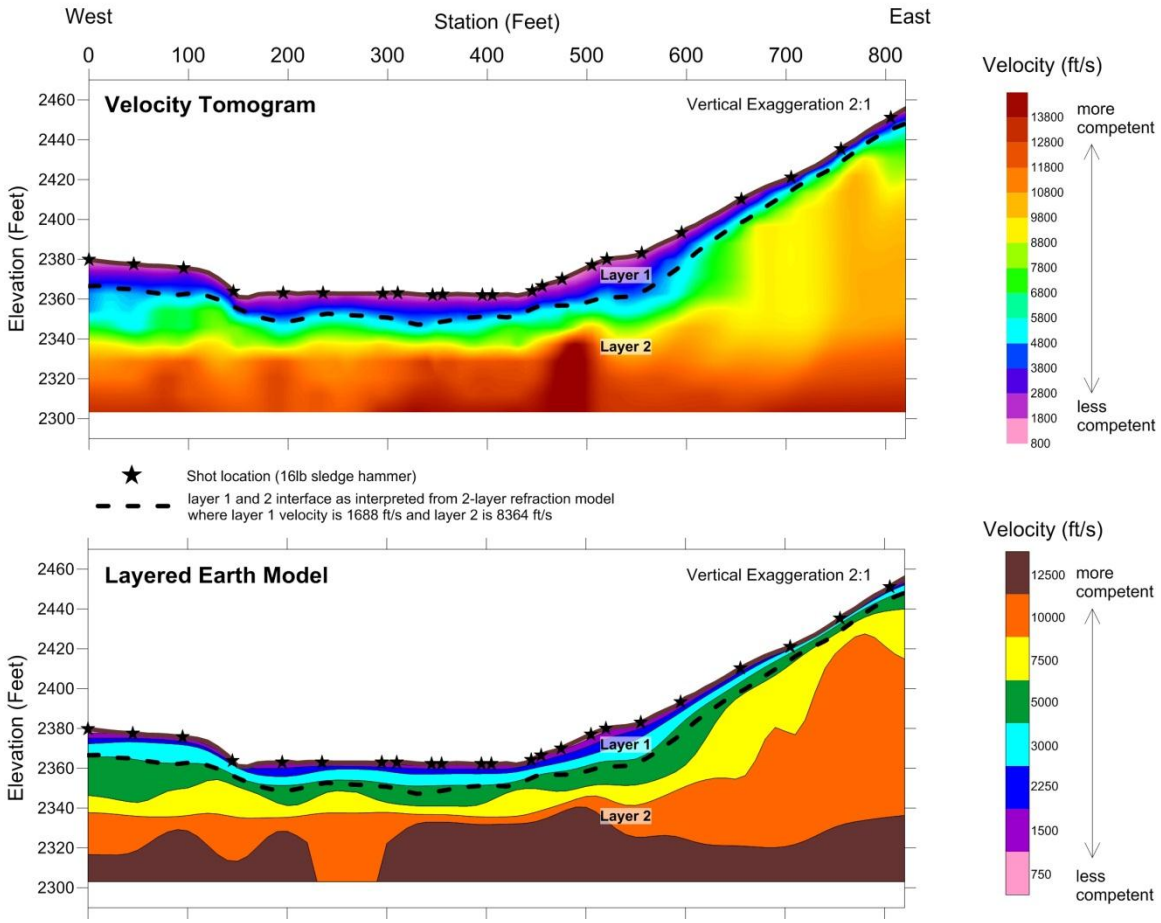


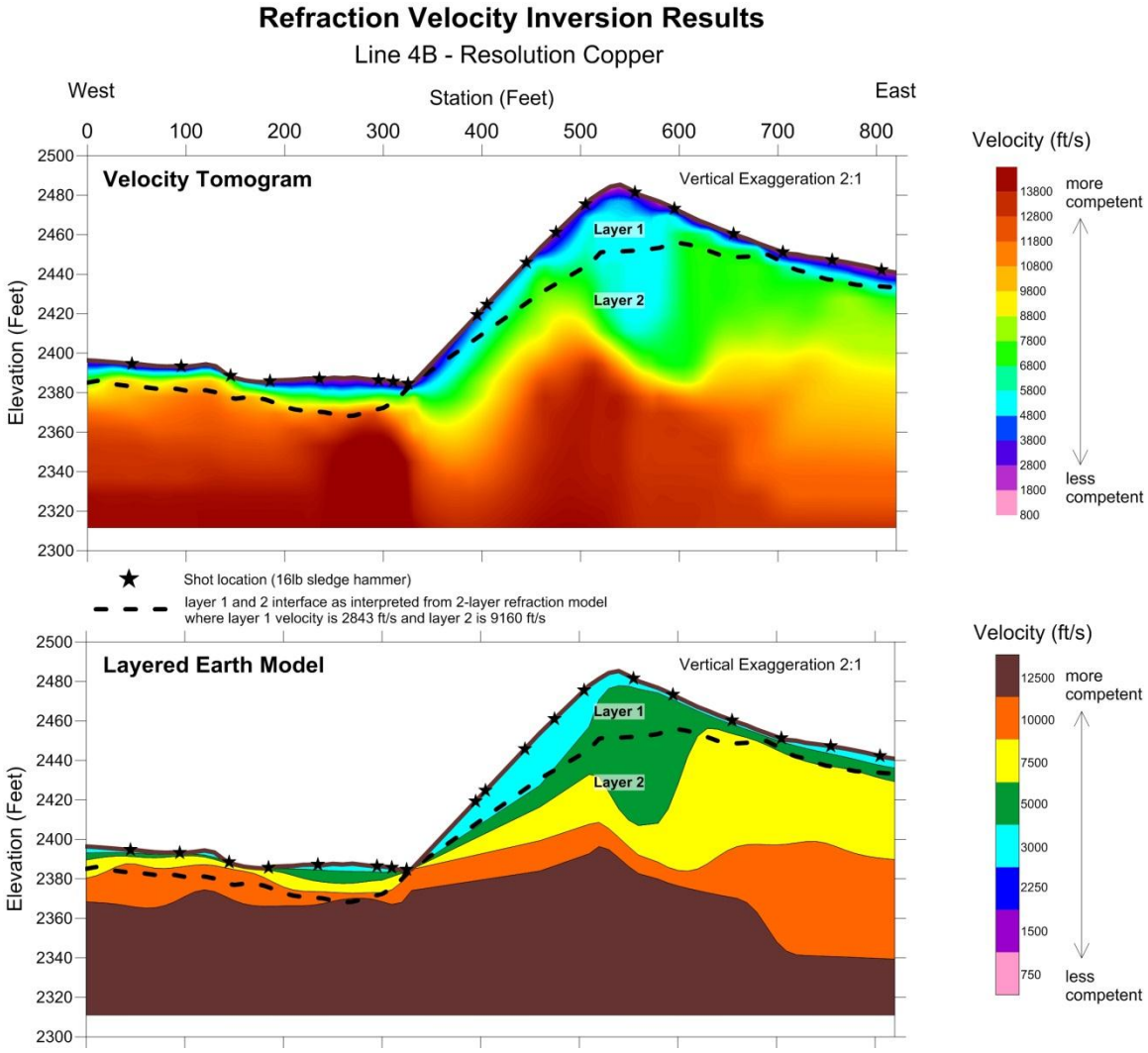
Figure 4-15 Profile 4A Results.

4.4.2 Profile 4B

Figure 4-16 displays the results from Profile 4B, which was acquired in a west to east direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 2,843 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 0.1 to 33.8 feet, with an average of 13.6 feet. The thickness of Layer 1 is relatively constant until 230 feet along the profile, where it thins to practical nothing before thickening to a maximum beneath the topographic high along the profile, before once again thinning towards the the east end of the profile. Layer 2 has an average apparent velocity of 9,160 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 4B, Layer 2 could represent either a weathered or competent layer of the Conglomerate unit, or a weathered layer of the Basalt unit.

The low apparent seismic velocity contours of the tomographic inversion results, upper portion of Figure 4-16, display a mixed agreement with the two layer model. The two layer model is at a greater depth than the cooler low velocity shades at the western end of the profile, between 0 and 230 feet along the profile. The two display good agreement between 230 and 420 feet along the profile and beyond approximately 600 feet along the profile, between these 2 regions a steep gradient is observed in the velocity with horizontal distance, which the time-term inversion struggles to model.

Figure 4-16 Profile 4B Results.



Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-16, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth

to competent bedrock varies between 10.7 to 69.8 feet below ground surface (bgs), with an average depth of 22.7 feet (bgs). Depth to the competent bedrock is relatively shallow on the western side of the profile, with depths increasing once the topography increase up the hill slope. Due to this sharp increase in topography towards the east end of the profile, beyond 500 feet along the profile the information below a depth of approximately 70 feet (bgs) is unreliable due to the lack of resolution at this depth. In addition, resolution suffers on the steep western side of the hill slope due to the topography making it difficult to keep shot points locations a constant distance apart. In the tomographic model and layered earth model of Figure 4-16 we observe some very steep gradients and transitions in the velocity structure around approximately 600 feet along the profile. These gradients coincide approximately with the contact between the conglomerate and basalt units from the geological map, and could represent the higher velocity (weathered) basalt underlying the eastern end of the profile.

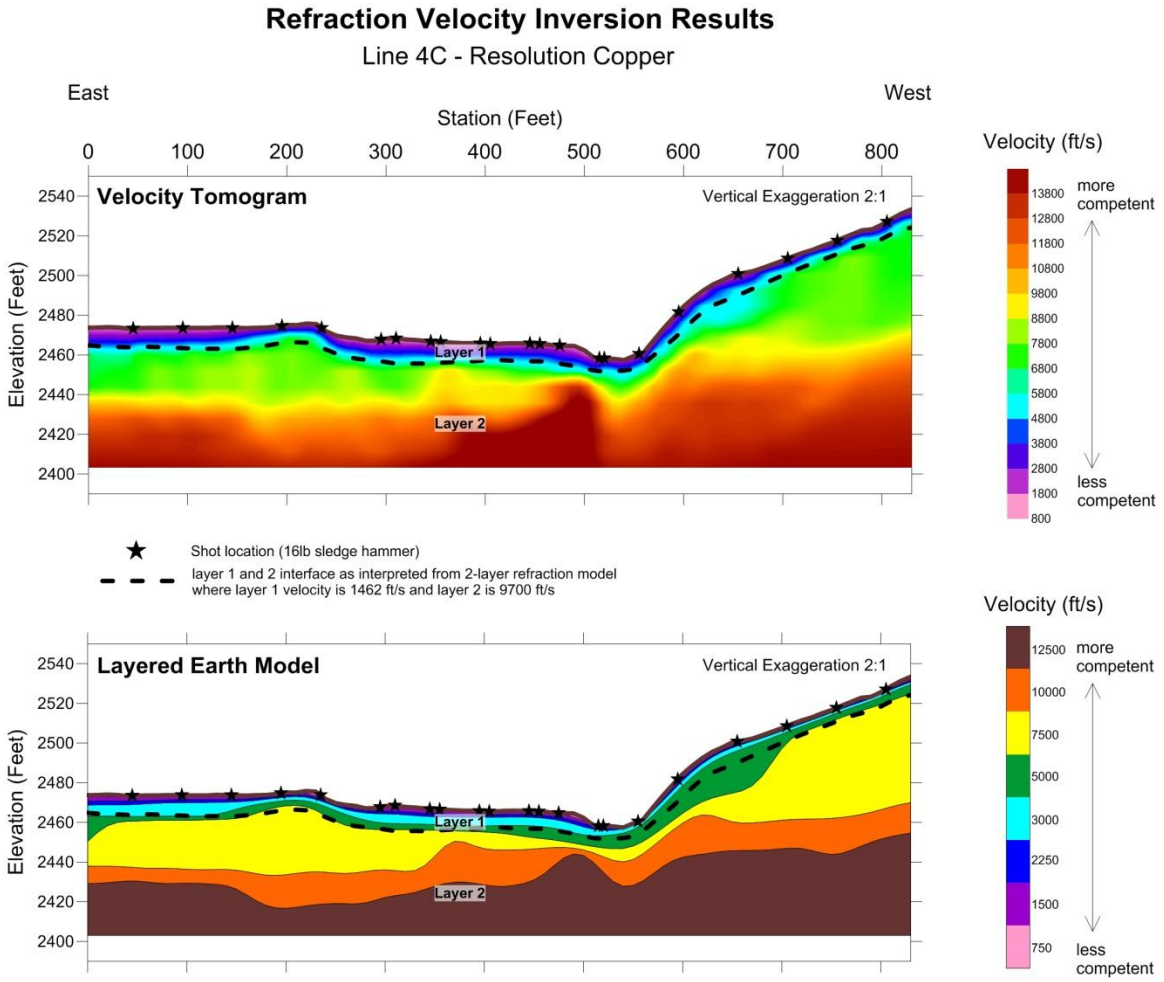
4.4.3 Profile 4C

Figure 4-17 displays the results from Profile 4C, which was acquired in an east to west direction. One refractor was detected and two layers were interpreted for this profile. Layer 1 has an average apparent seismic velocity of 1,462 ft/s, which based on typical reported literature values would be indicative of unsaturated alluvium or surficial deposits. Thickness of Layer 1 ranged from 5.3 to 12.8 feet, with an average of 9.1 feet. The thickness of Layer 1 is relatively constant, thinning briefly under the creek bed between 510 and 570 feet along the profile, and towards the western end of the profile beyond 690 feet along the profile. Layer 2 has an average apparent velocity of 9,700 ft/s, which is slow for competent bedrock and is indicative of weathered bedrock or more competent alluvial deposits. Based on the geology in the vicinity of Profile 4C, Layer 2 could represent a weathered or competent layer of the Conglomerate unit.

The tomographic inversion results, upper portion of Figure 4-17, displays low apparent seismic velocities as cool shades (purple and blue) and high apparent seismic velocities as warm shades (orange and red). The two layer model display a good agreement with the contoured low velocity values. Topographic variations in the velocity structure of the near surface vary smoothly allowing for the good agreement between the two models.

Average velocities from the tomographic inversions are also presented for eight different velocity ranges. The layered earth model, lower portion of Figure 4-17, provides a visual aid to indirectly determining the ease of rippability of the material with depth. The upper apparent seismic velocity bound of the layered model, 12,500 ft/s, is taken to be a conservative estimate for competent bedrock based on the geology across the site. From the layered earth model, depth to competent bedrock varies between 18.6 to 78.8 feet (bgs), with an average depth of 47.5 feet (bgs). The shallowest depths occur beneath the creek bed between 480 and 520 feet along the profile.

Figure 4-17 Profile 4C Results.



4.5 MASW PROFILES

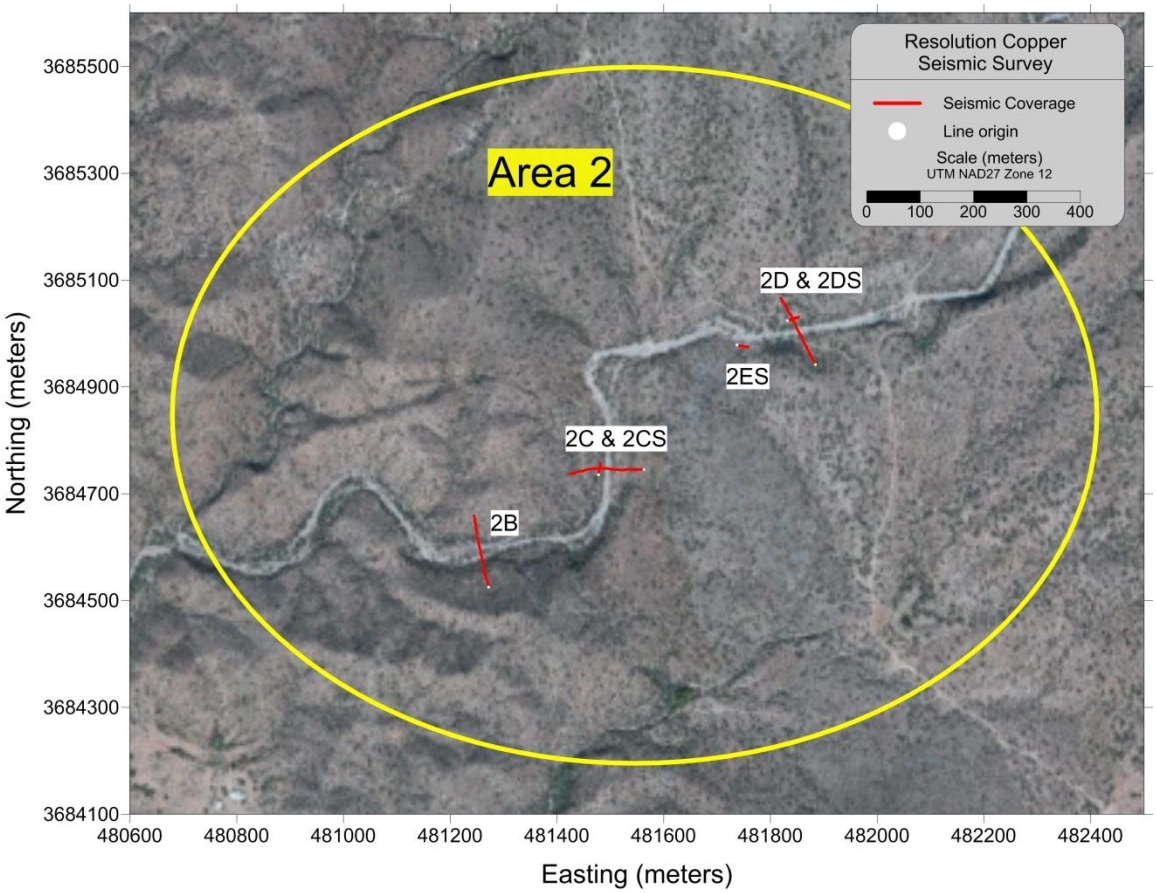
Three short MASW profiles were collected within Area 2. Profile 2CS and 2DS were acquired in the same location as their respective P-wave seismic refraction profiles. The two profiles were aligned orthogonal two the seismic refraction profiles, and positioned out of the creek bed to take advantage of the required minimal topography the terraces provided in this orientation. Profile 2ES was acquired a short distance downstream of Profile 2D, again orientated parallel to the creek, on the terrace above the creek bed for minimal topography variation. These three locations were chosen due to the differing geology underlying each profile:

Profile 2CS - Pinal Schist

Profile 2DS - Conglomerate

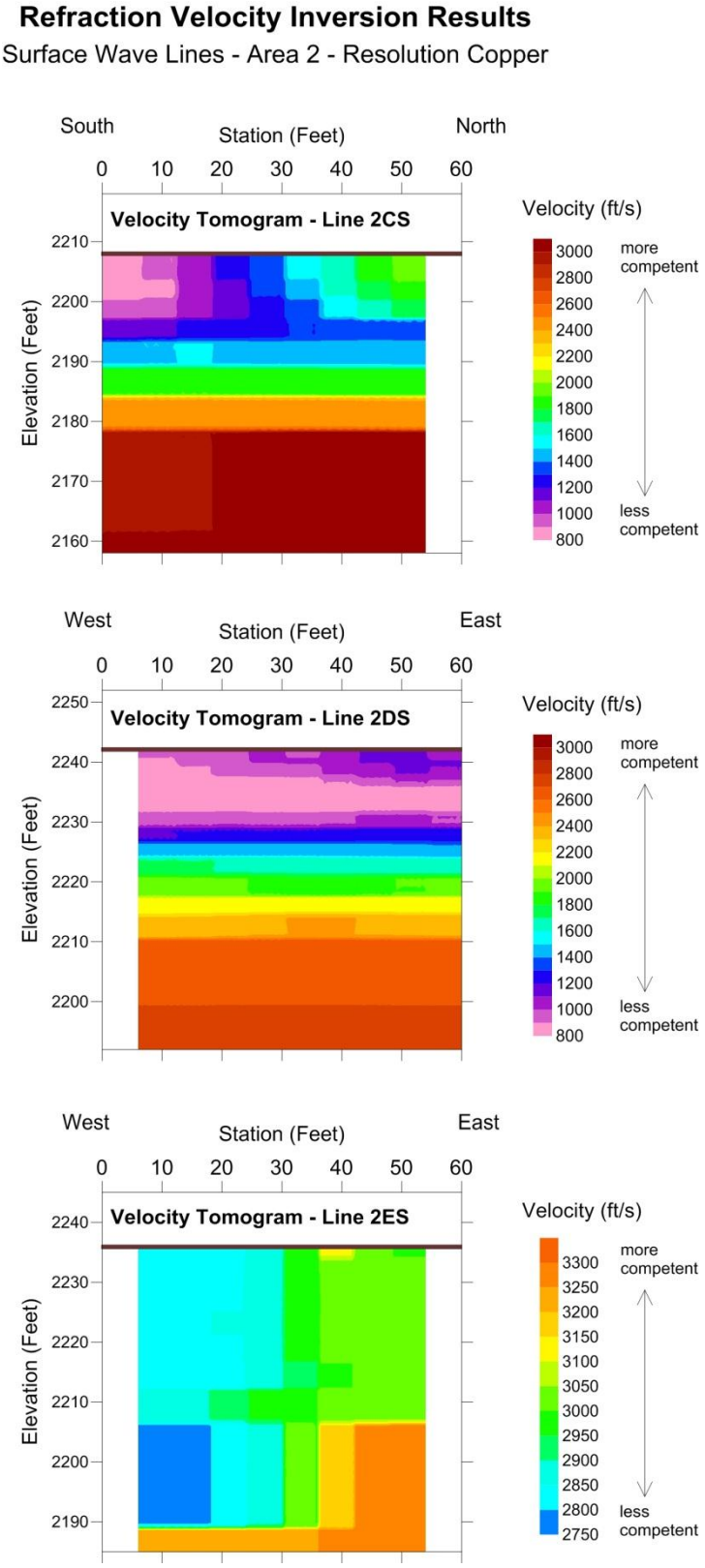
Profile 2ES - Basalt

Figure 4-18 Area 2 Profile Locations, with the 3 MASW Profiles 2CS, 2DS, and 2ES.



The MASW results for the three profiles are displayed in Figure 4-19. The main aim for these profiles was to determine if any variations in shear wave velocity exists in the upper 30 feet of the subsurface. While we are actually modeling the phase velocity of surface waves, this is typically equivalent to 90-95% of the shear wave velocity. Both of Profiles 2CS and 2DS display a general layered structure, with shear wave velocity increasing with depth. The near-surface cooler colors, representing low velocity material, most likely represent the unsaturated alluvium or surficial deposits. The shear wave velocity of this material ranges between 800 and 1600 ft/s. Below approximately 20 feet (bgs) in Profile 2CS and 24 feet (bgs) in Profile 2DS we observe a sharp increase in shear wave velocity possibly indicating a transition to the weathered underlying bedrock material. Beneath this transition the shear wave velocity remains relatively constant; there appears to be a slight horizontal variation in Profile 2CS and shear wave velocity increase slightly towards the bottom of Profile 2DS. The maximum shear wave velocities calculated are 3271 and 2721 ft/s for Profile 2Cs and 2DS respectively. This is as expected since the typically P-wave velocities for the Pinal Schist (Profile 2CS) are greater than those expected for the Conglomerate (Profile 2DS).

Figure 4-19 MASW Results for Profiles 2CS, 2DS, and 2ES.



The MASW results for Profile 2ES display a much tighter range in calculated shear wave velocity, ranging between 2750 and 3300 ft/s. There is no apparent near-surface low velocity layer present, which would tend to indicate the model is responding only to the underlying weathered basalt. This is backed by the poor data quality for this profile, which is a result of the data being dominated by higher modes of surface waves from the hard rock basalt formation (which are discarded in the modeling process). The poor data quality results in the much blockier nature of this velocity tomogram. However, the data shows that the weathered basalt has much higher shear wave velocity, and therefore stiffness than the other two geological units surveyed. It is also much closer to the surface at this profile locations, visually confirmed by the outcrops in the creek bed to the immediate north of this location.

5.0 SUMMARY

Geophysical characterization, in the form of P-wave seismic refraction and Multi-channel Analysis of Surface Waves, was completed in four areas located between 3.5 and 8.0 miles northwest of Superior, AZ. Data were acquired between February 15 and February 20, 2013.

The objectives of the P-wave seismic refraction survey were to:

- Map the top of the buried bedrock surface,
- Determine the thickness of the overlying alluvium,
- Indirectly determine the rippability of the overlying alluvium.

In summary;

The P-wave seismic refractions results from the Time-Term inversion are summarized in Table 5-1.

- The overall P-wave seismic refraction data quality was good. A number of individual shots suffered poor quality data due to meteorological conditions (high winds, rain) or steep topography.
- A single refractor and two distinct velocity layers were detected in all thirteen profiles. The assigned velocities for the majority of Layer 1 profiles ranged between 821 and 2,843 ft/s, with Profile 1D displaying a faster velocity of 4,042 ft/s. The assigned velocities for the majority of Layer 2 profiles ranged between 7,435 and 10,791 ft/s, with Profile 1B displaying a faster velocity of 12,415 ft/s.
- Layer 1 is interpreted as unsaturated alluvium or surficial deposits, and Layer 2 as weathered basalt, Pinal schist, or conglomerate depending on the profile area.
- The tomographic inversion, and resulting layered earth model, results provides a more detailed breakdown of the subsurface velocity structure and indirectly the rippability of the subsurface materials. The velocity structure agrees well with the interpreted underlying geology, for example; Profile 1A to 1C, 2A to 2B display distinct low velocity near-surface layers associated with the alluvium, with high velocity at depth associated with the competent Pinal Schist. Profile 1D displays a very thin low velocity near-surface layer indicating little or no alluvium, with mid-range velocity at depth possible indicating Mescal Limestone or Dripping Spring Quartzite. Profiles 2D, 3A to 3C displays a very thin low velocity near-surface layer indicating little or no alluvium, with low mid-range velocity at depth possible indicating competent Conglomerate. Profile 4A to 4C display distinct relatively thin low velocity near-surface layers associated with the alluvium, with high velocity at depth associated with the competent Conglomerate, this differs from previous profiles where conglomerate velocities were lower possible suggesting a difference in the strength of the rock here.

The objectives of the MASW survey were to:

- Determine the shear wave velocity of the underlying weathered bedrock in the top 10 meters (32 feet) of the subsurface,
- Map any variations in shear wave velocity with depth in the near surface.

In summary;

- Both of Profiles 2CS and 2DS display a general layered structure, with shear wave velocity increasing with depth.
- The near-surface, to an approximate depth of 22 feet (bgs), is interpreted as unsaturated alluvium in both profiles, with a shear wave velocity range of from 800 to 1600 ft/s.

- Beneath this a sharp transition, interpreted as the weathered bedrock interface, occurs, with maximum shear wave velocities of 3271 and 2721 ft/s observed for Profile 2Cs and 2DS respectively. This relationship is as expected since typically P-wave velocities for the Pinal Schist (Profile 2CS) are greater than those expected for the Conglomerate (Profile 2DS). Little variation is observed at depth in the MASW profiles.

- The MASW results for Profile 2ES display a much tighter range in calculated shear wave velocity, ranging between 2750 and 3300 ft/s. There is no apparent near-surface low velocity layer present, which would tend to indicate the model is responding only to the underlying weathered basalt.

Table 5-1. Summary of time-term 2-layer model inversion results for each profile.

Profile	Layer 1 Thickness (ft)			Layer 1		Layer 2	
	Min.	Max.	Av.	Velocity (ft/s)	Interpreted Material(1)	Velocity (ft/s)	Interpreted Material(1)
1A	4.0	21.0	14.0	1,540	Unsaturated Alluvium / Surficial Deposits	10,791	Weathered Pinal Schist
1B	2.4	12.4	7.5	1,088	Unsaturated Alluvium / Surficial Deposits	12,415	Weathered Pinal Schist
1C	4.8	14.7	8.1	1,306	Unsaturated Alluvium / Surficial Deposits	10,419	Weathered Pinal Schist
1D	9.7	39.5	24.0	4,042	Unsaturated Alluvium / Weathered Mescal Limestone or Weathered Dripping Spring Quartzite	9,003	Weathered Mescal Limestone or Weathered Dripping Spring Quartzite
2B	4.4	10.5	7.1	821	Unsaturated Loose Alluvium / Surficial Deposits	9,856	Weathered Pinal Schist
2C	2.1	10.7	6.7	945	Unsaturated Loose Alluvium / Surficial Deposits	9,577	Weathered Pinal Schist
2D	6.5	15.5	11.5	1,618	Unsaturated Alluvium / Surficial Deposits	10,638	Weathered / Competent Conglomerate
3A	0.3	28.1	19.1	2,266	Unsaturated Alluvium / Surficial Deposits	9,293	Weathered / Competent Conglomerate or Weathered Basalt
3B	6.8	23.5	14.4	2,370	Unsaturated Alluvium / Surficial Deposits	7,737	Weathered / Competent Conglomerate
3C	3.6	27.58	17.4	2,259	Unsaturated Alluvium / Surficial Deposits	7,435	Weathered / Competent Conglomerate
4A	5.5	19.9	11.9	1,688	Unsaturated Alluvium / Surficial Deposits	8,364	Weathered / Competent Conglomerate
4B	0.1	33.8	13.6	2,843	Unsaturated Alluvium / Surficial Deposits	9,160	Weathered / Competent Conglomerate or Weathered Basalt
4C	5.3	12.8	9.1	1,462	Unsaturated Alluvium / Surficial Deposits	9,700	Weathered / Competent Conglomerate

(1) Subsurface material interpretation based on calculated apparent velocities and geological map analysis.

APPENDIX III

Near West Climate and Hydrology

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Florian Baltoi **FILE NO:** M09441A14.730

SUBJECT: Appendix III - Near West Climate and Hydrology

This memorandum presents climate and hydrology for the Near West Tailings Storage Facility (TSF) site.

1 TSF PRECIPITATION

1.1 Average Monthly Precipitation

There are two climate stations near the site: Superior (ID: 028348) and Superior 2 ENE (ID: 028349) (See Table 1.1 and Figure 3). Monthly precipitation normals for the period 1981 - 2010 are available for the two climate stations from the Western Regional Climate Center. Based on elevation and distance to the site, it was considered that the precipitation values for the Superior Station would be applicable to the Near West TSF site. These values are presented in Table 1.2.

Table 1.1 Climate Stations near the Resolution Near West TSF Site

Station	Location		Elevation (m) *(ft)*	Distance from the Site
	Lat (Deg)	Long (Deg)		
Superior	33.300	-111.100	915 *(3002)*	8.5 km *(5 mi)* east-southeast
Superior 2 ENE	33.300	-111.066	1270 *(4167)*	11.5 km *(7 mi)* east-southeast

Table 1.2 Average Monthly Precipitation for the Near West TSF Site

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (mm)	55	59	54	16	9	6	50	74	40	23	36	52	474
Precipitation (inches)	*2.2*	*2.3*	*2.1*	*0.6*	*0.4*	*0.2*	*2.0*	*2.9*	*1.6*	*0.9*	*1.4*	*2.1*	*18.7*

1.2 TSF Precipitation Depth-Duration-Frequency Estimates

The NOAA precipitation frequency estimates for the TSF were determined for a point of coordinates Lat 33.3176, Long -111.1883, at an elevation of 745 m *(2444.2 ft),* and located within the proposed TSF area (See Figure 1). The precipitation depths for storm events up to 60-days in duration and return periods up to 1000 years are presented in Table 1.3.

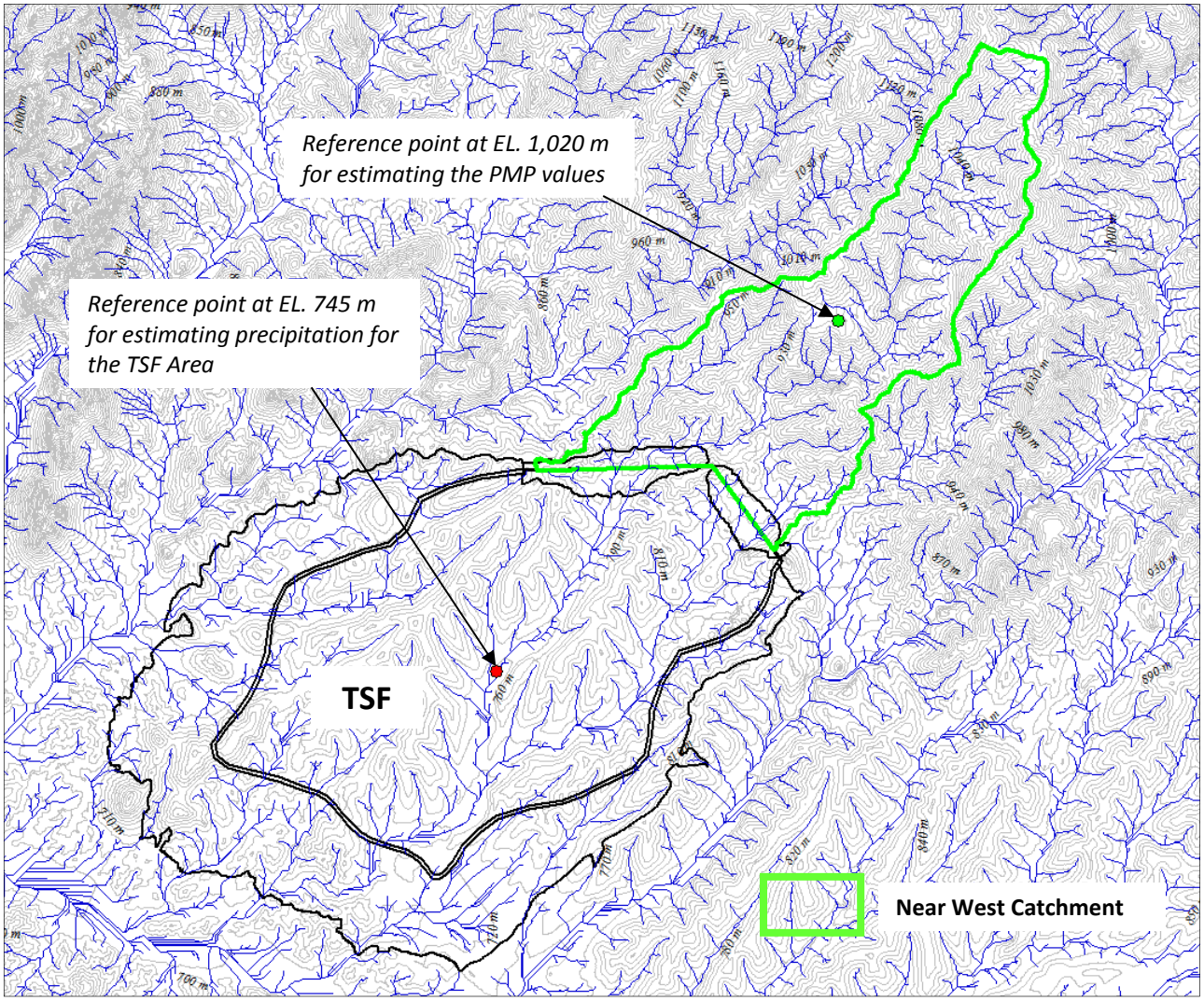


Figure 1 Resolution Near West - TSF Area

Table 1.3 Precipitation Depth-Duration-Frequency Estimates for the TSF

Average Recurrence Interval (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr	2 day	3 day	4 day	7 day	10 day	20 day	30 day	45 day	60 day
Precipitation in mm																			
1	6	9	12	16	19	22	24	29	34	42	48	52	56	63	70	87	105	125	144
2	8	12	15	20	25	29	30	36	43	53	60	65	71	80	88	111	133	158	182
5	11	16	20	27	34	38	39	45	54	67	77	84	91	103	113	142	170	201	230
10	13	19	24	33	40	45	46	53	62	78	90	99	107	123	134	167	199	235	267
25	16	24	29	39	49	54	56	64	74	94	109	120	131	151	164	202	240	279	315
50	18	27	33	45	55	62	64	72	83	106	123	137	150	174	188	229	272	315	351
100	20	30	37	50	62	69	72	80	92	119	139	155	171	200	214	257	305	351	389
200	22	33	41	56	69	76	81	89	101	132	155	174	193	228	242	287	338	386	424
500	25	38	47	63	78	86	92	100	113	151	177	200	224	269	282	328	386	434	472
1000	27	41	51	68	85	94	102	109	123	165	194	221	249	302	315	358	424	470	511
Precipitation in inches																			
1	*0.24*	*0.37*	*0.46*	*0.61*	*0.76*	*0.88*	*0.93*	*1.13*	*1.35*	*1.66*	*1.88*	*2.04*	*2.2*	*2.49*	*2.74*	*3.44*	*4.13*	*4.91*	*5.65*
2	*0.32*	*0.48*	*0.59*	*0.8*	*0.99*	*1.13*	*1.19*	*1.42*	*1.69*	*2.09*	*2.37*	*2.57*	*2.78*	*3.14*	*3.46*	*4.36*	*5.22*	*6.21*	*7.15*
5	*0.42*	*0.64*	*0.8*	*1.07*	*1.33*	*1.5*	*1.54*	*1.79*	*2.12*	*2.64*	*3.02*	*3.29*	*3.57*	*4.05*	*4.44*	*5.6*	*6.68*	*7.92*	*9.04*
10	*0.5*	*0.77*	*0.95*	*1.28*	*1.58*	*1.77*	*1.82*	*2.09*	*2.45*	*3.08*	*3.55*	*3.89*	*4.22*	*4.83*	*5.26*	*6.59*	*7.83*	*9.23*	*10.47*
25	*0.61*	*0.93*	*1.15*	*1.55*	*1.92*	*2.14*	*2.21*	*2.5*	*2.91*	*3.7*	*4.28*	*4.72*	*5.15*	*5.95*	*6.43*	*7.95*	*9.43*	*11.01*	*12.38*
50	*0.69*	*1.06*	*1.31*	*1.76*	*2.18*	*2.43*	*2.52*	*2.82*	*3.26*	*4.18*	*4.86*	*5.38*	*5.91*	*6.87*	*7.39*	*9.02*	*10.68*	*12.37*	*13.82*
100	*0.78*	*1.18*	*1.47*	*1.98*	*2.45*	*2.72*	*2.84*	*3.15*	*3.62*	*4.69*	*5.46*	*6.09*	*6.72*	*7.88*	*8.43*	*10.13*	*11.99*	*13.77*	*15.27*
200	*0.86*	*1.31*	*1.62*	*2.19*	*2.71*	*3.01*	*3.17*	*3.49*	*3.97*	*5.21*	*6.09*	*6.84*	*7.58*	*8.97*	*9.53*	*11.28*	*13.34*	*15.18*	*16.72*
500	*0.97*	*1.48*	*1.83*	*2.47*	*3.06*	*3.4*	*3.63*	*3.95*	*4.46*	*5.93*	*6.96*	*7.88*	*8.81*	*10.55*	*11.11*	*12.87*	*15.2*	*17.08*	*18.64*
1000	*1.06*	*1.61*	*2*	*2.69*	*3.33*	*3.7*	*4*	*4.31*	*4.83*	*6.5*	*7.64*	*8.72*	*9.8*	*11.87*	*12.4*	*14.11*	*16.65*	*18.54*	*20.08*

Note: From NOAA Atlas 14.

2 NEAR WEST CATCHMENT PROBABLE MAXIMUM PRECIPITATION (PMP)

The PMP values have been determined by KCB for the Far West site and by Schlumberger Water Services for the Pinto Valley site. For the design of diversions for the Near West site, the PMP estimates of interest are for the water management scheme within the catchment area upstream of the TSF. For calculation purposes, the reference point selected for this catchment was its centroid located at Lat 33.3423, Long -111.1597 and situated at an elevation of 1020 m *(3346.5 ft)(*Figure 1).

Relative to the Near West site, the Far West location is approximately 16 km *(10 mi)* southwest and the Pinto Valley location is approximately 19 km *(12 mi)* northeast. Far West is at an elevation of 680 m *(2231.0 ft)* and Pinto Valley is at an elevation of 1180 m *(3871.4 ft).* Based on elevation and location, it was considered that the PMP values estimated for PVO could be applicable to the Near West site, but it is recognized that given the difference in elevation between PVO and Near West, the numbers are conservative and likely overestimate the PMP values for the Near West site. Site specific PMP values are likely lower for the Near West site..

2.1.1 General Storm PMP

The General Storm PMP values adopted for Near West are presented in Table 2.1.

Table 2.1 General Storm PMP Estimates[1]

Duration	Precipitation Depth (mm)	*Precipitation Depth (inches)*
6 hr	267	*10.51*
12 hr	366	*14.41*
18 hr	432	*17.01*
24 hr	480	*18.90*
48 hr	599	*23.58*
72 hr	653	*25.71*
30 day	1,575	*62.01*

1. The PMP values have been obtained from the nearby Pinto Valley (PVO) site

2.1.2 Local Storm PMP

The Local Storm PMP values adopted for Near West are presented in Table 2.2.

Table 2.2 Local Storm PMP Estimates[1]

Duration	Precipitation Depth (mm)	*Precipitation Depth (inches)*
15 min	132	*5.20*
30 min	170	*6.69*
45 min	191	*7.52*
1 hr	206	*8.11*
2 hr	244	*9.61*
3 hr	262	*10.31*
4 hr	277	*10.91*
5 hr	287	*11.31*
6 hr	295	*11.61*

1. The PMP values have been obtained from the nearby Pinto Valley (PVO) site

Storm distributions for the 6-hour period are presented in Table 2.3 based on two recommendations presented in the HMR 49: one from the U. S. Weather Bureau (HMR No. 5), and one from the U. S. Army Corps of Engineers (EM1110-2-1411).

Table 2.3 Local Storm PMP Average Values – Hourly Distribution for 6-hour Storm

Duration	Precipitation Depth (mm) *(inches)*	
	HMR No. 5 Distribution	EM1110-2-1411 Distribution
1 hr	10 *(0.39)*	8 *(0.31)*
2 hr	28 *(1.10)*	23 *(0.91)*
3 hr	234 *(9.21)*	61 *(2.40)*
4 hr	272 *(10.71)*	267 *(10.51)*
5 hr	287 *(11.30)*	285 *(11.22)*
6 hr	295 *(11.61)*	295 *(11.61)*

3 EVAPORATION

Monthly pan evaporation was estimated for the site assuming the same values as for the Roosevelt 1 WNW station, which is located at Lat 33.667, Long -111.150, approximately 39 km *(24 mi)* north of the site, and is situated at elevation 880 m *(2887.1 ft).* The monthly pan evaporation values for this station were estimated by the Western Regional Climate Center (WRCC) based on a period of record from 1905 to 2005.

In order to estimate the evaporation from naturally existing surfaces such as lakes or saturated soils, WRCC recommends that the pan evaporation values be multiplied by a pan evaporation coefficient of 0.7 or 0.8. The pan coefficient estimated for the Near West site was estimated in two steps:

1. From Map 3 of the Evaporation Atlas for the Contiguous 48 United States (NOAA, 1982) it was estimated that the annual Free Water Surface (FWS) evaporation is 65 in (1,651 mm);
2. The pan coefficient was then determined as the ratio between the annual FWS evaporation (1,651 mm *(65 inches)*) and the annual pan evaporation for the site (2,451 mm *(96.5 inches)*). This ratio is 0.67, or approximately 0.7.

To determine the monthly average FWS evaporation, the pan evaporation values were multiplied by a coefficient of 0.7 (Table 3.1).

Table 3.1 Monthly Average Evaporation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pan Evaporation (mm)	62	90	150	219	304	368	365	312	257	172	93	59	2,451
FWS Evaporation	43	63	105	153	213	258	256	218	180	120	65	41	1,715
Pan Evaporation (inches)	*2.4*	*3.5*	*5.9*	*8.6*	*12.0*	*14.5*	*14.4*	*12.3*	*10.1*	*6.8*	*3.7*	*2.3*	*96.5*
FWS Evaporation (inches)	*1.7*	*2.5*	*4.1*	*6.0*	*8.4*	*10.2*	*10.1*	*8.6*	*7.1*	*4.7*	*2.6*	*1.6*	*67.5*

4 RUNOFF COEFFICIENT

The runoff coefficient is needed for the monthly water balance of the TSF.

The runoff coefficient over a time period is the fraction of the precipitation that does not infiltrate into the soil or transfers into the atmosphere through evapotranspiration over that time period.

This coefficient is defined by the equation:

$$C = \frac{R}{P}$$

Where: C=runoff coefficient;

R=runoff (mm);

P=precipitation (mm).

This section presents several ways of estimating a runoff coefficient for the area.

4.1 Estimation of Average Annual Runoff Coefficient Using USGS Map

The United States Geological Survey (USGS) has produced a map showing the distribution of the average annual runoff in the United States based on 1951 to 1980 data. This map indicates that the average annual runoff at the Near West site is between 0.5 in (13 mm) and 1 in (25 mm) (see Figure 2).

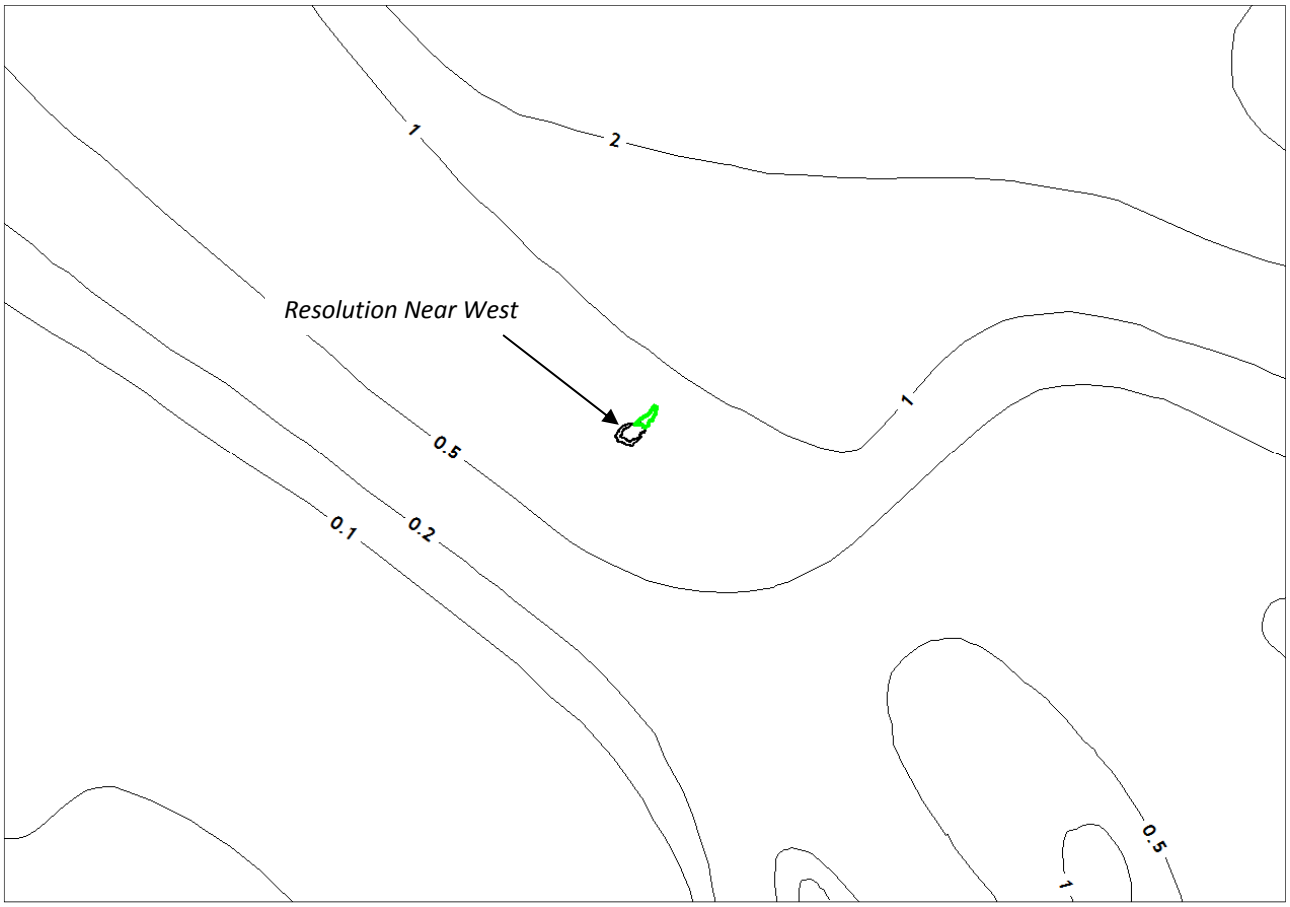


Figure 2 Average Annual Runoff from USGS Map (values in inches)

Assuming that the average annual precipitation is 474 mm *(18.7 inches)* (See Section 1.1), the average annual runoff coefficient for the site is between 0.03 and 0.05.

4.2 Estimation of Average Monthly and Annual Runoff Coefficients using Data from Regional Catchments

With this method, runoff coefficients were estimated for three regional gaged watersheds using USGS stream flow data (See Table 4.1). The locations of the stream flow gages in relation to the Near West site are shown in Figure 3. The years for which analyses were performed were selected based on availability of discharge data in conjunction with precipitation data (See Table 4.2 and Table 4.3). The runoff values in Table 4.2 were determined based on available discharge information and watershed areas.

Table 4.1 Regional Stream Gages

Stream Gage	Location		Drainage Area (km^2) *(sq mi)*	Gage Elevation (m) *(ft)*	Period of Record
	Lat (Deg)	Long (Deg)			
USGS 09479000 Queen Creek Near Florence Junction	33.288	-111.325	497 *(192)*	585 *(1919)*	Sep 1939 – Jun 1941
USGS 094985005 Pinto Creek Above Haunted Canyon Near Miami	33.406	-110.999	44 *(17)*	991 *(3251)*	Nov 2007 – Sep 2012
USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami	33.419	-111.009	97 *(37)*	969 *(3179)*	Oct 1995 – Sep 2012

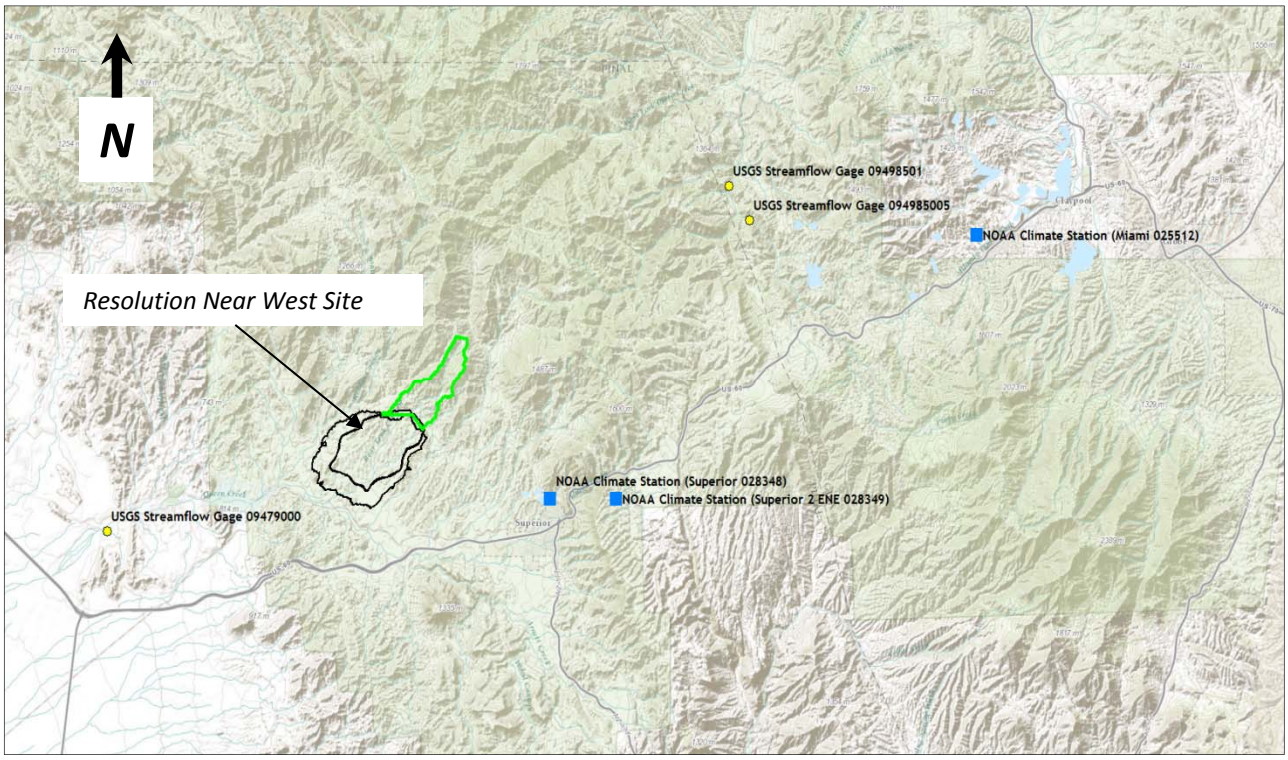


Figure 3 Regional Stream Flow Gages and Climate Stations

Table 4.2 Runoff for Regional Stream Gages

Stream Gage	Year	Runoff (mm) *(inches)*												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
USGS 09479000 Queen Creek Near Florence Junction	1940	0	0	0	0	0	0	0	0	0	1 *(0.04)*	5 *(0.20)*	40 *(1.57)*	46 *(1.81)*
USGS 094985005 Pinto Creek Above Haunted Canyon Near Miami	2010	115 *(4.53)*	54 *(2.13)*	44 *(1.73)*	1 *(0.04)*	0	0	0	0	0	0	0	3 *(0.12)*	217 *(8.54)*
	2011	1 *(0.04)*	0	0	0	0	0	0	0	0	0	0	5 *(0.20)*	6 *(0.24)*
USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami	1996	0 (0)	1 *(0.04)*	1 *(0.04)*	0	0	0	0	0	0	0	0	0	2 *(0.08)*
	1997	9 *(0.35)*	10 *(0.39)*	6 *(0.24)*	0	0	0	0	0	0	0	0	3 *(0.12)*	28 *(1.10)*
	1999	0	0	0	2 *(0.08)*	0	0	1 *(0.04)*	1 *(0.04)*	0	0	0	0	4 *(0.16)*
	2000	0	0	2 *(0.08)*	0	0	0	0	1 *(0.04)*	0	4 *(0.16)*	13 *(0.51)*	1 *(0.04)*	21 *(0.83)*
	2001	3 *(0.12)*	8 *(0.31)*	12 *(0.47)*	7 *(0.28)*	1 *(0.04)*	0	1 *(0.04)*	1 *(0.04)*	0	0	0	0	33 *(1.30)*
	2002	0	0	0	0	0	0	0	0	0	0	0	0	0
	2003	0	14 *(0.55)*	9 *(0.35)*	1 *(0.04)*	0	0	0	0	0	0	0	0	24 *(0.94)*
	2004	1 *(0.04)*	0	16 *(0.63)*	1 *(0.04)*	0	0	0	0	0	0	0	5 *(0.20)*	23 *(0.91)*
	2005	48 *(1.89)*	143 *(5.63)*	16 *(0.63)*	1 *(0.04)*	1 *(0.04)*	0	0	3 *(0.12)*	1 *(0.04)*	0	0	0	213 *(8.39)*
	2006	0	0	2 *(0.08)*	0	0	0	2 *(0.08)*	2 *(0.08)*	0	0	0	0	6 *(0.24)*
	2007	0	0	0	0	0	0	1 *(0.04)*	0	0	0	0	34 *(1.34)*	35 *(1.38)*
	2010	125 *(4.92)*	45 *(1.77)*	43 *(1.69)*	2 *(0.08)*	0	0	0	0	0	0	0	2 *(0.08)*	217 *(8.54)*
	2011	1 *(0.04)*	0	0	0	0	0	0	0	0	0	0	4 *(0.16)*	5 *(0.20)*

Table 4.3 Precipitation for Regional Stream Gages

Stream Gage	Year	Precipitation (mm) (inches)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
USGS 09479000 Queen Creek Near Florence Junction	1940	25 *(0.98)*	57 *(2.24)*	10 *(0.39)*	12 *(0.47)*	4 *(0.16)*	6 *(0.24)*	7 *(0.28)*	28 *(1.10)*	32 *(1.26)*	64 *(2.52)*	66 *(2.60)*	139 *(5.47)*	450 *(17.72)*
USGS 094985005 Pinto Creek Above Haunted Canyon Near Miami	2010	196 *(7.72)*	59 *(2.32)*	36 *(1.42)*	3 *(0.12)*	0	2 *(0.08)*	105 *(4.13)*	33 *(1.30)*	28 *(1.10)*	25 *(0.98)*	4 *(0.16)*	80 *(3.15)*	571 *(22.48)*
	2011	3 *(0.12)*	15 *(0.59)*	5 *(0.20)*	14 *(0.55)*	5 *(0.20)*	0	94 *(3.70)*	26 *(1.02)*	35 *(1.38)*	17 *(0.67)*	40 *(1.57)*	77 *(3.03)*	331 *(13.03)*
USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami	1996	0	85 *(3.35)*	11 *(0.43)*	0	1 *(0.04)*	9 *(0.35)*	70 *(2.76)*	22 *(0.87)*	45 *(1.77)*	22 *(0.87)*	40 *(1.57)*	0	305 *(12.00)*
	1997	109 *(4.29)*	61 *(2.40)*	6 *(0.24)*	7 *(0.28)*	10 *(0.39)*	2 *(0.08)*	11 *(0.43)*	67 *(2.64)*	18 *(0.71)*	20 *(0.79)*	16 *(0.63)*	83 *(3.27)*	***410 (16.14)***
	1999	4 *(0.16)*	16 *(0.63)*	5 *(0.20)*	52 *(2.05)*	0	7 *(0.28)*	125 *(4.92)*	43 *(1.69)*	32 *(1.26)*	0	0	1 *(0.04)*	285 *(11.22)*
	2000	7 *(0.28)*	11 *(0.43)*	66 *(2.60)*	3 *(0.12)*	0	42 *(1.65)*	29 *(1.14)*	136 *(5.35)*	0	145 *(5.71)*	59 *(2.32)*	2 *(0.08)*	***500 (19.69)***
	2001	61 *(2.40)*	43 *(1.69)*	21 *(0.83)*	65 *(2.56)*	9 *(0.35)*	4 *(0.16)*	88 *(3.46)*	42 *(1.65)*	18 *(0.71)*	17 *(0.67)*	6 *(0.24)*	38 *(1.50)*	***412 (16.22)***
	2002	0	0	12 *(0.47)*	3 *(0.12)*	0	0	10 *(0.39)*	33 *(1.30)*	9 *(0.35)*	8 *(0.31)*	19 *(0.75)*	21 *(0.83)*	115 *(4.53)*
	2003	18 *(0.71)*	117 *(4.61)*	43 *(1.69)*	8 *(0.31)*	0	0	52 *(2.05)*	93 *(3.66)*	61 *(2.40)*	4 *(0.16)*	34 *(1.34)*	24 *(0.94)*	***454 (17.87)***
	2004	58 *(2.28)*	18 *(0.71)*	65 *(2.56)*	28 *(1.10)*	0	2 *(0.08)*	50 *(1.97)*	43 *(1.69)*	31 *(1.22)*	29 *(1.14)*	17 *(0.67)*	73 *(2.87)*	***414 (16.30)***
	2005	135 *(5.31)*	176 *(6.93)*	33 *(1.30)*	18 *(0.71)*	0	2 *(0.08)*	51 *(2.01)*	69 *(2.72)*	5 *(0.20)*	11 *(0.43)*	0	1 *(0.04)*	***501 (19.72)***
	2006	0	0	75 *(2.95)*	6 *(0.24)*	0	8 *(0.31)*	84 *(3.31)*	54 *(2.13)*	30 *(1.18)*	45 *(1.77)*	0	8 *(0.31)*	310 *(12.20)*
	2007	43 *(1.69)*	30 *(1.18)*	30 *(1.18)*	9 *(0.35)*	13 *(0.51)*	0	64 *(2.52)*	61 *(2.40)*	19 *(0.75)*	4 *(0.16)*	10 *(0.39)*	141 *(5.55)*	***424 (16.69)***
	2010	196 *(7.72)*	59 *(2.32)*	36 *(1.42)*	3 *(0.12)*	0	2 *(0.08)*	105 *(4.13)*	33 *(1.30)*	28 *(1.10)*	25 *(0.98)*	4 *(0.16)*	80 *(3.15)*	***571 (22.48)***
	2011	3 *(0.12)*	15 *(0.59)*	5 *(0.20)*	14 *(0.55)*	5 *(0.20)*	0	94 *(3.70)*	26 *(1.02)*	35 *(1.38)*	17 *(0.67)*	40 *(1.57)*	77 *(3.03)*	331 *(13.03)*

NOTES:

1. Precipitation data from Superior Climate Station was used for USGS 09479000 watershed. Precipitation data from Miami Climate Station was used for USGS 094985005 and USGS 09498501 watersheds.
2. The USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami station was selected for the site runoff analysis. For this station, the bolded and italicized values represent annual rainfalls close to the site's annual rainfall of 474 mm *(18.66 inches).*

Table 4.4 Regional Runoff Coefficients

Stream Gage	Year	Runoff Coefficient												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
USGS 09479000 Queen Creek Near Florence Junction	1940	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.29	0.10
USGS 094985005 Pinto Creek Above Haunted Canyon Near Miami	2010	0.59	0.92	1.22	0.33	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.38
	2011	0.33	0.00	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.06	0.02
USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami	1996	N/A	0.01	0.09	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	0.01
	1997	0.08	0.16	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	***0.07***
	1999	0.00	0.00	0.00	0.04	N/A	0.00	0.01	0.02	0.00	N/A	N/A	0.00	0.01
	2000	0.00	0.00	0.03	0.00	N/A	0.00	0.00	0.01	N/A	0.03	0.22	0.50	***0.04***
	2001	0.05	0.19	0.57	0.11	0.11	0.00	0.01	0.02	0.00	0.00	0.00	0.00	***0.08***
	2002	N/A	N/A	0.00	0.00	N/A	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2003	0.00	0.12	0.21	0.13	N/A	N/A	0.00	0.00	0.00	0.00	0.00	0.00	***0.05***
	2004	0.02	0.00	0.25	0.04	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.07	***0.06***
	2005	0.36	0.81	0.48	0.06	N/A	0.00	0.00	0.04	0.20	0.00	N/A	0.00	***0.43***
	2006	N/A	N/A	0.03	0.00	N/A	0.00	0.02	0.04	0.00	0.00	N/A	0.00	0.02
	2007	0.00	0.00	0.00	0.00	0.00	N/A	0.02	0.00	0.00	0.00	0.00	0.24	***0.08***
	2010	0.64	0.76	1.19	0.67	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.03	***0.38***
	2011	0.33	0.00	0.00	0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.05	0.02
	Average (for station's annual rainfalls close to TSF annual rainfall of 474 mm *(18.66 inches)*)	**0.14**	**0.26**	**0.47**	**0.12**	**0.04**	**0.00**	**0.00**	**0.01**	**0.03**	**0.00**	**0.03**	**0.11**	**0.15**

NOTES: 1. The "N/A" label was used for cases where the precipitation for that month was zero.
2. The USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami station was selected for the site runoff analysis. For this station, the bolded and italicized values correspond to the years with annual rainfall close to the site's annual rainfall of 474 mm *(18.66 inches)*.

The USGS 09498501 Pinto Creek Below Haunted Canyon Near Miami station was selected to represent runoff for the site as it has a good data record. Based on the data from the years with precipitation values close to the site's annual precipitation, the average annual runoff coefficient is 0.15, as shown in Table 4.4.

On a monthly basis, the runoff coefficients are higher during the winter and spring months.

4.3 Runoff Coefficient for Water Balance

A runoff coefficient of 0.3 was selected for the water balance modeling at the Near West TSF site. A higher value was chosen because the TSF site has a smaller catchment, is founded in shallow bedrock and does not have a lot of alluvial storage for attenuation of runoff.

REFERENCES

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Weather Service. 1982. NOAA Technical Report NWS 33. Evaporation Atlas for the Contiguous 48 United States.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Weather Service. 1982. NOAA Technical Report NWS 34. Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States.

Western Regional Climate Center. Climate Summaries. http://www.wrcc.dri.edu/climate-summaries/

APPENDIX IV

Tailings Staging Plan for Near West Site

MEMORANDUM

TO:	File	**DATE:**	September 5, 2014
FROM:	Meredith Kealty	**FILE NO:**	M09441A14.730
SUBJECT:	Appendix IV - Tailings Staging Plan for Near West Site		

1 INTRODUCTION

The tailings deposition plan for the Near West Site was completed using the tailings deposition program Muck3D (Wruffware, Ltd.).

The objective of the staging plan is to determine the required ultimate height of the upstream scavenger tailings embankment, the ultimate height of the internal cleaner tailings starter dam, the length of the scavenger beach for dam safety requirements, and the feasibility of continued saturation of the cleaner tailings.

The cleaner tailings will initially be deposited behind a separate starter dam 1 km *(0.62 mi)* upstream of the ultimate embankment toe. Later the cleaner tailings will be deposited in the vicinity of the "east cell" reclaim pond from pipelines running along upstream ridges.

Tailings deposition is characterized by three stages:

- Stage I – East cell development (Years 0 – 10):
  a. scavenger upstream embankment construction with a minimum beach length of 150 m *(492 ft)*;
  b. cleaner tailings deposited behind general fill starter dam until the end of Year 8; and
  c. after Year 8, cleaner tailings deposited in scavenger reclaim pond from pipelines along upstream ridges.
- Stage II – East and west cell development (Years 11 – 18):
  a. cleaner tailings deposited in east cell scavenger reclaim pond from pipelines along upstream ridges;
  b. 100% western cell scavenger deposition, for Years 11 – 12;
  c. 20% eastern and 80% western cell scavenger deposition, respectively, for Years 13 – 14, and Years 16 – 17;
  d. 40% eastern and 60% western cell scavenger deposition, respectively, for Year 15; and
  e. 90% western cell scavenger deposition and 10% scavenger tailings deposited in the northeast corner of the east cell to control the reclaim pond location, for Year 18.

- Stage III – Combined cell development (Years 19 – 45):
  a. scavenger upstream embankment construction with a minimum beach length of 500 m *(1640 ft)*;
  b. cleaner tailings deposited in east cell scavenger reclaim pond from pipelines along upstream ridges until the end of year 20;
  c. cleaner tailings deposited in coalesced east and west reclaim ponds from pipelines along upstream ridges until the end of year 29; and
  d. cleaner tailings deposited in coalesced reclaim pond from access berms constructed into the interior of the tailings basin until the end of year 45.

Muck3D screenshots illustrate the tailings configuration; tailings discharge elevation, beach length and pond elevation, volume and depth at the end of every stage. The annual staging plan is provided as Attachment I. Muck3D calculates the tailings elevation given the volume of tailings and beach slopes.

The impoundment filling schedule, attached, estimates the elevation of the tailings assuming horizontal slopes. The beach slope (Muck3D) tailings elevations were used to obtain an estimate of the required embankment elevations.

2 MODEL INPUT PARAMETERS AND ASSUMPTIONS

2.1 General

The model input parameters for Muck3D are:

- Tailings beach slopes;
- Deposition rate (m^3/year);
- Discharge location; and
- Existing topography.

Sub-aerial (or beach) deposition is modeled in this analysis.

2.2 Tailings Properties

The tailings production schedule is given in Table 2.1. Tailings densities were based on specific gravity and experience. The tailings parameters used in the Muck3D analysis are given in Table 2.3.

Table 2.1 Ore and Tailings Production Schedule (Metric Units)

Year	Milled Ore (tonnes/year)	Cumulative Milled Ore (tonnes)	Scavenger Tailings (tonnes/year)	Cleaner Tailings (tonnes/year)
0	0	0	0	0
1	6,171,992	6,171,992	5,538,690	495,225
2	8,395,000	14,566,992	7,471,246	661,697
3	8,701,243	23,268,235	7,545,719	686,564
4	16,657,269	39,925,504	14,349,158	1,412,179
5	24,488,070	64,413,574	20,875,530	2,275,100
6	32,311,276	96,724,850	27,329,511	3,216,081
7	38,325,416	135,050,266	32,175,112	4,056,212
8	43,800,000	178,850,266	36,259,601	5,040,212
9	43,800,000	222,650,266	35,716,908	5,485,048
10	43,800,000	266,450,266	35,454,959	5,920,093
11	43,800,000	310,250,266	35,513,639	6,194,342
12	43,800,000	354,050,266	35,969,299	6,082,999
13	42,050,972	396,101,238	35,221,380	5,184,075
14	43,669,902	439,771,140	37,056,736	4,779,488
15	43,800,000	483,571,140	37,251,248	4,645,505
16	43,800,000	527,371,140	36,989,046	4,858,105
17	43,800,000	571,171,140	36,591,092	5,213,321
18	43,800,000	614,971,140	36,242,366	5,604,554
19	43,800,000	658,771,140	35,989,950	5,944,612
20	43,800,000	702,571,140	35,899,854	6,128,564
21	43,800,000	746,371,140	36,130,214	5,986,571
22	43,800,000	790,171,140	36,479,308	5,625,597
23	43,800,000	833,971,140	36,526,334	5,426,242
24	43,800,000	877,771,140	36,438,403	5,416,826
25	43,800,000	921,571,140	36,329,275	5,525,785
26	43,800,000	965,371,140	36,468,912	5,482,660
27	43,800,000	1,009,171,140	36,827,839	5,239,728
28	43,800,000	1,052,971,140	37,239,401	4,836,528
29	43,800,000	1,096,771,140	37,378,247	4,613,150
30	43,800,000	1,140,571,140	37,243,983	4,722,152
31	43,800,000	1,184,371,140	37,155,170	4,913,018
32	43,800,000	1,228,171,140	37,279,009	4,936,547
33	43,800,000	1,271,971,140	37,279,009	4,936,547
34	43,800,000	1,315,771,140	37,279,009	4,936,547
35	43,800,000	1,359,571,140	37,279,009	4,936,547
36	43,800,000	1,403,371,140	37,279,009	4,936,547
37	30,895,309	1,434,266,449	26,293,939	3,408,583
38	24,017,416	1,458,283,865	20,341,454	2,709,730
39	17,613,126	1,475,896,991	14,776,495	2,128,664
40	13,238,965	1,489,135,956	11,074,850	1,656,503
41	8,565,135	1,497,701,091	7,180,783	1,076,781
42	3,917,502	1,501,618,593	3,259,509	519,033
43	1,674,880	1,503,293,472	1,365,175	249,270
44	837,009	1,504,130,482	675,197	132,826
45	240,131	1,504,370,613	193,784	38,692
TOTAL	1,504,370,613	-	1,261,214,362	178,275,049

Note: Supplied by Resolution Copper in an email dated March 4, 2013.

Table 2.2 Ore and Tailings Production Schedule (US Customary Units)

Year	Milled Ore (tn/year)	Cumulative Milled Ore (tn)	Scavenger Tailings (tn/year)	Cleaner Tailings (tn/year)
0	0	0	0	0
1	6,803,455	6,803,455	6,105,359	545,892
2	9,253,901	16,057,356	8,235,637	729,396
3	9,591,476	25,648,831	8,317,729	756,807
4	18,361,491	44,010,322	15,817,235	1,556,660
5	26,993,469	71,003,791	23,011,326	2,507,868
6	35,617,075	106,620,866	30,125,621	3,545,121
7	42,246,528	148,867,394	35,466,980	4,471,207
8	48,281,222	197,148,616	39,969,357	5,555,881
9	48,281,222	245,429,837	39,371,141	6,046,229
10	48,281,222	293,711,059	39,082,391	6,525,784
11	48,281,222	341,992,281	39,147,075	6,828,091
12	48,281,222	390,273,503	39,649,354	6,705,357
13	46,353,249	436,626,752	38,824,915	5,714,463
14	48,137,813	484,764,565	40,848,048	5,268,482
15	48,281,222	533,045,787	41,062,460	5,120,791
16	48,281,222	581,327,009	40,773,432	5,355,143
17	48,281,222	629,608,231	40,334,763	5,746,701
18	48,281,222	677,889,452	39,950,359	6,177,962
19	48,281,222	726,170,674	39,672,118	6,552,811
20	48,281,222	774,451,896	39,572,804	6,755,584
21	48,281,222	822,733,118	39,826,732	6,599,063
22	48,281,222	871,014,340	40,211,542	6,201,157
23	48,281,222	919,295,561	40,263,380	5,981,406
24	48,281,222	967,576,783	40,166,452	5,971,027
25	48,281,222	1,015,858,005	40,046,159	6,091,134
26	48,281,222	1,064,139,227	40,200,083	6,043,596
27	48,281,222	1,112,420,449	40,595,732	5,775,810
28	48,281,222	1,160,701,670	41,049,401	5,331,358
29	48,281,222	1,208,982,892	41,202,453	5,085,126
30	48,281,222	1,257,264,114	41,054,452	5,205,280
31	48,281,222	1,305,545,336	40,956,553	5,415,674
32	48,281,222	1,353,826,558	41,093,062	5,441,610
33	48,281,222	1,402,107,779	41,093,062	5,441,610
34	48,281,222	1,450,389,001	41,093,062	5,441,610
35	48,281,222	1,498,670,223	41,093,062	5,441,610
36	48,281,222	1,546,951,445	41,093,062	5,441,610
37	34,056,239	1,581,007,684	28,984,098	3,757,319
38	26,474,662	1,607,482,346	22,422,609	2,986,965
39	19,415,143	1,626,897,488	16,288,293	2,346,450
40	14,593,457	1,641,490,945	12,207,929	1,825,981
41	9,441,443	1,650,932,387	7,915,456	1,186,948
42	4,318,306	1,655,250,693	3,592,993	572,136
43	1,846,239	1,657,096,930	1,504,847	274,773
44	922,644	1,658,019,576	744,277	146,416
45	264,699	1,658,284,275	213,610	42,651
TOTAL	1,658,284,275	-	1,390,250,465	196,514,548

Notes: Supplied by Resolution Copper in an email dated March 4, 2013.

Table 2.3 Tailings Parameters

Tailings	Thickened (t/m^3) *(pcf)*	Total Tonnes (Mt) *(ST)*	Beach Slope Above Water (%)	Beach Slope Below Water (%)
Scavenger	1.4 *(87.4)*	1,260 *(1388.9 million)*	1	2
Cleaner	1.7 *(106.1)*	178 *(196.2 million)*	1	2

2.3 Impoundment Layout

The impoundment layout was based on the following:

- Scavenger toe offset a minimum of 10 m *(32.8 ft)* elevation below catchment divides;
- Southern scavenger toe offset a minimum of 500 m *(1640.4 ft)* from Queen Creek; and
- Western scavenger toe offset a minimum of 300 m *(984.3 ft)* from Roblas Creek.

2.4 Flood Storage Capacity

Table 2.4 and Table 2.5 outline the minimum flood storage design criteria and flood storage requirements for the east cell, west cell and combined cells. Table 2.6 details the annual available flood storage capacity based on preliminary Muck3D modeling.

Table 2.4 Minimum Flood Storage Design Criteria

Year	Stage	Minimum Design Criteria
1	Cleaner Dam	Half 30-day PMF
	Scavenger Dam	100 year 24-hr Storm and Spillway
2 to 18	Merged Cleaner and Scavenger East Cell and West Cell	Half 30-day PMF
19 to Closure	Combined	Full 30-day PMF

Table 2.5 Flood Storage Capacity Requirements

Year	Cell	Stage	Catchment Area (m^2) *(sq. mi)*	30-day PMP (Mm^3) *(acre-ft)*		100-year 24-hr (Mm^3) *(acre-ft)*	
				half	full	half	full
YR 1 to 8	East Cell	Cleaner Pond	10,395,000 *(4.01)*	8.2 *(6647.8)*	16.4 *(13295.7)*	0.6 *(486.4)*	1.2 *(972.9)*
		Scavenger Pond	3,291,000 *(1.27)*	2.6 *(2107.9)*	5.2 *(4215.7)*	0.2 *(162.1)*	0.4 *(324.3)*
YR 9 to 18		Merged Ponds	13,202,000 *(5.10)*	10.4 *(8431.4)*	20.8 *(16862.8)*	0.8 *(648.6)*	1.6 *(1297.1)*
YR 11 to 18	West Cell		4,796,000 *(1.85)*	3.8 *(3080.7)*	7.6 *(6161.4)*	0.3 *(243.2)*	0.6 *(486.4)*
YR 19 to 45	Both Cells		16,861,000 *(6.51)*	13.3 *(10782.5)*	26.6 *(21565.0)*	1.0 *(810.7)*	2.0 *(1621.4)*

Table 2.6 Annual Flood Storage Capacity

Year	Total (Mm^3) *(acre-ft)*	East Cell (Mm^3) *(acre-ft)*			West Cell (Mm^3) *(acre-ft)*	Combined Cells (Mm^3) *(acre-ft)*
		Cleaner Pond	Scavenger Pond	Merged		
1	18.1*(14673.9)*	17.6 *(14268.6)*	0.5* *(405.4)*			
2	20.2 *(16376.4)*	17.2 *(13944.3)*	3.0 *(2432.1)*			
3	20.2 *(16376.4)*	16.8 *(13620.0)*	3.4 *(2756.4)*			
4	21.3 *(17268.2)*	16.0 *(12971.4)*	5.4 *(4377.9)*			
5	19.7 *(15971.0)*	14.6 *(11836.4)*	5.0 *(4053.6)*			
6	19.8 *(16052.1)*	12.7 *(10296.1)*	7.0 *(5675.0)*			
7	18.1 *(14673.9)*	10.4 *(8431.4)*	7.7 *(6242.5)*			
8	13.9 *(11268.9)*	7.4 *(5999.3)*	6.5 *(5269.6)*			
9	30.8 *(24970.0)*			30.8 *(24970.0)*		
10	40.5 *(32833.9)*			40.5 *(32833.9)*		
11	47.2 *(38265.7)*			36.9 *(29915.3)*	10.3 *(8350.3)*	
12	40.0 *(32428.5)*			33.3 *(26996.7)*	6.7 *(5431.8)*	
13	37.3 *(30239.6)*			25.2 *(20430.0)*	12.1 *(9809.6)*	
14	33.3 *(26996.7)*			17.9 *(14511.8)*	15.4 *(12485.0)*	
15	49.1 *(39806.0)*			35.6 *(28861.4)*	13.5 *(10944.6)*	
16	38.2 *(30969.2)*			27.5 *(22294.6)*	10.7 *(8674.6)*	
17	30.2 *(24483.5)*			20.3 *(16457.5)*	9.9 *(8026.1)*	
18	28.1 *(22781.0)*			14.4 *(11674.3)*	13.6 *(11025.7)*	
19	34.8 *(28212.8)*					34.8 *(28212.8)*
20	44.3 *(35914.6)*					44.3 *(35914.6)*
21	53.4 *(43292.1)*					53.4 *(43292.1)*
22	43.0 *(34860.7)*					43.0 *(34860.7)*
23	39.0 *(31617.8)*					39.0 *(31617.8)*
24	46.5 *(37698.2)*					46.5 *(37698.2)*
25	37.9 *(30726.0)*					37.9 *(30726.0)*
26	46.1 *(37373.9)*					46.1 *(37373.9)*
27	41.2 *(33401.4)*					41.2 *(33401.4)*
28	32.1 *(26023.9)*					32.1 *(26023.9)*
29	31.6 *(25618.5)*					31.6 *(25618.5)*
30	35.8 *(29023.5)*					35.8 *(29023.5)*
31	34.3 *(27807.5)*					34.3 *(27807.5)*
32	32.9 *(26672.5)*					32.9 *(26672.5)*
33	40.1 *(32509.6)*					40.1 *(32509.6)*
34	27.3 *(22132.5)*					27.3 *(22132.5)*
35	41.1 *(33320.3)*					41.1 *(33320.3)*
36	30.7 *(24888.9)*					30.7 *(24888.9)*
37	30.3 *(24564.6)*					30.3 *(24564.6)*
38	31.7 *(25699.6)*					31.7 *(25699.6)*
39	37.0 *(29996.4)*					37.0 *(29996.4)*
40	29.1 *(23591.8)*					29.1 *(23591.8)*
41	31.6 *(25618.5)*					31.6 *(25618.5)*
42	29.3 *(23753.9)*					29.3 *(23753.9)*
43	28.3 *(22943.2)*					28.3 *(22943.2)*
44	27.9 *(22619.0)*					27.9 *(22618.9)*
45	27.3 *(22132.5)*					27.3 *(22132.5)*

*This value was calculated before the starter dam was designed. The starter dam will be designed to meet the design criteria in Table 2.4 (100-year 24-hr storm and spillway).

2.5 Cleaner Starter Dam

A separate starter dam will be built for the cleaner tailings. The starter dam will hold 8 years of cleaner tailings.

The dam will have 2H:1V downstream and 2.5H:1V upstream embankment slopes and a crest width of 15 m *(49.2 ft)* . Figure 2.1 provides the starter dam layout to El. 768 masl (*2520 fasl)*. The starter dam volume is 1.7 Mm^3 *(2.2 Myd^3)*.

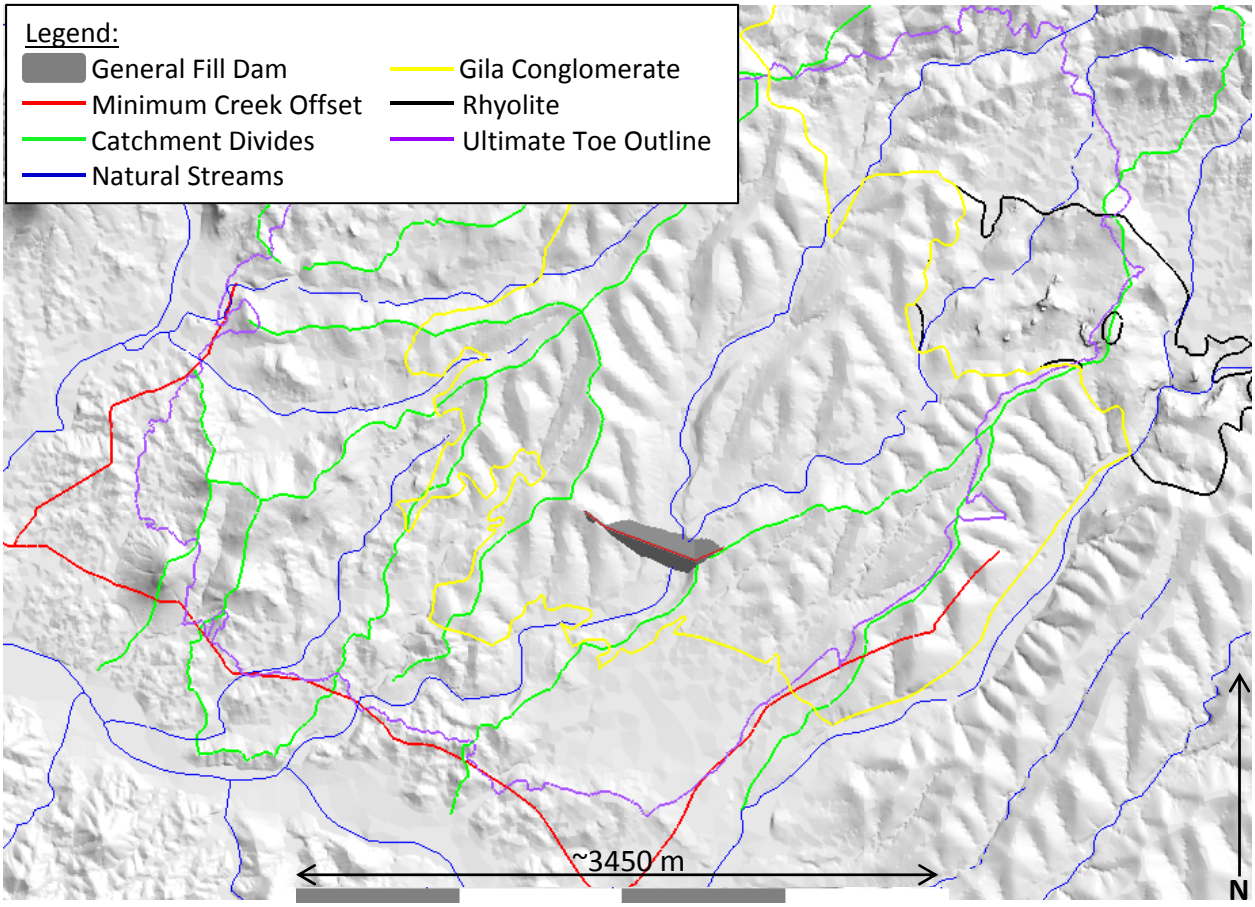


Figure 2.1 Cleaner Starter Dam at El. 768 masl *(2520 fasl)*

2.6 Upstream Scavenger Embankment

The impoundment layout assessed in the staging plan will be constructed as an upstream embankment, with a 5H:1V embankment slope and a 30 m *(98.4 ft)* crest width. Figure 2.2 provides the facility layout at an ultimate elevation of 855 masl *(2805 fasl)*.

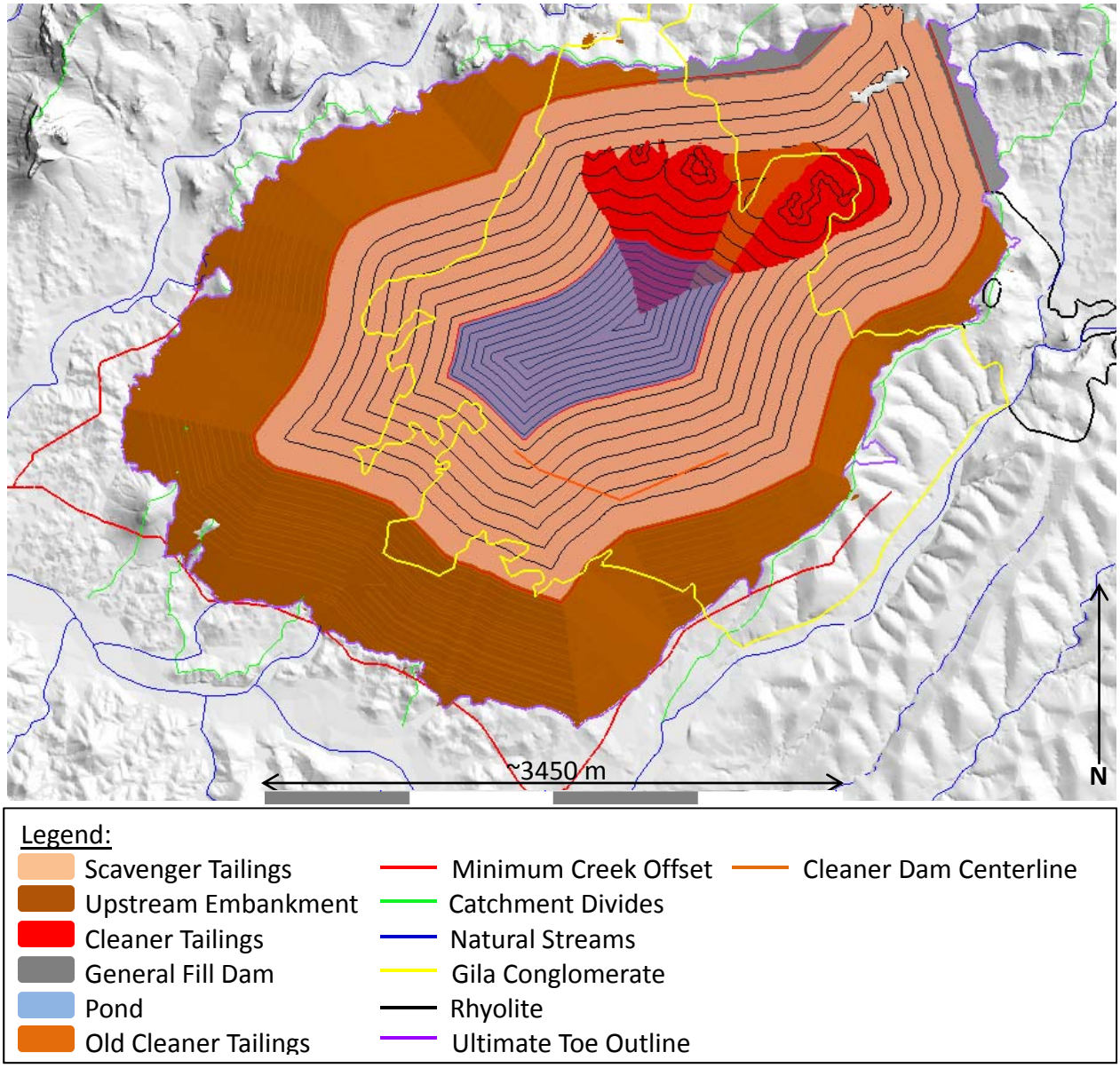


Figure 2.2 Ultimate Embankment at El. 855 masl *(2805 fasl)*

2.7 Staging

2.7.1 Stage I

Scavenger tailings are initially placed behind a general fill starter dam. Thereafter, the scavenger tailings will be deposited off of berms on the embankment crest. A separate starter facility is constructed from general fill for the cleaner tailings with a crest elevation of 768 m *(2519.7 ft)* (43 m *(141.1 ft)* high). Cleaner tailings are deposited sub-aqueously along the crest of the starter dam until the end of Year 8, at which point the tailings are discharged from pipelines extending into the TSF along upstream ridges. A 0.5 Mm^3 *(405.4 acre-ft)* pond is maintained to keep the cleaner tailings

saturated and to allow for clarification of the water in the reclaim pond. A minimum scavenger beach above water of 150 m *(492.1 ft)* is required for embankment stability and flood storage.

2.7.2 Stage II

In Year 11 of operation, scavenger tailings deposition in the west cell begins. A minimum reclaim pond volume based on a 20 day retention period is maintained in the west cell. Cleaner tailings continue to be deposited into the east cell's reclaim pond, which is maintained to have a volume of 3 Mm^3 *(2432.1 acre-ft).* From Year 13 to the end of Year 18, scavenger tailings are typically distributed 20% and 80% between the east and west cells, respectively. To minimize the southern movement of cleaner tailings, the scavenger tailings is divided 40% and 60% respectively between the east and west cells in Year 15. In Year 18, 10% scavenger tailings are deposited from a pipeline along ridges within the extents of the north east crest of the east cell. This forces the east tailings pond towards the center of the east cell to decrease the length of the cleaner tailings beach.

2.7.3 Stage III

At the end of Stage II, the east and west cells reach the same embankment elevation. In Year 19, the joined cells are raised together increasing the scavenger beach length to a minimum of 500 m *(1640.4 ft)*, which is considered the preferred beach length for embankment stability and flood storage. In Year 21, the east and west cells coalesce maintaining an operating pond water volume of the 20 day retention minimum annual pond for the scavenger tailings plus 3 Mm^3 *(2432.1 acre-ft)*. From Year 29 to Year 45, cleaner tailings are deposited from a pipeline along access berms constructed within the impoundment. This pipeline maintains the deposition of the cleaner tailings to the center of the TSF, generally above Gila Conglomerate.

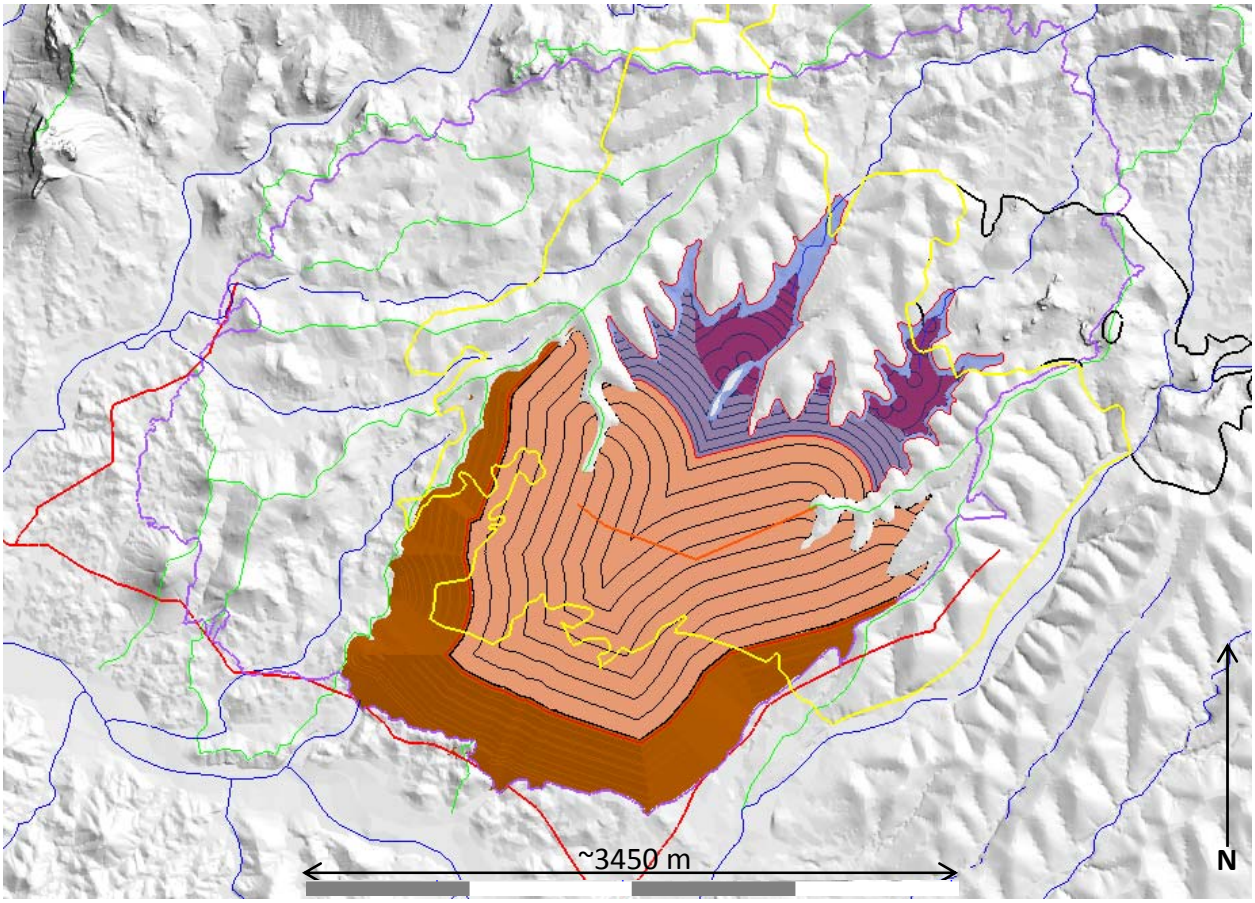
3 SUMMARY

Table 3.1 summarizes the results of the tailings staging.

Table 3.1 Tailings Staging Plan Summary

Stage	End of Year	Description	Ultimate Tailings Elevation (masl) *(fasl)*			Total Scavenger Tailings Volume (Mm^3) *(acre-ft)*	Total Cleaner Tailings Volume (Mm^3) *(acre-ft)*
			Scavenger		Cleaner		
			East	West			
I	10	East cell development	784 *(2572.2)*	-	769.4 *(2524.3)*	159 *(128903.4)*	17 *(13782.1)*
II	18	East and west cell development	791.6 *(2595.1)*	792.4 *(2599.7)*	790.6 *(2593.8)*	367 *(297531.7)*	42 *(34050.0)*
III	45	Combined cell development	854.5 *(2803.5)*			901 *(730452.6)*	105 *(85124.9)*

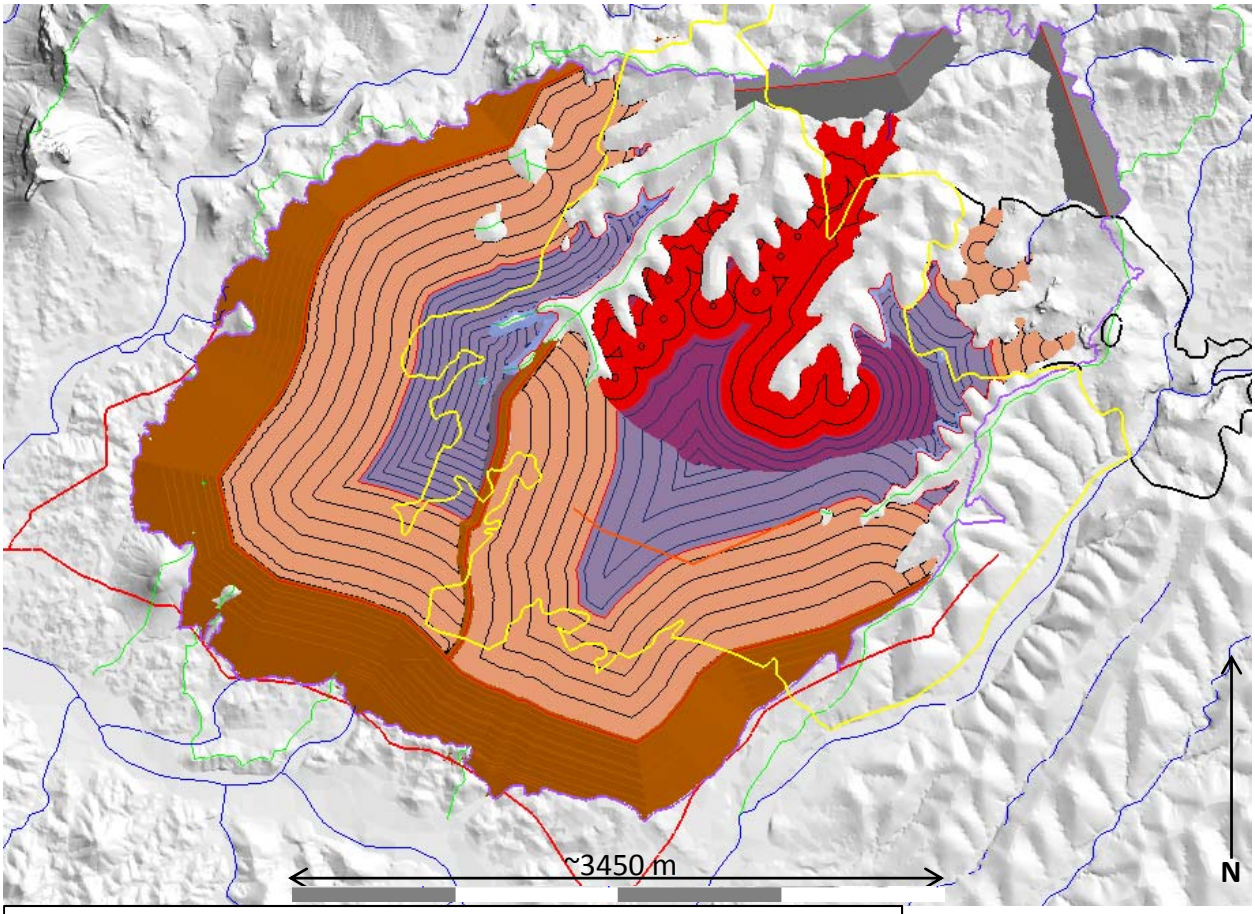
Figure 3.1 to Figure 3.4 illustrate the tailings deposition plan, the pond location and the upstream dam layout at the end of each stage. Yearly summaries of the staging plan are provided in Attachment I.



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Figure 3.1 End of Stage I (Year 10)



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Figure 3.2 End of Stage II (Year 18)

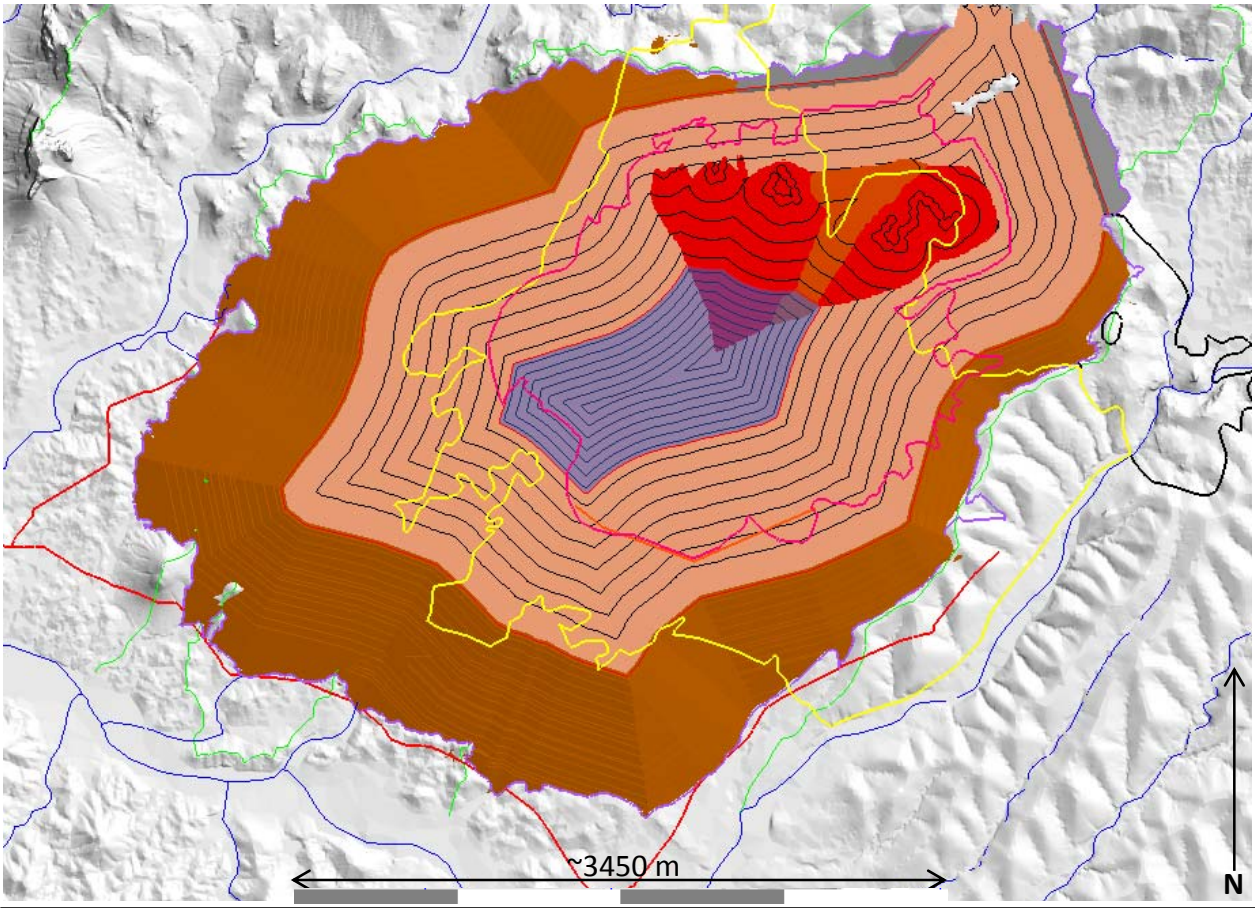
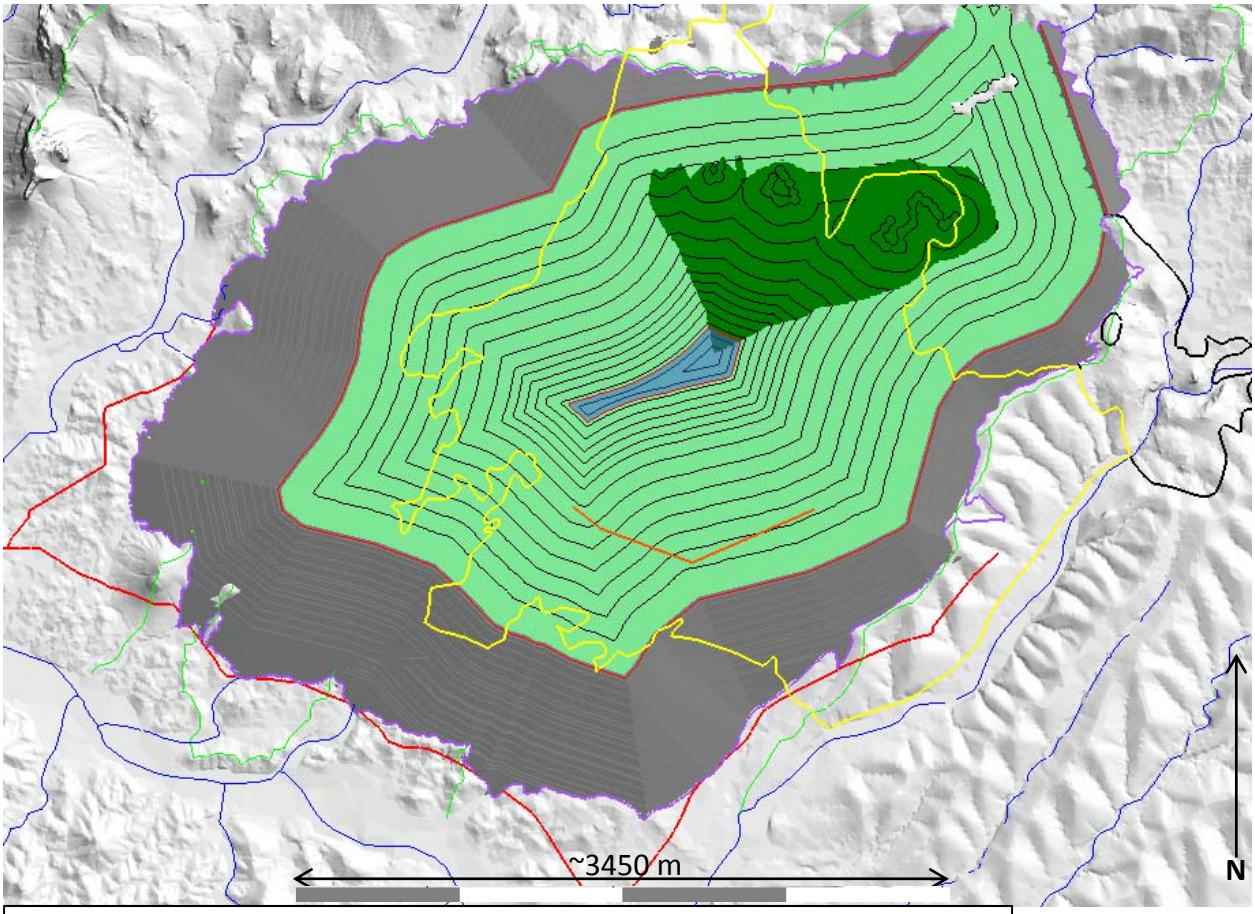


Figure 3.3 End of Stage III (Year 45)



Legend:

- Reclaimed Scavenger Tailings
- Reclaimed Cleaner Tailings
- Reclaimed Dam Slopes
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

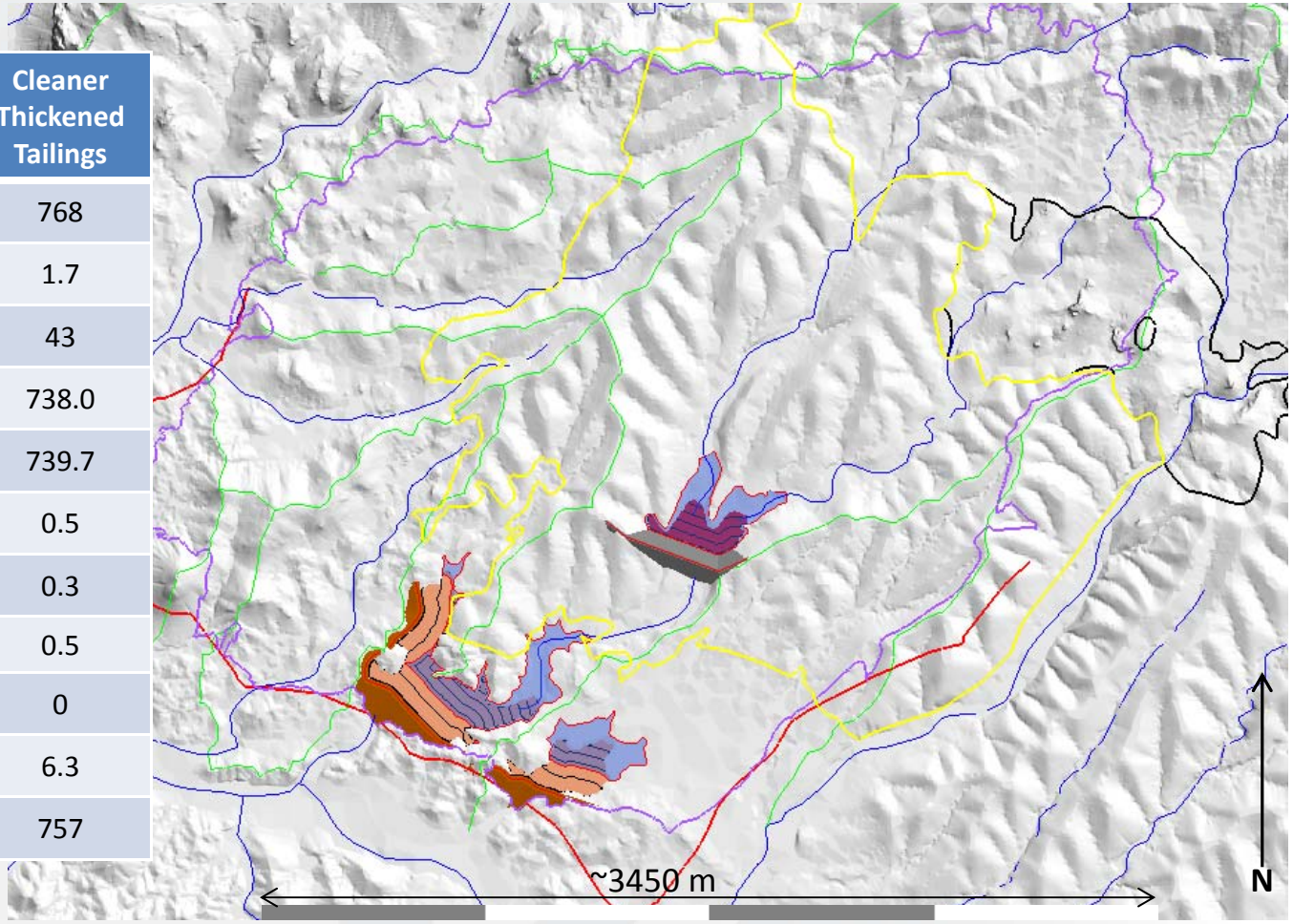
Figure 3.4 Closure

ATTACHMENT I

Summary of MUCK 3D Staging

Stage I: Year 1

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	712.5	768
Dam Volume (Mm^3)	-	1.7
Dam Height (m)	27.5	43
Tailings Elevation (masl)	711.8	738.0
Pond Elevation (masl)	711.5	739.7
Pond Volume (Mm^3)	0.51	0.5
Tailings Volume (Mm^3)	4.0[1]	0.3
Tonnage (Mtonnes)	5.5[1]	0.5
Beach Length (m)	150	0
Max Pond Depth (m)	7.5	6.3
0.5PMF Elevation (masl)	-[2]	757



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline

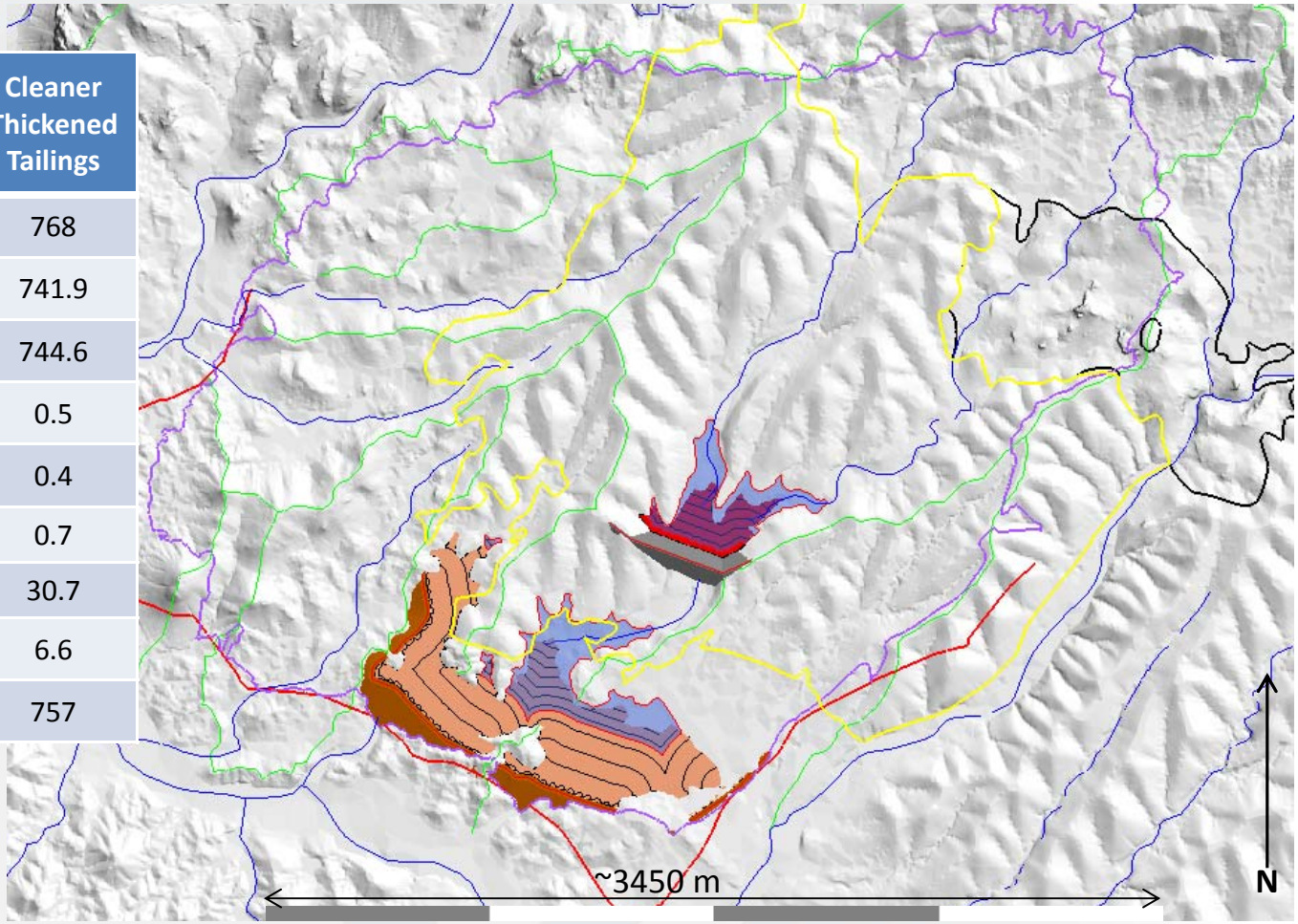
Notes: [1]Includes upstream embankment volume/tonnage
Contours drawn at 1m intervals
[2]Elevation for 100-year 24-hr storm and spillway

Klohn Crippen Berger

Stage I: Year 2

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	722	768
Tailings Elevation (masl)	720.2	741.9
Pond Elevation (masl)	716.5	744.6
Pond Volume (Mm^3)	1.0	0.5
Tailings Volume (Mm^3)	5.1	0.4
Tonnage (Mtonnes)	7.5	0.7
Beach Length (m)	364.2	30.7
Max Pond Depth (m)	7.4	6.6
0.5PMF Elevation (masl)	720	757

Note: Contours drawn at 1m intervals



Legend:

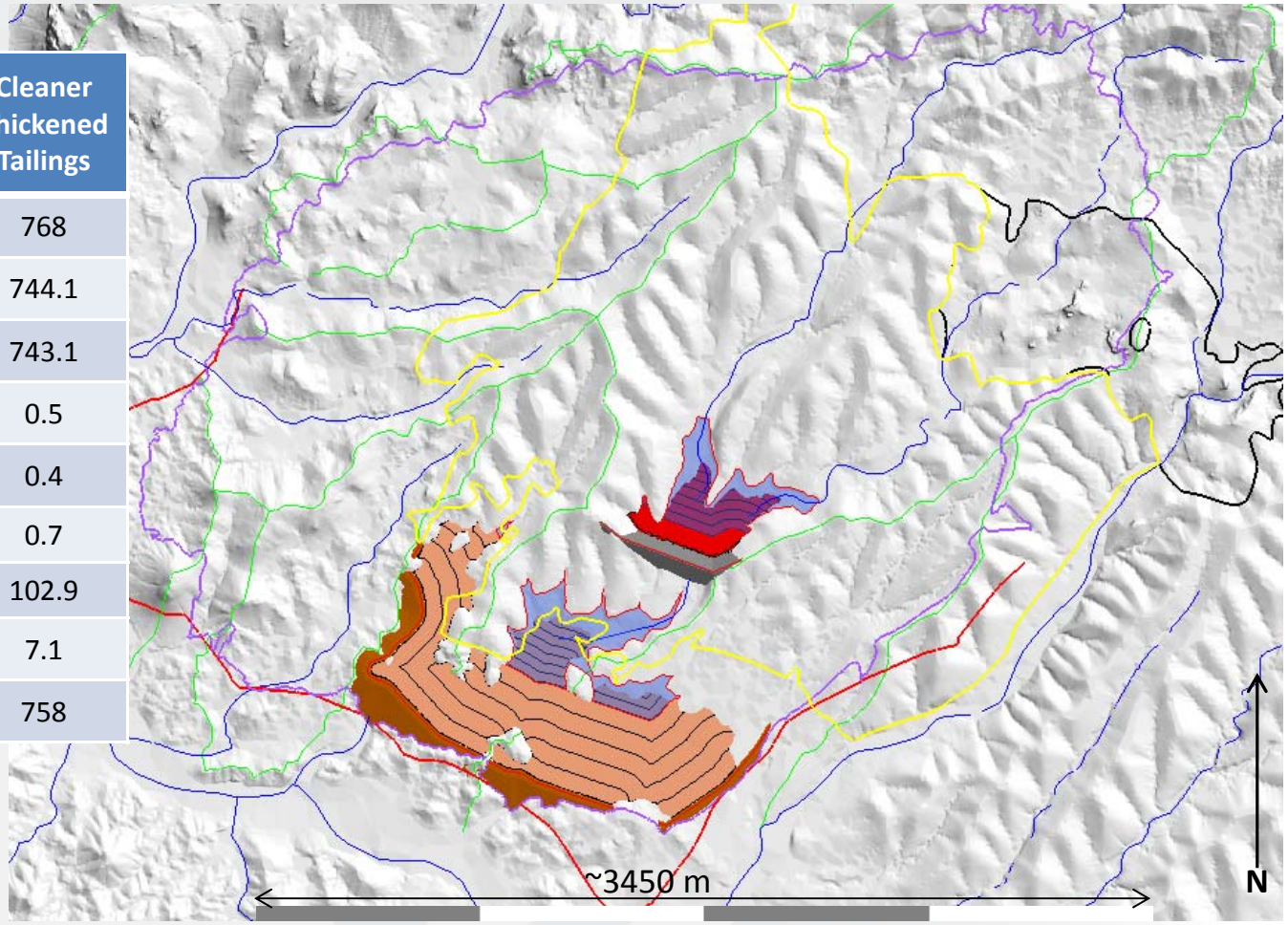
- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline

Klohn Crippen Berger

Stage I: Year 3

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	726	768
Tailings Elevation (masl)	724.9	744.1
Pond Elevation (masl)	720.1	743.1
Pond Volume (Mm^3)	1.0	0.5
Tailings Volume (Mm^3)	5.4	0.4
Tonnage (Mtonnes)	7.5	0.7
Beach Length (m)	480.5	102.9
Max Pond Depth (m)	6.9	7.1
0.5PMF Elevation (masl)	723	758

Note: Contours drawn at 1m intervals



Legend:

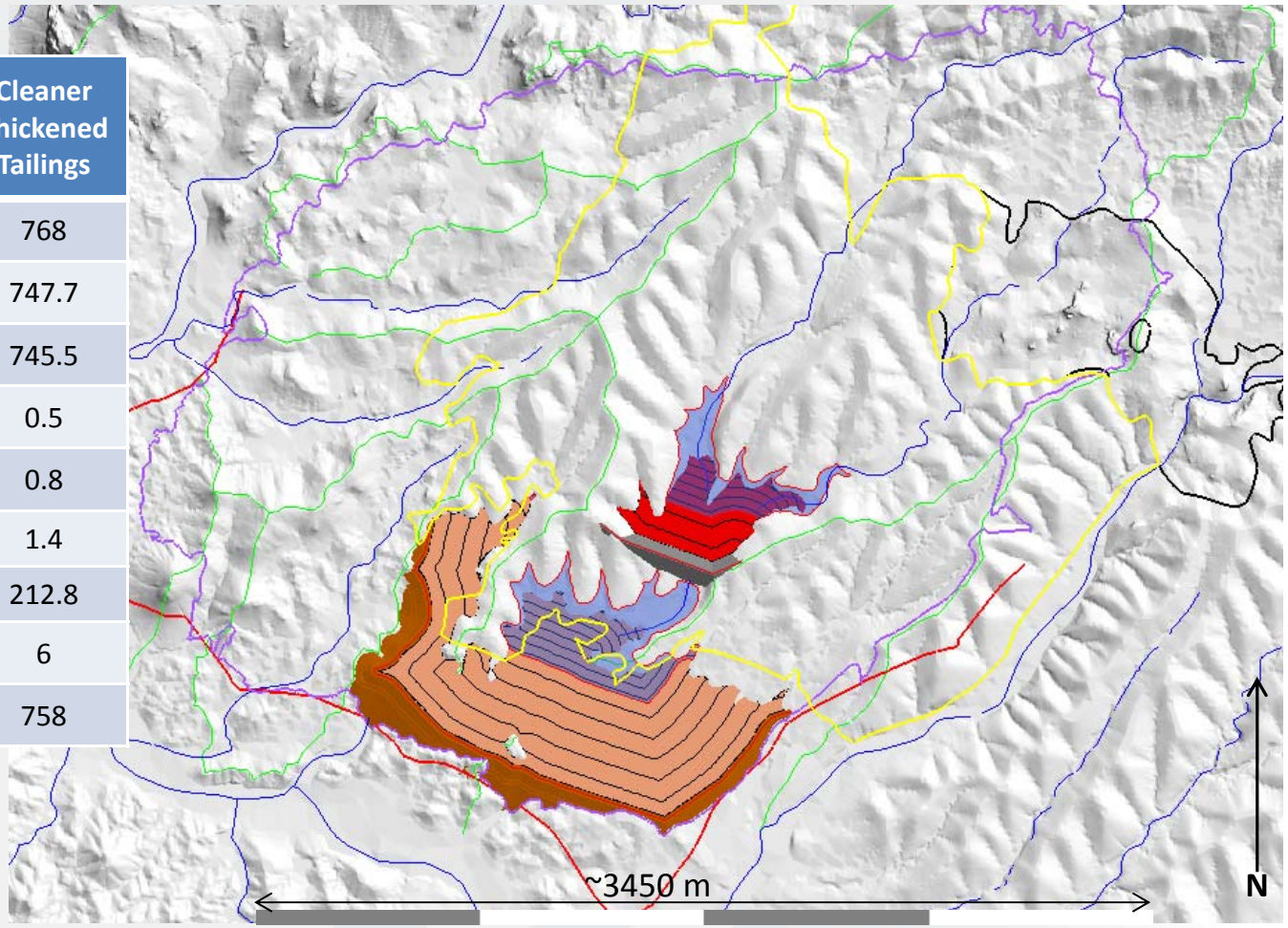
- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline

Klohn Crippen Berger

Stage I: Year 4

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	733	768
Tailings Elevation (masl)	731.7	747.7
Pond Elevation (masl)	726.3	745.5
Pond Volume (Mm^3)	1.8	0.5
Tailings Volume (Mm^3)	10.2	0.8
Tonnage (Mtonnes)	14.3	1.4
Beach Length (m)	539.9	212.8
Max Pond Depth (m)	9.2	6
0.5PMF Elevation (masl)	729	758

Note: Contours drawn at 1m intervals



Legend:

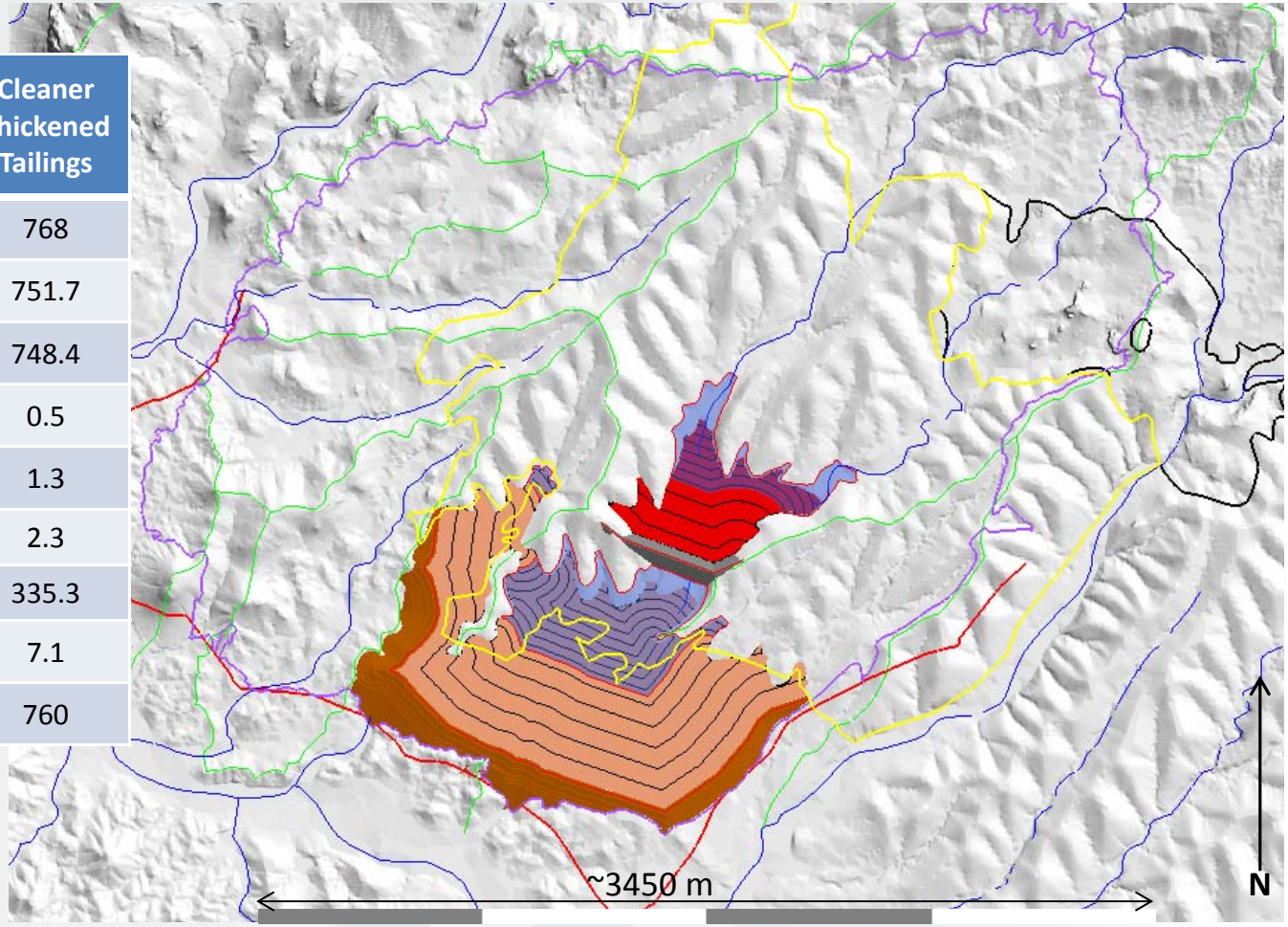
- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline

Klohn Crippen Berger

Stage I: Year 5

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	740	768
Tailings Elevation (masl)	739.9	751.7
Pond Elevation (masl)	734.6	748.4
Pond Volume (Mm^3)	2.7	0.5
Tailings Volume (Mm^3)	14.9	1.3
Tonnage (Mtonnes)	20.9	2.3
Beach Length (m)	530.5	335.3
Max Pond Depth (m)	9.8	7.1
0.5PMF Elevation (masl)	736	760

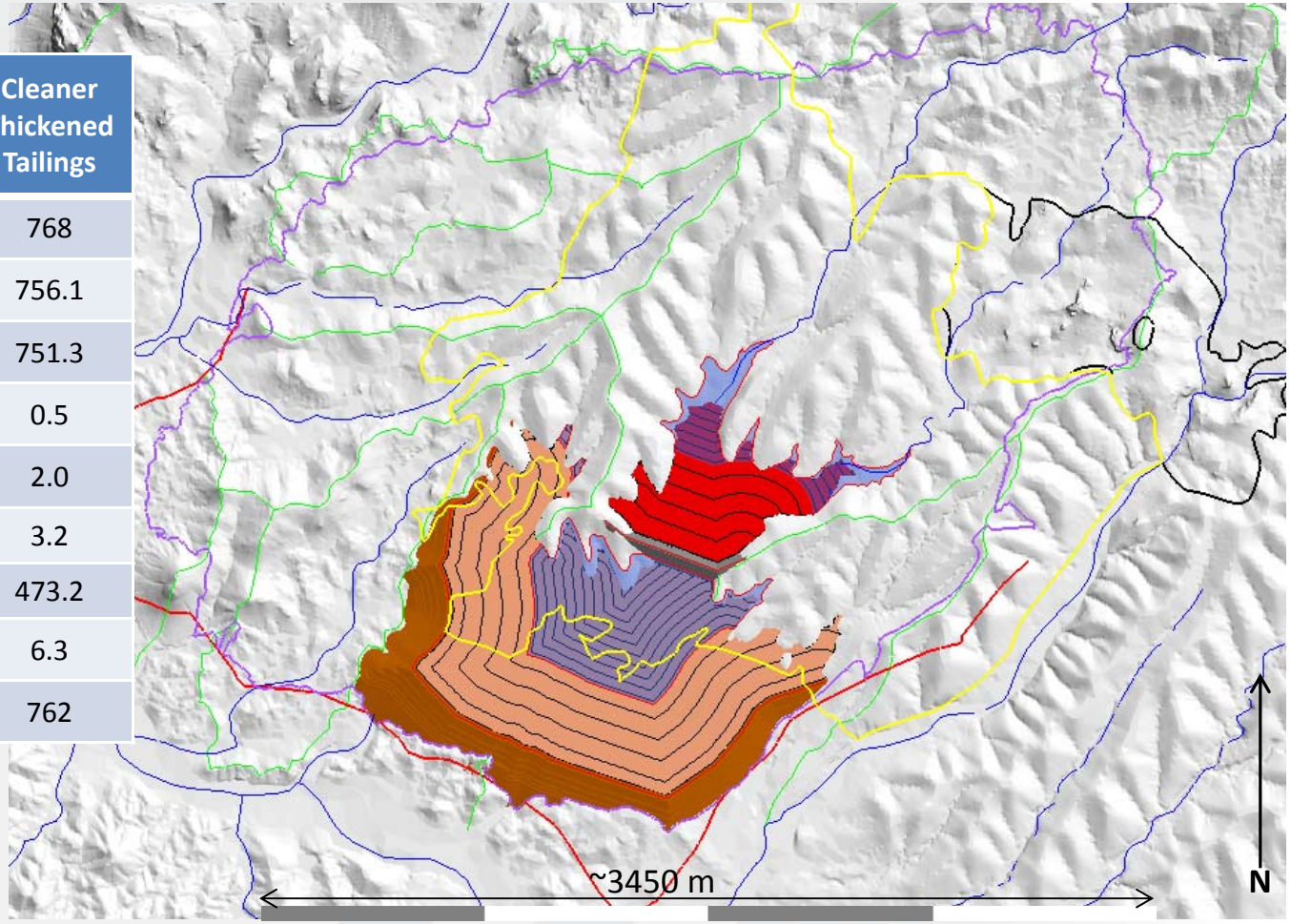
Note: Contours drawn at 1m intervals



Stage I: Year 6

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	750	768
Tailings Elevation (masl)	748.6	756.1
Pond Elevation (masl)	744.3	751.3
Pond Volume (Mm^3)	3.5	0.5
Tailings Volume (Mm^3)	19.5	2.0
Tonnage (Mtonnes)	27.3	3.2
Beach Length (m)	430.3	473.2
Max Pond Depth (m)	10.3	6.3
0.5PMF Elevation (masl)	744	762

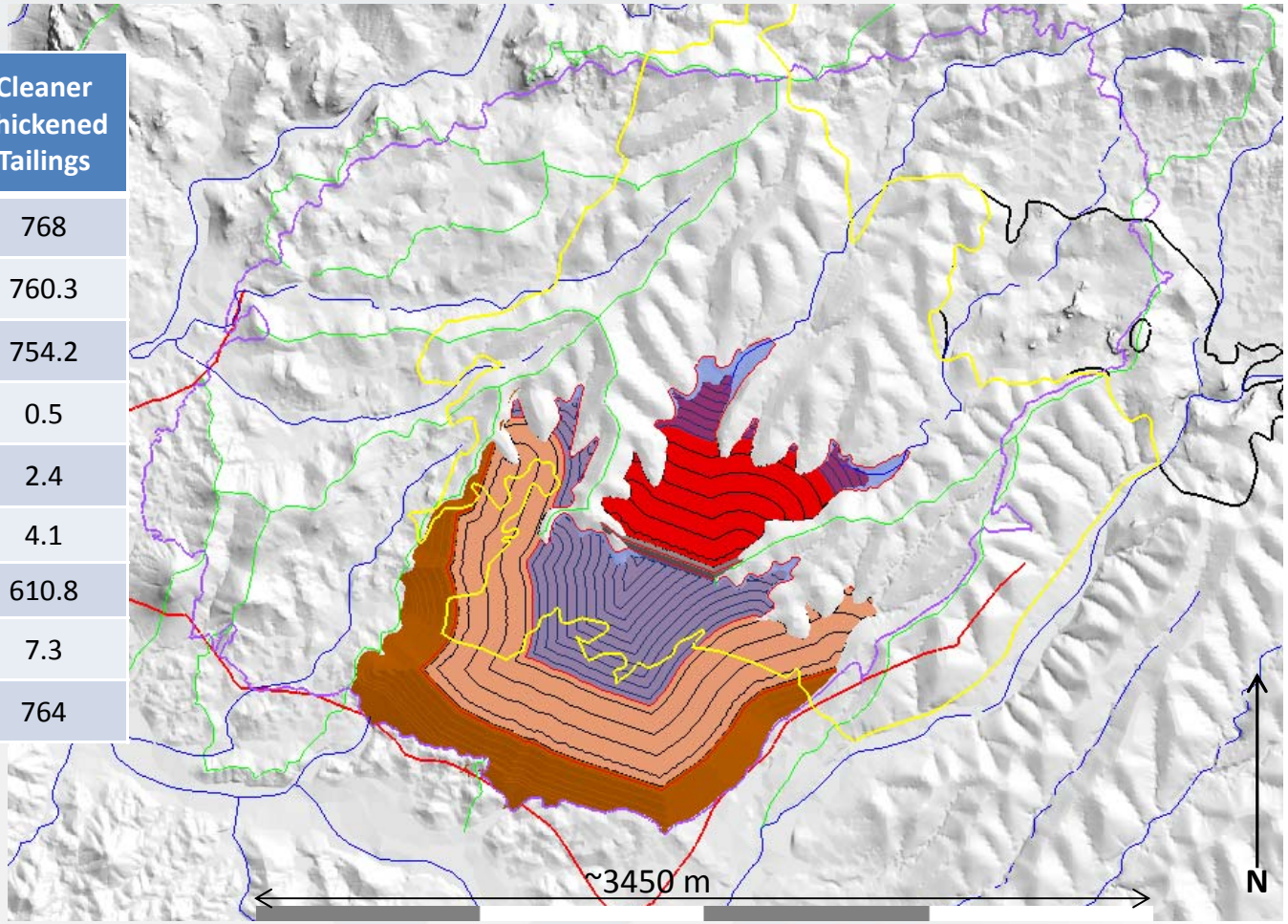
Note: Contours drawn at 1m intervals



Stage I: Year 7

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	760	768
Tailings Elevation (masl)	758.5	760.3
Pond Elevation (masl)	754.6	754.2
Pond Volume (Mm^3)	4.1	0.5
Tailings Volume (Mm^3)	23.0	2.4
Tonnage (Mtonnes)	32.2	4.1
Beach Length (m)	383.7	610.8
Max Pond Depth (m)	11.2	7.3
0.5PMF Elevation (masl)	754	764

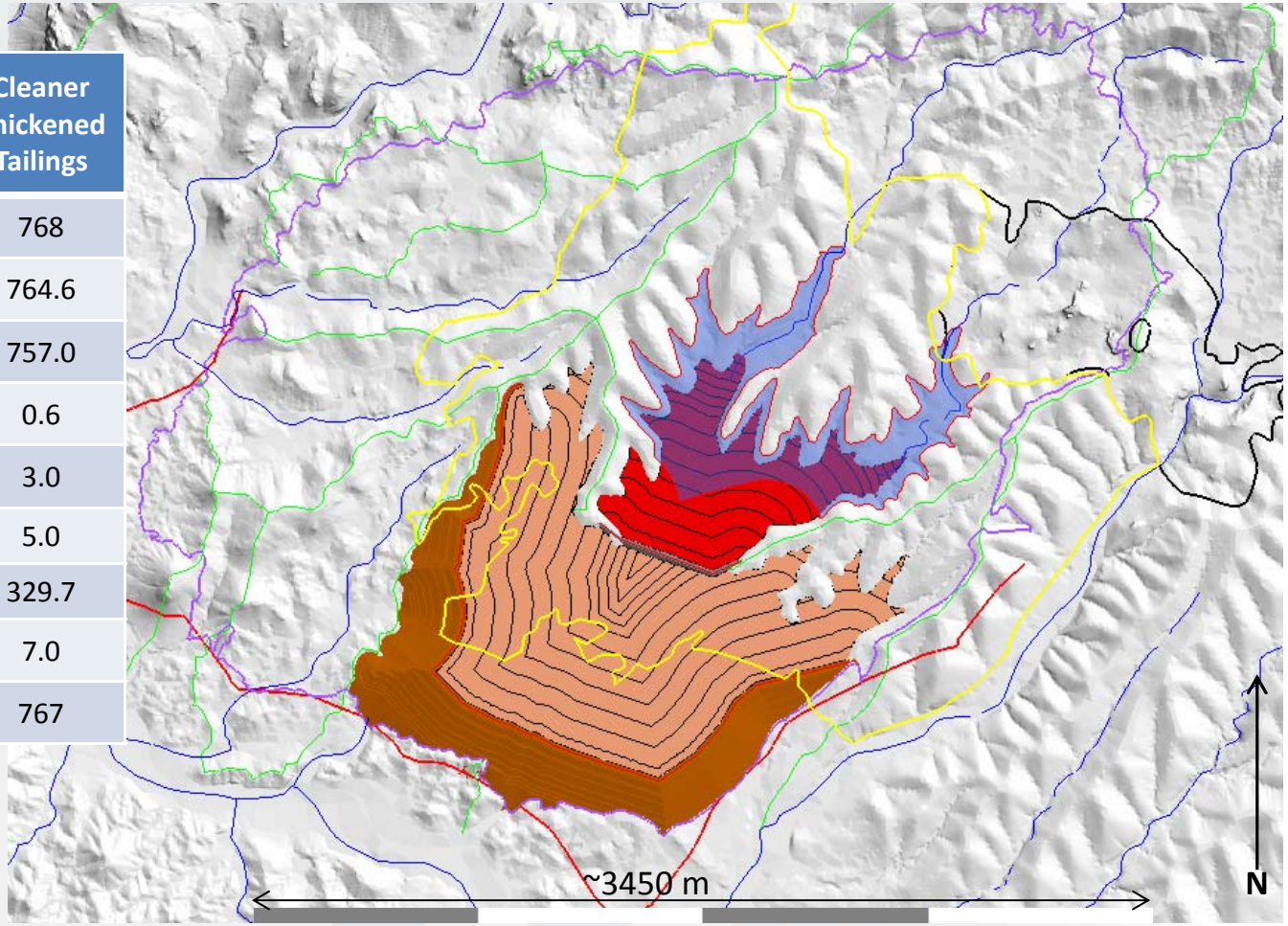
Note: Contours drawn at 1m intervals



Stage I: Year 8

	Scavenger Thickened Tailings	Cleaner Thickened Tailings
Dam Elevation (masl)	770	768
Tailings Elevation (masl)	768.4	764.6
Pond Elevation (masl)	762.0	757.0
Pond Volume (Mm^3)	4.6	0.6
Tailings Volume (Mm^3)	25.9	3.0
Tonnage (Mtonnes)	36.3	5.0
Beach Length (m)	642.8	329.7
Max Pond Depth (m)	12.0	7.0
0.5PMF Elevation (masl)	766	767

Note: Contours drawn at 1m intervals

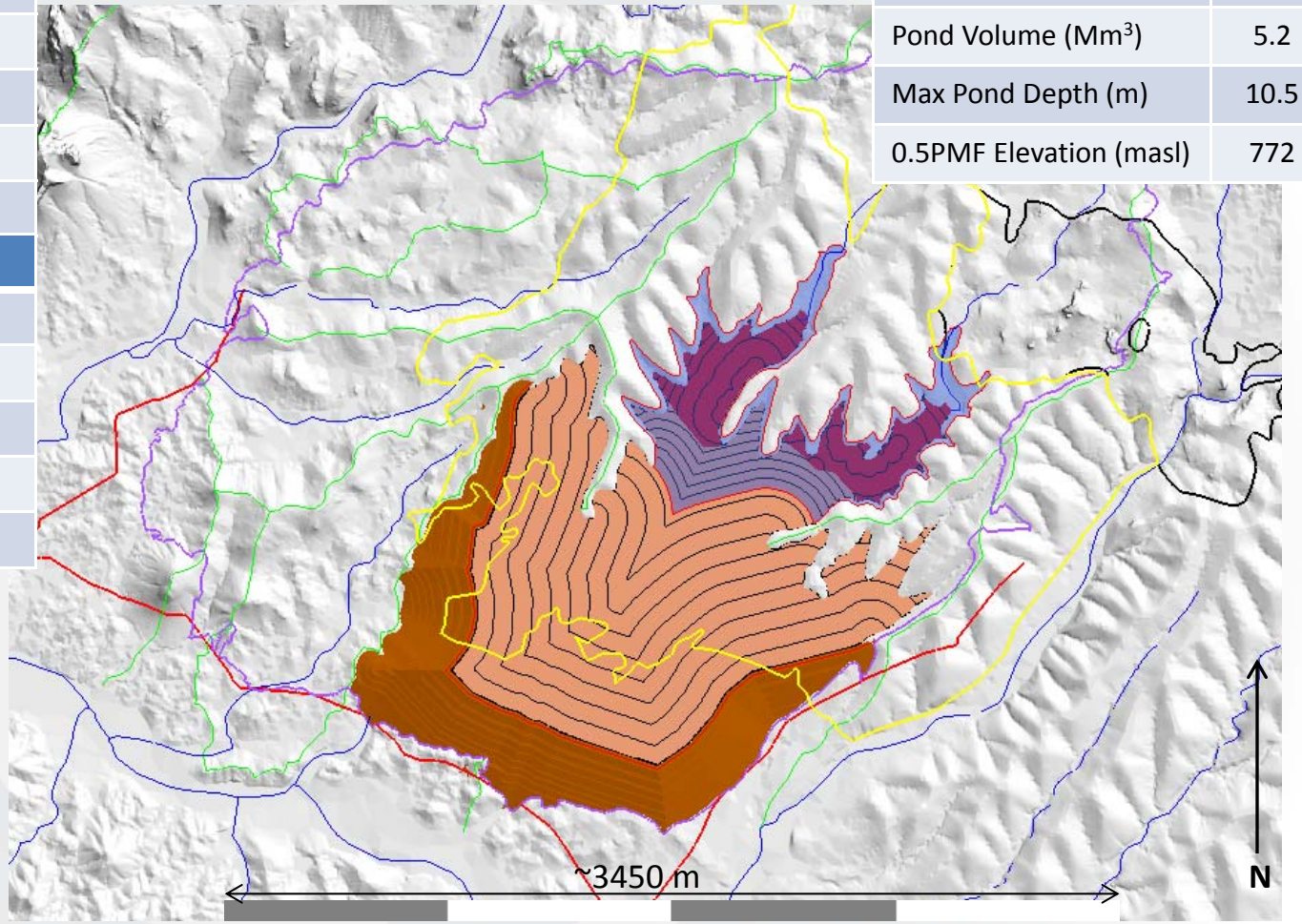


Stage I: Year 9

Scavenger Thickened Tailings	
Dam Elevation (masl)	780
Tailings Elevation (masl)	776.9
Tailings Volume (Mm^3)	25.5
Tonnage (Mtonnes)	35.7
Beach Length (m)	976.5
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	764.5
Tailings Volume (Mm^3)	3.2
Tonnage (Mtonnes)	5.5
Beach Length (m)	0

Note: Contours drawn at 1m intervals

Pond Details	
Pond Elevation (masl)	767.6
Pond Volume (Mm^3)	5.2
Max Pond Depth (m)	10.5
0.5PMF Elevation (masl)	772



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline

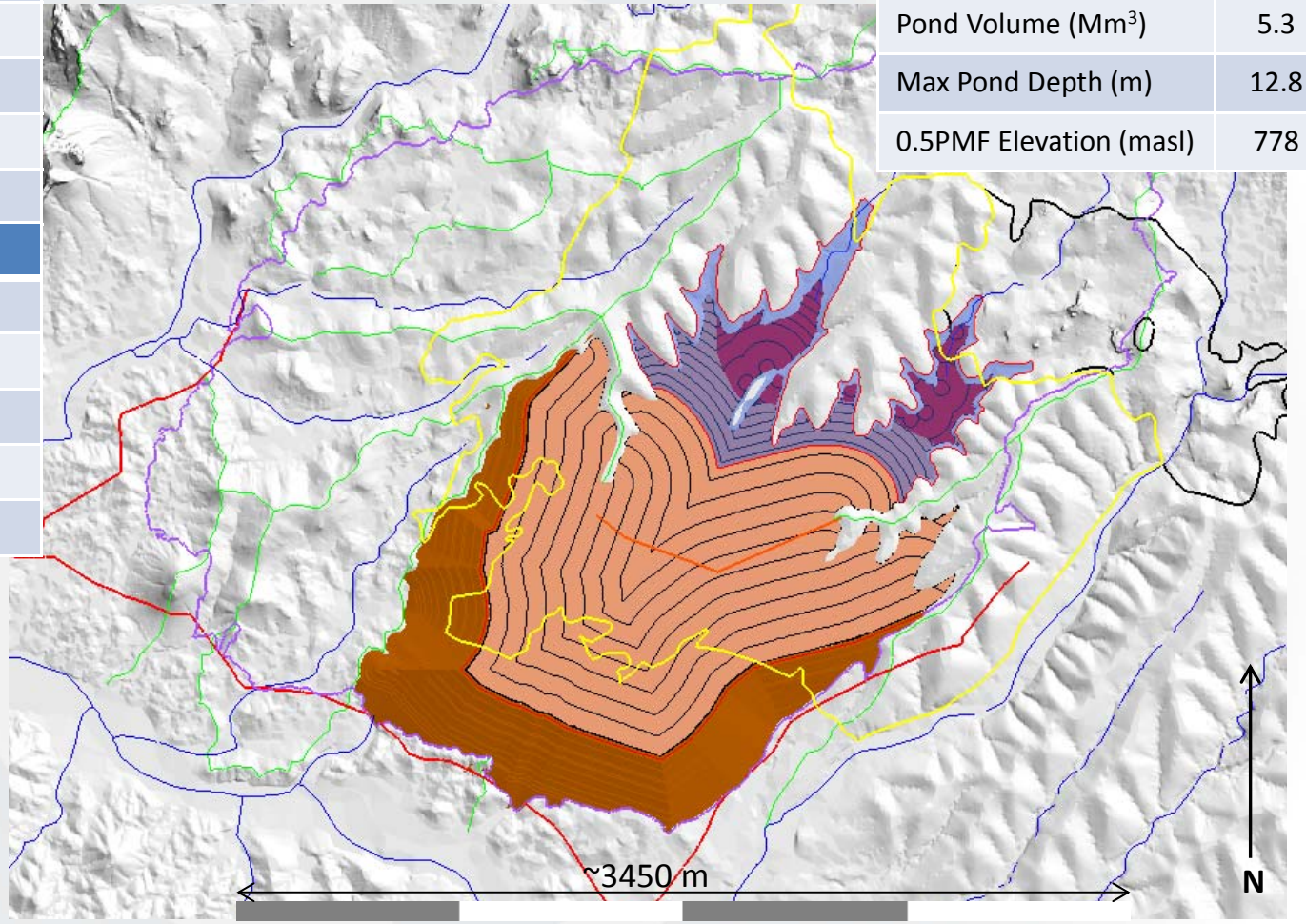
Klohn Crippen Berger

Stage I: Year 10

Scavenger Thickened Tailings	
Dam Elevation (masl)	788
Tailings Elevation (masl)	784.0
Tailings Volume (Mm^3)	25.3
Tonnage (Mtonnes)	35.5
Beach Length (m)	1,047
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	769.4
Tailings Volume (Mm^3)	3.5
Tonnage (Mtonnes)	5.9
Beach Length (m)	0

Note: Contours drawn at 1m intervals

Pond Details	
Pond Elevation (masl)	773.5
Pond Volume (Mm^3)	5.3
Max Pond Depth (m)	12.8
0.5PMF Elevation (masl)	778

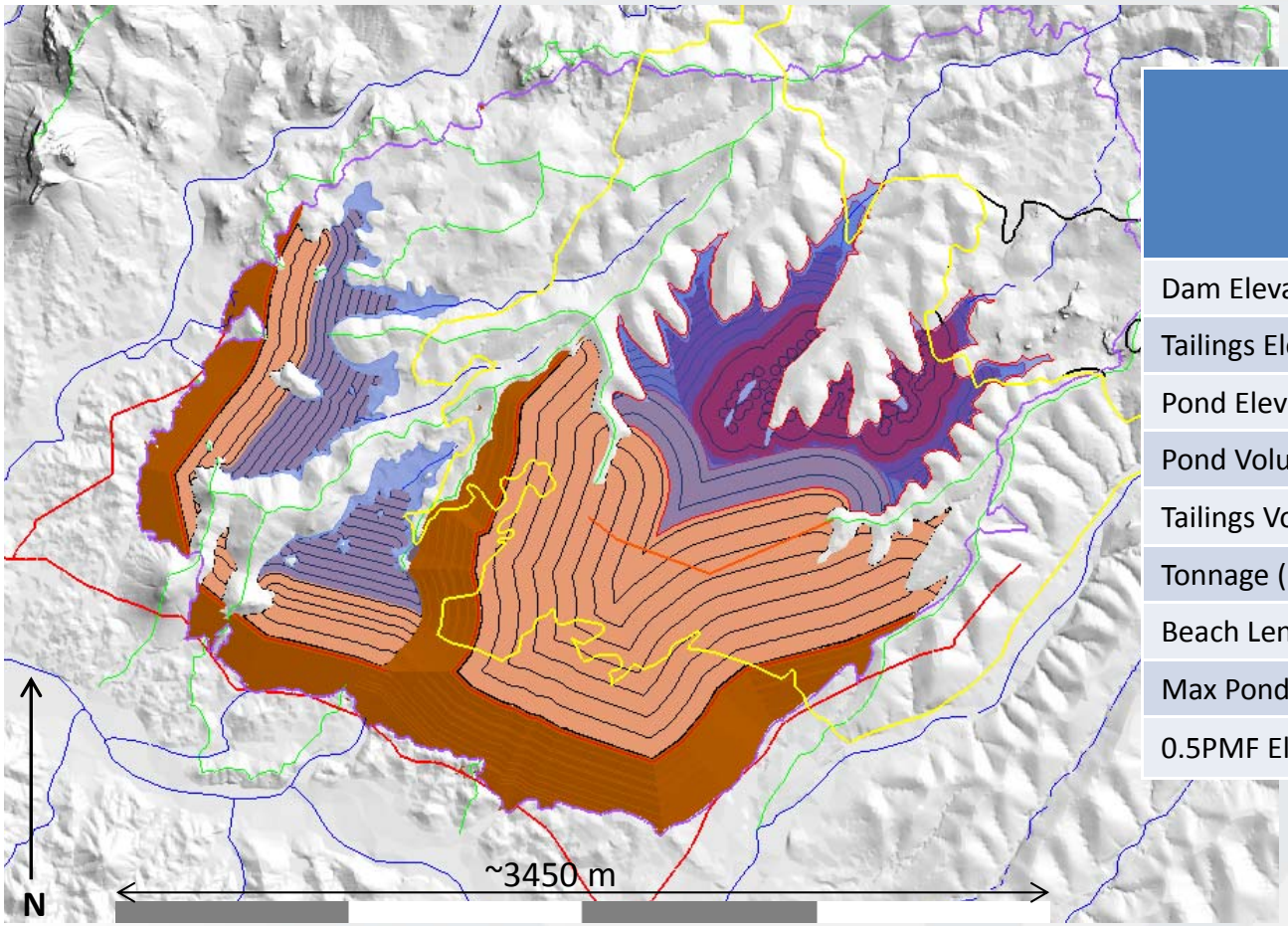


Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Natural Streams
- Rhyolite
- Cleaner Dam Centerline
- Catchment Divides
- Gila Conglomerate
- Ultimate Toe Outline

Klohn Crippen Berger

Stage II: Year 11



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	740	788	768
Tailings Elevation (masl)	736.7	784	775.3
Pond Elevation (masl)	731.7	775.7	775.7
Pond Volume (Mm^3)	3.5	3.0	3.0
Tailings Volume (Mm^3)	25.4	-	3.6
Tonnage (Mtonnes)	35.5	-	6.2
Beach Length (m)	150	750	0
Max Pond Depth (m)	11.7	10.5	10.5
0.5PMF Elevation (masl)	737	779	779

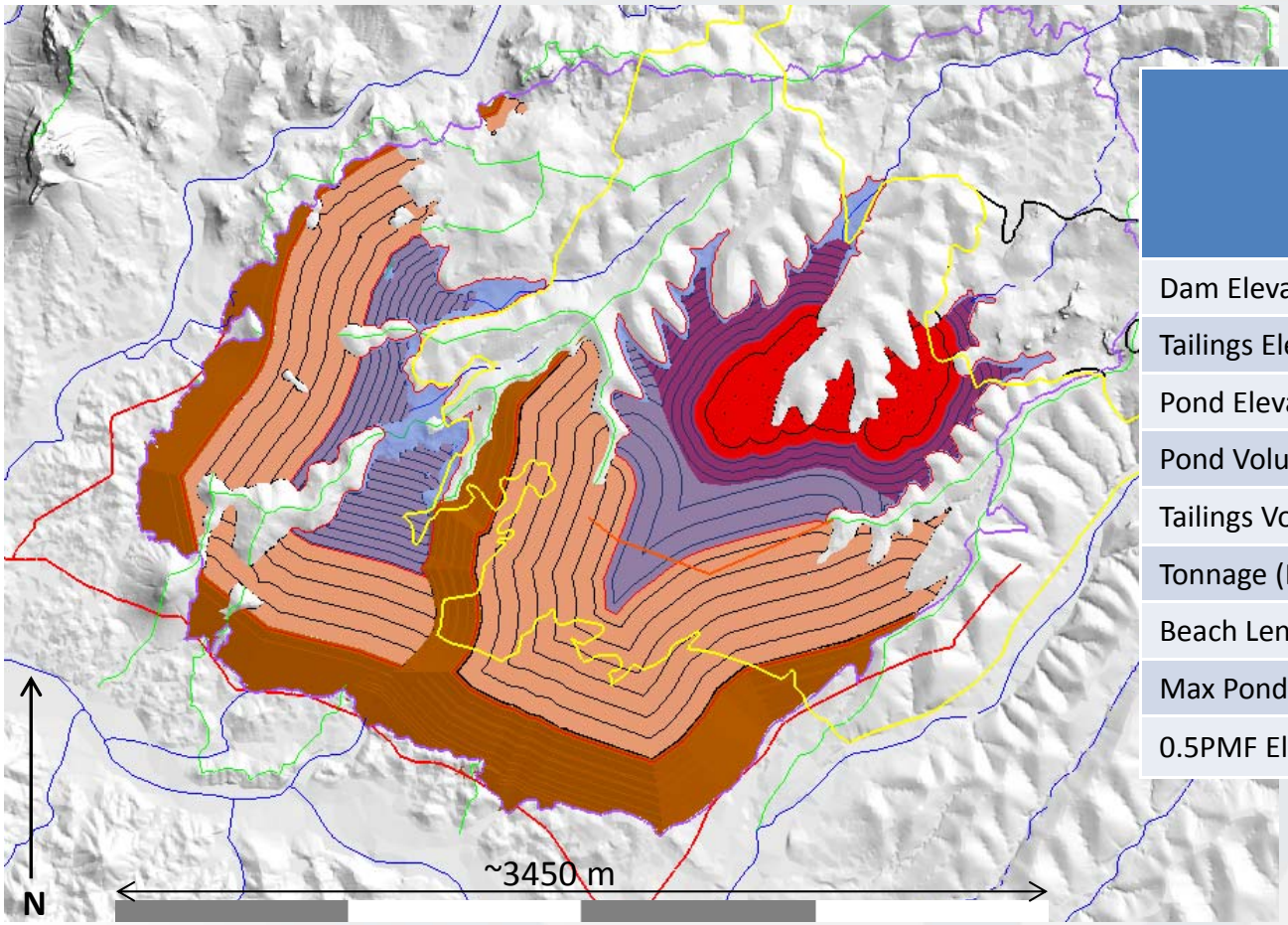
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 12



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	750	788	768
Tailings Elevation (masl)	749.8	784	779.0
Pond Elevation (masl)	745.2	777.4	777.4
Pond Volume (Mm^3)	3.3	3.0	3.0
Tailings Volume (Mm^3)	25.7	-	3.6
Tonnage (Mtonnes)	36.0	-	6.1
Beach Length (m)	464.9	650	158.1
Max Pond Depth (m)	14.3	9.6	9.6
0.5PMF Elevation (masl)	746	781	781

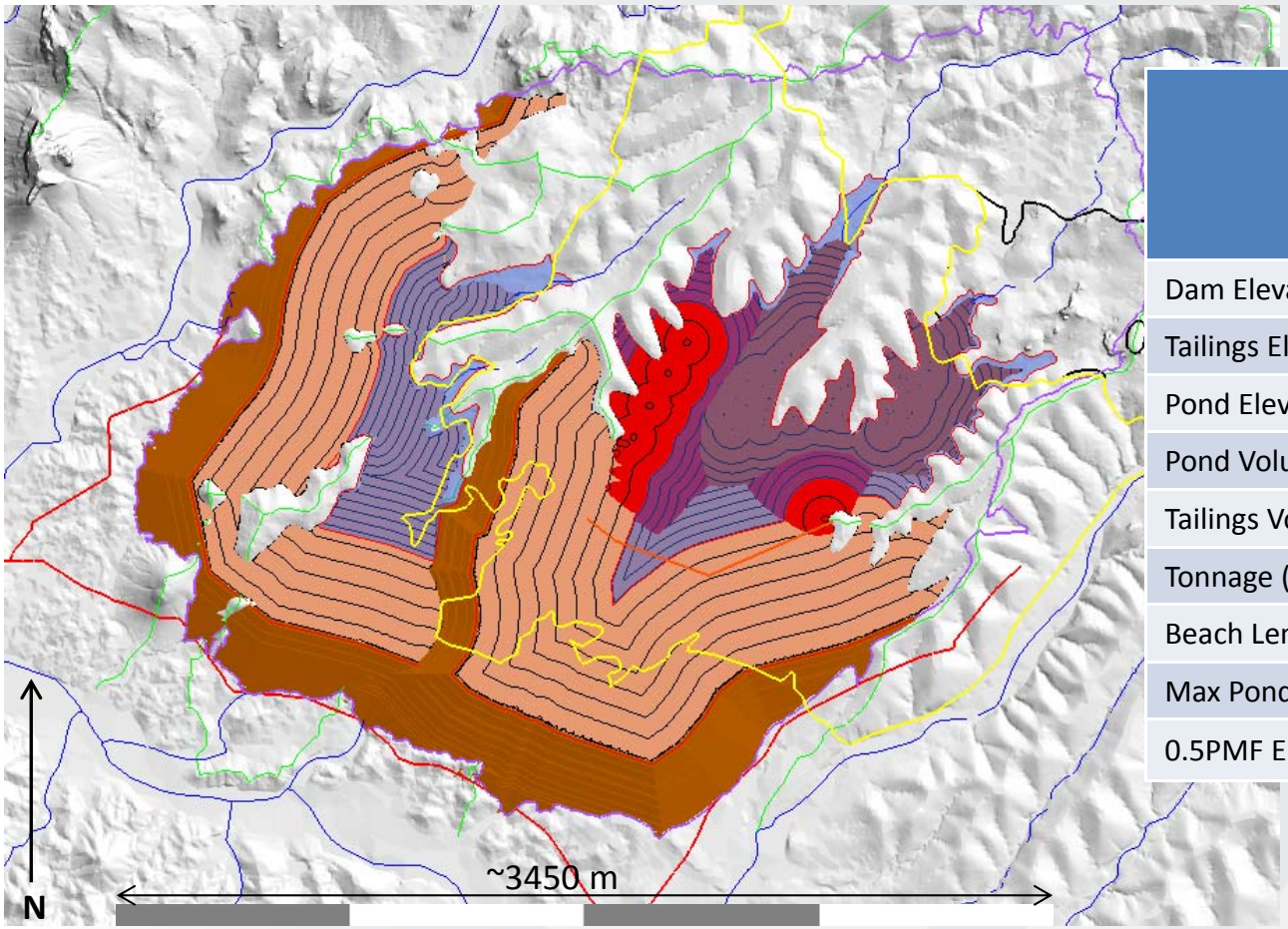
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 13



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	760	788	768
Tailings Elevation (masl)	757.8	786.1	781.2
Pond Elevation (masl)	752.5	779.1	779.1
Pond Volume (Mm^3)	4.5	3.0	3.0
Tailings Volume (Mm^3)	20.1	5.0	3.0
Tonnage (Mtonnes)	28.1	7.0	5.2
Beach Length (m)	526.0	697.9	220
Max Pond Depth (m)	12.0	9.1	9.1
0.5PMF Elevation (masl)	753	782	782

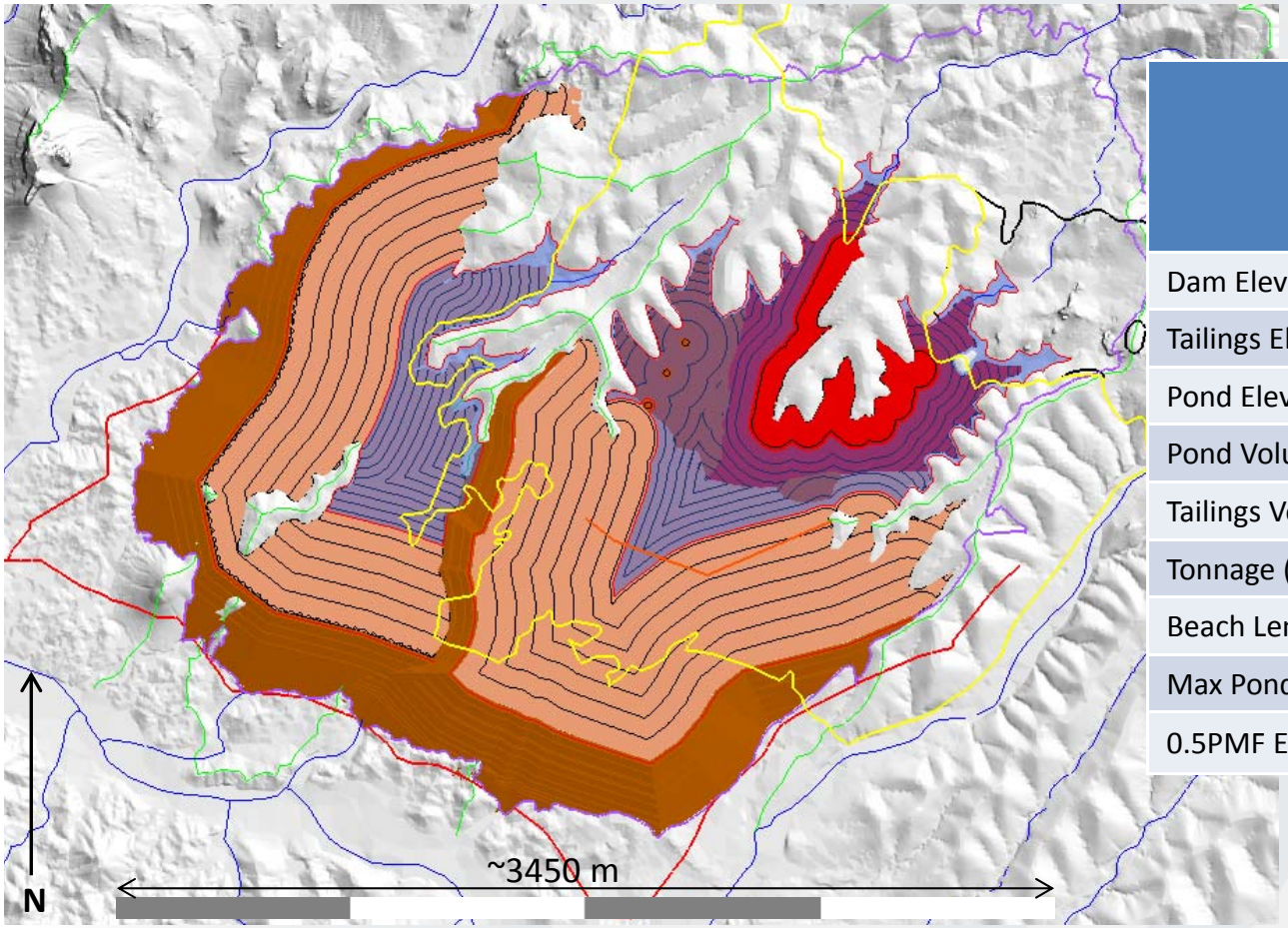
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 14



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	770	788	768
Tailings Elevation (masl)	767.1	788.0	782.0
Pond Elevation (masl)	761.5	780.8	780.8
Pond Volume (Mm^3)	4.7	3.0	3.0
Tailings Volume (Mm^3)	21.0	5.5	3.0
Tonnage (Mtonnes)	29.4	7.7	5.2
Beach Length (m)	569.4	716.1	100
Max Pond Depth (m)	13.2	8.3	8.3
0.5PMF Elevation (masl)	762	784	784

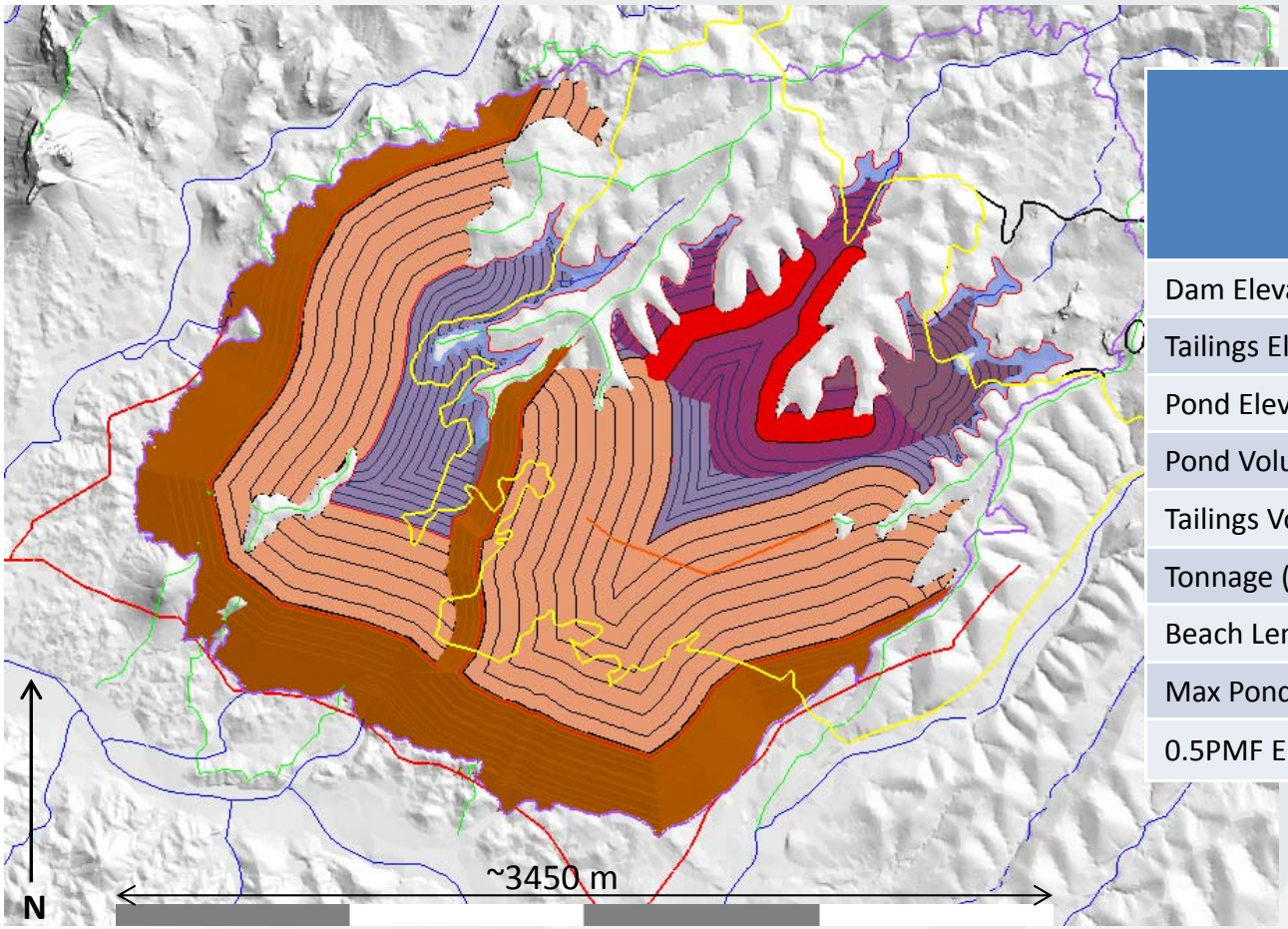
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 15



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	774	794	768
Tailings Elevation (masl)	771.7	790.8	783.8
Pond Elevation (masl)	766.2	783.0	783.0
Pond Volume (Mm^3)	4.8	3.0	3.0
Tailings Volume (Mm^3)	16.0	10.6	2.7
Tonnage (Mtonnes)	22.4	14.9	4.6
Beach Length (m)	548.7	778.2	120
Max Pond Depth (m)	11.5	10.5	10.5
0.5PMF Elevation (masl)	767	786	786

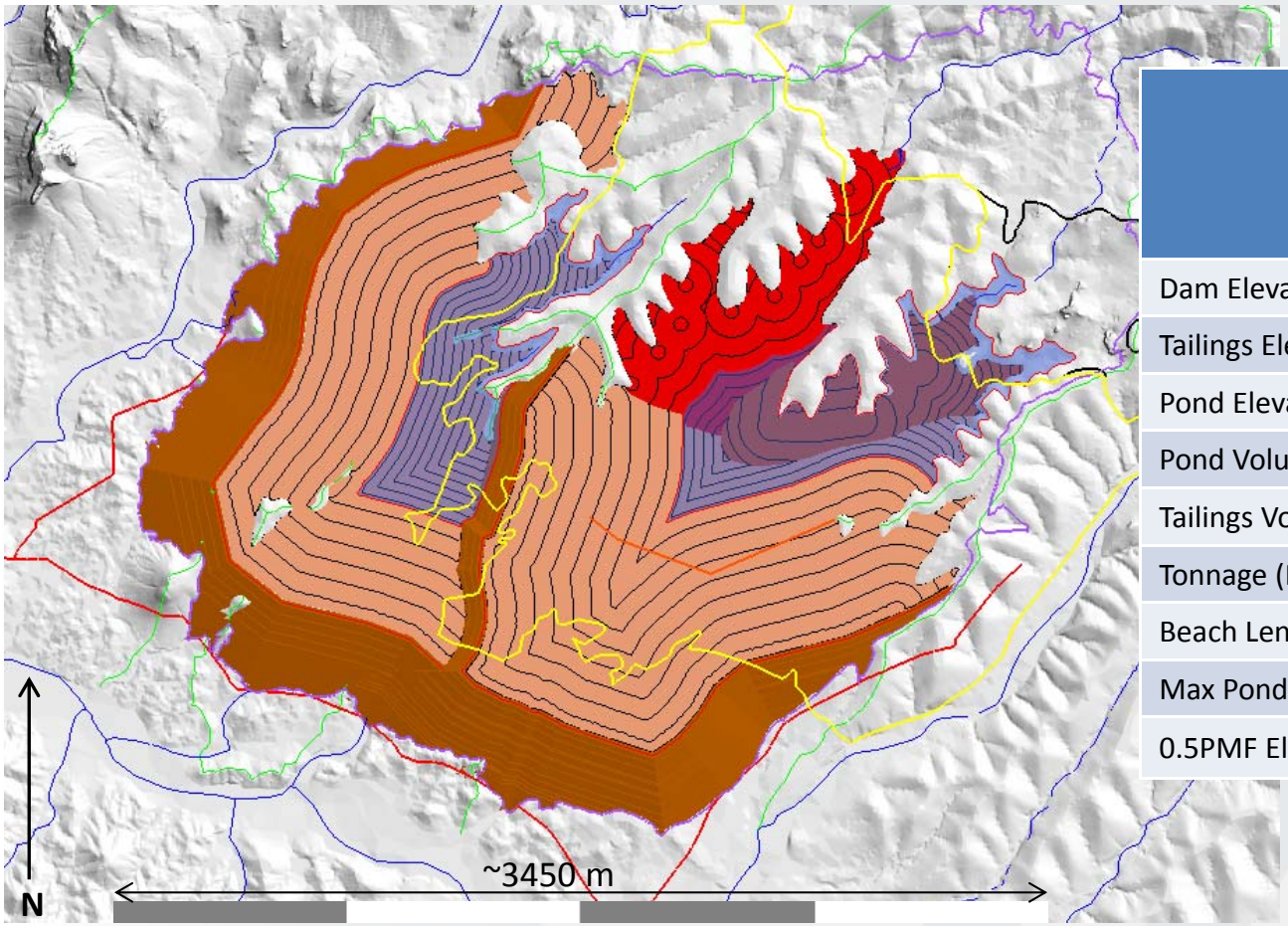
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 16



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	780	794	768
Tailings Elevation (masl)	779.5	792.5	787.4
Pond Elevation (masl)	773.3	784.3	784.3
Pond Volume (Mm^3)	4.7	3.0	3.0
Tailings Volume (Mm^3)	21.1	5.3	2.9
Tonnage (Mtonnes)	29.5	7.4	4.9
Beach Length (m)	619.4	819.9	616.7
Max Pond Depth (m)	13.3	11.8	11.8
0.5PMF Elevation (masl)	774	788	788

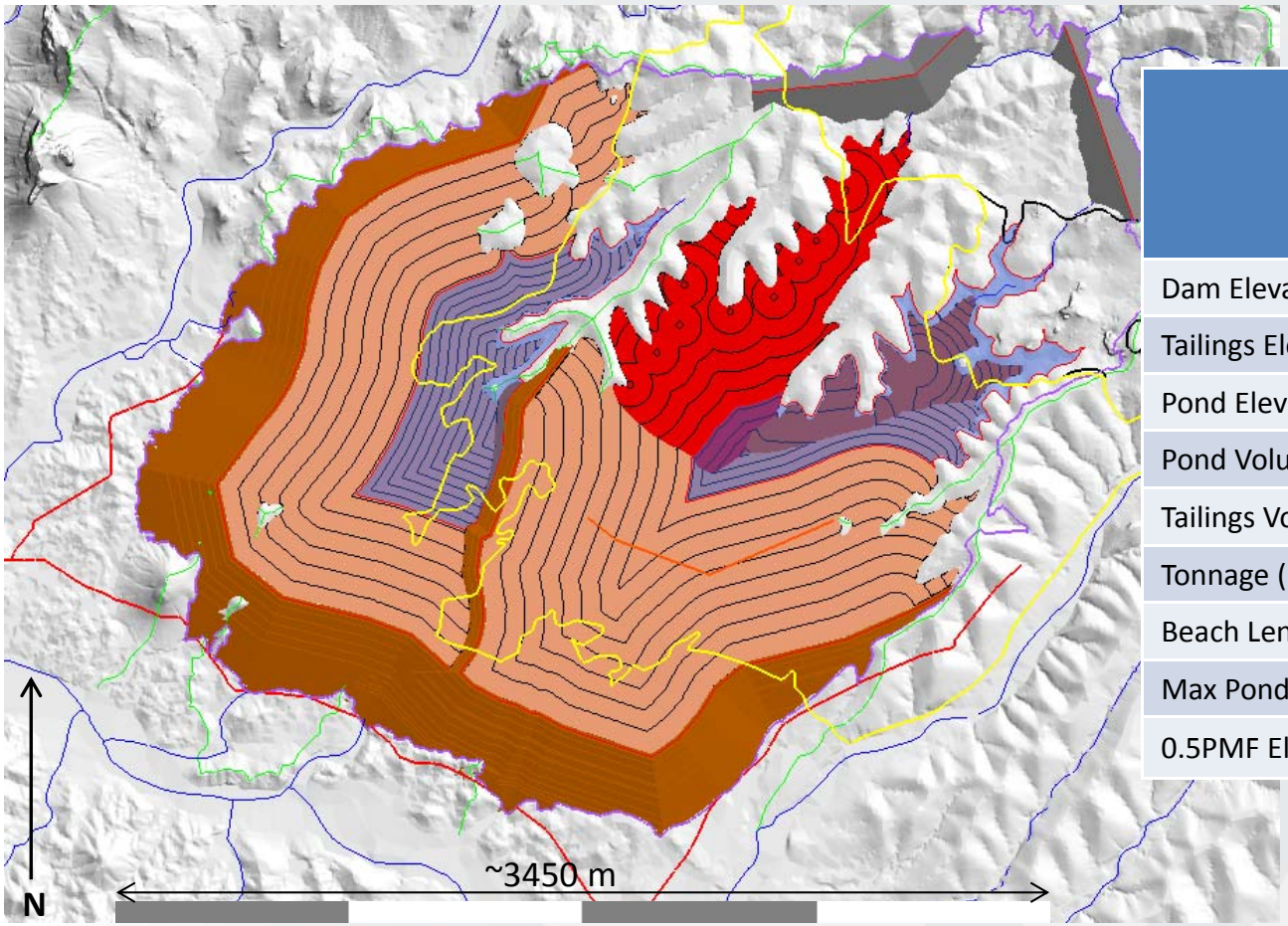
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 17



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	786	794	768
Tailings Elevation (masl)	785.8	794	790.2
Pond Elevation (masl)	779.9	785.2	785.2
Pond Volume (Mm^3)	4.7	3.0	3.0
Tailings Volume (Mm^3)	21.2	4.9	3.1
Tonnage (Mtonnes)	29.7	6.9	5.2
Beach Length (m)	596.3	879.8	1,176
Max Pond Depth (m)	12.9	12.7	12.7
0.5PMF Elevation (masl)	780	789	789

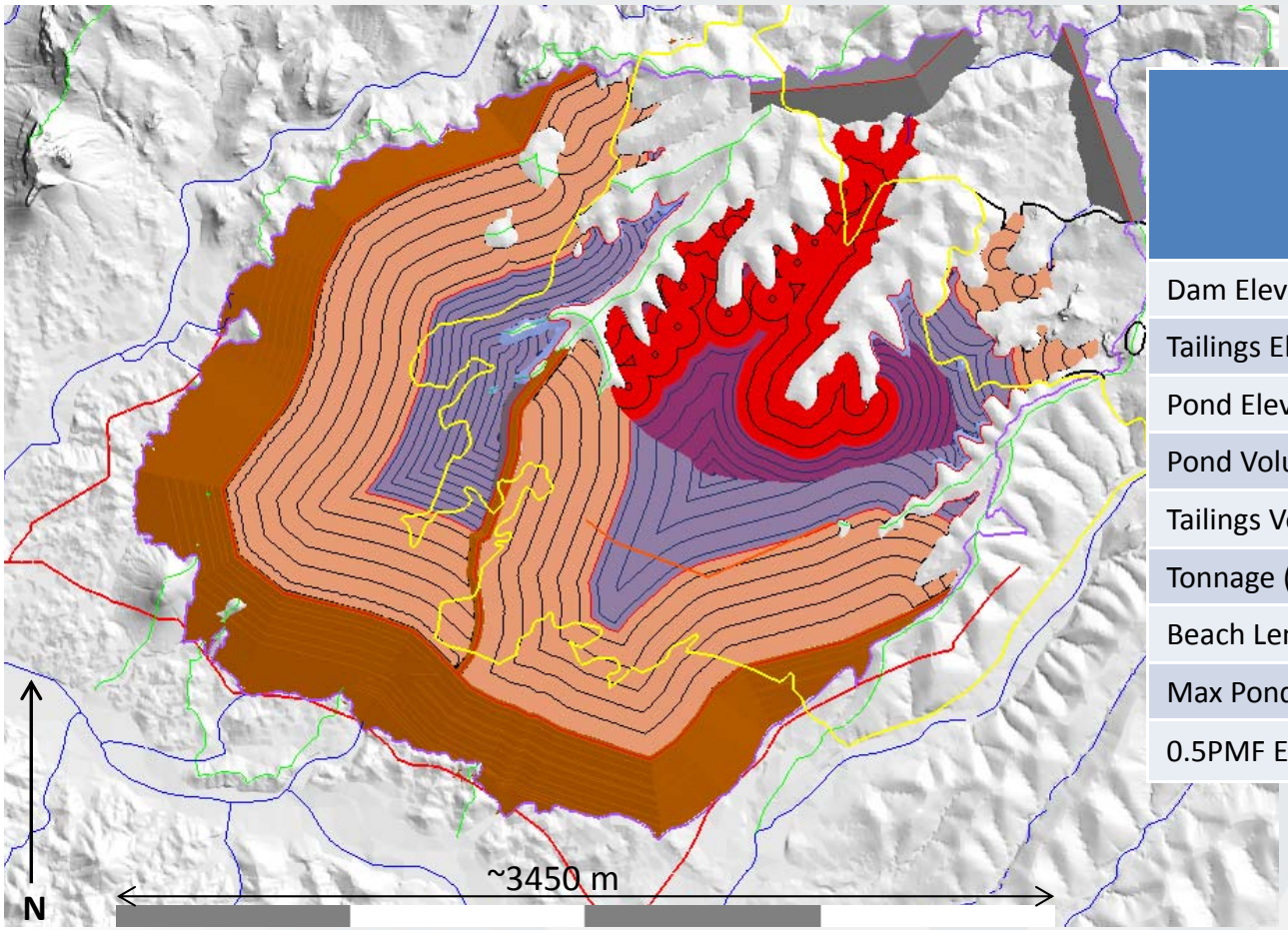
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage II: Year 18



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	794	794	768
Tailings Elevation (masl)	792.4	791.6	790.6
Pond Elevation (masl)	786.6	788.4	788.4
Pond Volume (Mm^3)	4.6	3.0	3.0
Tailings Volume (Mm^3)	23.3	2.6	3.3
Tonnage (Mtonnes)	32.6	3.6	5.6
Beach Length (m)	585.4	314	1,353
Max Pond Depth (m)	12.6	15.9	15.9
0.5PMF Elevation (masl)	787	791	791

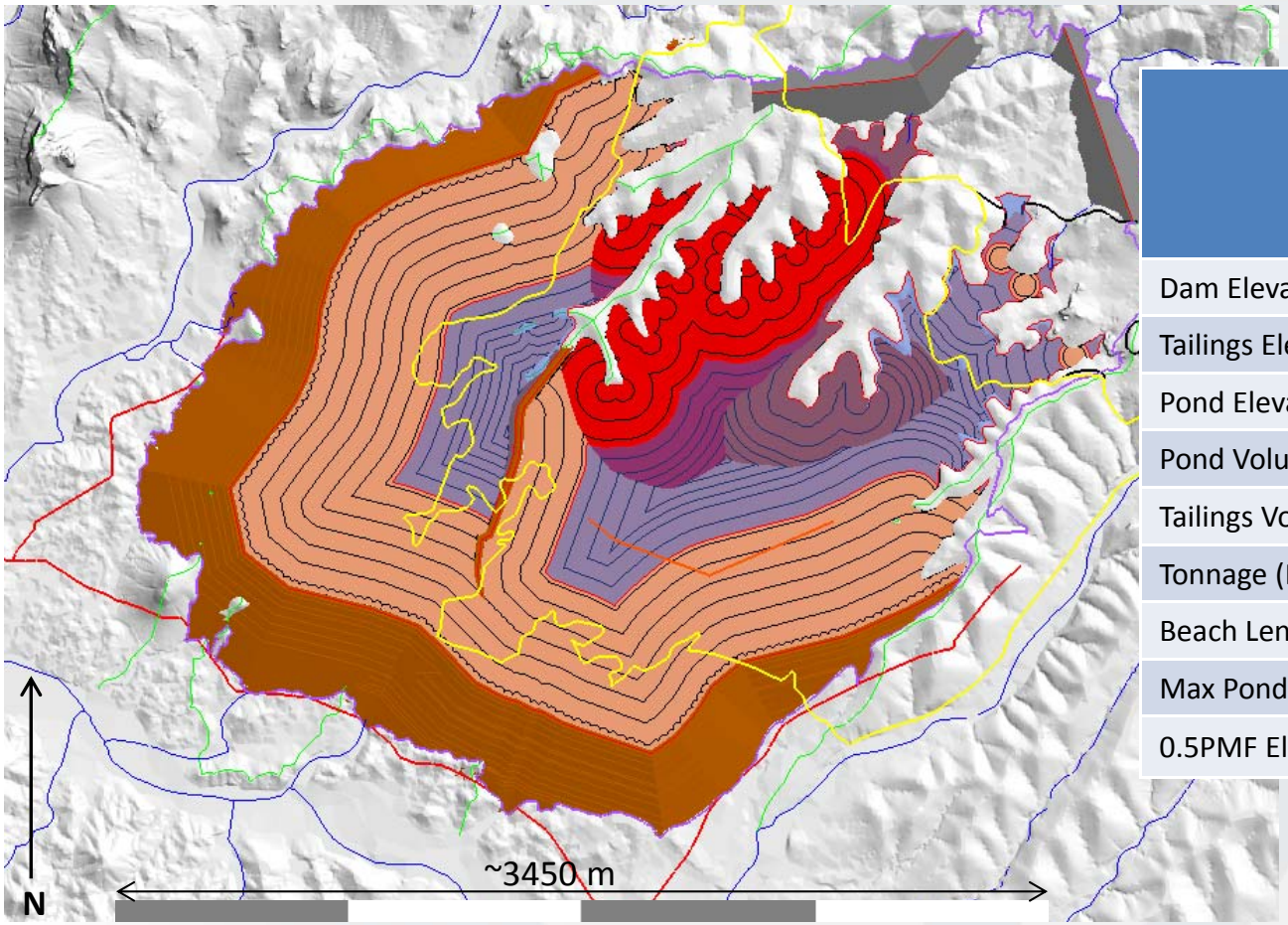
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage III: Year 19



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	798	798	768
Tailings Elevation (masl)	797.3	797.3	793.6
Pond Elevation (masl)	790.8	790.8	790.8
Pond Volume (Mm^3)	4.6	3.0	3.0
Tailings Volume (Mm^3)	12.9	12.9	3.4
Tonnage (Mtonnes)	18.0	18.0	5.9
Beach Length (m)	727.5	697.5	536
Max Pond Depth (m)	9.0	8.8	8.8
0.5PMF Elevation (masl)	795	795	795

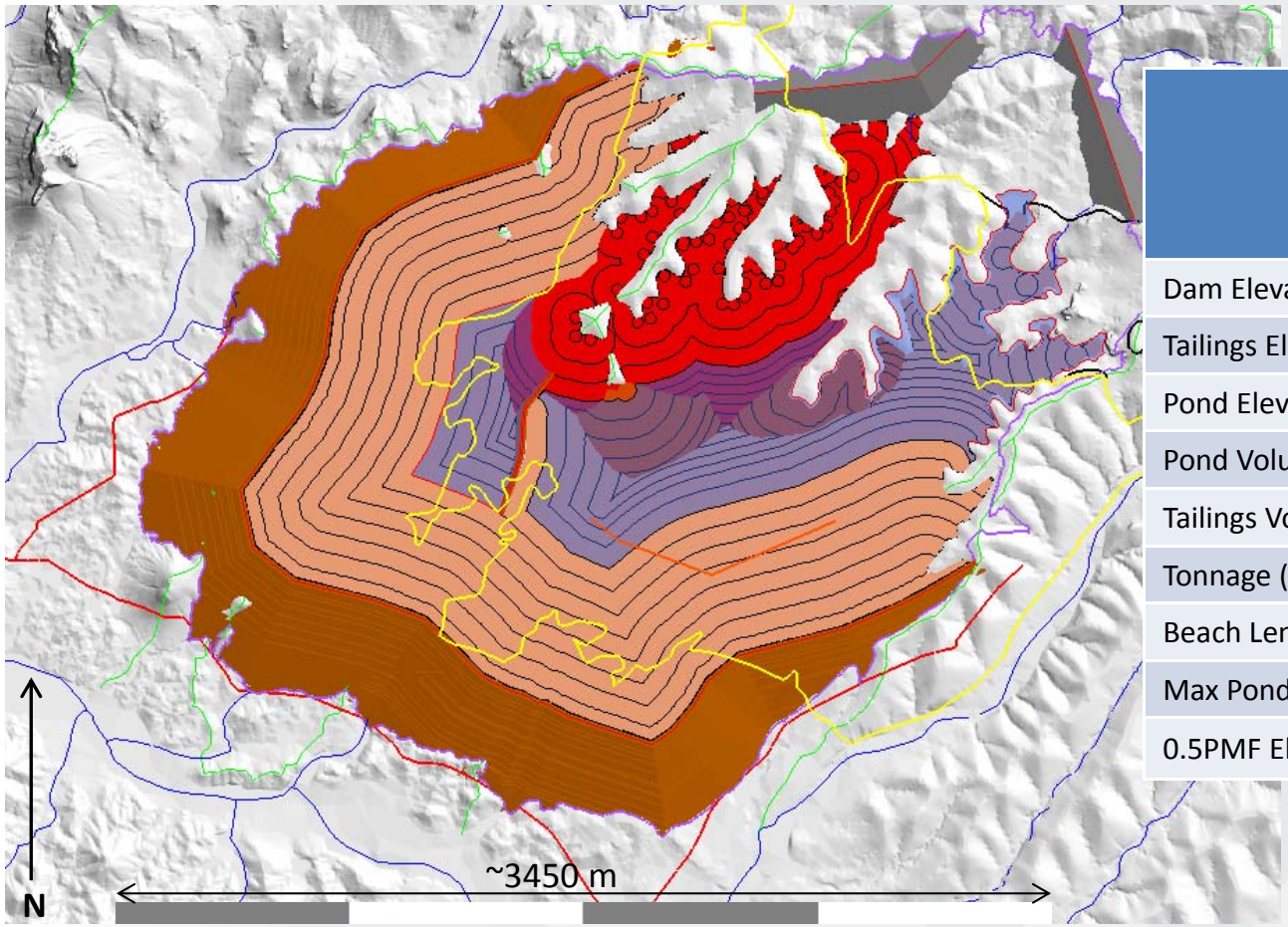
Note: Contours drawn at 1m intervals

Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage III: Year 20



	Scavenger Thickened Tailings		Cleaner Thickened Tailings
	West	East	
Dam Elevation (masl)	802	802	768
Tailings Elevation (masl)	800.6	800.6	797.8
Pond Elevation (masl)	794.0	793.0	793.0
Pond Volume (Mm^3)	4.6	3.0	3.0
Tailings Volume (Mm^3)	12.8	12.8	3.6
Tonnage (Mtonnes)	17.9	17.9	6.1
Beach Length (m)	656.7	790.2	863
Max Pond Depth (m)	12	11.0	11.0
0.5PMF Elevation (masl)	798	798	798

Note: Contours drawn at 1m intervals

Legend:

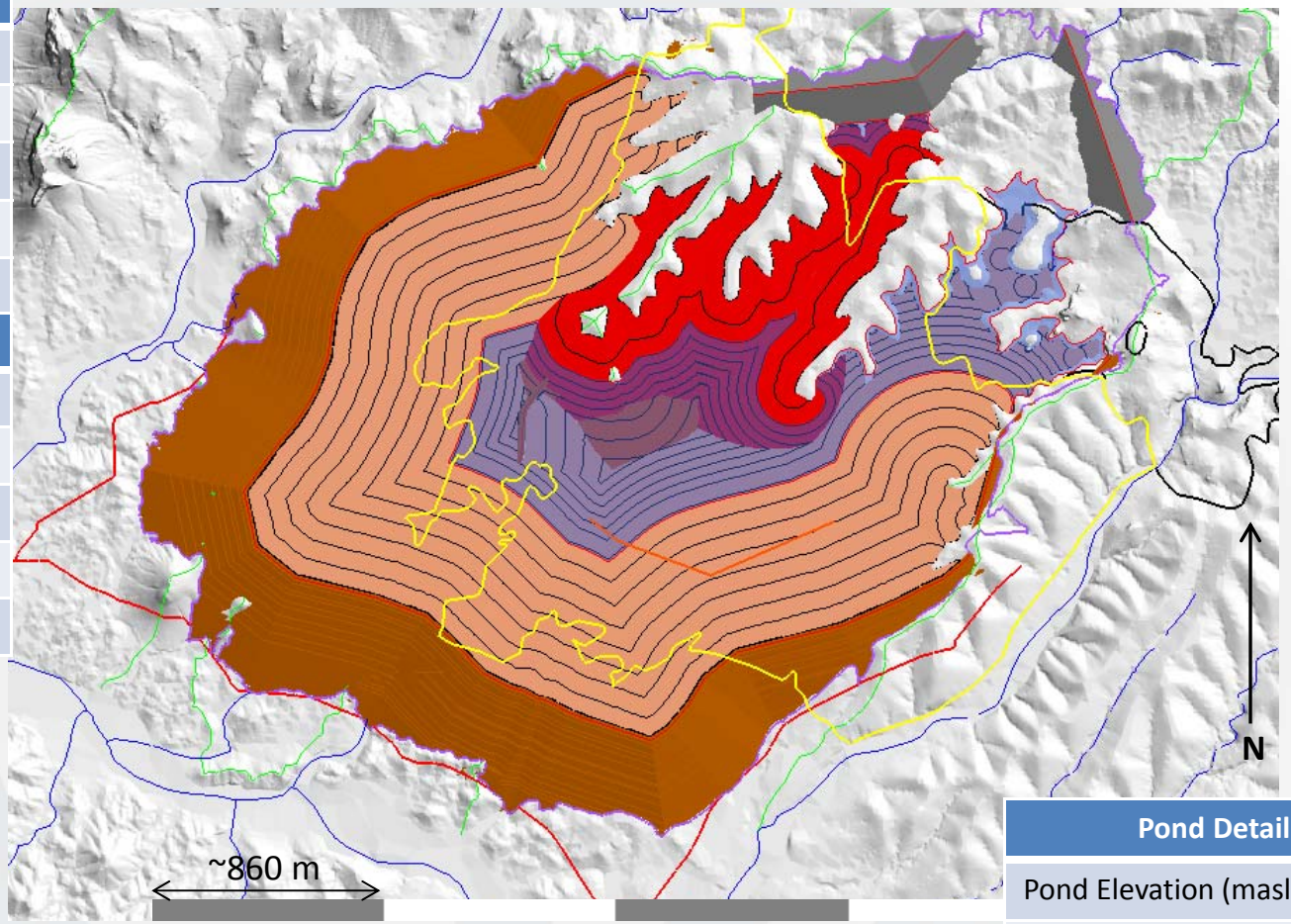
- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

Stage III: Year 21

Scavenger Thickened Tailings	
Dam Elevation (masl)	806
Tailings Elevation (masl)	803.9
Tailings Volume (Mm^3)	25.8
Tonnage (Mtonnes)	36.1
Beach Length (m)	780
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	798.0
Tailings Volume (Mm^3)	3.5
Tonnage (Mtonnes)	6.0
Beach Length (m)	585

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

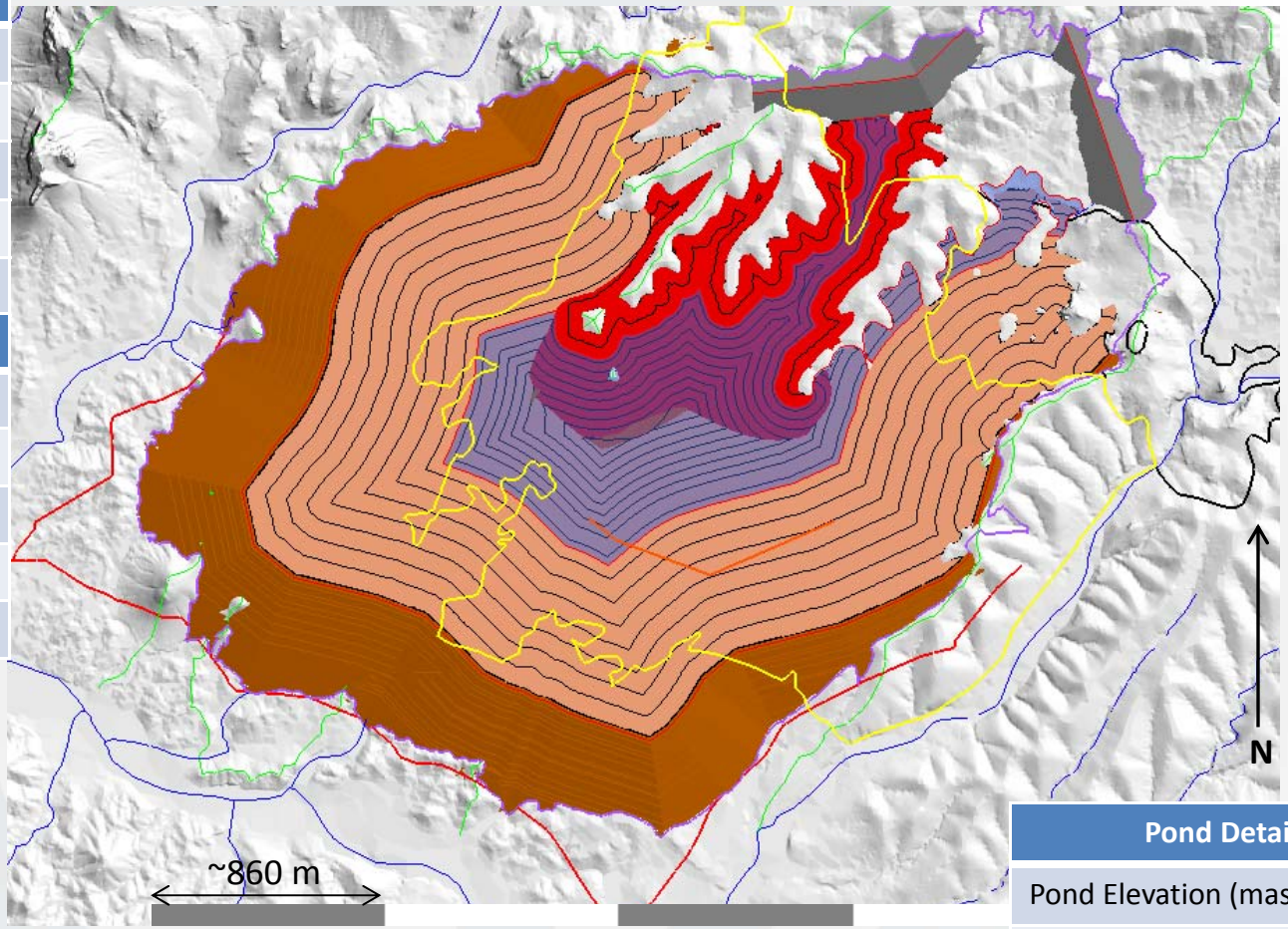
Pond Details	
Pond Elevation (masl)	796.1
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	9.1
PMF Elevation (masl)	801

Klohn Crippen Berger

Stage III: Year 22

Scavenger Thickened Tailings	
Dam Elevation (masl)	808
Tailings Elevation (masl)	807.0
Tailings Volume (Mm^3)	26.1
Tonnage (Mtonnes)	36.5
Beach Length (m)	775.1
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	800.4
Tailings Volume (Mm^3)	3.3
Tonnage (Mtonnes)	5.6
Beach Length (m)	106.2

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

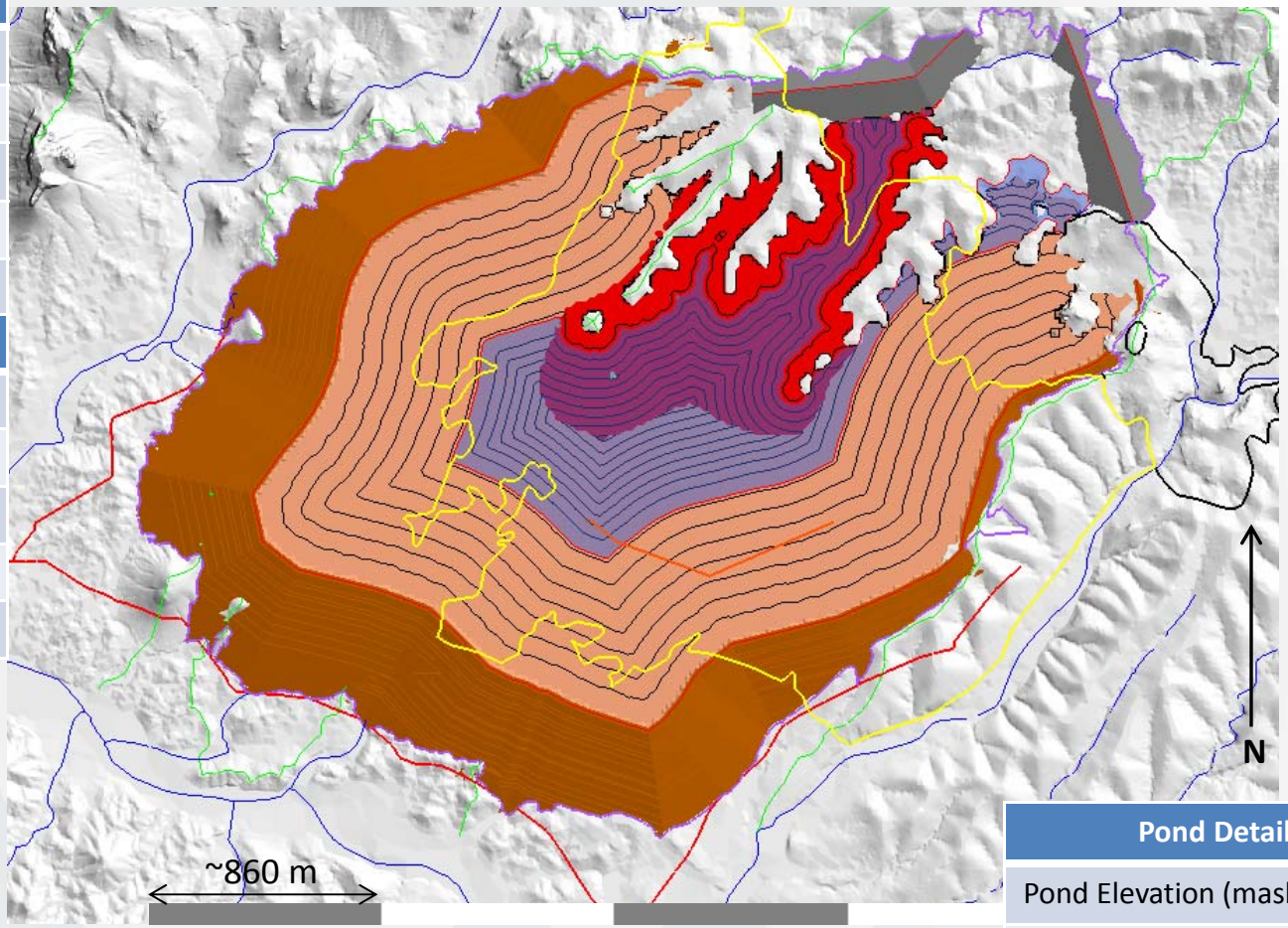
Pond Details	
Pond Elevation (masl)	799.4
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	9.4
PMF Elevation (masl)	804

Klohn Crippen Berger

Stage III: Year 23

Scavenger Thickened Tailings	
Dam Elevation (masl)	810
Tailings Elevation (masl)	809.1
Tailings Volume (Mm^3)	26.1
Tonnage (Mtonnes)	36.5
Beach Length (m)	737.1
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	802.6
Tailings Volume (Mm^3)	3.2
Tonnage (Mtonnes)	5.4
Beach Length (m)	75.8

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

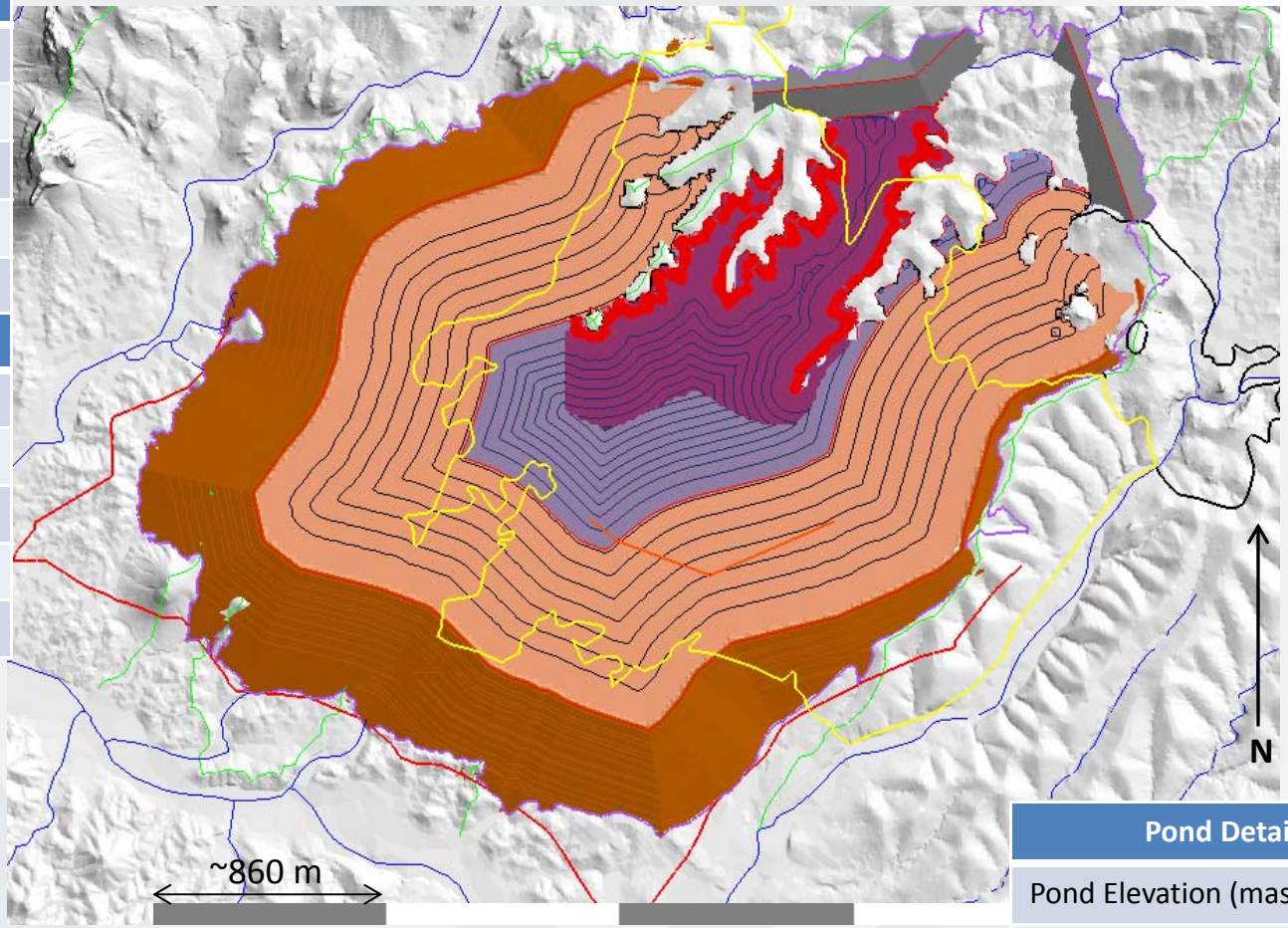
Pond Details	
Pond Elevation (masl)	801.8
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	9.3
PMF Elevation (masl)	806

Klohn Crippen Berger

Stage III: Year 24

Scavenger Thickened Tailings	
Dam Elevation (masl)	814
Tailings Elevation (masl)	812.6
Tailings Volume (Mm^3)	26.0
Tonnage (Mtonnes)	36.4
Beach Length (m)	772.1
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	805.2
Tailings Volume (Mm^3)	3.2
Tonnage (Mtonnes)	5.4
Beach Length (m)	32.0

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

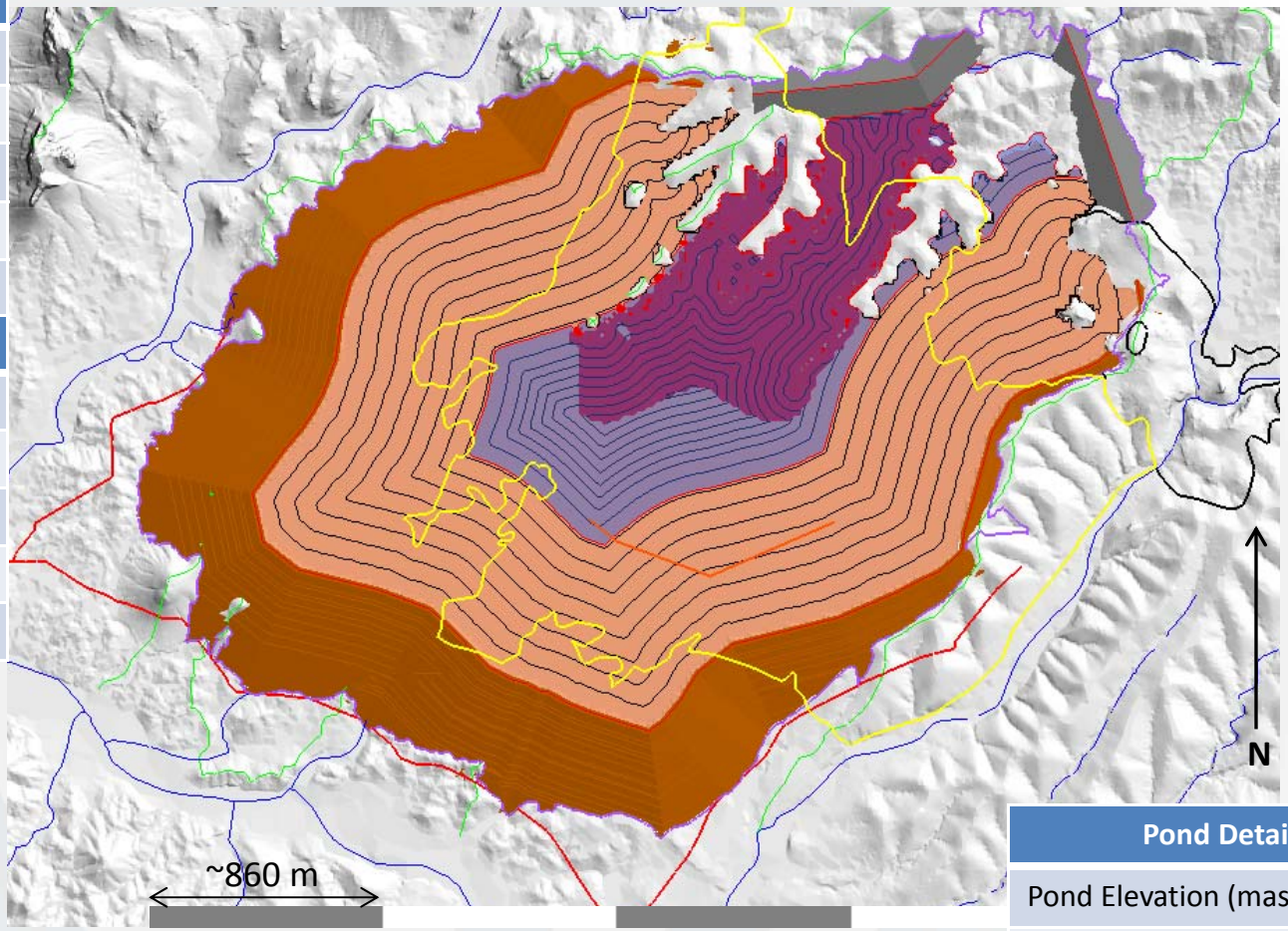
Pond Details	
Pond Elevation (masl)	804.9
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	9.4
PMF Elevation (masl)	809

Klohn Crippen Berger

Stage III: Year 25

Scavenger Thickened Tailings	
Dam Elevation (masl)	816
Tailings Elevation (masl)	815.9
Tailings Volume (Mm^3)	25.9
Tonnage (Mtonnes)	36.3
Beach Length (m)	830.9
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	808
Tailings Volume (Mm^3)	3.3
Tonnage (Mtonnes)	5.5
Beach Length (m)	16.2

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

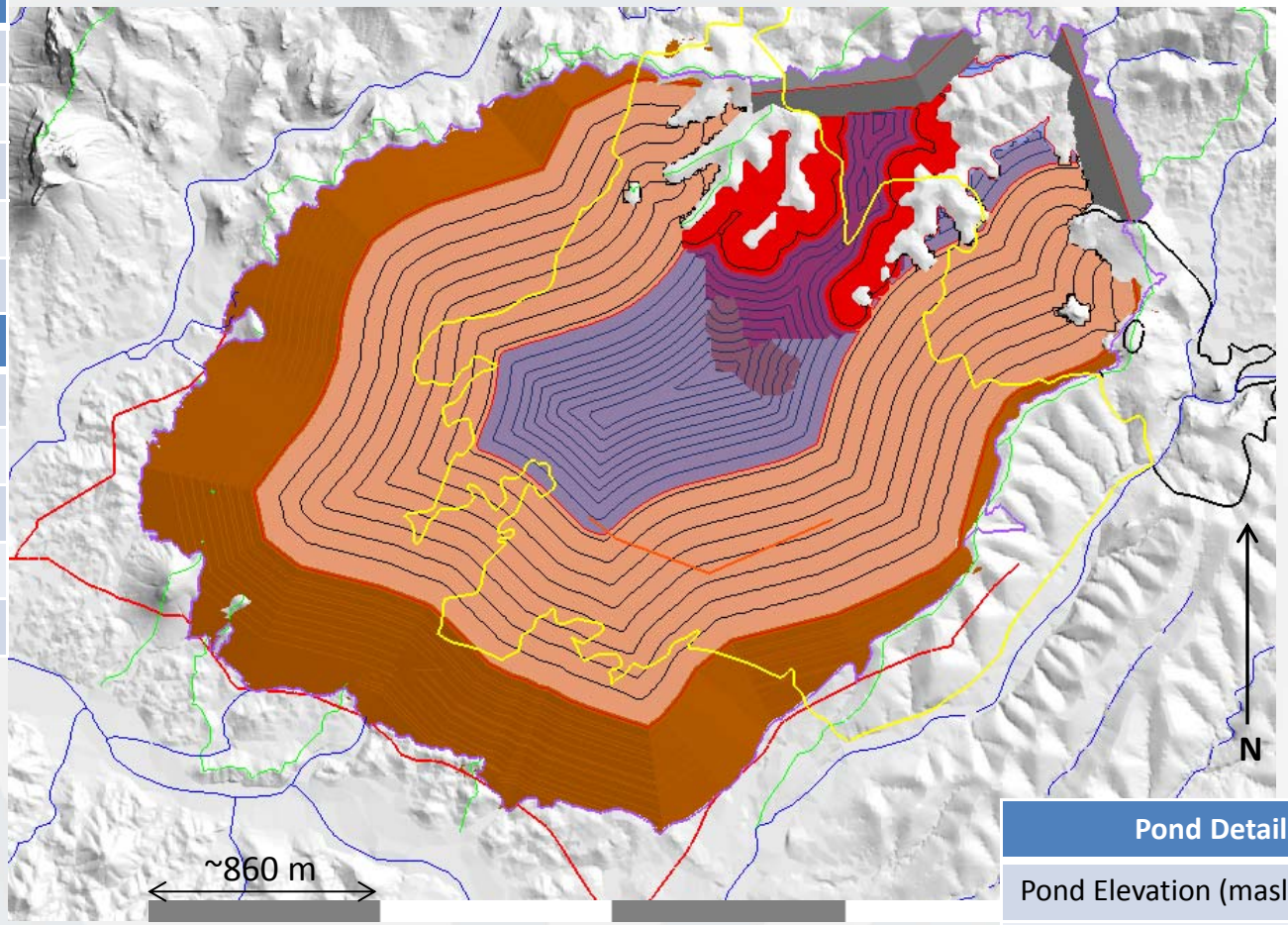
Pond Details	
Pond Elevation (masl)	807.9
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	9.3
PMF Elevation (masl)	812

Klohn Crippen Berger

Stage III: Year 26

Scavenger Thickened Tailings	
Dam Elevation (masl)	820
Tailings Elevation (masl)	819.1
Tailings Volume (Mm^3)	26.0
Tonnage (Mtonnes)	36.5
Beach Length (m)	850
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	811.9
Tailings Volume (Mm^3)	3.2
Tonnage (Mtonnes)	5.5
Beach Length (m)	116.9

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

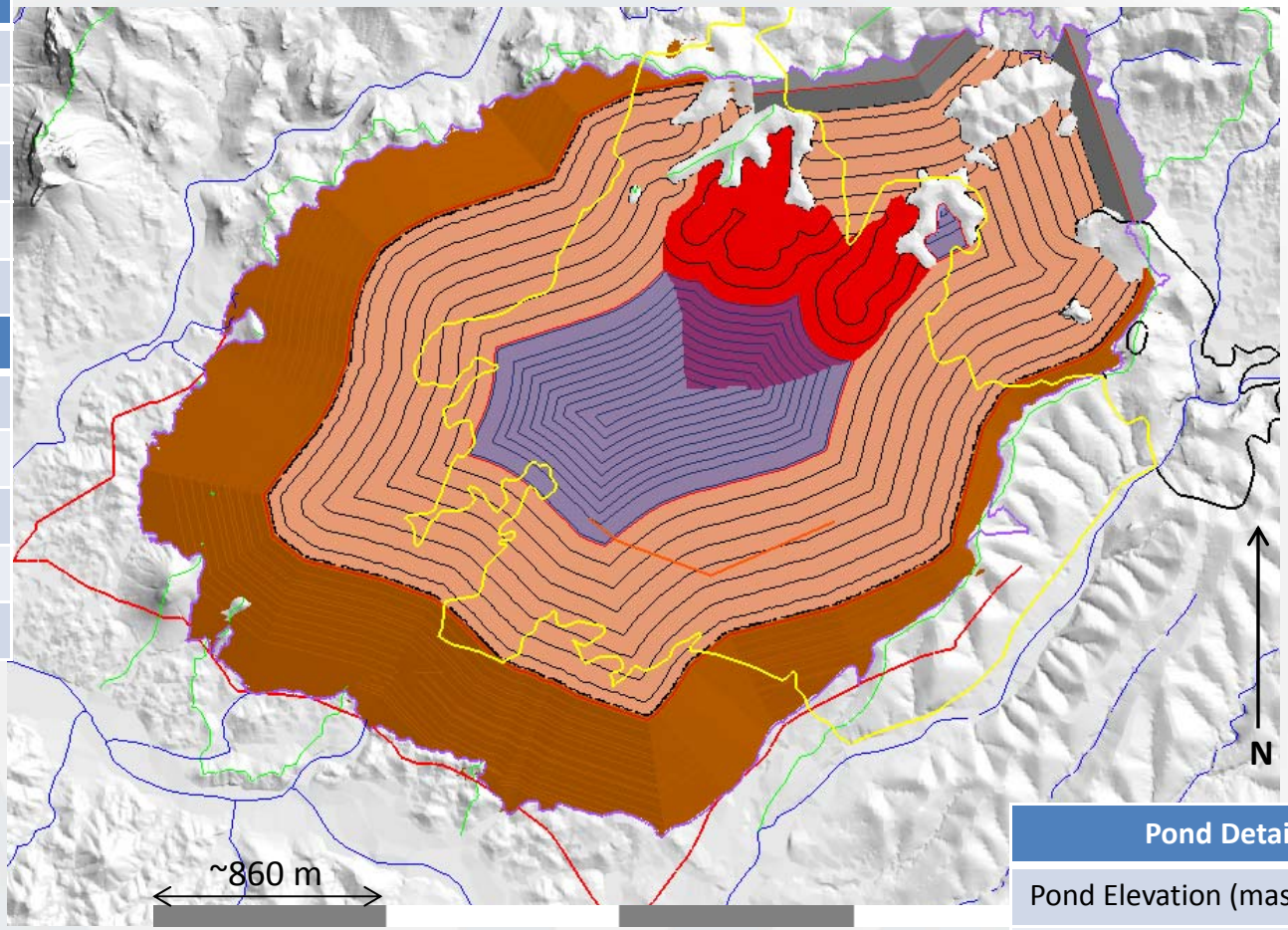
Pond Details	
Pond Elevation (masl)	810.7
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	9.6
PMF Elevation (masl)	816

Klohn Crippen Berger

Stage III: Year 27

Scavenger Thickened Tailings	
Dam Elevation (masl)	822
Tailings Elevation (masl)	820.6
Tailings Volume (Mm^3)	26.3
Tonnage (Mtonnes)	36.8
Beach Length (m)	756.1
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	815.8
Tailings Volume (Mm^3)	3.1
Tonnage (Mtonnes)	5.2
Beach Length (m)	266.8

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

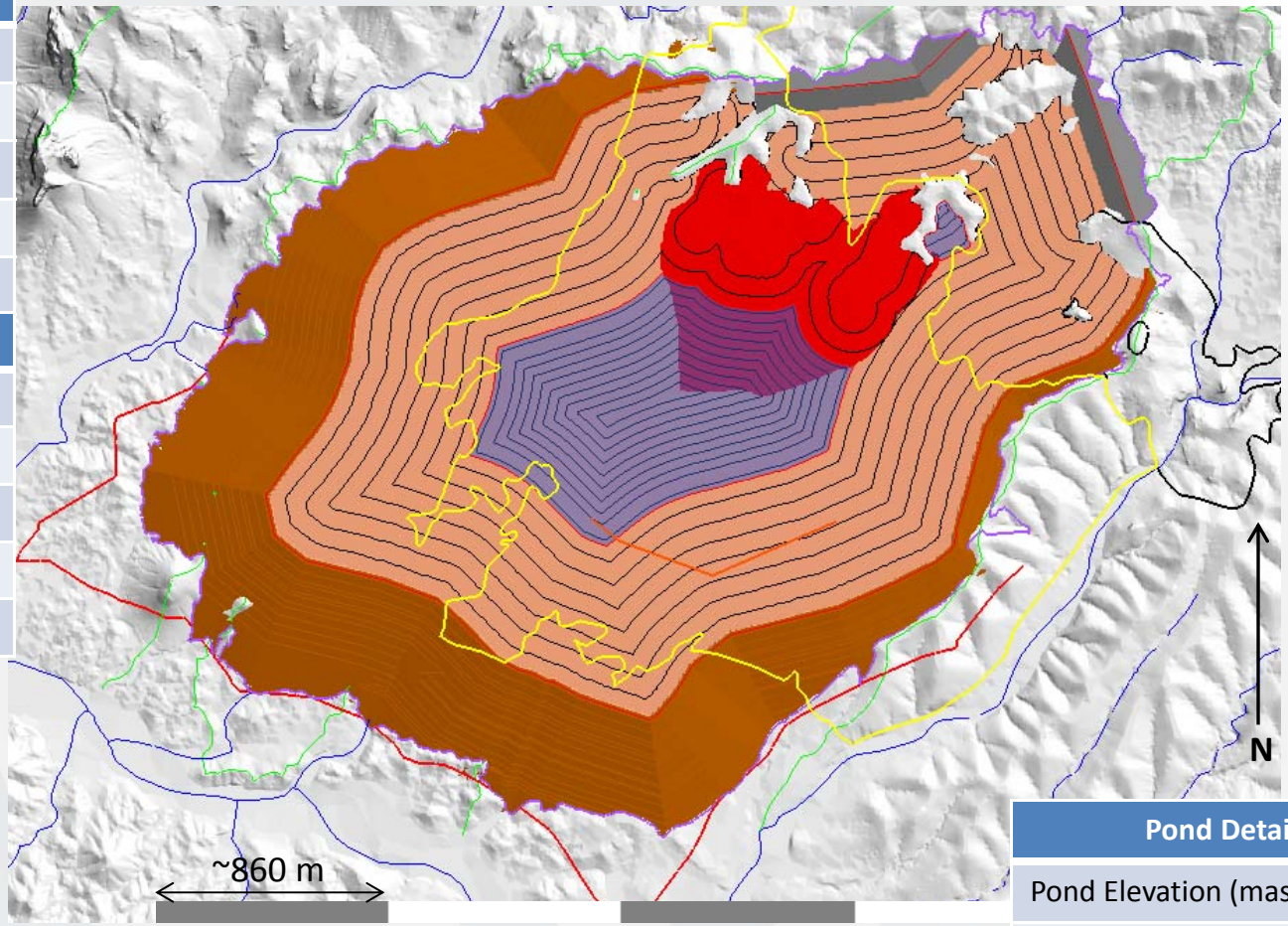
Pond Details	
Pond Elevation (masl)	813.1
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10
PMF Elevation (masl)	818

Klohn Crippen Berger

Stage III: Year 28

Scavenger Thickened Tailings	
Dam Elevation (masl)	824
Tailings Elevation (masl)	823.7
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.2
Beach Length (m)	783
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	819.2
Tailings Volume (Mm^3)	2.8
Tonnage (Mtonnes)	4.8
Beach Length (m)	296.4

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

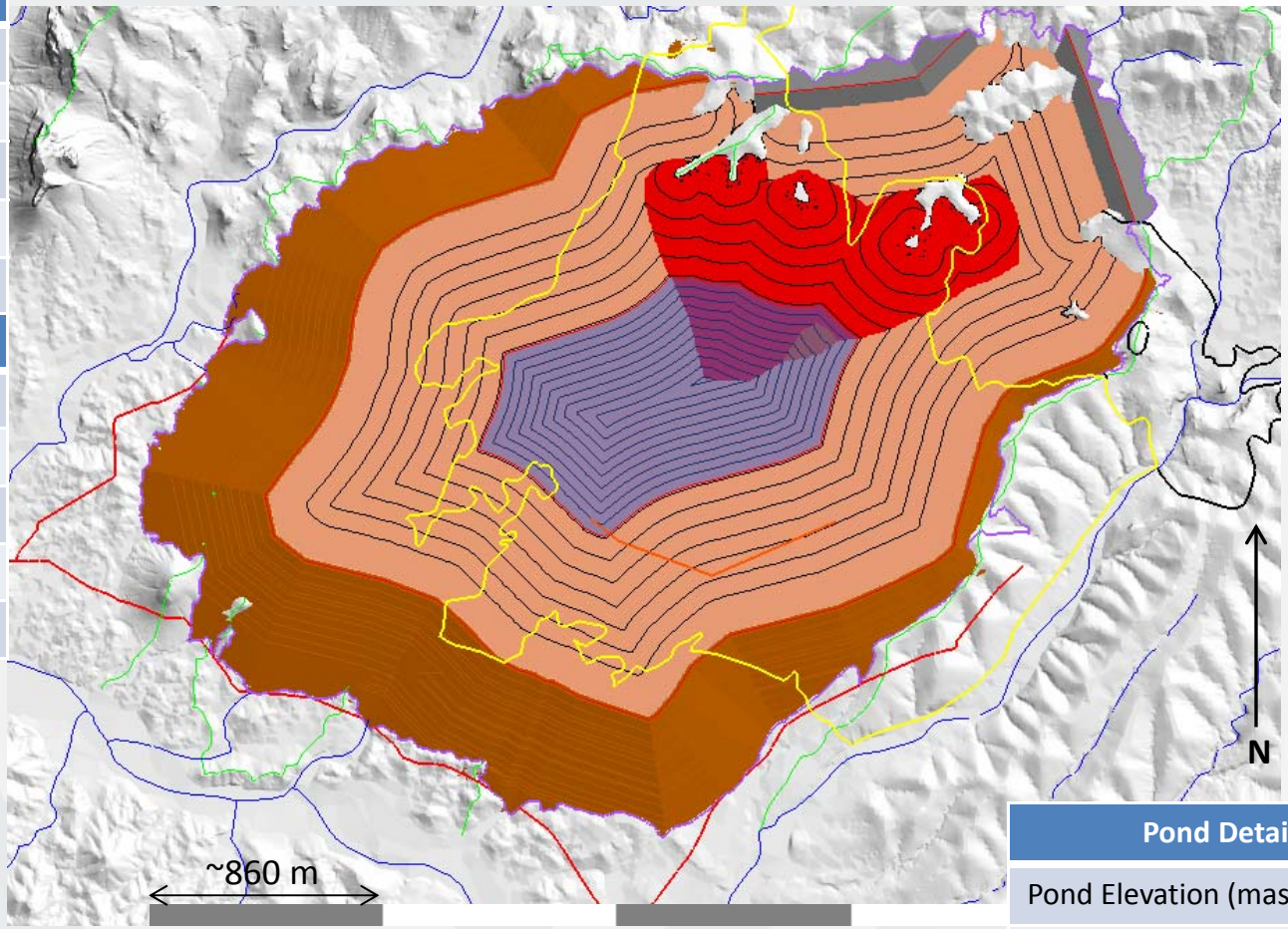
Pond Details	
Pond Elevation (masl)	816.3
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.1
PMF Elevation (masl)	821

Klohn Crippen Berger

Stage III: Year 29

Scavenger Thickened Tailings	
Dam Elevation (masl)	827
Tailings Elevation (masl)	826.8
Tailings Volume (Mm^3)	26.7
Tonnage (Mtonnes)	37.4
Beach Length (m)	810.2
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	824.0
Tailings Volume (Mm^3)	2.7
Tonnage (Mtonnes)	4.6
Beach Length (m)	515.0

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

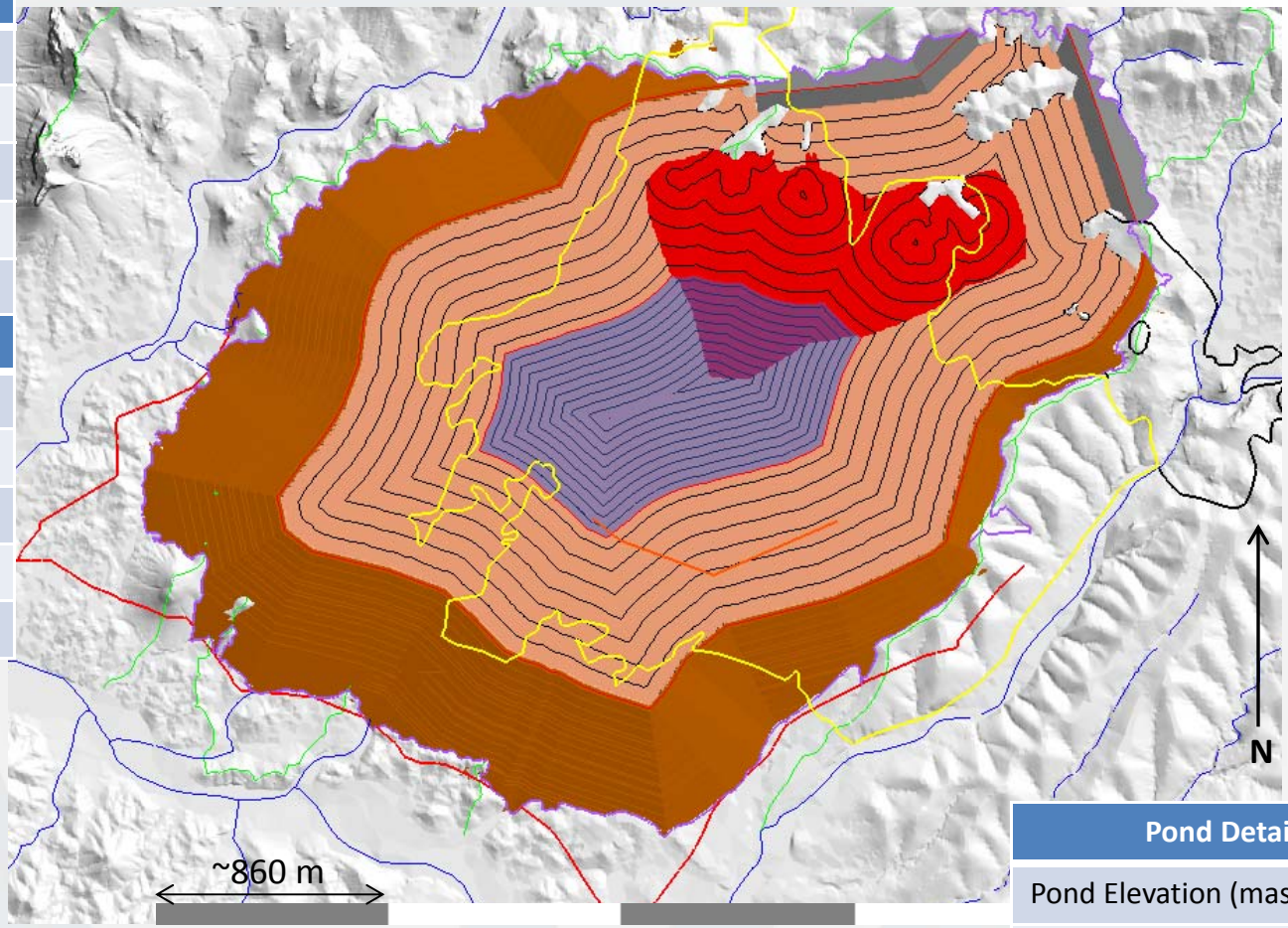
Pond Details	
Pond Elevation (masl)	818.9
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.2
PMF Elevation (masl)	824

Klohn Crippen Berger

Stage III: Year 30

Scavenger Thickened Tailings	
Dam Elevation (masl)	830
Tailings Elevation (masl)	828.8
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.2
Beach Length (m)	744.6
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	826.5
Tailings Volume (Mm^3)	2.8
Tonnage (Mtonnes)	4.7
Beach Length (m)	503

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

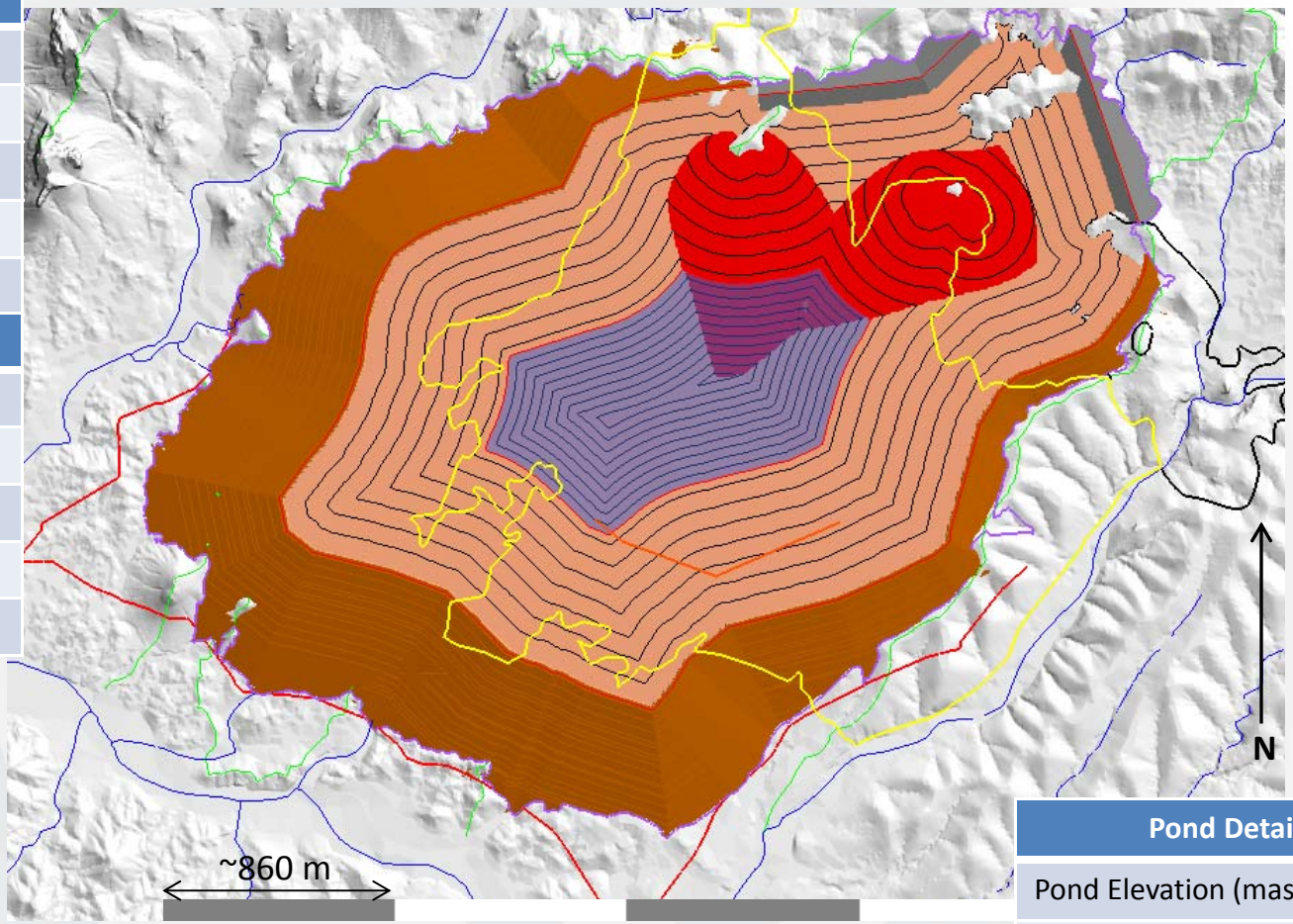
Pond Details	
Pond Elevation (masl)	821.5
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.2
PMF Elevation (masl)	827

Klohn Crippen Berger

Stage III: Year 31

Scavenger Thickened Tailings	
Dam Elevation (masl)	833
Tailings Elevation (masl)	832.1
Tailings Volume (Mm^3)	26.5
Tonnage (Mtonnes)	37.2
Beach Length (m)	754.8
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	831.1
Tailings Volume (Mm^3)	2.9
Tonnage (Mtonnes)	4.9
Beach Length (m)	659.0

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

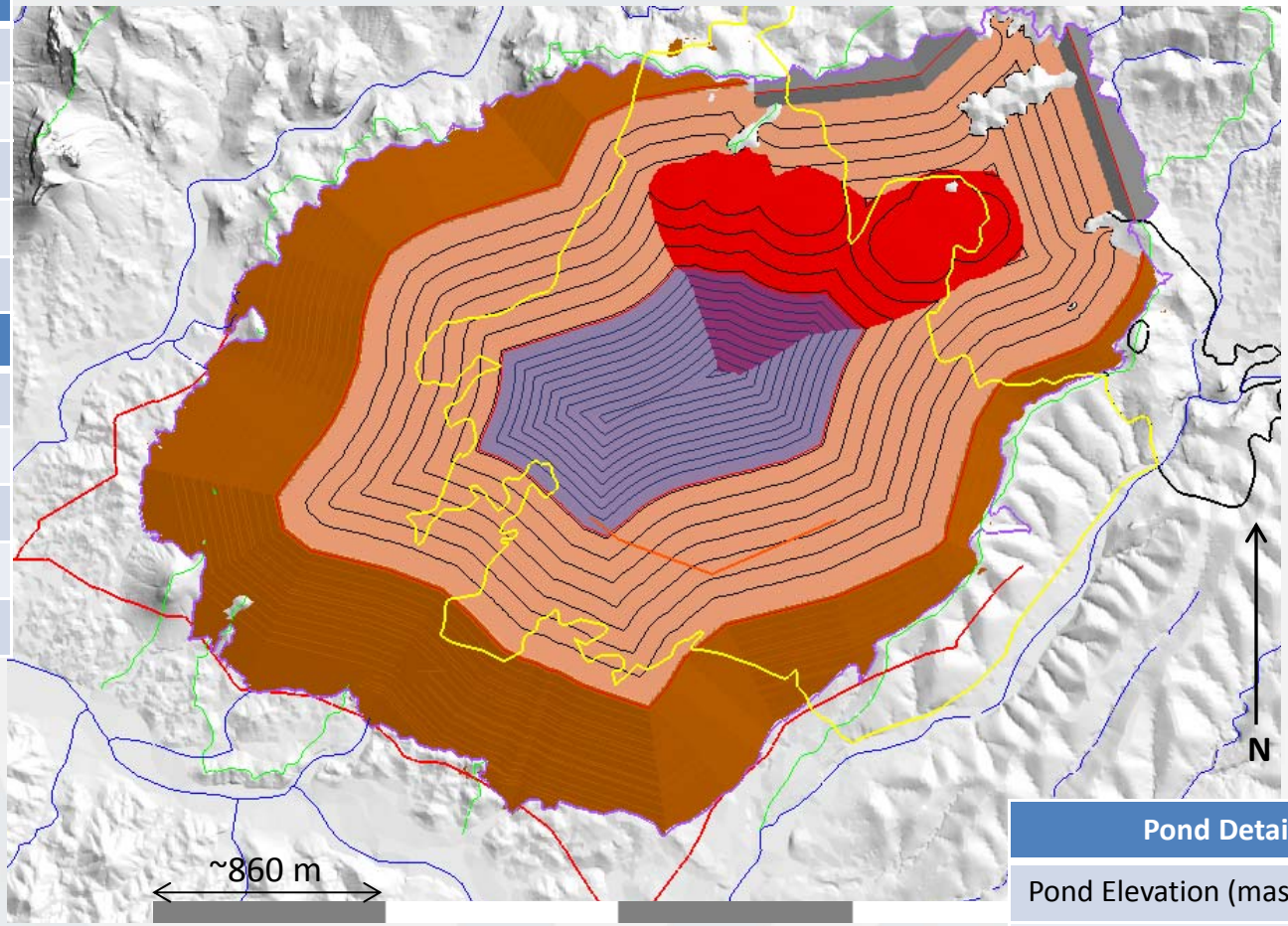
Pond Details	
Pond Elevation (masl)	824.6
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.0
PMF Elevation (masl)	830

Klohn Crippen Berger

Stage III: Year 32

Scavenger Thickened Tailings	
Dam Elevation (masl)	836
Tailings Elevation (masl)	835.3
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.3
Beach Length (m)	740.1
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	832.5
Tailings Volume (Mm^3)	2.9
Tonnage (Mtonnes)	4.9
Beach Length (m)	465.2

Note: Contours drawn at 1m intervals



Legend:
- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

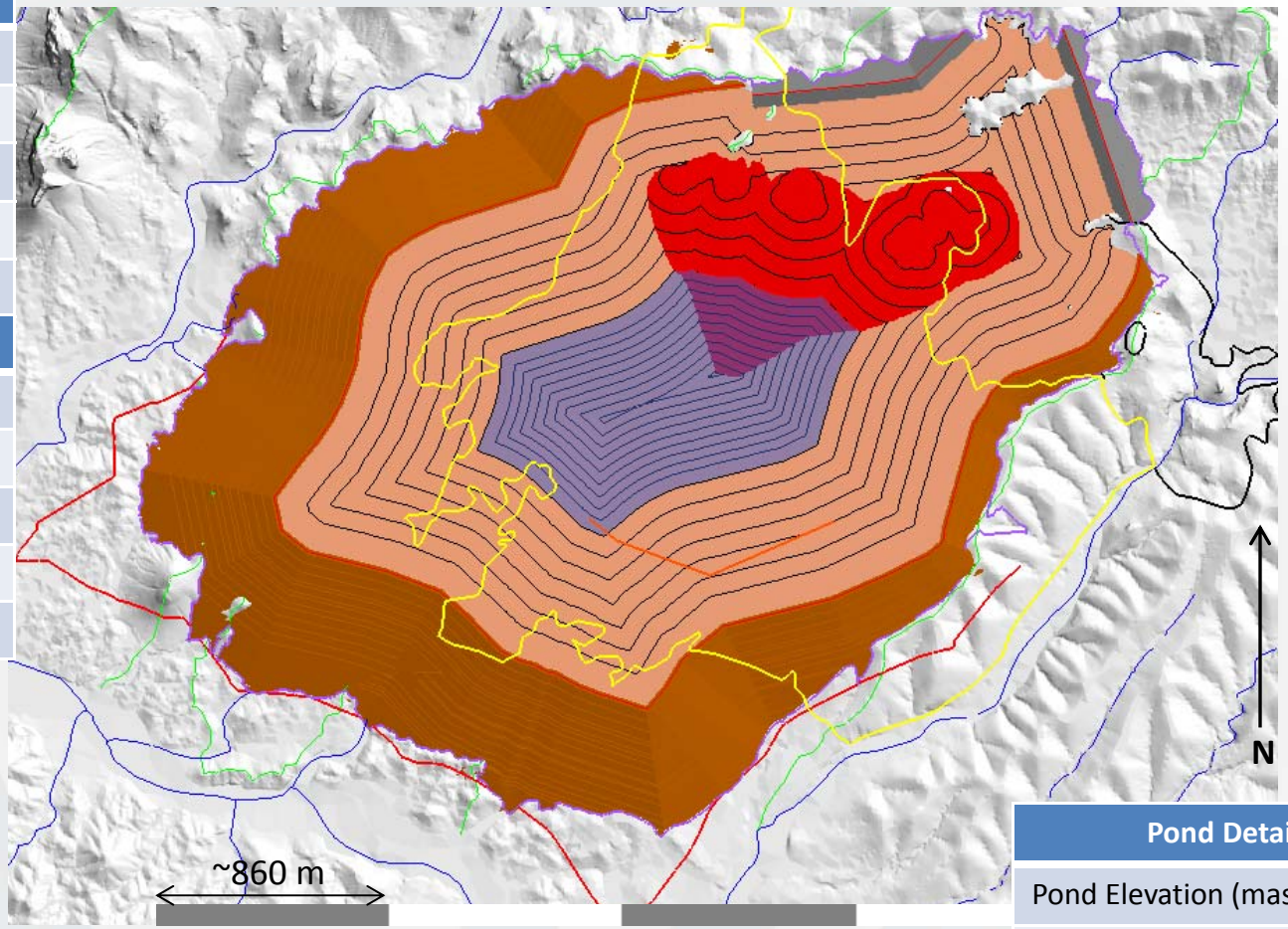
Pond Details	
Pond Elevation (masl)	827.9
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.3
PMF Elevation (masl)	833

Klohn Crippen Berger

Stage III: Year 33

Scavenger Thickened Tailings	
Dam Elevation (masl)	840
Tailings Elevation (masl)	838.4
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.3
Beach Length (m)	748.9
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	835.7
Tailings Volume (Mm^3)	2.9
Tonnage (Mtonnes)	4.9
Beach Length (m)	469.6

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

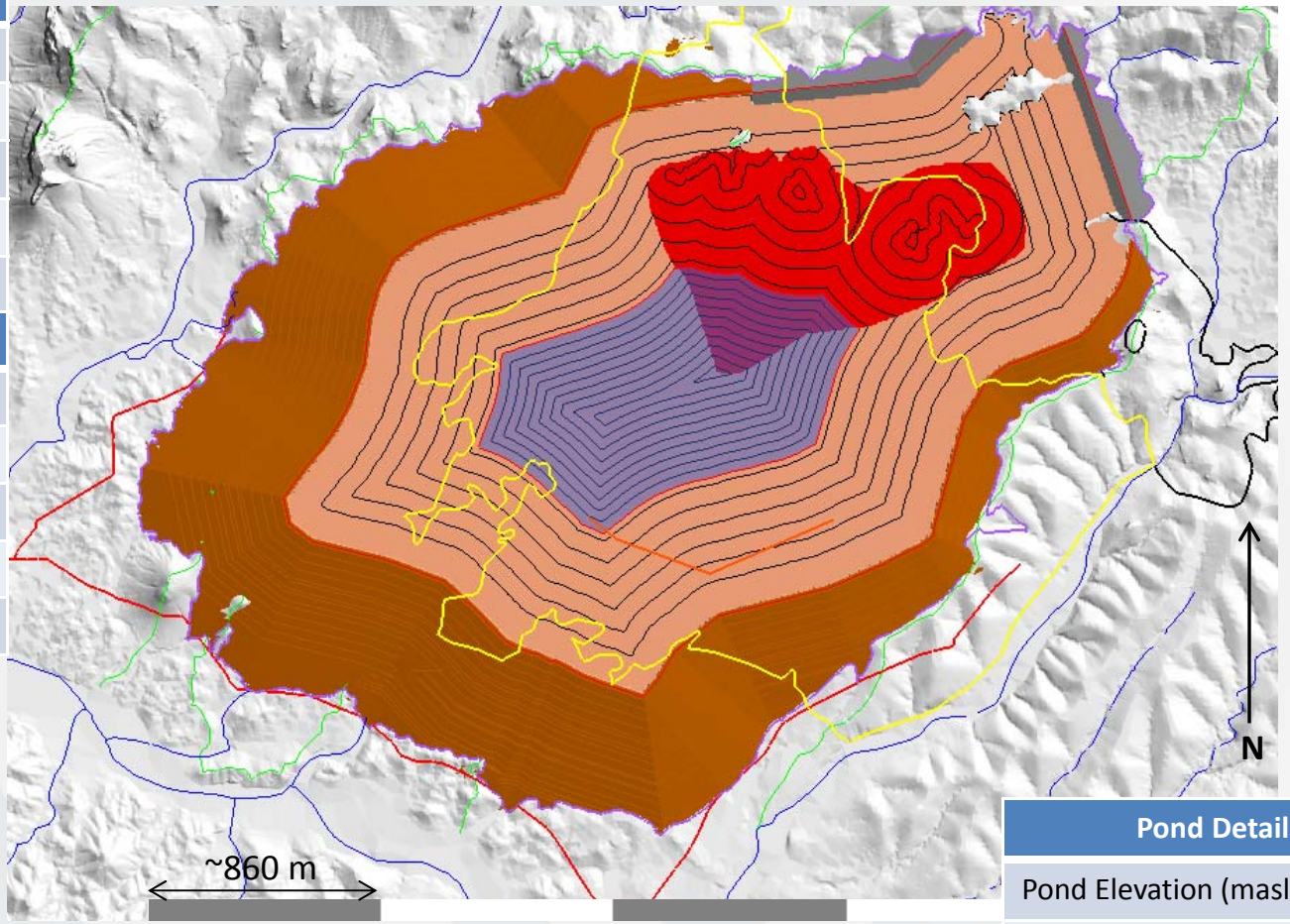
Pond Details	
Pond Elevation (masl)	831.0
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.2
PMF Elevation (masl)	836

Klohn Crippen Berger

Stage III: Year 34

Scavenger Thickened Tailings	
Dam Elevation (masl)	841
Tailings Elevation (masl)	840.6
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.3
Beach Length (m)	717.2
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	838.3
Tailings Volume (Mm^3)	2.9
Tonnage (Mtonnes)	4.9
Beach Length (m)	469.2

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

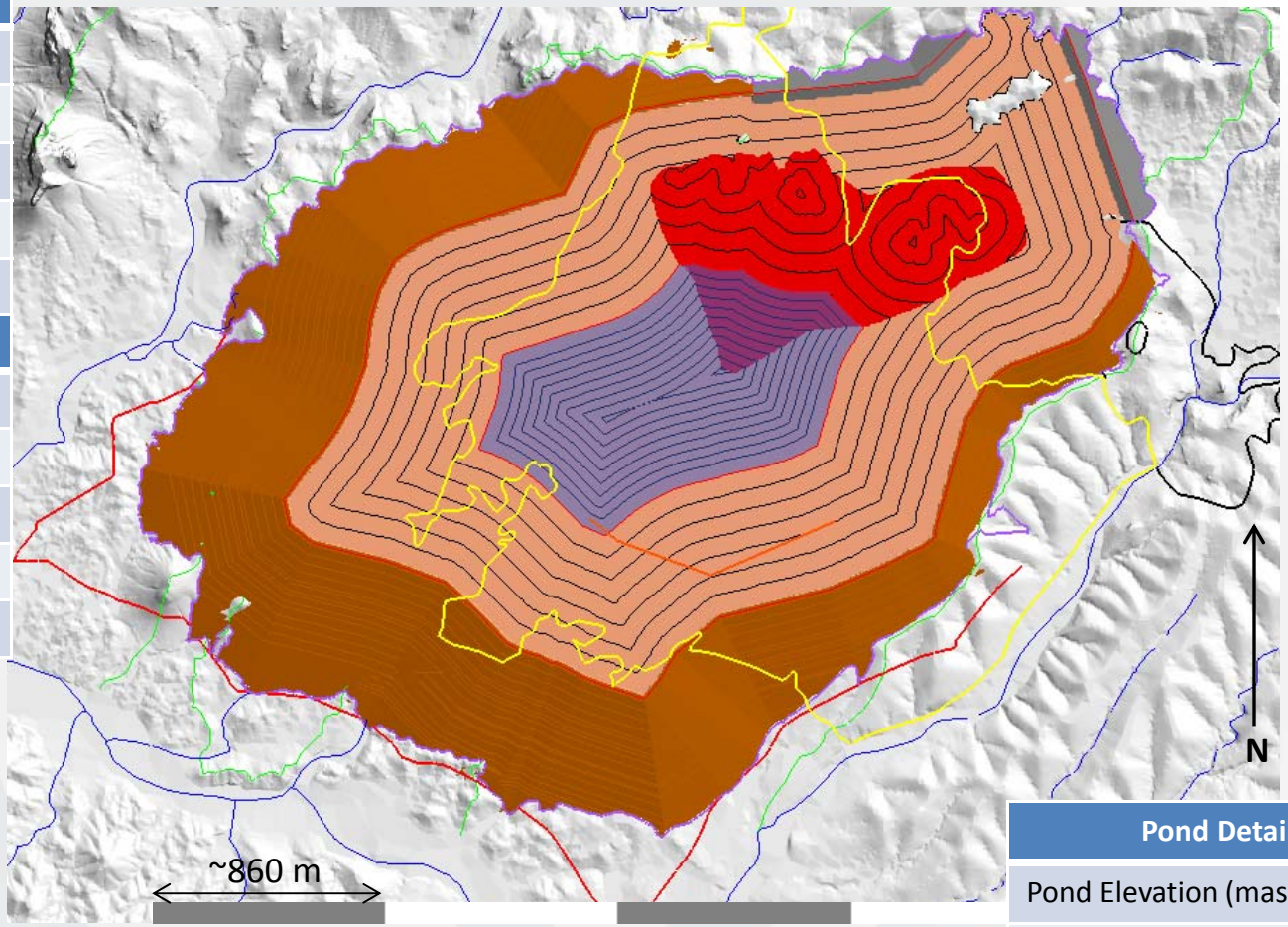
Pond Details	
Pond Elevation (masl)	833.7
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.3
PMF Elevation (masl)	839

Klohn Crippen Berger

Stage III: Year 35

Scavenger Thickened Tailings	
Dam Elevation (masl)	846
Tailings Elevation (masl)	844.0
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.3
Beach Length (m)	713.8
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	841.4
Tailings Volume (Mm^3)	2.9
Tonnage (Mtonnes)	4.9
Beach Length (m)	443.8

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

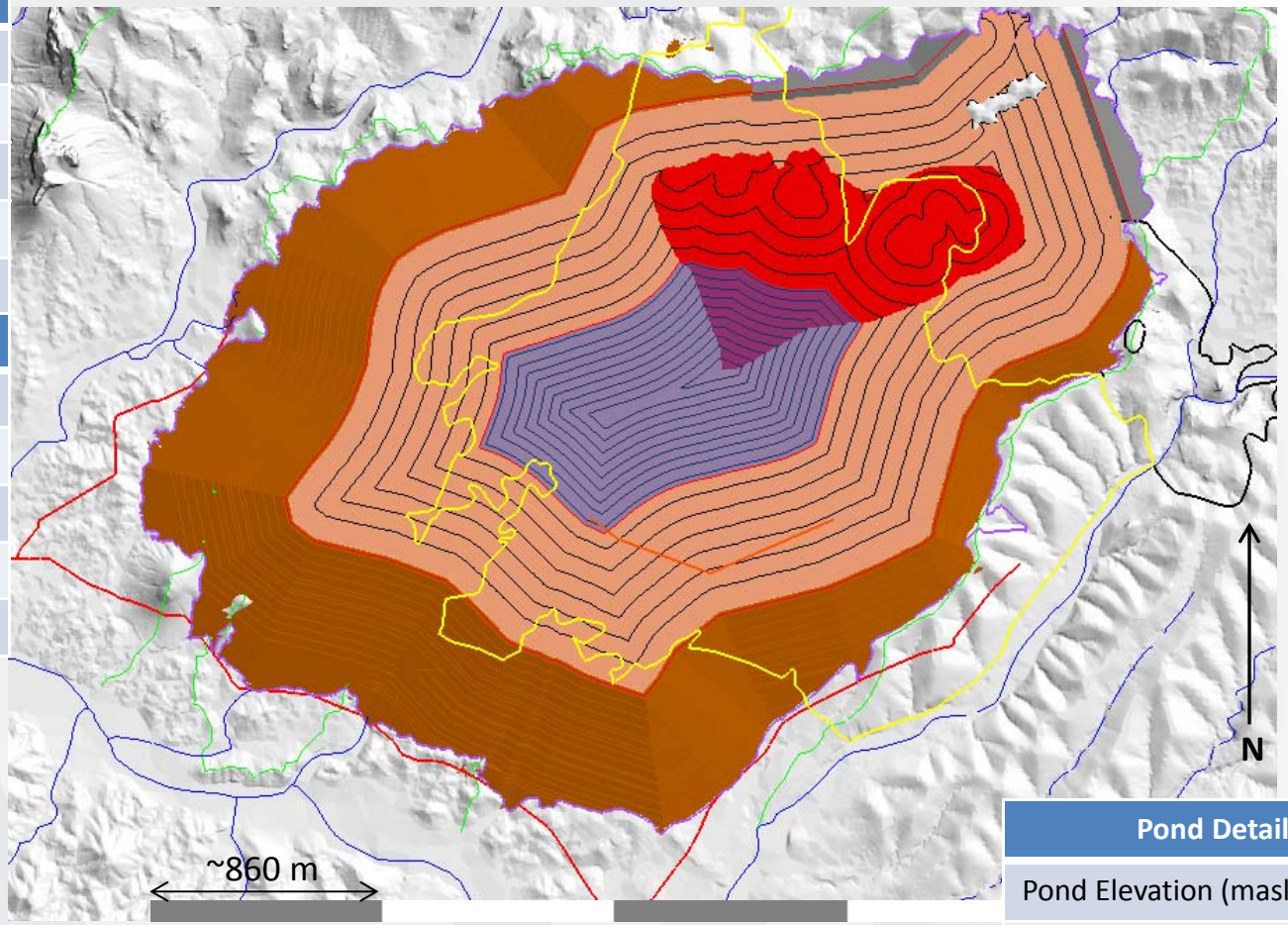
Pond Details	
Pond Elevation (masl)	837.0
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.3
PMF Elevation (masl)	842

Klohn Crippen Berger

Stage III: Year 36

Scavenger Thickened Tailings	
Dam Elevation (masl)	848
Tailings Elevation (masl)	847.3
Tailings Volume (Mm^3)	26.6
Tonnage (Mtonnes)	37.3
Beach Length (m)	708
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	844.6
Tailings Volume (Mm^3)	2.9
Tonnage (Mtonnes)	4.9
Beach Length (m)	435.7

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

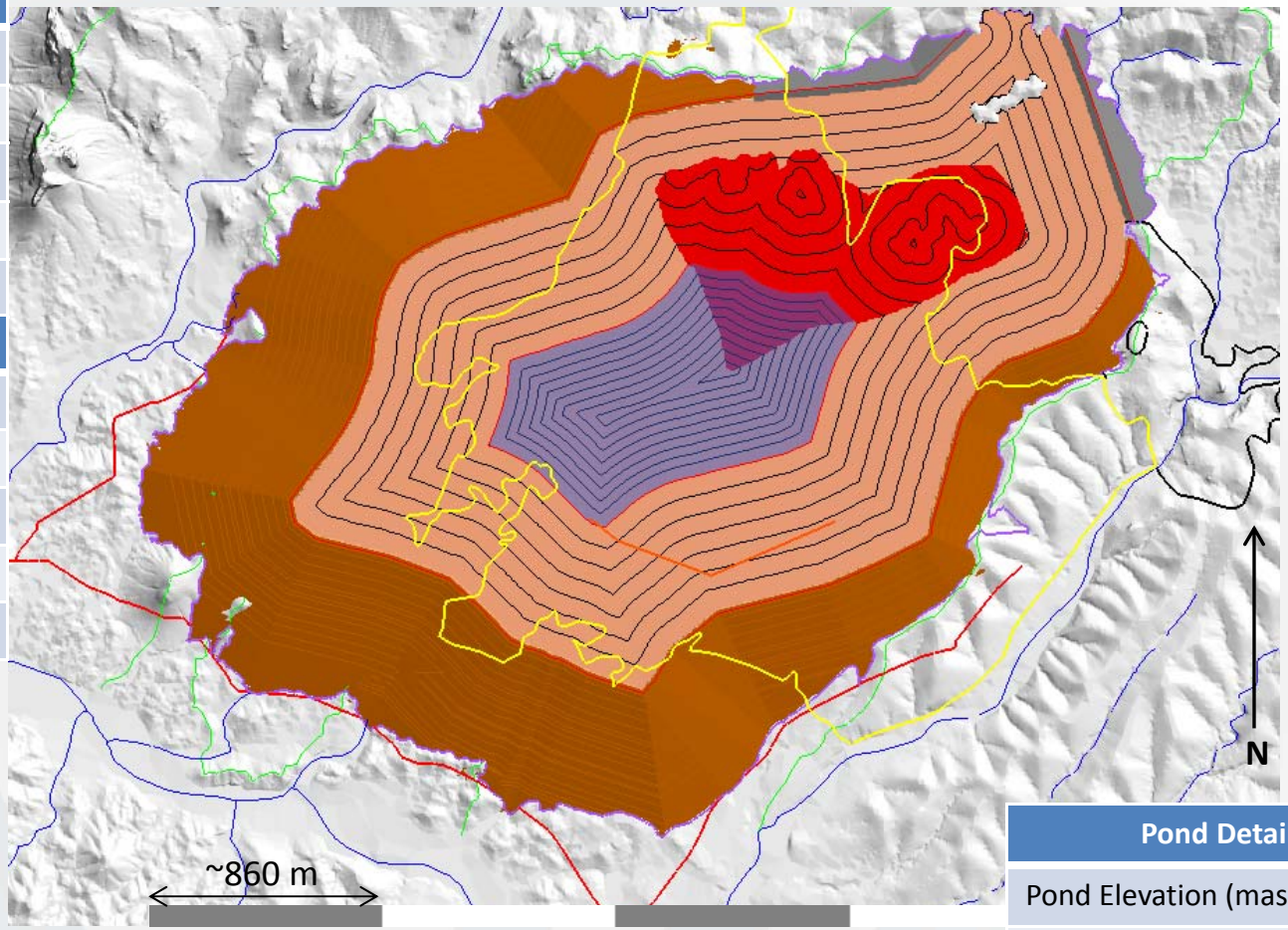
Pond Details	
Pond Elevation (masl)	840.3
Pond Volume (Mm^3)	6.3
Max Pond Depth (m)	10.3
PMF Elevation (masl)	845

Klohn Crippen Berger

Stage III: Year 37

Scavenger Thickened Tailings	
Dam Elevation (masl)	850
Tailings Elevation (masl)	849.1
Tailings Volume (Mm^3)	18.8
Tonnage (Mtonnes)	26.3
Beach Length (m)	726.9
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	846.5
Tailings Volume (Mm^3)	2.0
Tonnage (Mtonnes)	3.4
Beach Length (m)	445.3

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

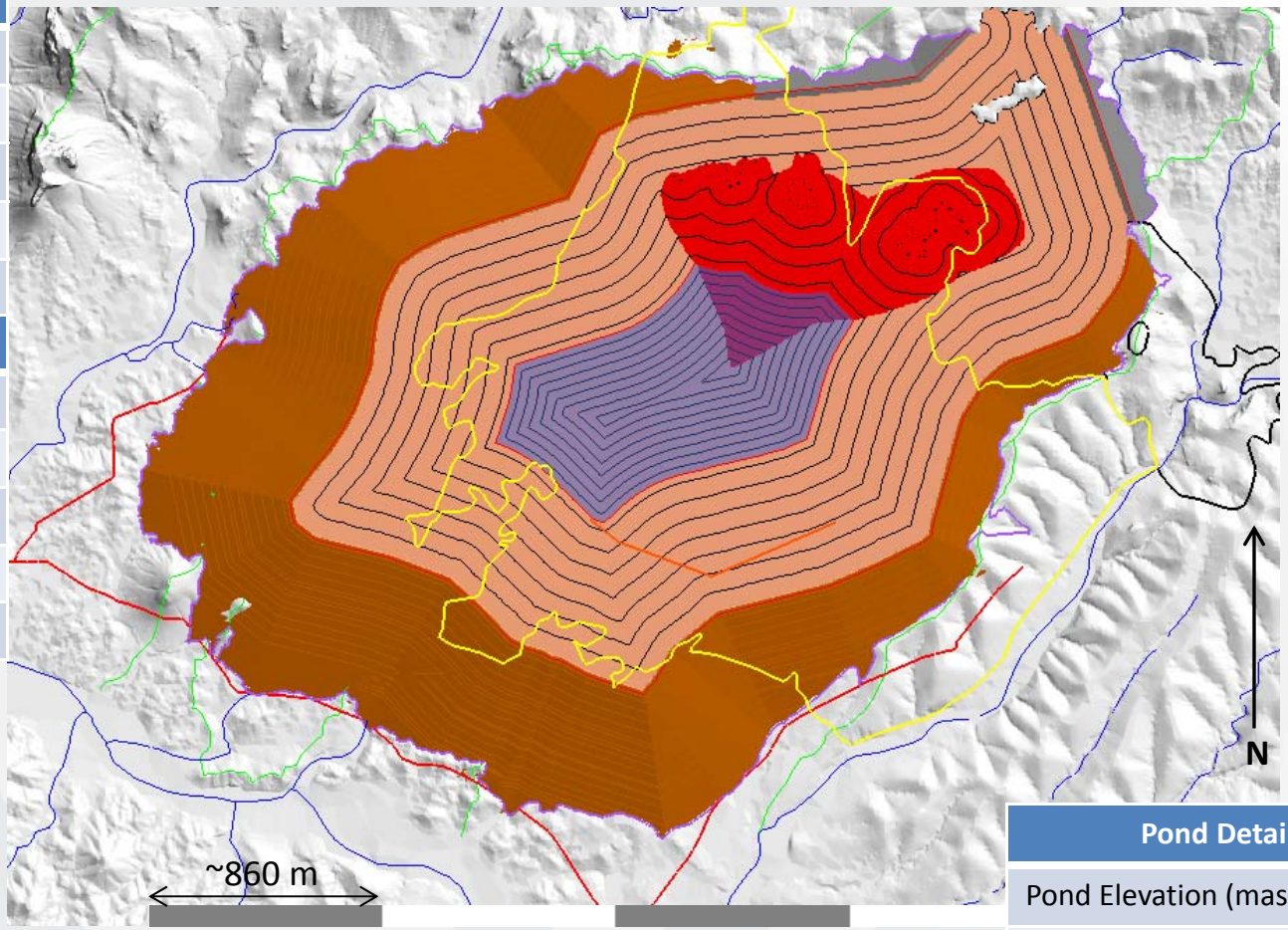
Pond Details	
Pond Elevation (masl)	842.0
Pond Volume (Mm^3)	5.4
Max Pond Depth (m)	9.8
PMF Elevation (masl)	847

Klohn Crippen Berger

Stage III: Year 38

Scavenger Thickened Tailings	
Dam Elevation (masl)	852
Tailings Elevation (masl)	850.9
Tailings Volume (Mm^3)	14.5
Tonnage (Mtonnes)	20.3
Beach Length (m)	745.9
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	848
Tailings Volume (Mm^3)	1.6
Tonnage (Mtonnes)	2.7
Beach Length (m)	444.4

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

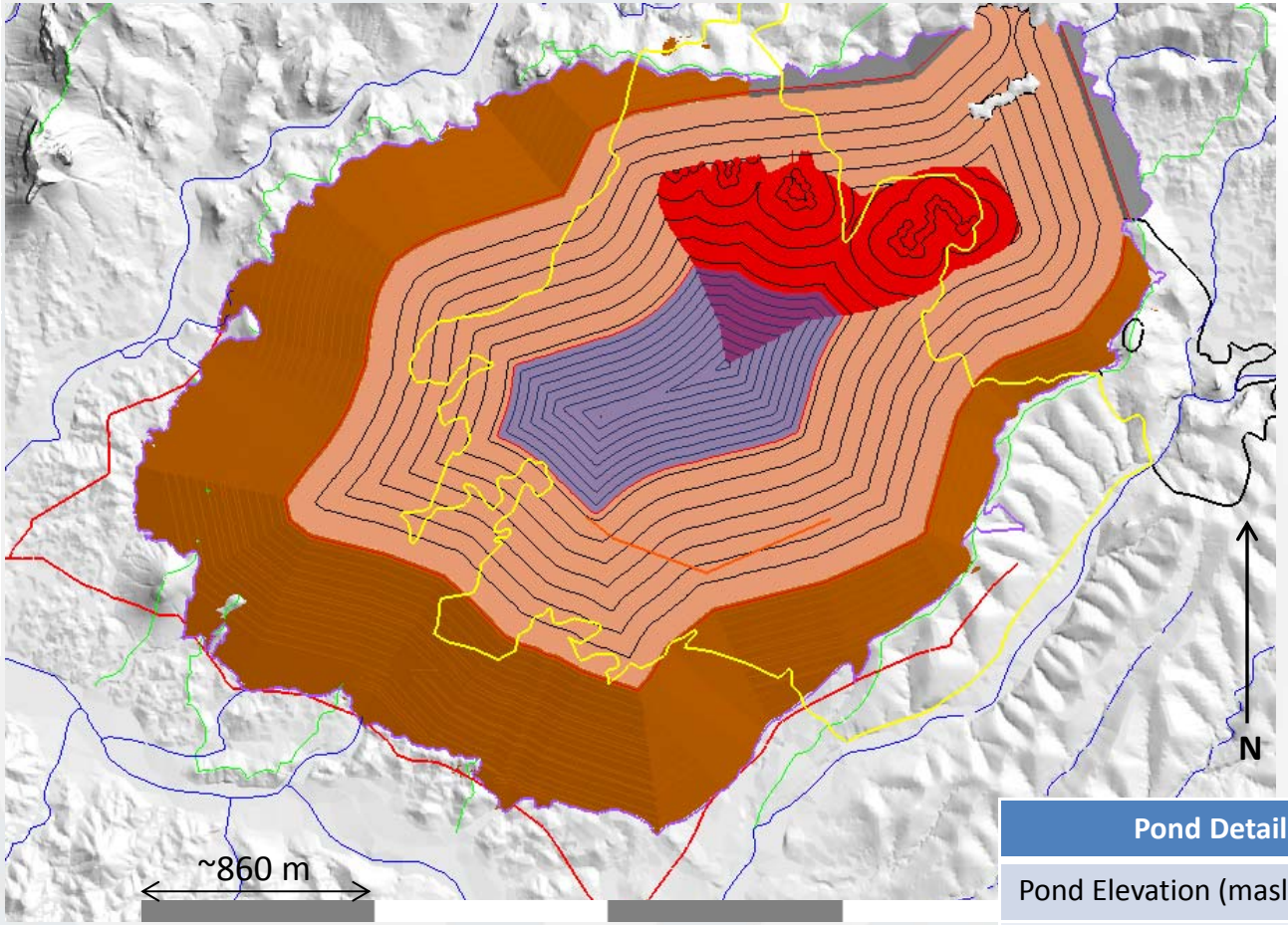
Pond Details	
Pond Elevation (masl)	843.6
Pond Volume (Mm^3)	4.9
Max Pond Depth (m)	9.5
PMF Elevation (masl)	849

Klohn Crippen Berger

Stage III: Year 39

Scavenger Thickened Tailings	
Dam Elevation (masl)	854
Tailings Elevation (masl)	852.3
Tailings Volume (Mm^3)	10.6
Tonnage (Mtonnes)	14.8
Beach Length (m)	765.6
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	849.2
Tailings Volume (Mm^3)	1.3
Tonnage (Mtonnes)	2.1
Beach Length (m)	459.4

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

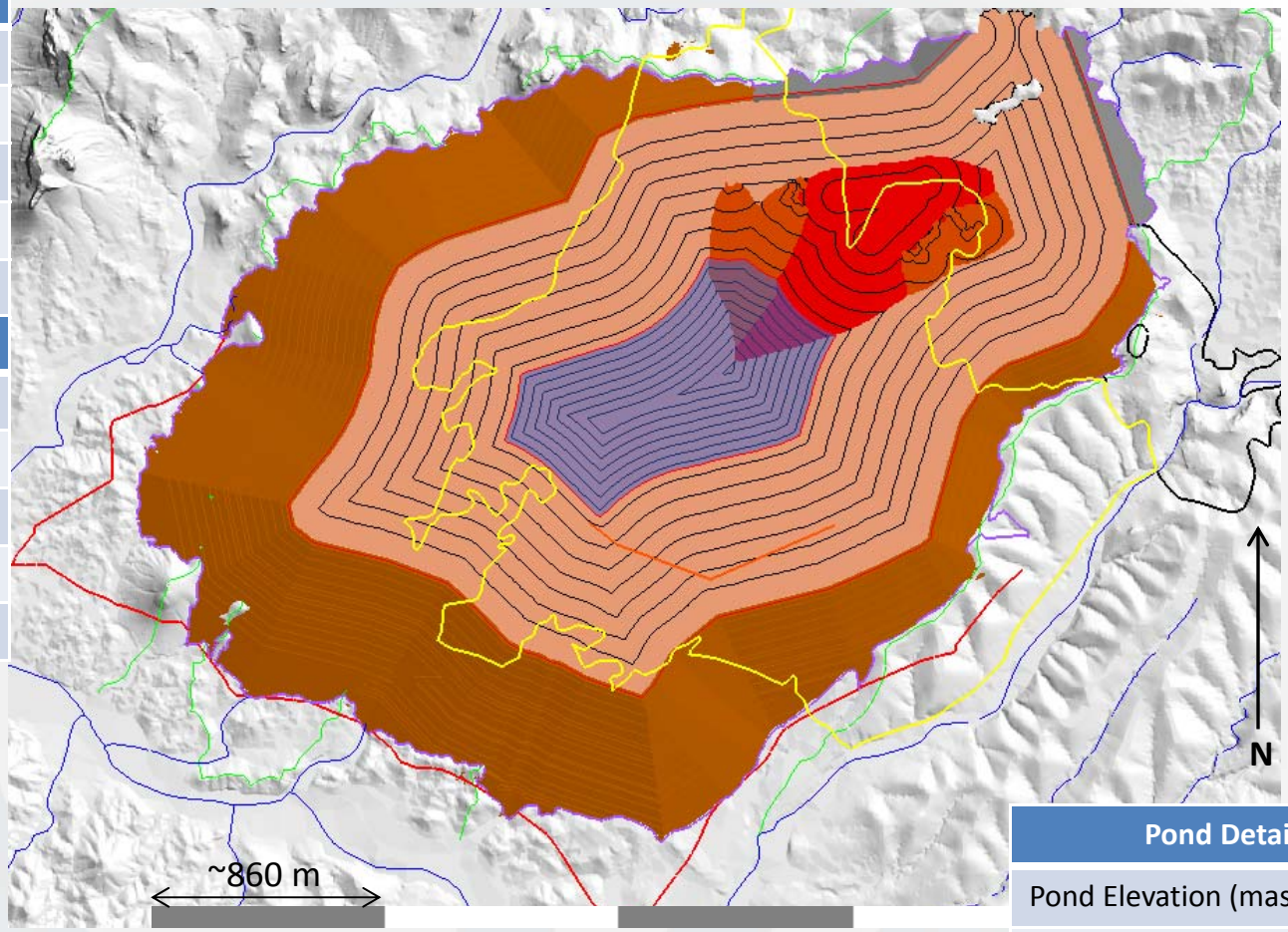
Pond Details	
Pond Elevation (masl)	844.7
Pond Volume (Mm^3)	4.3
Max Pond Depth (m)	9.0
PMF Elevation (masl)	851

Klohn Crippen Berger

Stage III: Year 40

Scavenger Thickened Tailings	
Dam Elevation (masl)	854
Tailings Elevation (masl)	853.3
Tailings Volume (Mm^3)	7.9
Tonnage (Mtonnes)	11.1
Beach Length (m)	791.4
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	850.9
Tailings Volume (Mm^3)	0.1
Tonnage (Mtonnes)	1.7
Beach Length (m)	537.0

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

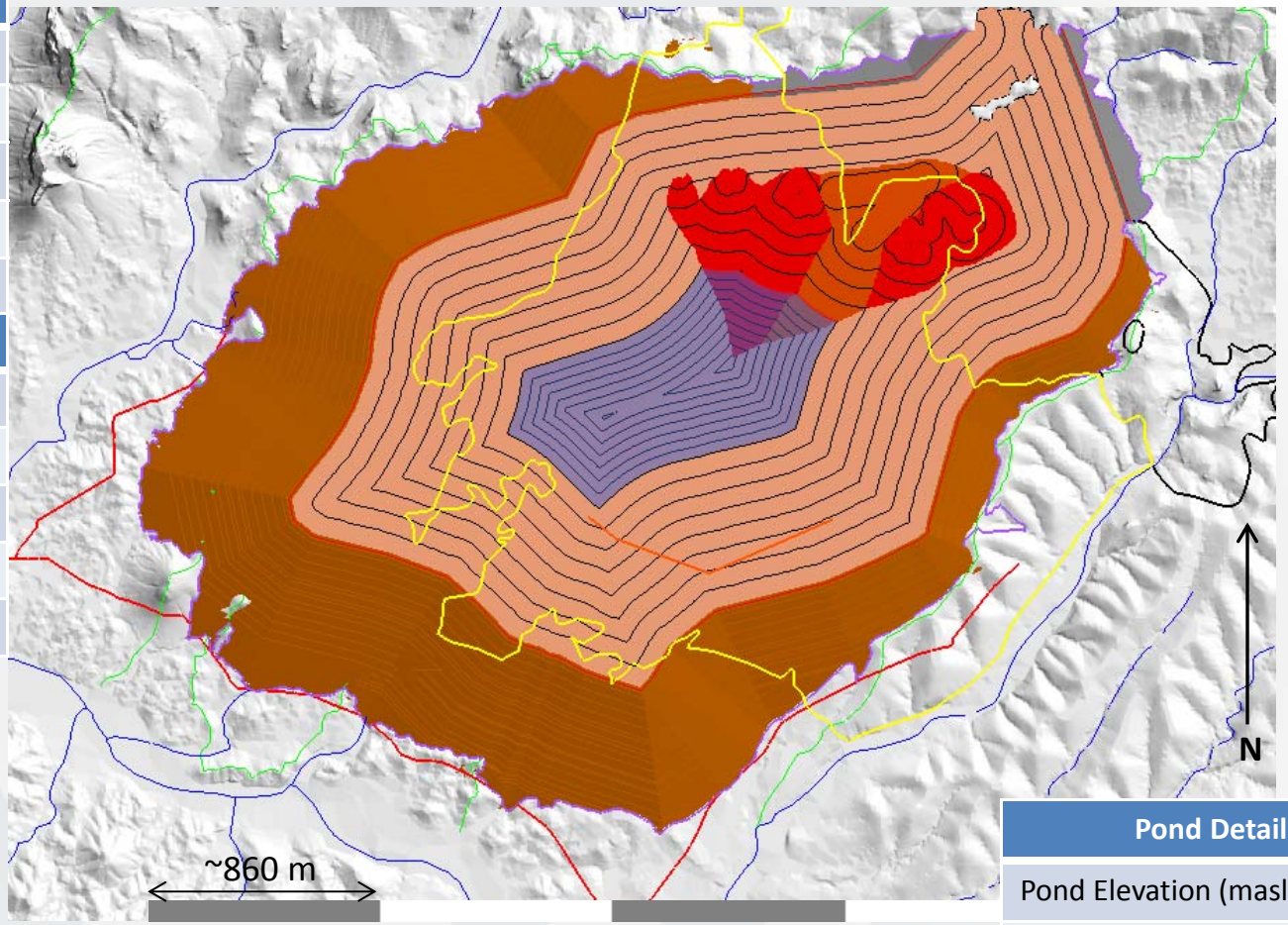
Pond Details	
Pond Elevation (masl)	845.5
Pond Volume (Mm^3)	4.0
Max Pond Depth (m)	8.7
PMF Elevation (masl)	852

Klohn Crippen Berger

Stage III: Year 41

Scavenger Thickened Tailings	
Dam Elevation (masl)	855
Tailings Elevation (masl)	853.9
Tailings Volume (Mm^3)	5.1
Tonnage (Mtonnes)	7.2
Beach Length (m)	813.8
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	850.5
Tailings Volume (Mm^3)	0.6
Tonnage (Mtonnes)	1.1
Beach Length (m)	453.8

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Pond Details	
Pond Elevation (masl)	846.0
Pond Volume (Mm^3)	3.7
Max Pond Depth (m)	8.4
PMF Elevation (masl)	852

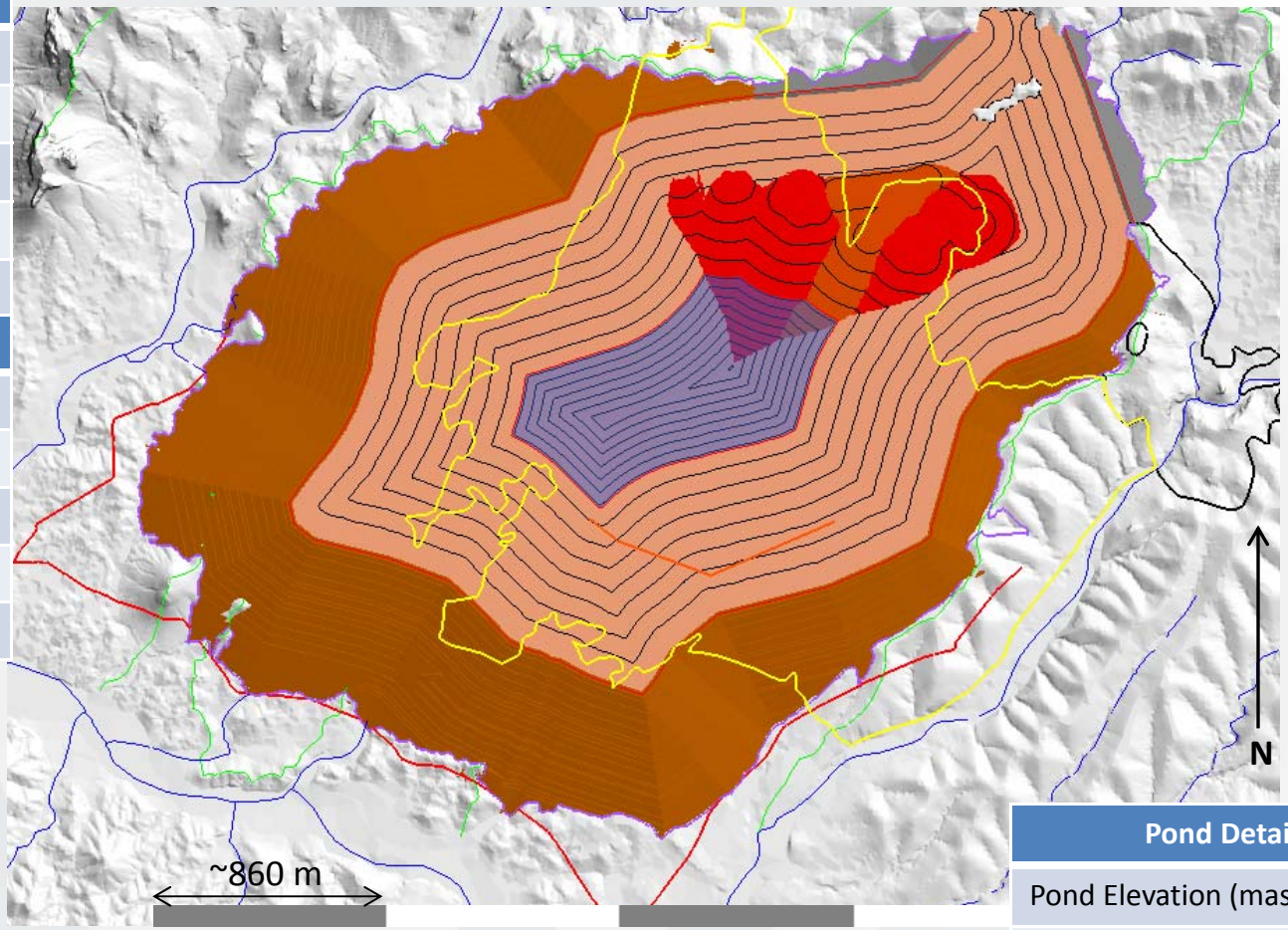
Klohn Crippen Berger

Stage III: Year 42

Scavenger Thickened Tailings	
Dam Elevation (masl)	855
Tailings Elevation (masl)	854.2
Tailings Volume (Mm^3)	2.3
Tonnage (Mtonnes)	3.3
Beach Length (m)	827.9

Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	850.9
Tailings Volume (Mm^3)	0.3
Tonnage (Mtonnes)	0.5
Beach Length (m)	471.8

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Pond Details	
Pond Elevation (masl)	846.2
Pond Volume (Mm^3)	3.5
Max Pond Depth (m)	8.3
PMF Elevation (masl)	853

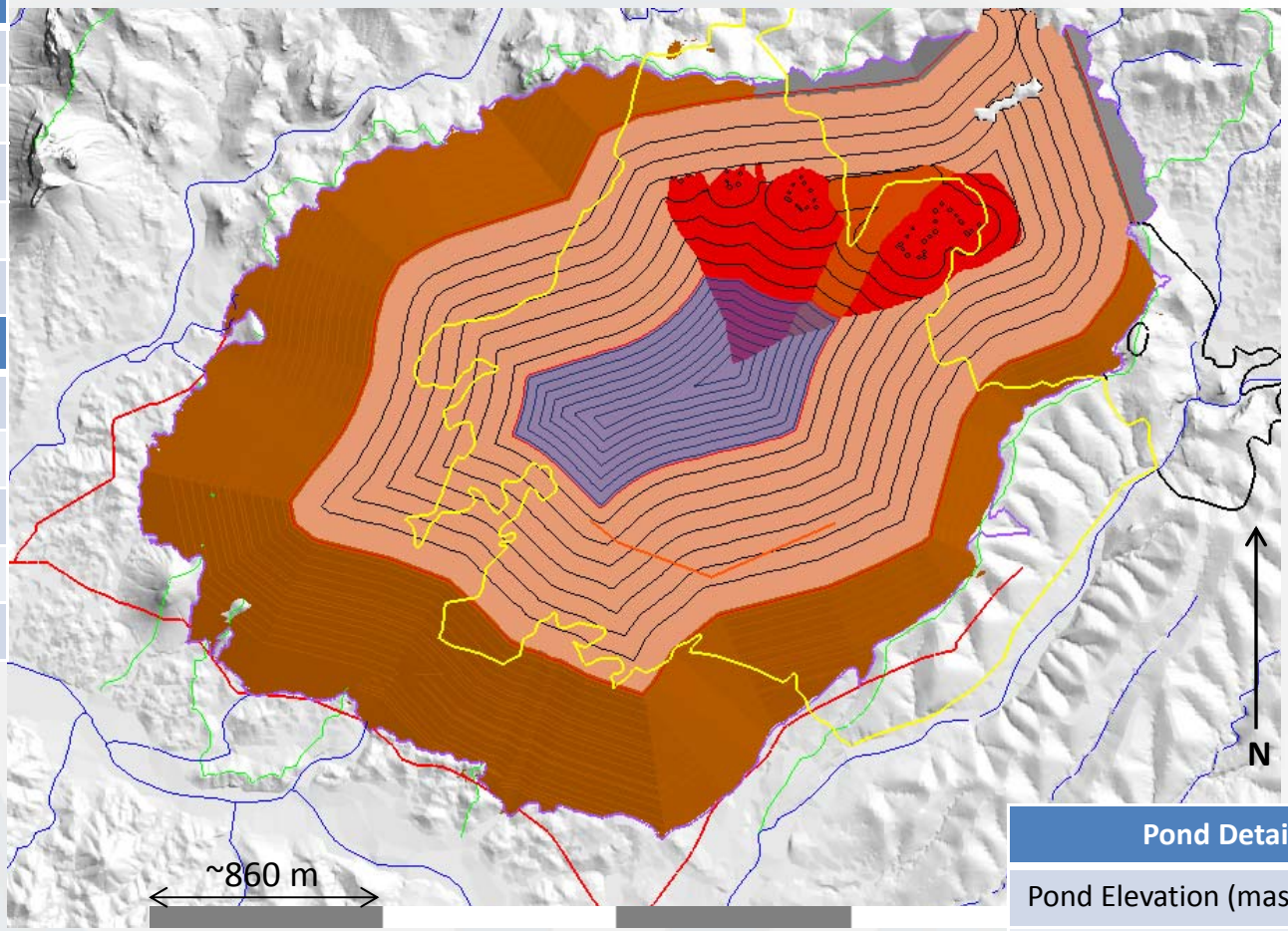
Klohn Crippen Berger

Stage III: Year 43

Scavenger Thickened Tailings	
Dam Elevation (masl)	855
Tailings Elevation (masl)	854.4
Tailings Volume (Mm^3)	1.0
Tonnage (Mtonnes)	1.4
Beach Length (m)	828.9

Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	851.1
Tailings Volume (Mm^3)	0.1
Tonnage (Mtonnes)	0.2
Beach Length (m)	480.4

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

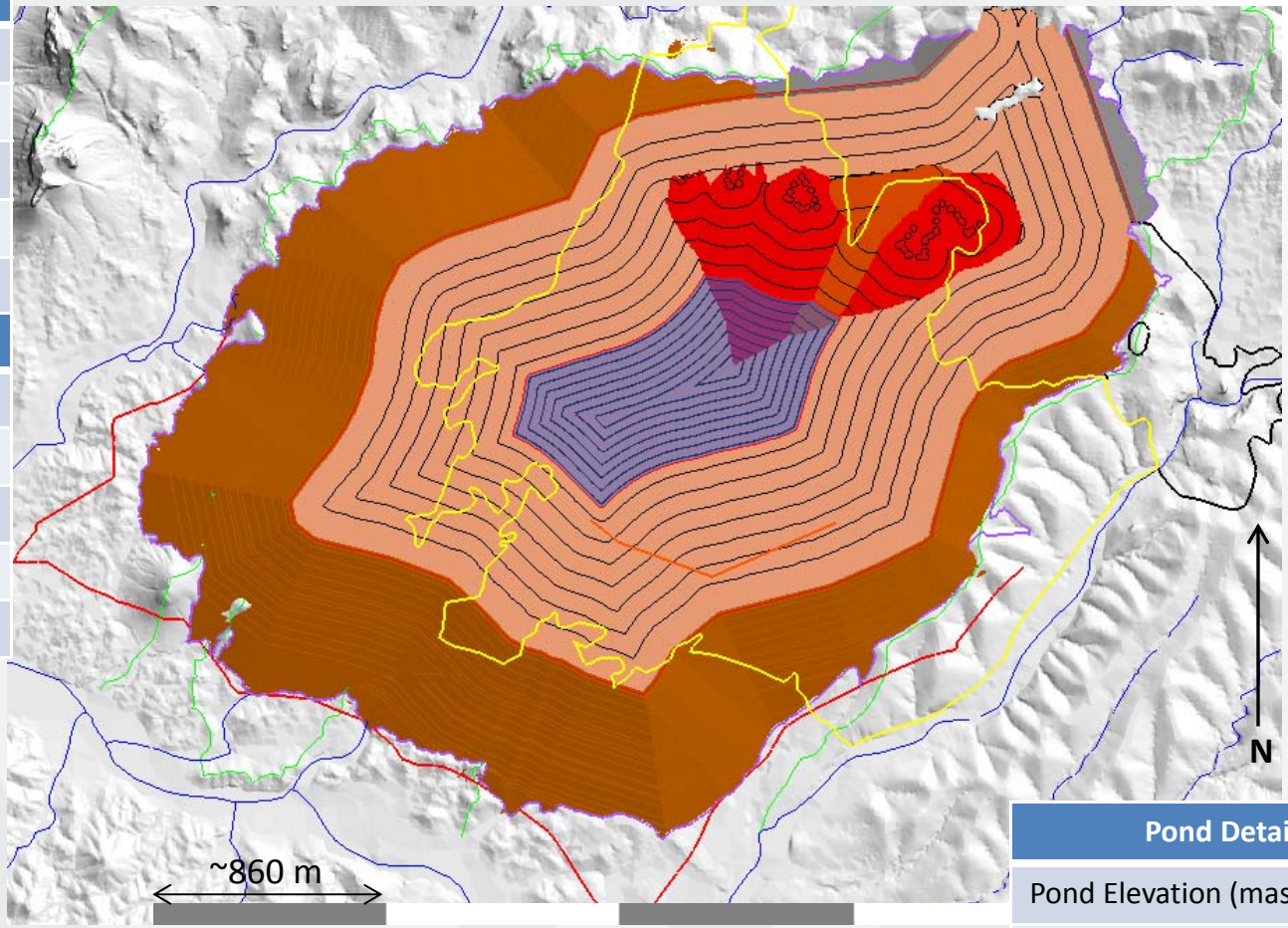
Pond Details	
Pond Elevation (masl)	846.3
Pond Volume (Mm^3)	3.5
Max Pond Depth (m)	8.3
PMF Elevation (masl)	853

Klohn Crippen Berger

Stage III: Year 44

Scavenger Thickened Tailings	
Dam Elevation (masl)	855
Tailings Elevation (masl)	854.4
Tailings Volume (Mm^3)	0.5
Tonnage (Mtonnes)	0.8
Beach Length (m)	822.3
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	851.2
Tailings Volume (Mm^3)	0.08
Tonnage (Mtonnes)	0.1
Beach Length (m)	482.4

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

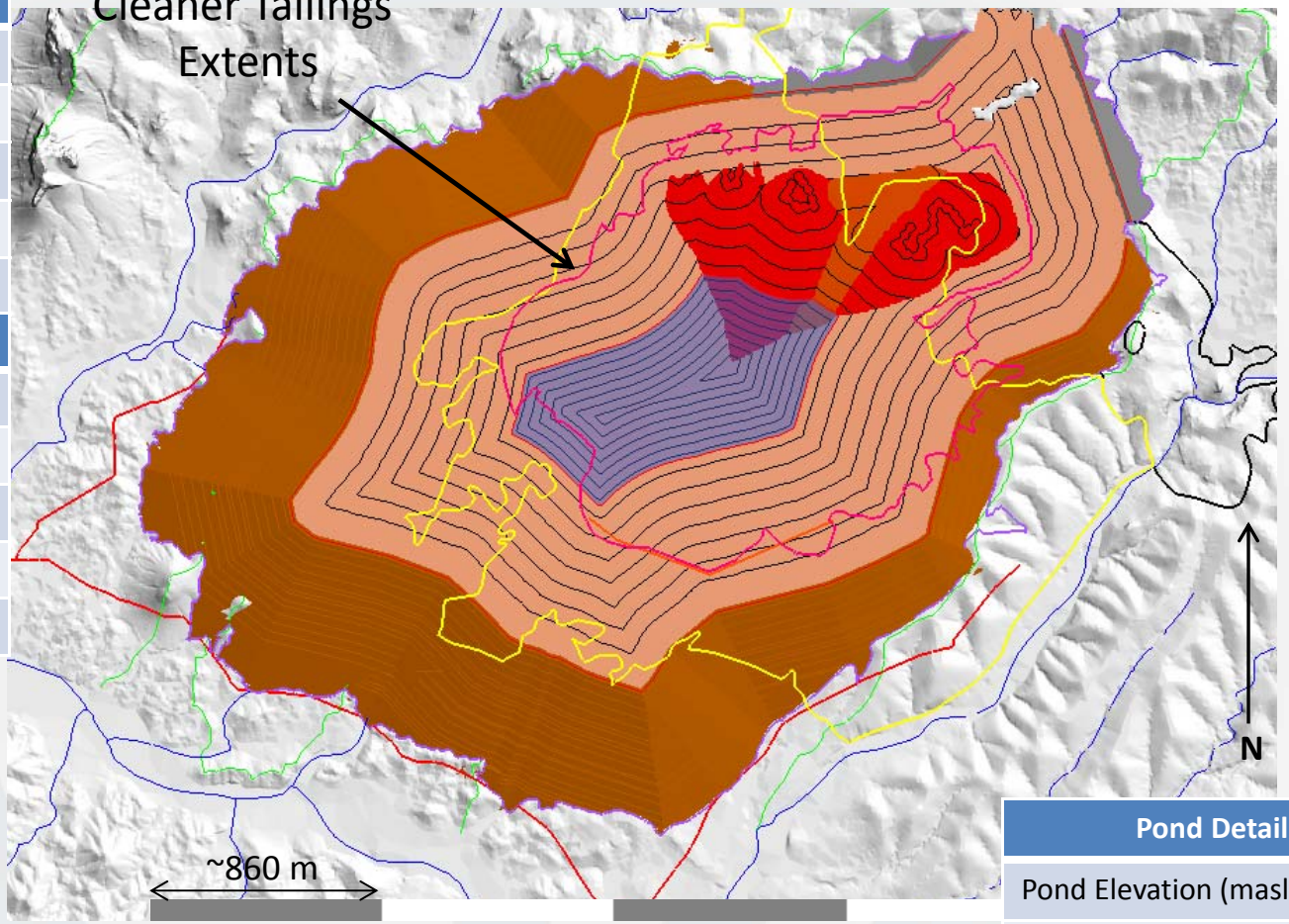
Pond Details	
Pond Elevation (masl)	846.4
Pond Volume (Mm^3)	3.5
Max Pond Depth (m)	8.3
PMF Elevation (masl)	853

Klohn Crippen Berger

Stage III: Year 45

Scavenger Thickened Tailings	
Dam Elevation (masl)	855
Tailings Elevation (masl)	854.5
Tailings Volume (Mm^3)	0.1
Tonnage (Mtonnes)	0.2
Beach Length (m)	824.9
Cleaner Thickened Tailings	
Dam Elevation (masl)	768
Tailings Elevation (masl)	851.3
Tailings Volume (Mm^3)	0.02
Tonnage (Mtonnes)	0.04
Beach Length (m)	480.2

Note: Contours drawn at 1m intervals



Legend:

- Scavenger Tailings
- Upstream Embankment
- Cleaner Tailings
- General Fill Dam
- Pond
- Old Cleaner Tailings
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

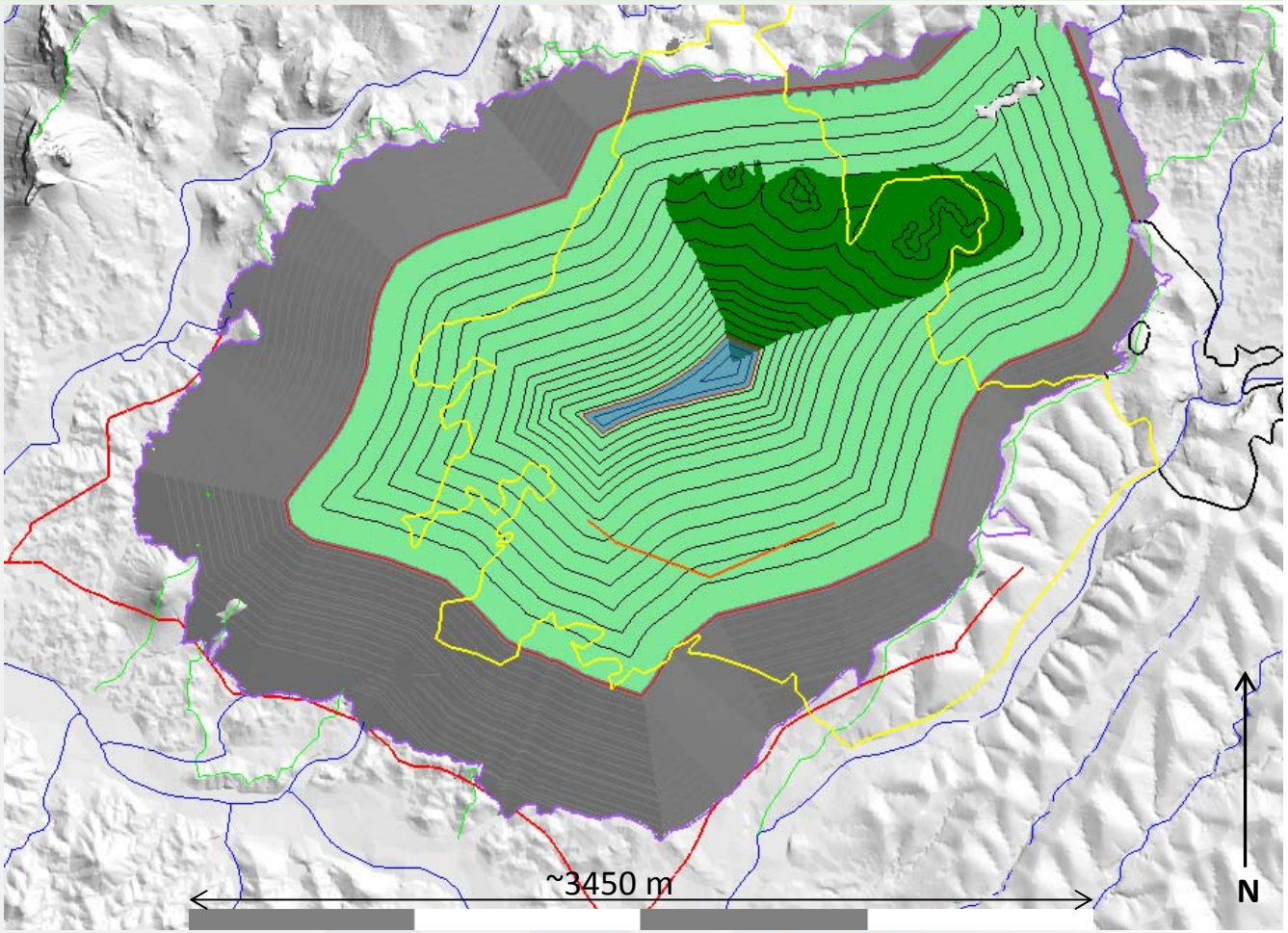
Pond Details	
Pond Elevation (masl)	846.4
Pond Volume (Mm^3)	3.5
Max Pond Depth (m)	8.2
PMF Elevation (masl)	853

Klohn Crippen Berger

Closure

Scavenger Thickened Tailings	
Dam Elevation (masl)	855
Tailings Elevation (masl)	854.5
Beach Length (m)	1,121.7
Cleaner Thickened Tailings	
Max Tailings Elevation (masl)	851.3
Beach Length (m)	729.7
Pond Details	
Pond Elevation (masl)	840.6
Pond Volume (Mm^3)	0.1
Max Pond Depth (m)	2.4
Pond Area (km^2)	0.14

Note: Contours drawn at 1m intervals



Legend:

- Reclaimed Scavenger Tailings
- Reclaimed Cleaner Tailings
- Reclaimed Dam Slopes
- Pond
- Minimum Creek Offset
- Catchment Divides
- Natural Streams
- Gila Conglomerate
- Rhyolite
- Ultimate Toe Outline
- Cleaner Dam Centerline

Klohn Crippen Berger

APPENDIX V

Seismic Stability Analysis

MEMORANDUM

TO:	File	**DATE:**	September 5, 2014
FROM:	Drew Hegadoren/Thava Thavaraj	**FILE NO:**	M09441A14.730
SUBJECT:	Appendix V - Seismic Stability Analysis		

1 INTRODUCTION

The proposed design for the Near West tailings storage facility (TSF) involves using the upstream construction method to create a tailings embankment with a height of approximately 180 m *(590.6 ft)*. The purpose of the analyses described in this memo is to determine a suitable design for the embankment that is stable under the design earthquakes.

URS Corporation (URS 2013) conducted a site specific seismic hazard assessment and provided seismic design parameters for the tailings embankments. URS (2013) also provided a suite of time histories representing design scenario earthquakes. The seismic parameters and time histories provided by URS (2013) were used in the analyses presented in this memorandum.

2 PROPOSED DESIGN

The proposed cross sections for the tailings embankment are shown in Figure 1 and Figure 2. It is constructed using the upstream method with a 5H:1V slope on the embankment face and crest height of 180 m *(590.6 ft)* above the toe. A small starter dam is used as an initial deposition point for tailings. The embankment is assumed to be constructed entirely on rock. The following cases were considered in the analyses:

- Case A1: Water table is taken at 5 m *(16.4 ft)* below the tailings surface.
- Case A2: Water table is taken at 20 m *(65.6 ft)* below the tailings surface. It is assumed that appropriate drainage measures will be provided to depress the water table to 20 m *(65.6 ft)* depth.
- Case B1: A 20 m *(65.6 ft)* thick layer of free draining material is assumed to be placed over the tailings to improve the stability of the embankment. In this case, the water table is taken 25 m *(82.0 ft)* below surface (i.e., 5 m *(16.*4 ft*)* below the surface of tailings).
- Case B2: This is variation of Case B1. In this case, the water table is taken at 40 m *(131.2 ft)* depth below the surface (i.e., 20 m *(65.6 ft)* below the surface of tailings).

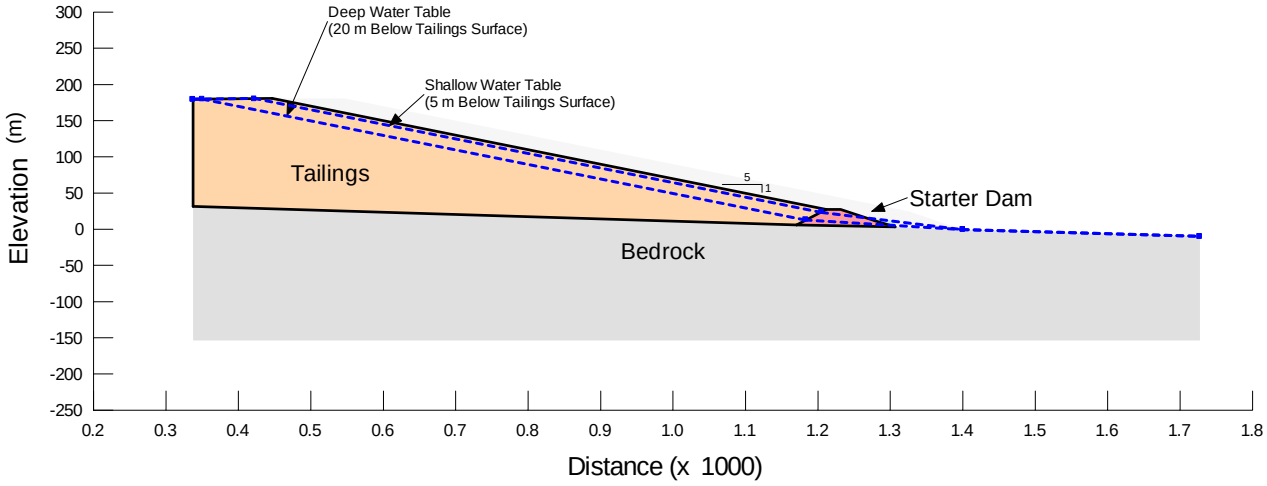


Figure 1 **Cross Section of Tailings Embankment used in Cases A1 and A2**

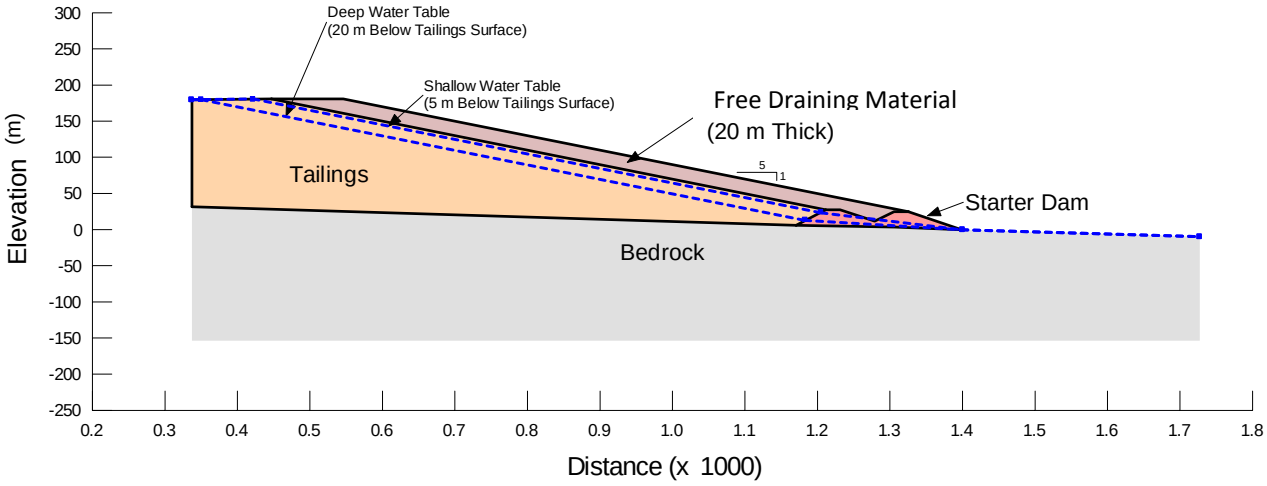


Figure 2 **Cross Section of Tailings Embankment used in Cases B1 and B2**

3 SEISMIC PARAMETERS AND TIME HISTORIES

5,000 year return period ground motions (or probability of exceedance of 1% in 50 years) were taken as the maximum design earthquake ground motions for the Near West site. URS (2013) provided the following site specific seismic design parameters:

- 5,000 year return period Peak Ground Acceleration (PGA) and spectral accelerations (Sa) at 0.2 second and 1 second periods uniform hazard response spectra (UHRS):
  - PGA=0.107 g, Sa(T=0.2 s)=0.26 g and Sa(T=1 s)=0.15 g

- PGAs corresponding to 5,000 year return period conditional mean spectra (CMS) at short period (0.2 s) and long period (1 s) are:
  - PGA=0.0987 g for CMS at 0.2 s
  - PGA=0.014 g for CMS at 1 s

- Controlling or Scenario Earthquakes corresponding to ground motions at PGA and 1 second spectral accelerations are a low magnitude local earthquake and a long distance large magnitude earthquake occurring near the San Andreas Fault. The representative local and long distance earthquake magnitudes and distances are:
  - For PGA, Earthquake Magnitude, M=5.4 and Distance, D=38 km *(23.6 mi)*
  - For Sa(T=1), Earthquake Magnitude, M=7.7 and Distance, D=373 km *(231.8 mi)*

- Two time histories were developed by URS by matching the CMS at 0.2 s and 5 time histories were developed by matching the CMS at 1.0 s. URS (2013) selected the records listed in Table 1 and modified them to match the CMS. The original earthquake magnitudes for the selected earthquake records are also listed in Table 1.

Table 1 Earthquake Time Histories Provided by URS (2013)

Conditional Mean Spectra (CMS)	Name of Matched Earthquake Record	Earthquake	Earthquake Magnitude	Peak Ground Acceleration of Matched Record (g)
CMS at 0.2 s	NW_CerroPrito	1979 Imperial Valley, CA	M6.5	0.087
	NW_Kozani	1995 Kozani, Greece	M6.4	0.086
CMS at 1.0 s	NW_Kau046	1999 Chi-Chi, Taiwan	M7.6	0.028
	NW_Kau081	1999 Chi-Chi, Taiwan	M7.6	0.035
	NW_FireStation1	2002 Denali, Alaska	M7.9	0.031
	NW_ValdezCityHall	2002 Denali, Alaska	M7.9	0.037
	NW_Afyon	1999 Kocaeli, Turkey	M7.5	0.029

The ground motion parameters provided by URS (2013) are appropriate for bedrock conditions at the Near West site with representative shear wave velocity of 400 m/s *(1312.3 ft/s)*. Figure 3 shows the 5,000 year return period UHRS and CMS at 0.2 s and 1.0 s.

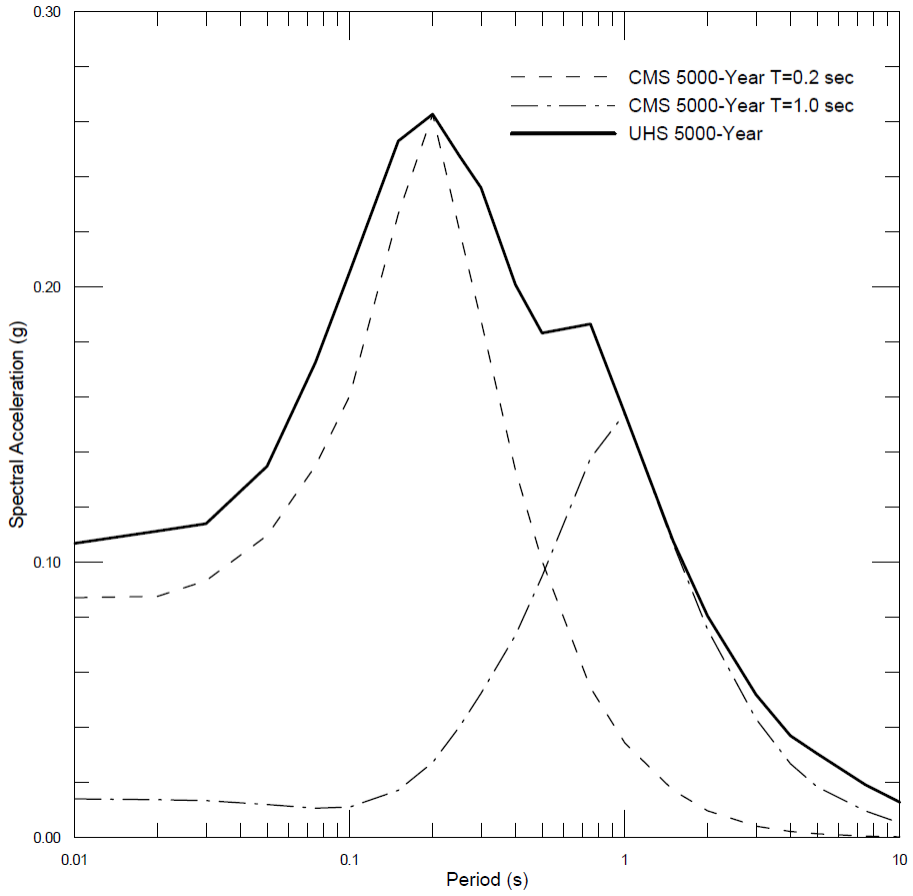


Figure 3 5,000-year Return Period UHS and CMS at Near West Site (URS 2013)

4 SEISMIC STABILITY AND LIQUEFACTION POTENTIAL ASSESSMENT USING EMPIRICAL DATA

A preliminary empirical assessment based on observations of the performance of tailings facilities and sites under earthquake loading was conducted. Conlin (1987) and Ambraseys (1988) have provided plots that correlate earthquake magnitude and distance to occurrences of liquefaction or dam failures. Conlin's relationship specifically considers the occurrence of tailings dam failures for operating and closure conditions.

URS Corporation (2013) provided M5.4 earthquake at 38 km *(23.6 mi)* distance and M7.7 earthquake at 373 km *(231.8 mi)* distance as controlling or scenario earthquakes corresponding to short period (PGA) and long period (1 s) ground motions. The hazard at long period (1 s) arises from a long distant earthquake and the PGA for CMS at this 1 s period is very small: 0.014 g.

Figures in Attachment I show that these two scenario earthquakes are plotted in the no or minor damage regions in Conlin's (1987) plots and in the non-liquefying region in Ambraseys' (1988) plot. Conlin's charts show that the margin of safety will increase after closure as the water levels in the

tailings embankment drain down. Thus, the empirical data show that liquefaction of tailings and significant damage to the tailings embankment are unlikely.

5 SEISMIC ANALYSIS

Ground response analyses were conducted for 1-D soil columns representing the proposed tailings embankment to determine the susceptibility of tailings to liquefaction. Analysis was done using the program PROSHAKE (Edupro 2005) for three soil columns representing locations where the tailings thickness is 50 m *(164.0 ft)*, 100 m *(328.1 ft)*, and 150 m *(492.1 ft)*. Analyses were completed for the low (5 m *(16.4 ft)* below tailings surface) and high (20 m *(65.6 ft)* below tailings surface) water table cases, as well as the cases with and without the free draining material layer over the tailings. Locations of the soil columns used for seismic analysis are shown in Figure 4.

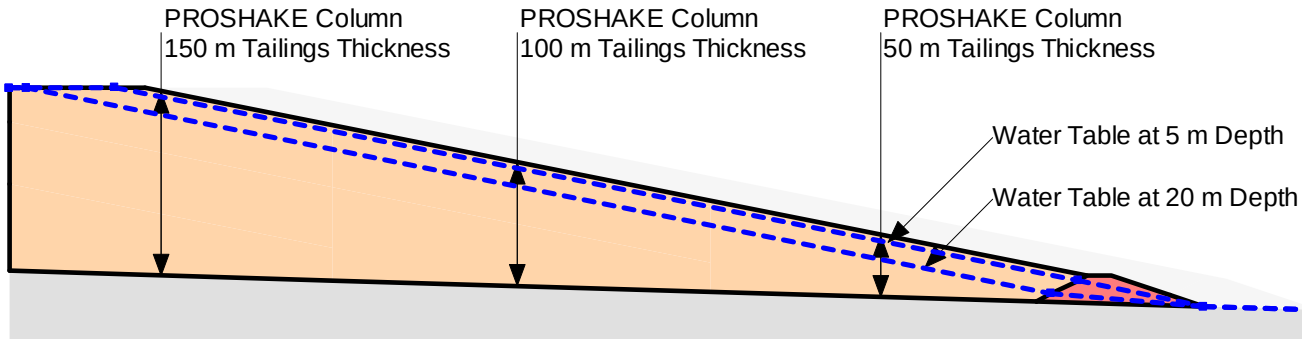


Figure 4 PROSHAKE Soil Column Locations for Cases A1 and A2

5.1 Input Parameters

A total of five columns representing the two tailings embankment designs were considered for the ground response analysis: two columns representing the scenario without free draining material cover (Cases A1 and A2) and 3 columns representing the scenario with free draining material cover (Cases B1 and B2). The columns are analyzed for phreatic surfaces at 5 m *(16.4 ft)* and 20 m *(65.6 ft)* below the tailings surface. Table 2 contains a summary of the soil columns analyzed.

Soil parameters used in the PROSHAKE analysis are based on experience from similar projects. A Standard Penetration Test, $(N_1)_{60}$ value of 7 is adopted for the tailings; values of 5 and 9 are analyzed to evaluate the sensitivity of the factor of safety (FOS) against liquefaction to the $(N_1)_{60}$. The SPT $(N_1)_{60}$ of the 20 m *(65.6 ft)* thick free draining material cover layer in Case B1 and B2 was taken as 15.

Table 2 PROSHAKE Analysis Soil Columns

Case	Column Name	Depth of Water Table (m) *(ft)*	Height of Column (m) *(ft)*	Free Draining Material Thickness (m) *(ft)*	Representative SPT $(N_1)_{60}$
A1	A50-5	5 *(16.4)*	50 *(164.0)*	0	5,7,9
A2	A50-20	20 *(65.6)*			
A1	A100-5	5 *(16.4)*	100 *(328.1)*		
A2	A100-20	20 *(65.6)*			
B1	B70-25	25 *(82.0)*	70 *(229.7)*	20 *(65.6)*	
B2	B70-40	40 *(131.2)*			
B1	B120-25	25 *(82.0)*	120 *(393.7)*		
B2	B120-40	40 *(131.2)*			
B1	B170-25	25 *(82.0)*	170 *(557.7)*		
B2	B170-40	40 *(131.2)*			

The input earthquake records provided by URS and listed in Table 1 were used in the analyses. Ground motions were applied at the top of bedrock (or at the bottom of each soil column) as "outcrop" motions.

5.2 Liquefaction Assessment Methodology

The liquefaction assessment of granular soils was carried out in general accordance with Seed's simplified approach recommended by Idriss and Boulanger (2008). The cyclic shear stress ratios (CSR) induced by design earthquakes are compared with the cyclic resistance ratios (CRR) derived from field observations of soils with known standard penetration test (SPT) resistances, at sites that have or have not liquefied during earthquakes to determine the liquefaction triggering potential.

The earthquake induced CSR profiles along the depth of each column were computed using PROSHAKE. The CSR values were normalized to a magnitude of 7.5 and an overburden effective stress of 1 atm using correction factors recommended by Idriss and Boulanger (2008). CRR values derived from $(N_1)_{60}$ blow counts for tailings based on experience from other sites were compared to the normalized CSR values. The FOS against liquefaction is the ratio between the CRR and CSR. If the factor of safety against liquefaction is greater than unity, liquefaction will not be triggered but excess pore-water pressure can still develop if the factor of safety is low (between 1 and 1.3). The excess pore-water pressure ratio, Ru (defined as the ratio of excess pore-water pressure generated by the earthquake divided by the initial effective overburden stress) coefficients were estimated based on a relationship with factor of safety against liquefaction suggested by Marcuson et al. (1990), as provided by Idriss and Boulanger (2008). Note that, in the evaluation of liquefaction triggering of tailings, corrections for the fines content were not applied.

5.3 Liquefaction Assessment Results

Table 3 summarizes seismic analysis results for the scenarios analyzed. Attachment II contains plots showing the results of the seismic analysis. It was found that the critical earthquakes were the

magnitude M7.7 earthquakes originating at the San Andreas Fault. Although the peak ground acceleration is less than that for the local earthquake, the CMS of 1.0 s for the more distant earthquakes is nearer to the natural frequency of the embankment, and thus results in a greater CSR due to amplification effects.

Table 3 Seismic Analysis Results

Column	Approximate Depth of Water Table (m) *(ft)*	Height of Column (m) *(ft)*	Representative SPT $(N_1)_{60}$	Minimum FOS*	Maximum, Ru*
A50-5	5 *(16.4)*	50 *(164.0)*	7	1.34	0.17
A50-20	20 *(65.6)*			1.81	0.06
A100-5	5 *(16.4)*	100 *(328.1)*		1.60	0.09
A100-20	20 *(65.6)*			2.06	0.04
B70-25	25 *(82.0)*	70 *(229.7)*		2.25	0.04
B70-40	40 *(131.2)*			2.60	0.03
B120-25	25 *(82.0)*	120 *(393.7)*		2.47	0.03
B120-40	40 *(131.2)*			2.79	0.03
C170-25	25 *(82.0)*	170 *(557.7)*		2.53	0.03
C170-40	40 *(131.2)*			2.88	0.03

Note: * corresponds to average of the five earthquake records representing the long distance earthquake.

Based on the results summarized in Table 3, liquefaction is unlikely to occur for any of the scenarios analyzed. Some buildup of pore-water pressure during shaking will occur, which is taken into account for stability analysis.

6 STABILITY ANALYSIS

Stability analyses were undertaken to determine the post-earthquake stability of the proposed upstream construction TSF at the Near West site. In addition to the four scenarios previously mentioned (5 m *(16.4 ft)* and 20 m *(65.6 ft)* deep water table, with and without a 20 m *(65.6 ft)* thick free draining material layer), an analysis was also carried out to determine how high a free draining material berm would be required to increase the post-earthquake FOS from the target minimum of 1.2 to 1.5.

6.1 Input Parameters

Base material parameters used for the stability analysis are given in Table 4.

Table 4 Base Material Parameters

Material	Unit Weight (kN/m^3) *(pcf)*	Friction Angle (degrees)
Free draining material cover	19 *(120.9)*	36
Tailings (above water table)	15 *(95.5)*	32
Tailings (below water table)	18 *(114.6)*	32
Starter Dam	19 *(120.9)*	36

To model pore pressures generated due to ground motion, the friction angle of tailings below the water table listed in Table 4 was reduced based on the Ru value calculated from the PROSHAKE analyses. The Ru values over 50 m *(164.0 ft)* intervals in each soil column were calculated based on the minimum of the average FOS over each interval using the relationship proposed by Marcuson et al. (1990). The following formula was used to reduce the friction angle of the tailings based on the Ru value:

$$\phi_{reduced} = \tan^{-1}(\tan\phi * (1 - R_u))$$

For stability modeling, the tailings region of the embankment cross section was divided into regions based on the locations of the PROSHAKE columns. Material properties were assigned for each 50 m *(164.0 ft)* layer of tailings below the water table. The divided model geometry is shown in Figure 5.

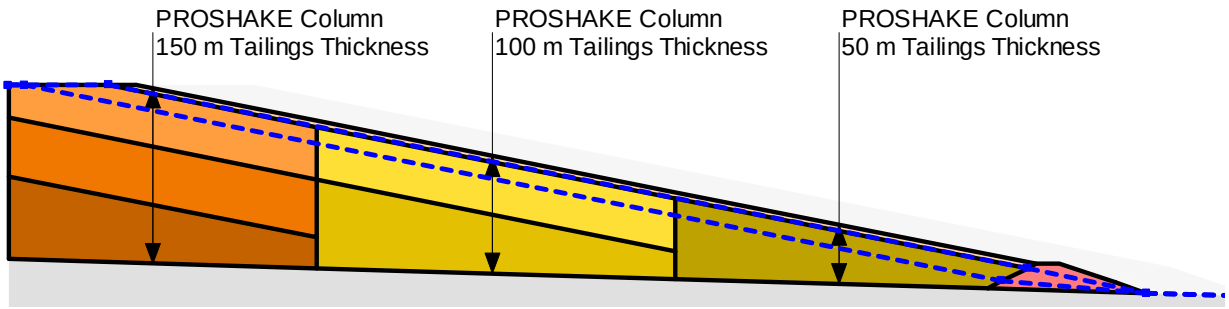


Figure 5 Divided Model Geometry

The reduced friction angles that were applied to tailings below the water table for each analysis are given in Table 5.

Table 5 Reduced Friction Angles for $(N_1)_{60cs}$ = 7

Free Draining Material Cover	Water Table Depth (m) *(ft)*	Location	Depth (m) *(ft)*	Average Minimum FOS	Average Minimum Ru	Adjusted Friction Angle
N	5 *(16.4)*	Toe	0 – 50 *(0 - 164.0)*	1.34	0.17	27.5
		Mid-Face	0 – 50 *(0 - 164.0)*	1.60	0.09	29.5
			50 – 100 *(164.0 – 328.1)*	1.73	0.07	30.0
	20 *(65.6)*	Toe	0 – 50 *(0 - 164.0)*	1.81	0.06	30.3
		Mid-Face	0 – 50 *(0 - 164.0)*	2.06	0.04	30.9
			50 – 100 *(164.0 – 328.1)*	2.06	0.04	30.9
Y	25 *(82.0)*	Toe	20 – 70 *(65.6 – 229.7)*	2.25	0.04	31.0
		Mid-Face	20 – 70 *(65.6 – 229.7)*	2.47	0.03	31.3
			70 – 120 *(229.7 – 393.7)*	2.55	0.03	31.3
		Crest	20 – 70 *(65.6 – 229.7)*	2.53	0.03	31.3
			70 – 120 *(229.7 – 393.7)*	2.68	0.03	31.4
			120 – 170 *(393.7 – 557.7)*	3.52	0.03	31.4

Free Draining Material Cover	Water Table Depth (m) *(ft)*	Location	Depth (m) *(ft)*	Average Minimum FOS	Average Minimum Ru	Adjusted Friction Angle
	40 *(131.2)*	Toe	20 – 70 *(65.6 – 229.7)*	2.60	0.03	31.4
		Mid-Face	20 – 70 *(65.6 – 229.7)*	2.79	0.03	31.4
			70 – 120 *(229.7 – 393.7)*	2.85	0.03	31.4
		Crest	20 – 70 *(65.6 – 229.7)*	2.88	0.03	31.4
			70 – 120 *(229.7 – 393.7)*	2.98	0.03	31.4
			120 – 170 *(393.7 – 557.7)*	3.68	0.03	31.4

6.2 Stability Analysis Results

Results of the post-earthquake stability analysis are given in Table 6. All critical failure surfaces involve failing the entire embankment face and exceed the minimum target FOS of 1.2.

Table 6 Post-Earthquake Stability Analysis Results

Free Draining Material Cover	Water Table Depth (m) *(ft)*	FOS
N	5 *(16.4)*	1.4
	20 *(65.6)*	1.9
Toe Berm Only	5 (below tailings surface) *(16.4)*	1.5
Y	25 *(82.0)*	2.2
	40 *(131.2)*	2.5

It was found that adding a 100 m *(328.1 ft)* wide toe berm from the base of the embankment to about the 1/3 height of the embankment is sufficient to raise the post-earthquake factor of safety to 1.5. The toe berm required is shown on Figure 6 with the predicted critical failure surface.

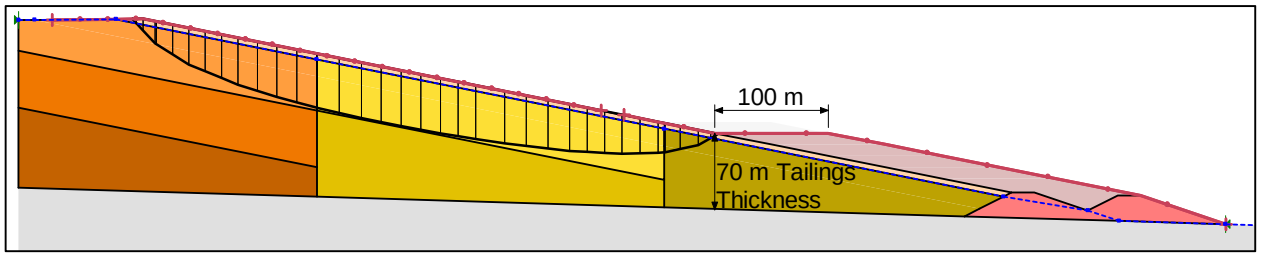


Figure 6 Toe Berm Required for FOS = 1.5

7 CONCLUSION

Stability of the proposed embankment under the modeled post-earthquake conditions is adequate for all scenarios analyzed. Results from the seismic and stability analyses are consistent with observations of existing facilities under similar seismic loading. Liquefaction is not expected to occur, however, some excess pore-water pressure during and after shaking is anticipated. Further reduction of the liquefaction potential can be achieved by either lowering the water table in the tailings through drains or other means, or providing a layer of free draining material over the tailings to increase the effective stress. Based on stability modeling, in order to increase the post-earthquake FOS to 1.5, a 100 m *(328.1 ft)* wide layer of free draining sand could be applied over the tailings extending from the toe to 1/3 height of the tailings slope.

REFERENCES

Ambraseys, N. N. 1988. “Engineering Seismology.” Earthquake Engineering and Structural Dynamics, 17, 1-105.

Conlin, B. H. 1987. “A Review of the Performance of Mine Tailings Impoundments Under Earthquake Loading Conditions”, Earthquake Geotechnique, The Canadian Geotechnical Society.

Edupro. 2005. “PROSHAKE-Ground Response Analysis Program”, EduPro Civil Systems Inc., Redmond, WA.

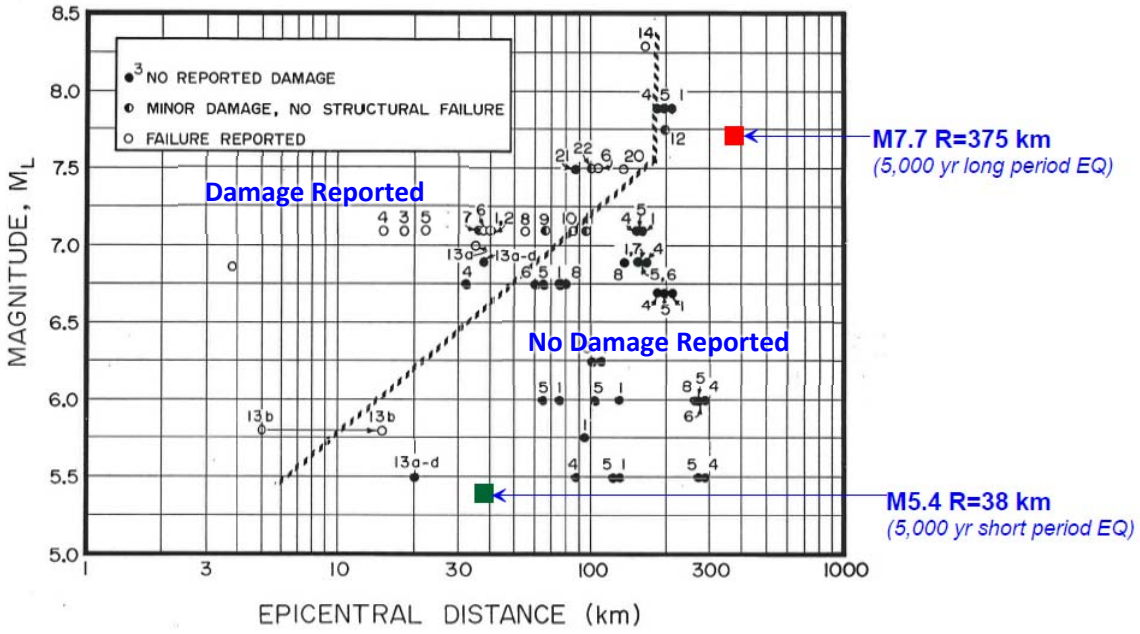
Idriss, I. M., and Boulanger, R. W. 2008. “Soil liquefaction during earthquakes.” Monograph MNO-12, Earthquake Engineering Research Institute, Oakland, California.

URS Corporation. 2013. “Site-Specific Seismic Hazard Analyses for the Resolution Mining Company Tailings Storage Facilities Options, Southern Arizona”. Draft report prepared for Resolution Copper Mining.

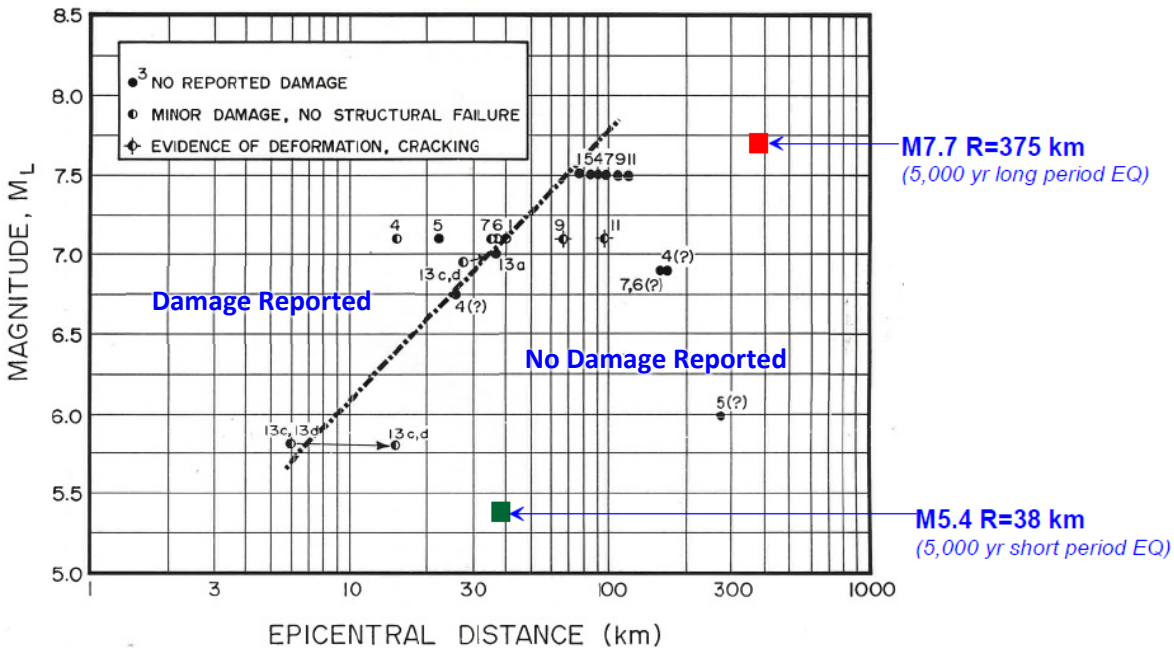
ATTACHMENT I

Seismic Performance of Dams

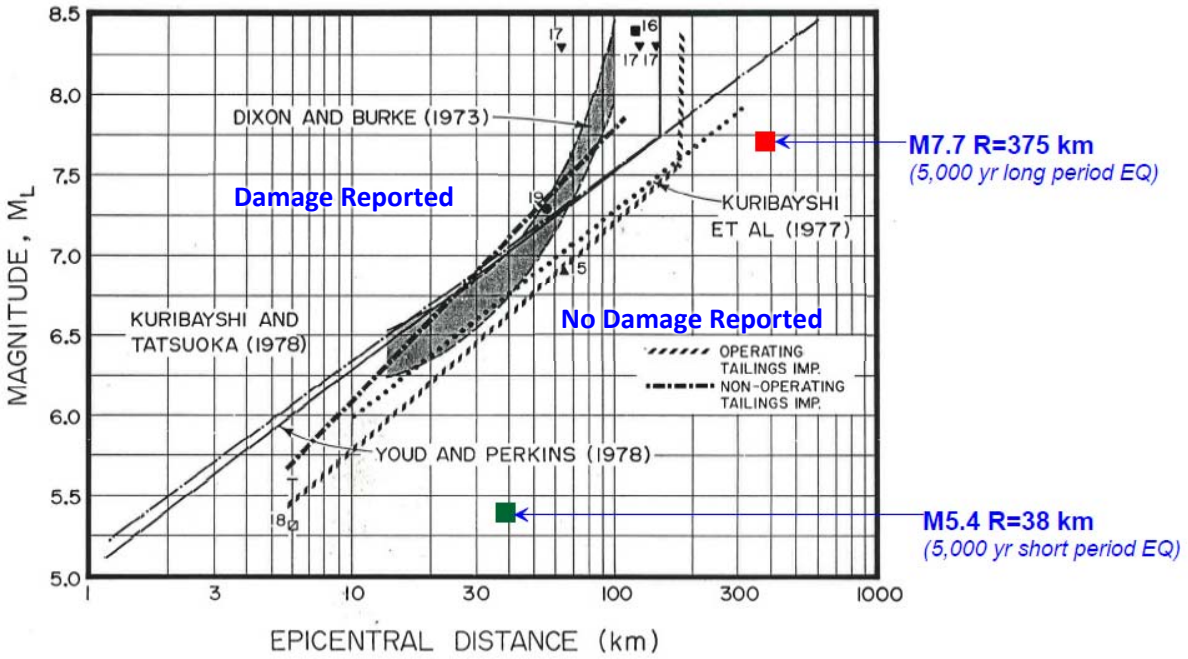
Performance of Operational Tailings Facilities (Conlin 1987)



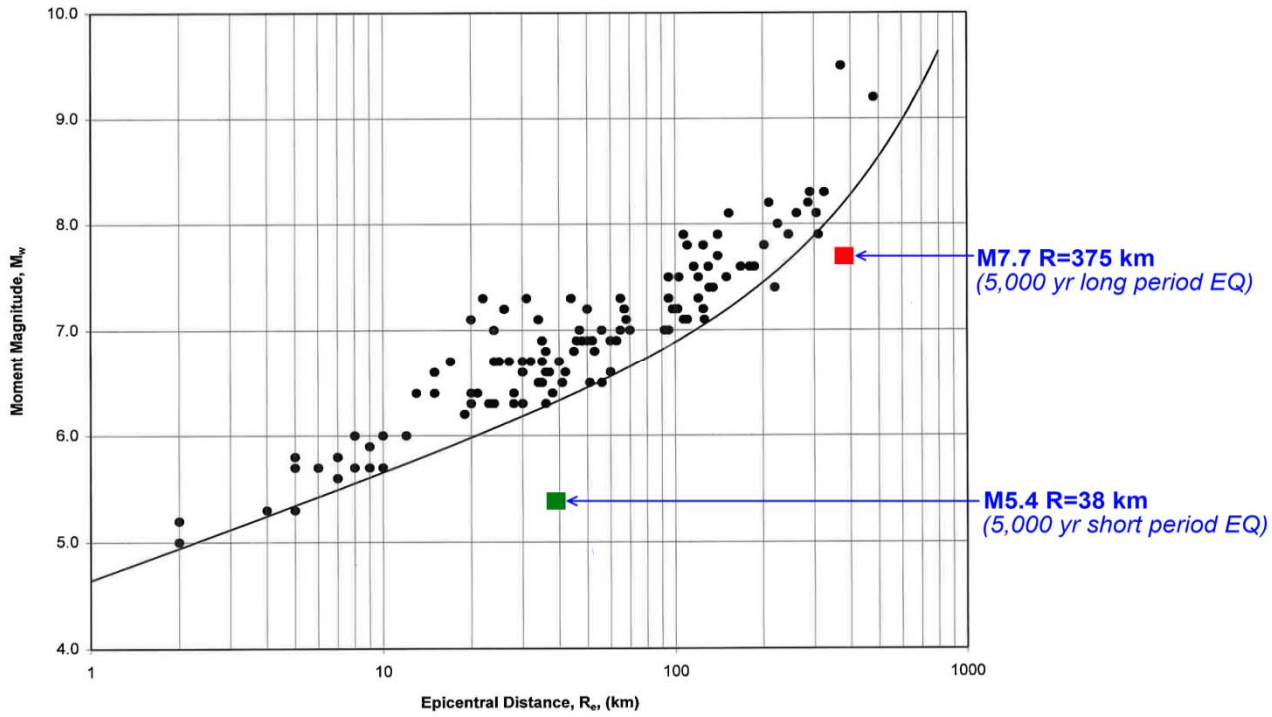
Performance of Non-operating Tailings Facilities (Conlin 1987)



Comparison of Conlin's Relationship to other Research (Conlin 1987)



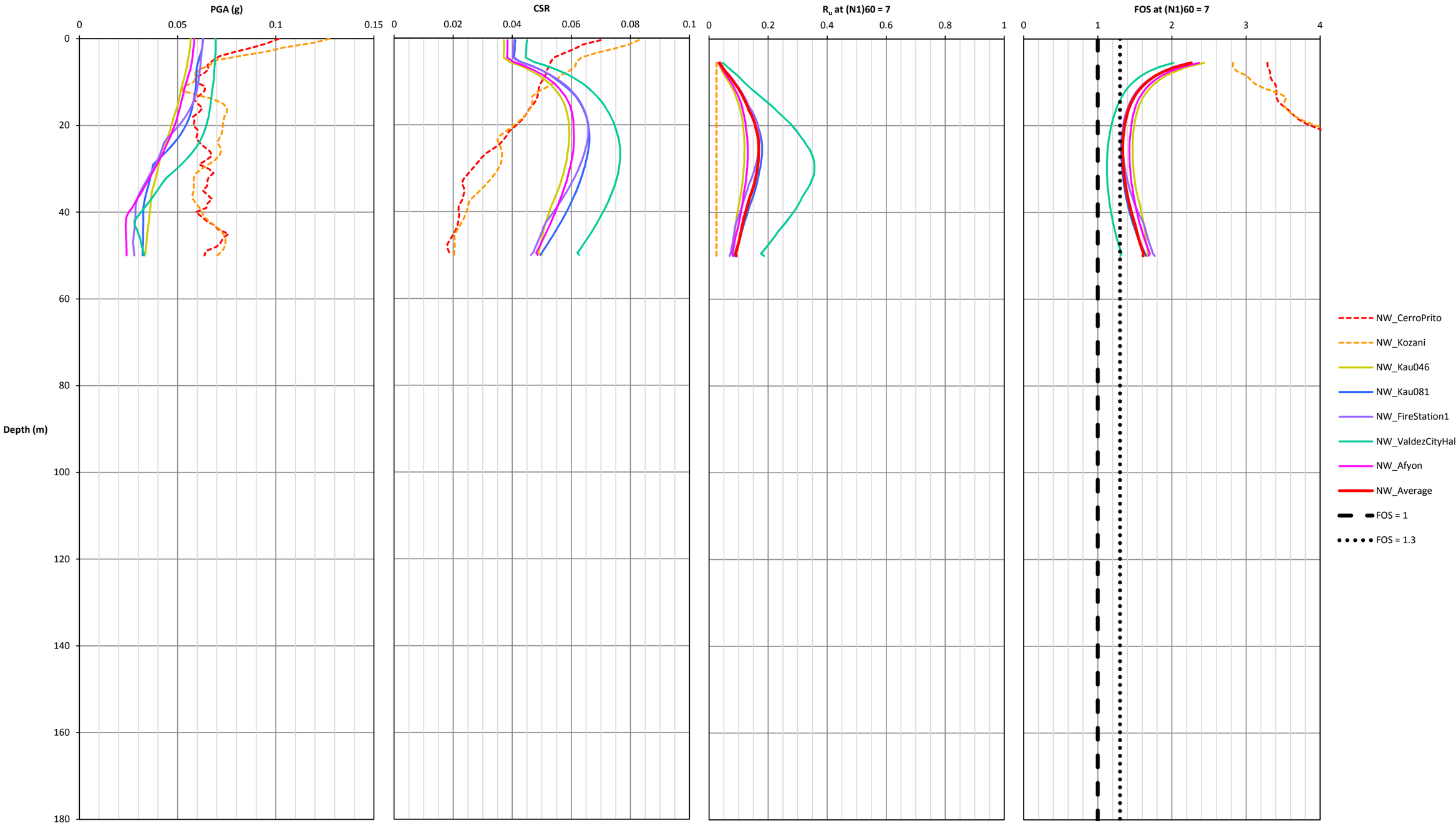
Sites Where Liquefaction has been Observed (Ambraseys 1988)



ATTACHMENT II

Seismic Analysis Results

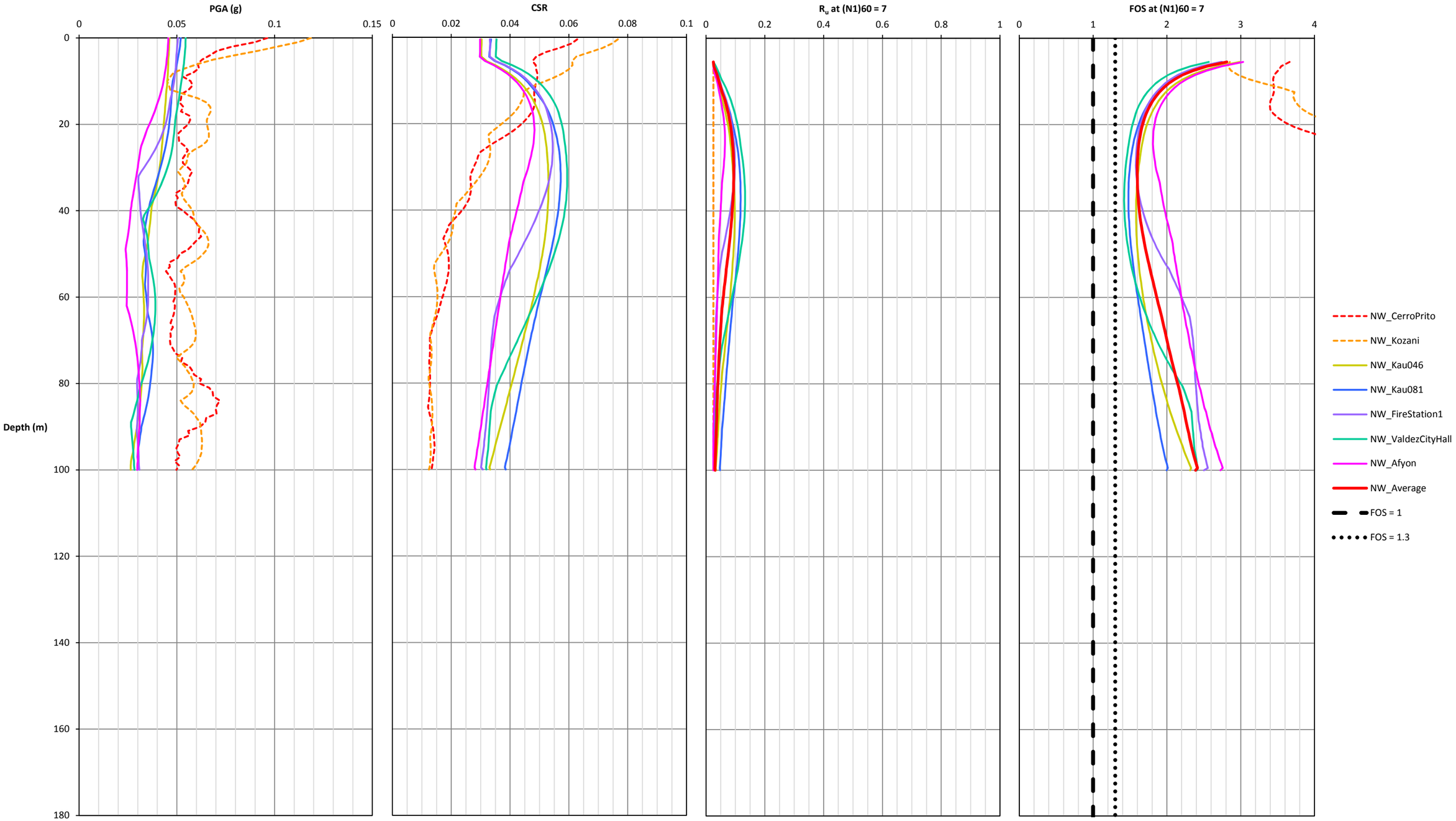
Proshake - 50m Column - WT at 5m - No Free Draining Material at the Top



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:46 PM

Proshake - 100m Column - WT at 5m - No Free Draining Material at the Top



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:53 PM

Proshake - 50m Column - WT at 20m - No Free Draining Material at the Top



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:50 PM

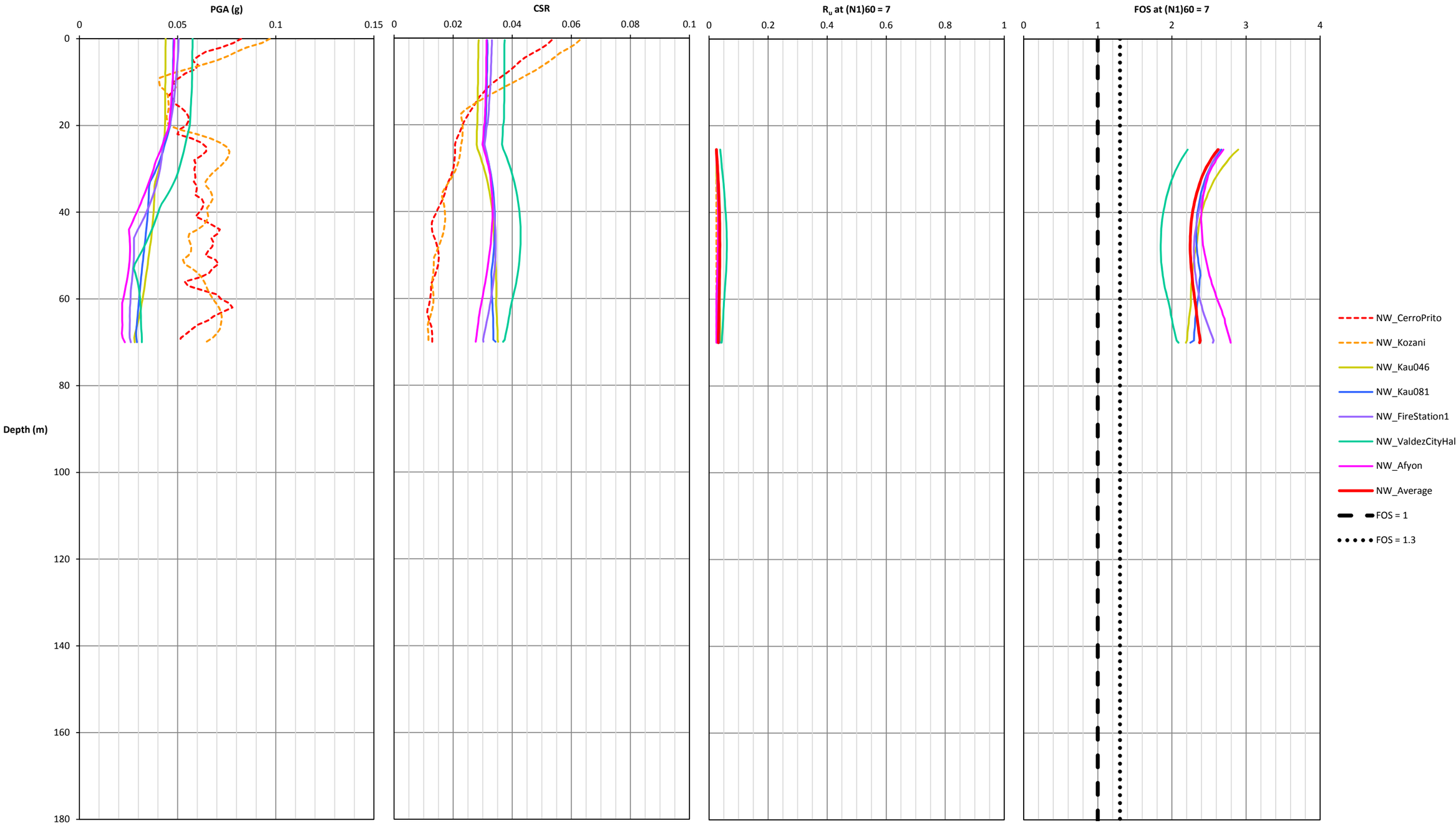
Proshake - 100m Column - WT at 20m - No Free Draining Material at the Top



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:52 PM

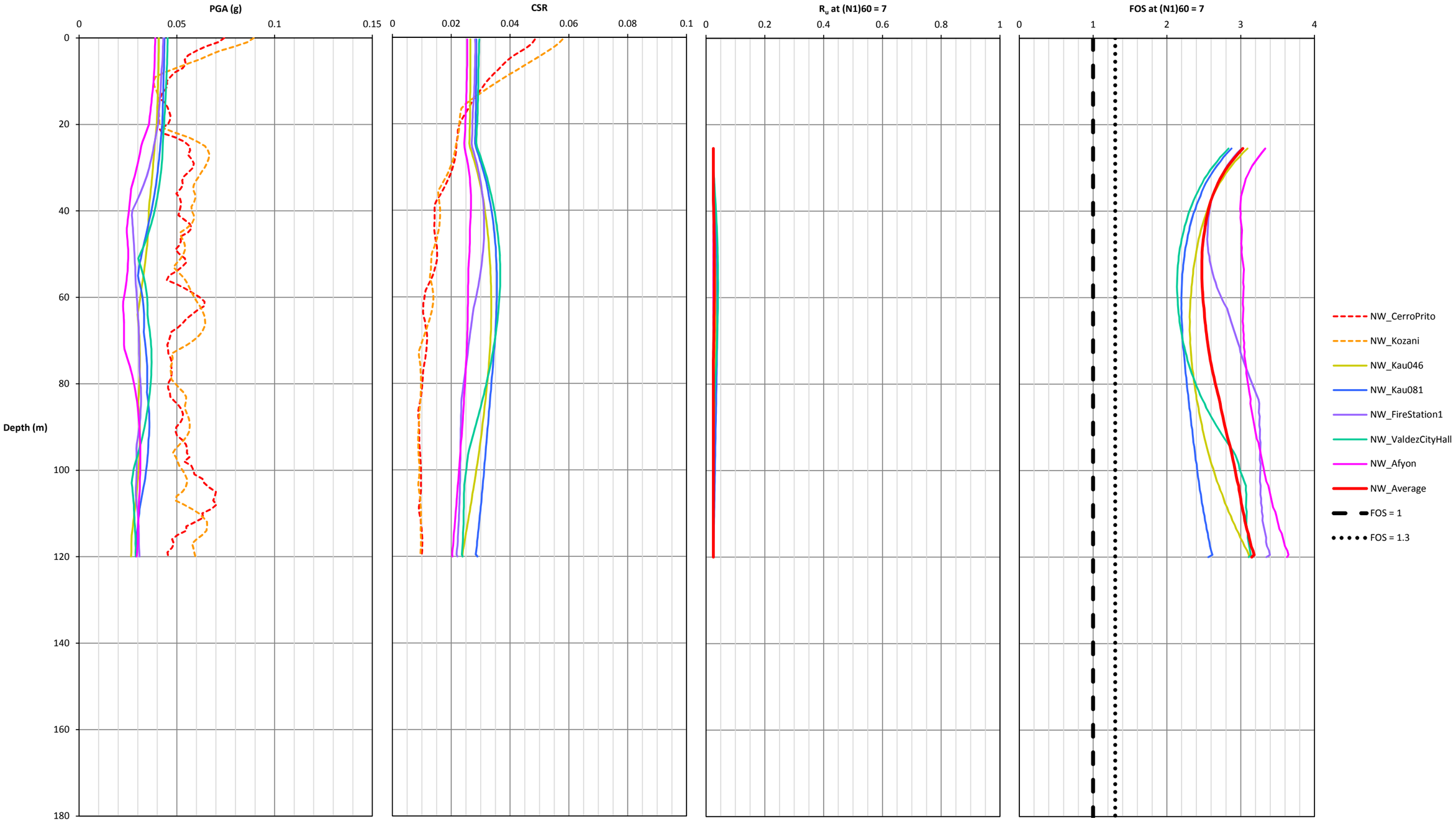
Proshake - 70m Column - WT at 25m - 20m Free Draining Material



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:55 PM

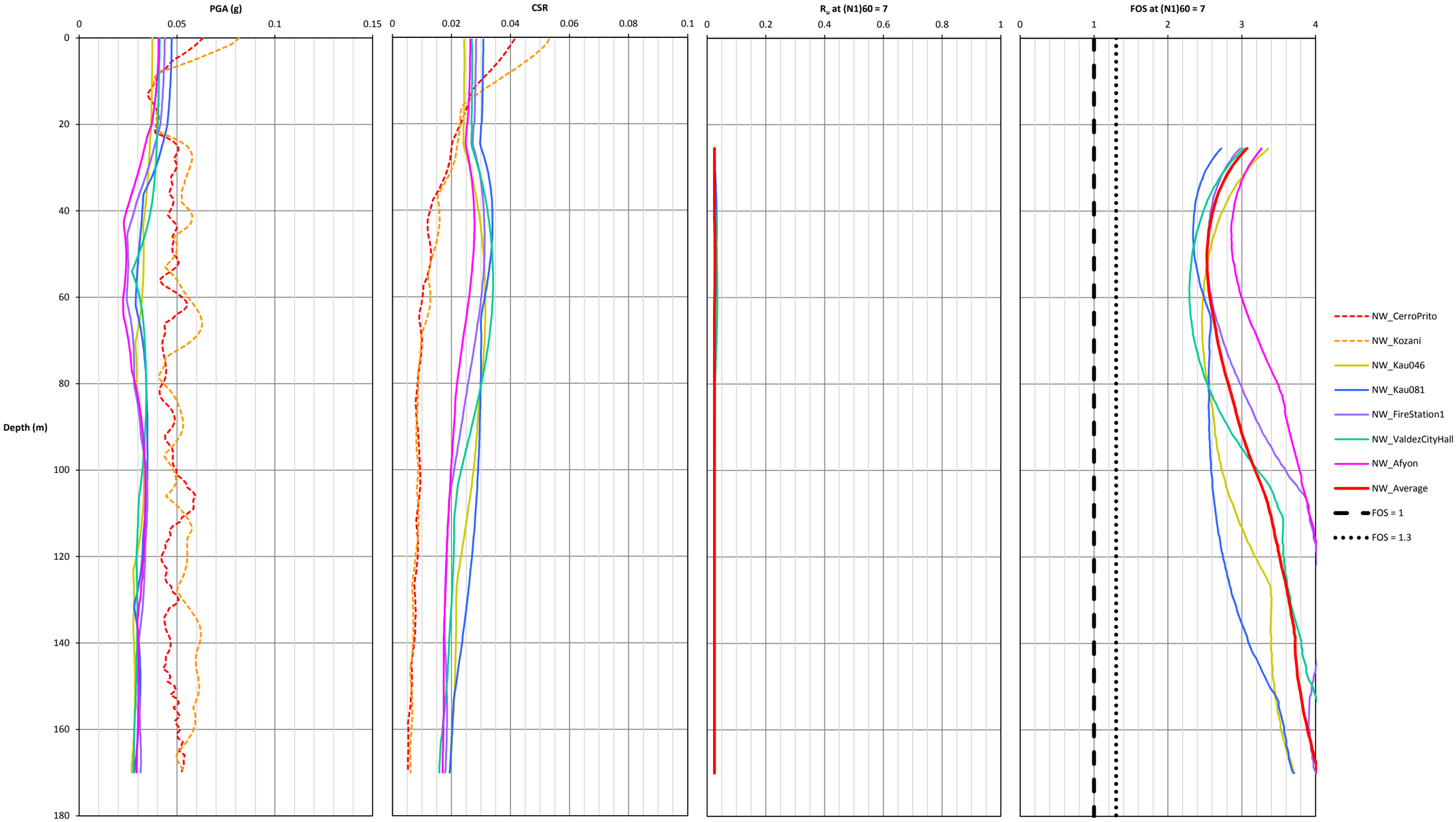
Proshake - 120m Column - WT at 25m - 20m Free Draining Material



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:58 PM

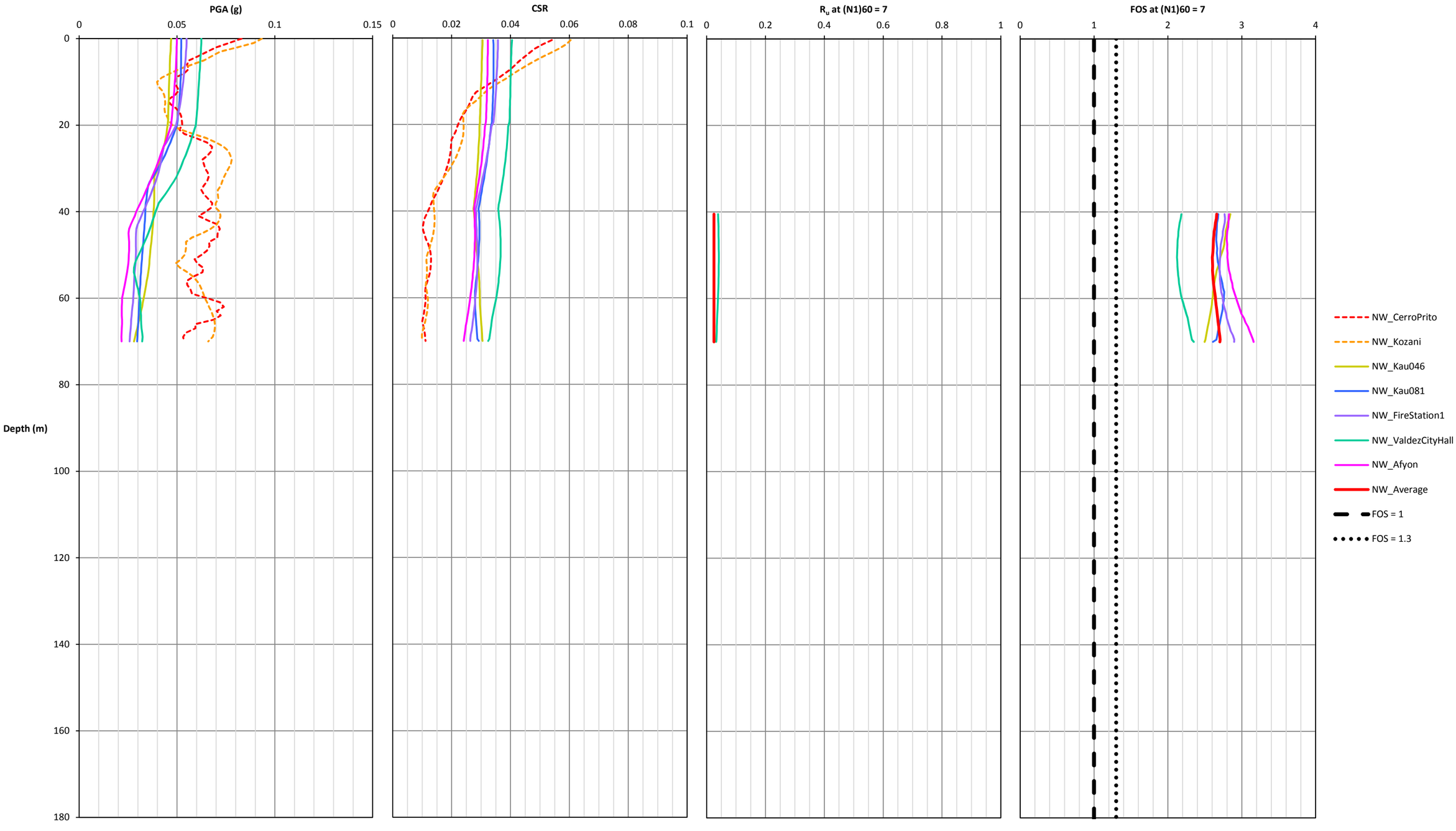
Proshake - 170m Column - WT at 25m - 20m Free Draining Material



FOS based on Idriss and Boulanger (2008)

15/05/2013 6:01 PM

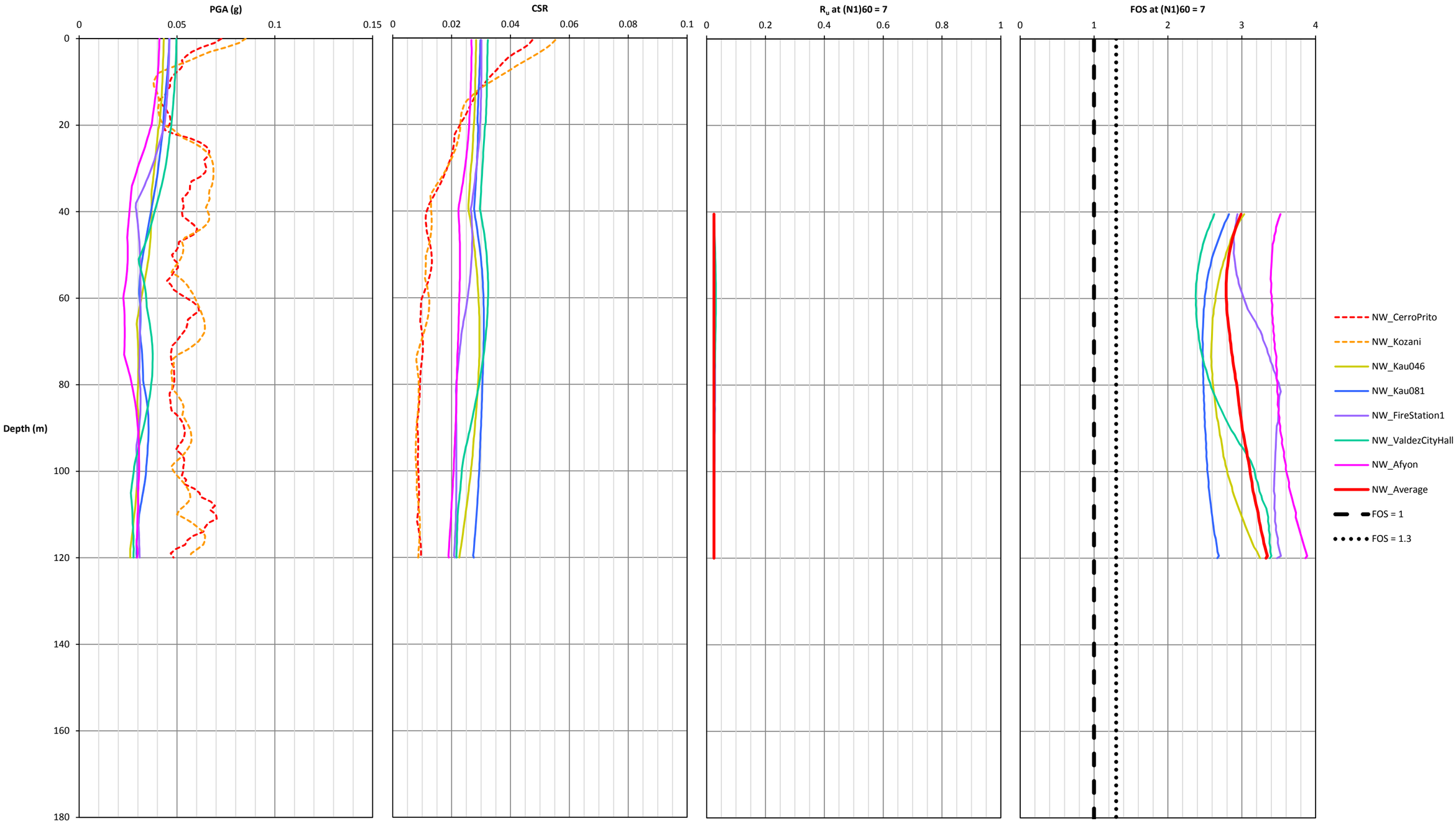
Proshake - 70m Column - WT at 40m - 20m Free Draining Material



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:54 PM

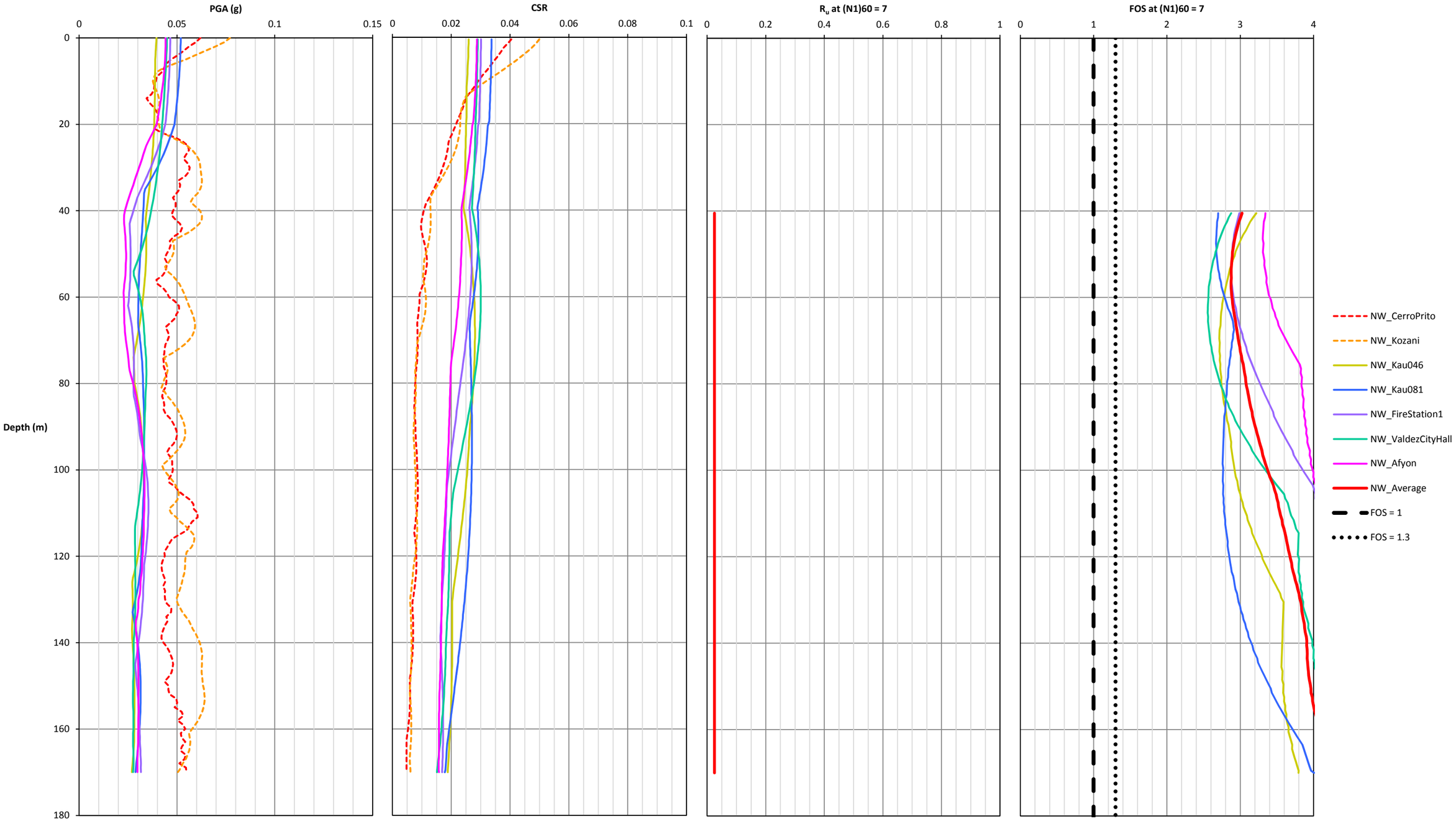
Proshake - 120m Column - WT at 40m - 20m Free Draining Material



FOS based on Idriss and Boulanger (2008)

15/05/2013 6:00 PM

Proshake - 170m Column - WT at 40m - 20m Free Draining Material



FOS based on Idriss and Boulanger (2008)

15/05/2013 5:59 PM

APPENDIX VI

Seepage Analysis

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Jim Casey **FILE NO:** M09441A14.730

SUBJECT: Appendix VI – Seepage Analysis for Operations and Stability

1 INTRODUCTION

Steady-state seepage analysis was conducted for the Near West Tailings Storage Facility (TSF) to determine the phreatic surface in the embankment for stability analysis during operations, underdrain design and for seepage recovery pond sizing. This seepage assessment has not estimated seepage bypassing the seepage recovery dams or seepage post closure. Five sections (Sections A through E) were analyzed; their locations are shown on Figure 1.

2 MODEL SET-UP

The two-dimensional finite element seepage modeling software, SEEP/W, was used for this analysis.

2.1 Boundary Conditions

Boundary conditions were established as follows:

- The tailings beach was assumed to be saturated starting 100 m *(328.1 ft)* upstream of the dam crest. This was modeled by setting a zero pressure head boundary condition along the beach surface.
- A “no-flow” boundary was set along the bedrock surface as the bulk bedrock permeability is assumed to be significantly less than the tailings.
- A constant total head boundary condition, equal to the elevation of the tailings beach, was assigned to the upstream side of the model.
- The entire downstream face of the ultimate dam and starter dam were allowed to be potential seepage faces.

2.2 Material Properties

The hydraulic conductivity values used in the analyses are listed in Table 2.1. Scavenger tailings were divided into 50 m *(164.0 ft)* thick layers to simulate decreasing hydraulic conductivity that is expected with consolidation. The finer-grained cleaner tailings were assigned the same conductivity as the most consolidated scavenger tailings. A saturated/unsaturated model was used for all materials and the hydraulic conductivity functions and volumetric water content functions are provided in Attachment I.

Table 2.1 Material Properties

Material	Saturated K_h (m/s) *(ft/s)*	K_v/K_h
Scavenger Tailings (1) (Least Consolidation)	5×10^{-7} *(1.64 x 10^{-6})*	0.11
Scavenger Tailings (2) (Intermediate Consolidation)	1×10^{-7} *(3.28x 10^{-7})*	0.11
Scavenger Tailings (3) (Most Consolidation)	5×10^{-8} *(1.64 x 10^{-7})*	0.11
Cleaner Tailings	5×10^{-8} *(1.64 x 10^{-7})*	0.11
Starter Dam Fill	5×10^{-5} *(1.64 x 10^{-4})*	1.0
Drains	1×10^{-1} *(0.3 x 10^{-1})*	1.0

3 ANALYZED CASES AND RESULTS

3.1 Cases without Drains (Base Case)

Seepage sections were modeled without drains to evaluate the reasonable "worst case" phreatic surface scenario with regards to embankment stability. Seepage flux was calculated at the toe of the starter dam or along the downstream face of the embankment. The seepage rates from the analyses are summarized in Table 3.1 and the model outputs are shown on Figures 2 through 6.

Table 3.1 Seepage Rates from Base Case Analyses

Seepage Section	Seepage Rate at Toe or Dam Slope	
	(m^3/day/m) *(ft^3/day/m)*	(L/s/m) (USgpm/ft)
A	0.22 *(2.4)*	2.5E-03 *(1.21E-02)*
B	0.27 *(2.9)*	3.1E-03 *(9.45E-03)*
C	0.28 *(3.0)*	3.3E-03 *(1.59E-02)*
D	0.28 *(3.0)*	3.2E-03 *(1.55E-02)*
E	0.19 *(2.0)*	2.2E-03 *(1.06E-02)*

3.2 Section C – with Underdrain

Section C was modeled with a 2 m *(6.56 ft)* thick underdrain to assess the effect of the underdrain on the location of the phreatic surface and the seepage rate. The phreatic surface was drawn down significantly with the addition of the drain and the seepage rate increased to 0.36 m^3/day/m *(3.9 ft^3/day/ft)*, 30% more than the base case as shown in Figure 7. The drain down effect is the maximum possible within the embankment as the drain is only present in the base of the creek drainages below the embankment. Embankment sections that do not overlie the creeks will not see the full effect of the underdrains. It is worth noting that the drains have been sized to convey 20 times the maximum design flow.

3.3 Section E – with Blanket Drain

On Section E, a 6 m *(19.7 ft)* high starter dam with a 1 m *(3.28 ft)* thick, 20 m *(65.6 ft)* long drainage blanket extending from the toe dam has been included in the design, as shown on Figure 8, as an additional measure to further depress the water table and enhance stability.

4 CONCLUSIONS

The primary conclusions of the seepage analysis are as follows:

- Starter dams are effective at drawing the phreatic surface down in the tailings and preventing a seepage face from developing on the embankment slope; provided the permeability of the dam fill is relatively high (5 x 10^{-5} m/s (16.4 x 10^{-5} ft/s) was used in analysis).
- At Section E, the starter dam must be augmented with a 20 m *(65.6 ft)* wide blanket drain to achieve acceptable drawdown of the phreatic surface.

An average seepage rate of 0.3 m^3/m/day *(3.2 ft^3/ft/day)* will be carried forward to design the seepage dams, size underdrains and input into the water balance. This rate is based on the seepage rate from the highest dam section, Section C, and assumes use of an underdrain system. This assessment represents a conservative estimate of seepage rate and is used for underdrain design.

Attachments:

Figures
Attachment I – Hydraulic Functions

FIGURES

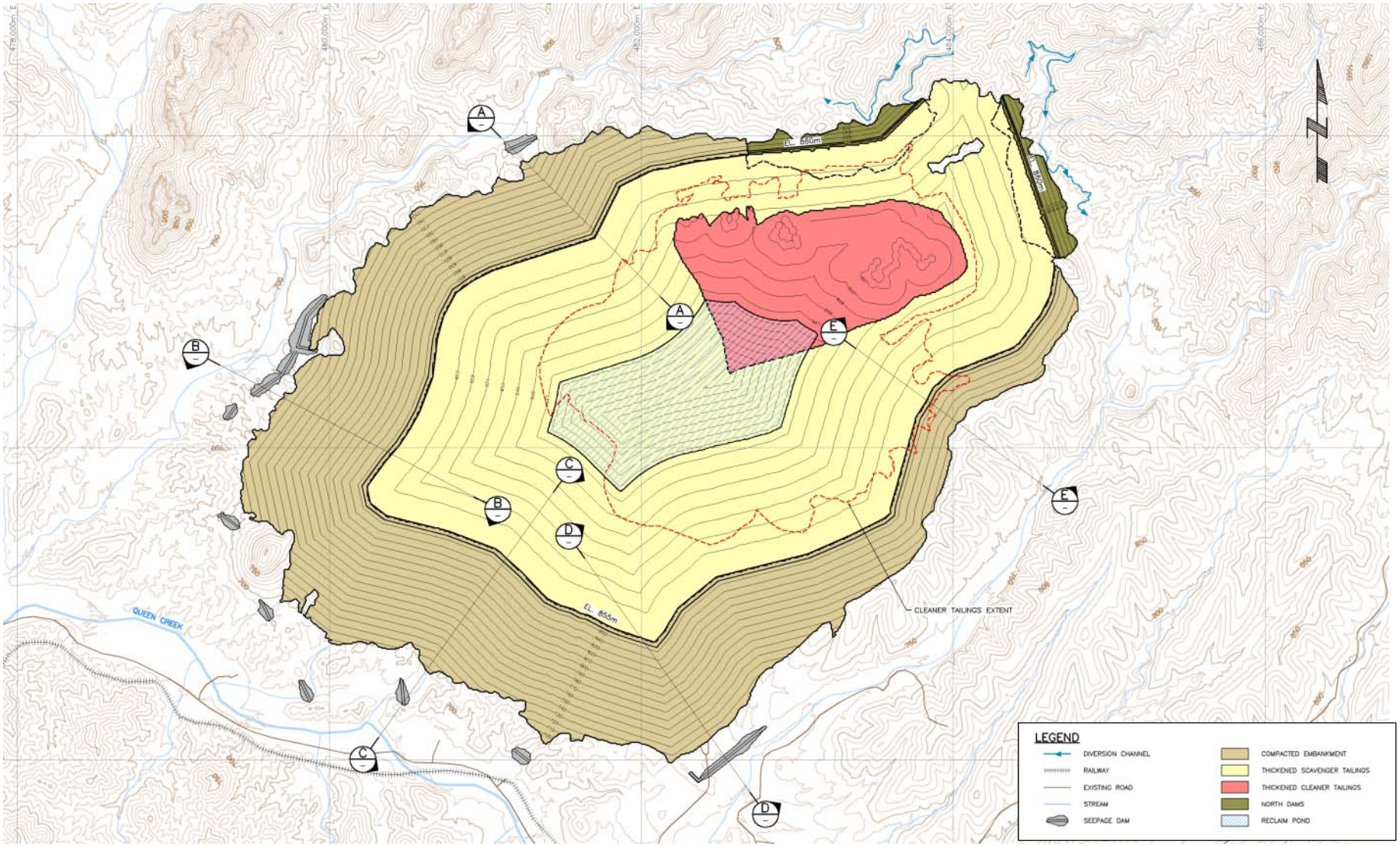


Figure 1 Location of Seepage Sections

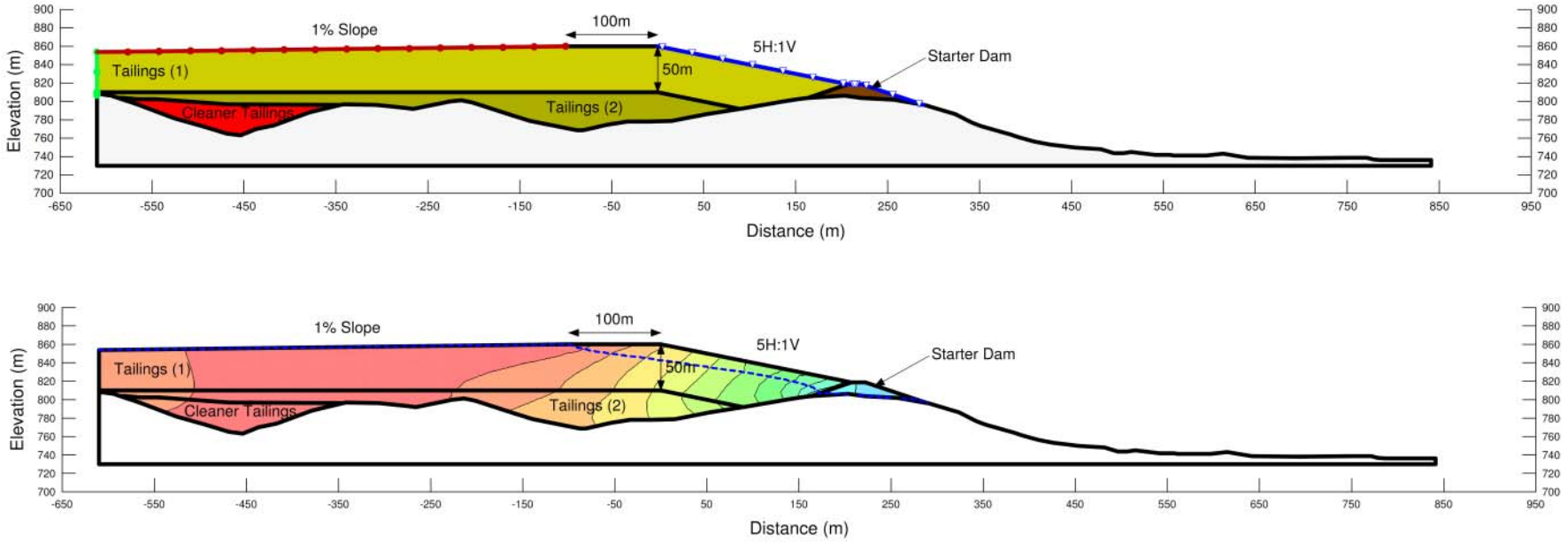


Figure 2 Section A – Model Set-Up (top) and Model Output with Total Head Contours (bottom)

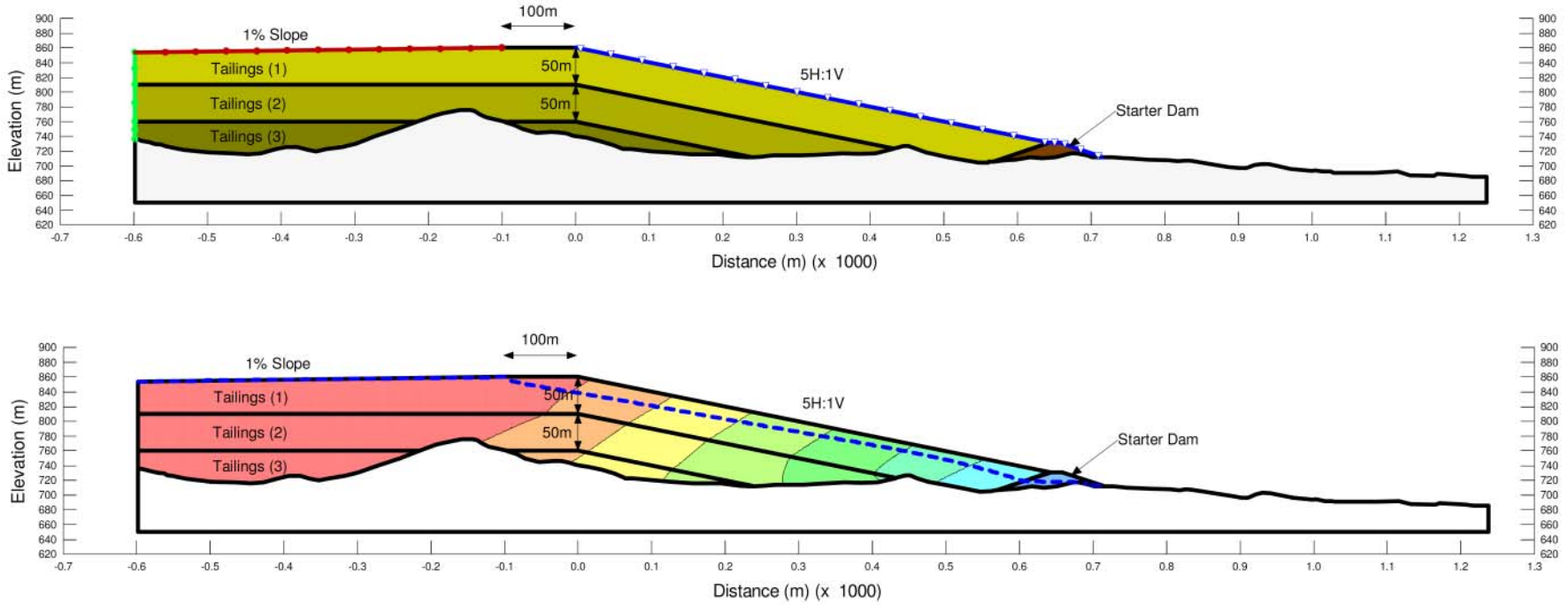


Figure 3 Section B – Model Set-Up (top) and Model Output with Total Head Contours (bottom)

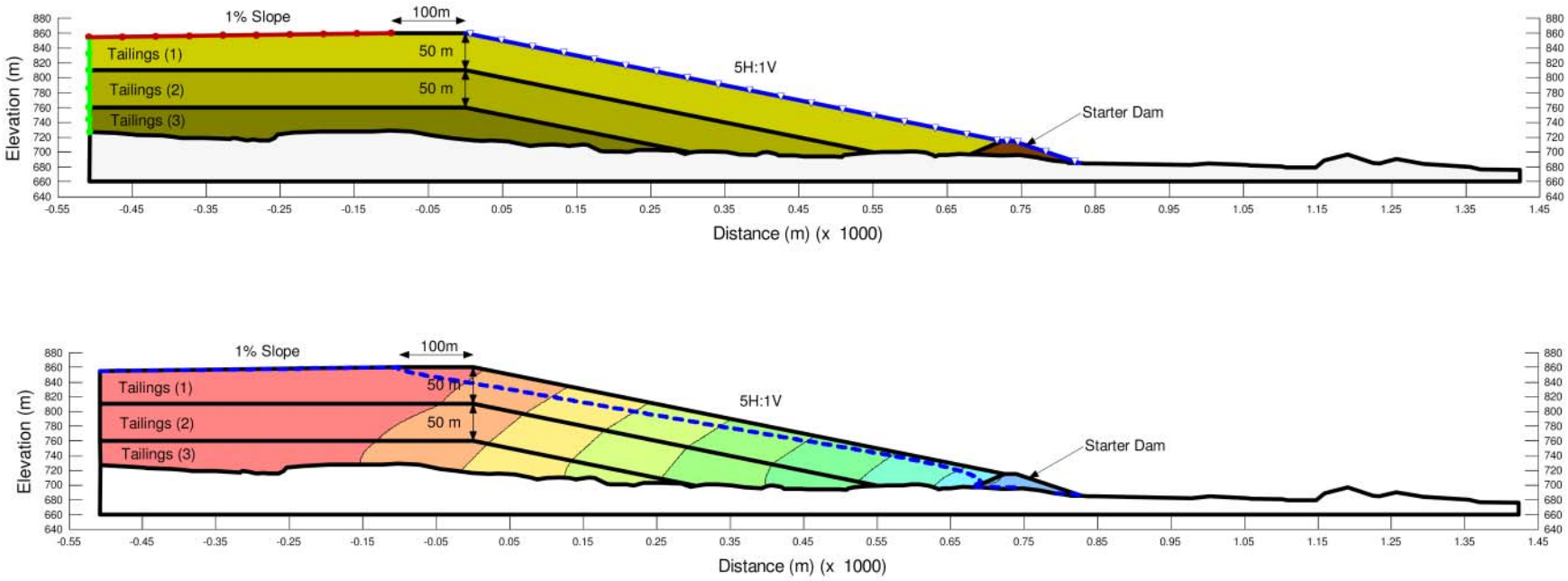


Figure 4 Section C (no underdrain) – Model Set-Up (top) and Model Output with Total Head Contours (bottom)

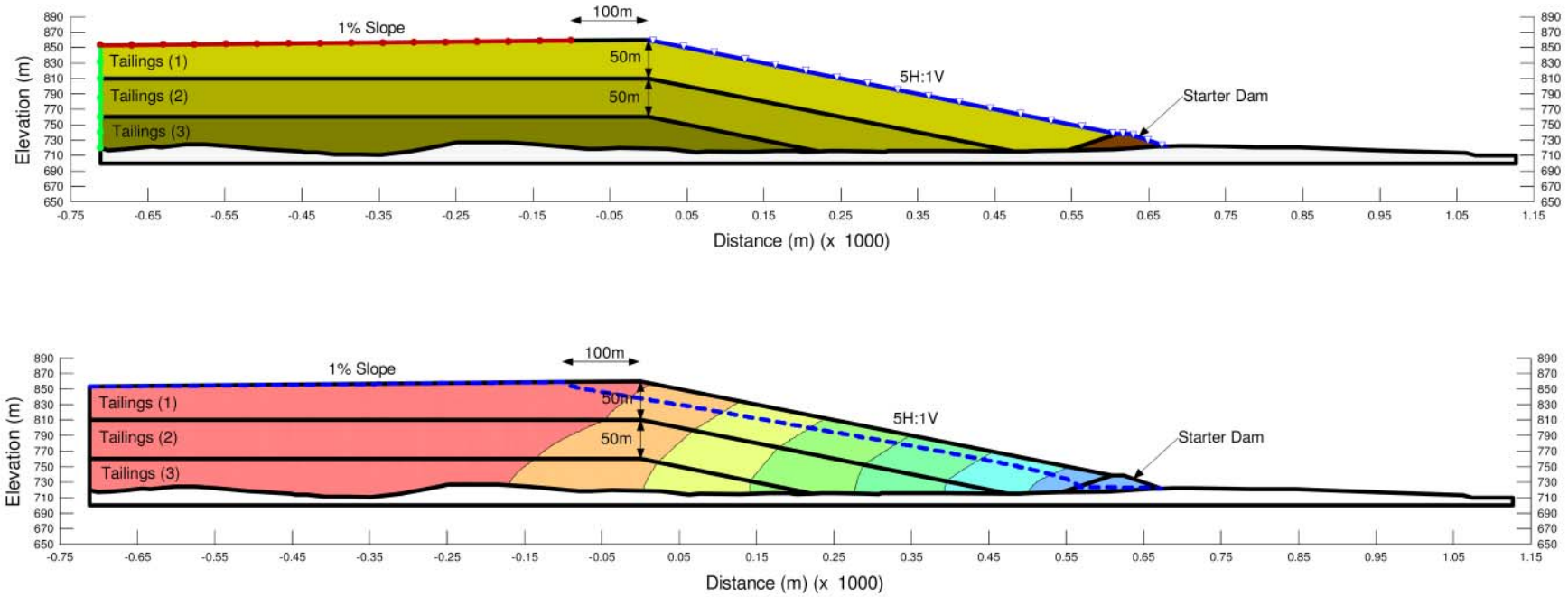


Figure 5 Section D – Model Set-Up (top) and Model Output with Total Head Contours (bottom)

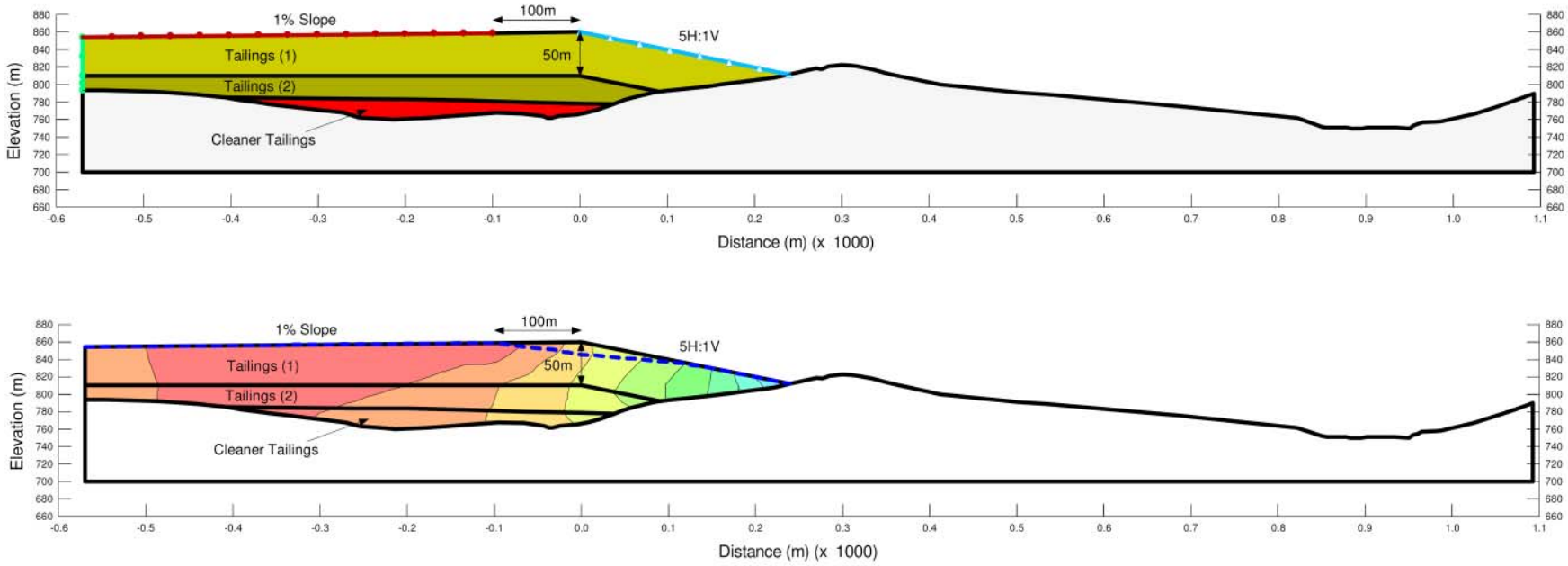


Figure 6 Section E – Model Set-Up (top) and Model Output with Total Head Contours (bottom)

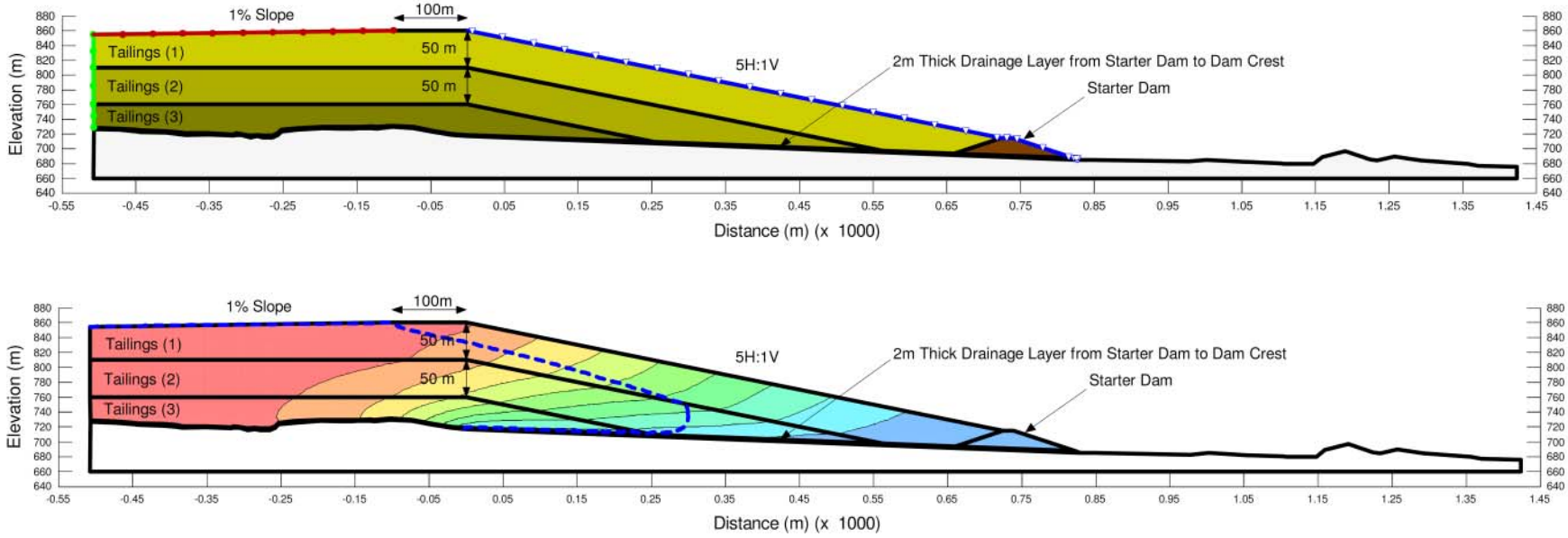


Figure 7 Section C (with underdrain) – Model Set-Up (top) and Model Output with Total Head Contours (bottom)

ATTACHMENT I

Hydraulic Functions

Attachment I
Hydraulic Functions

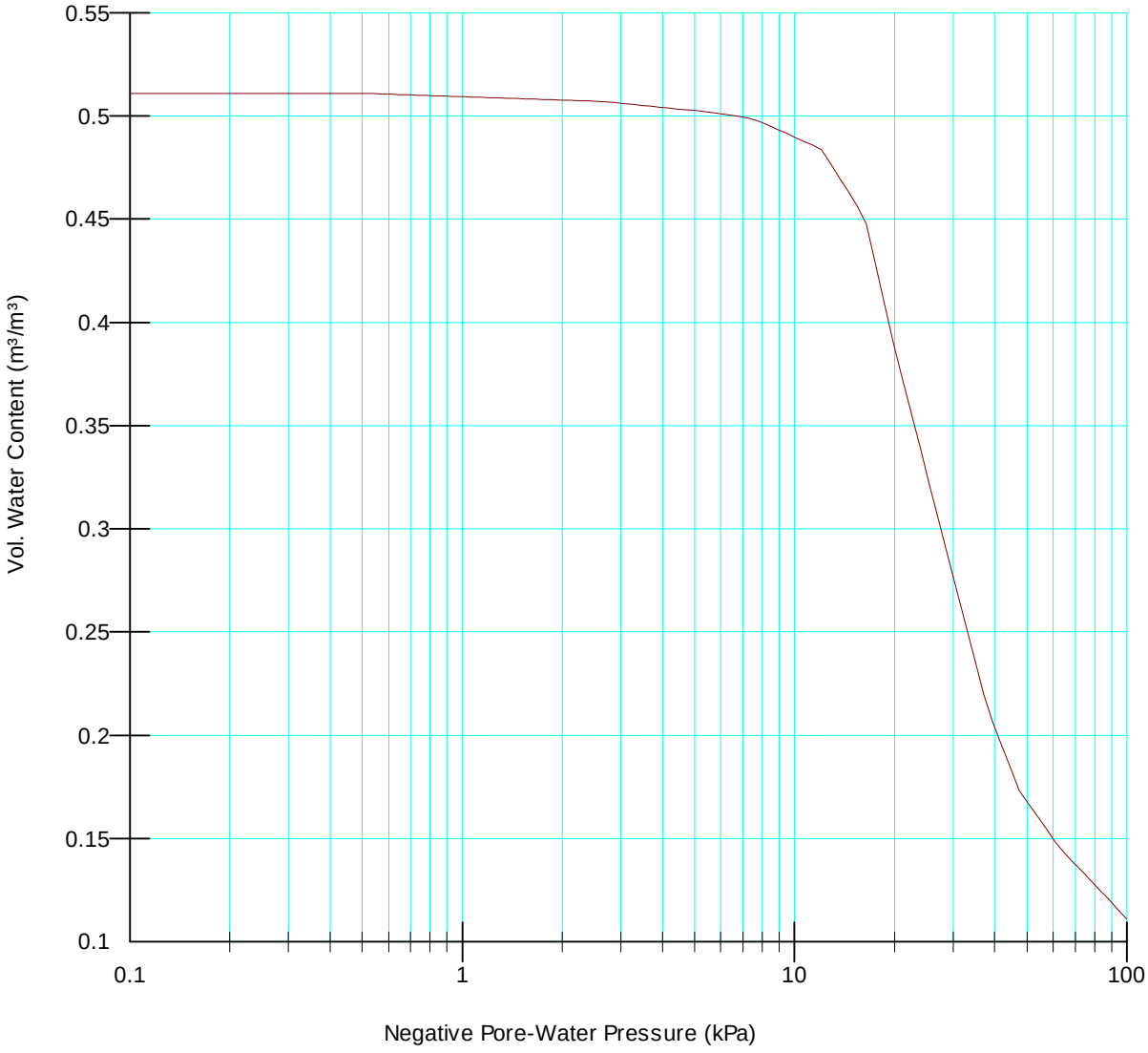


Figure 1 Scavenger Tailings (1) and Scavenger Tailings (2) Volumetric Water Content Function

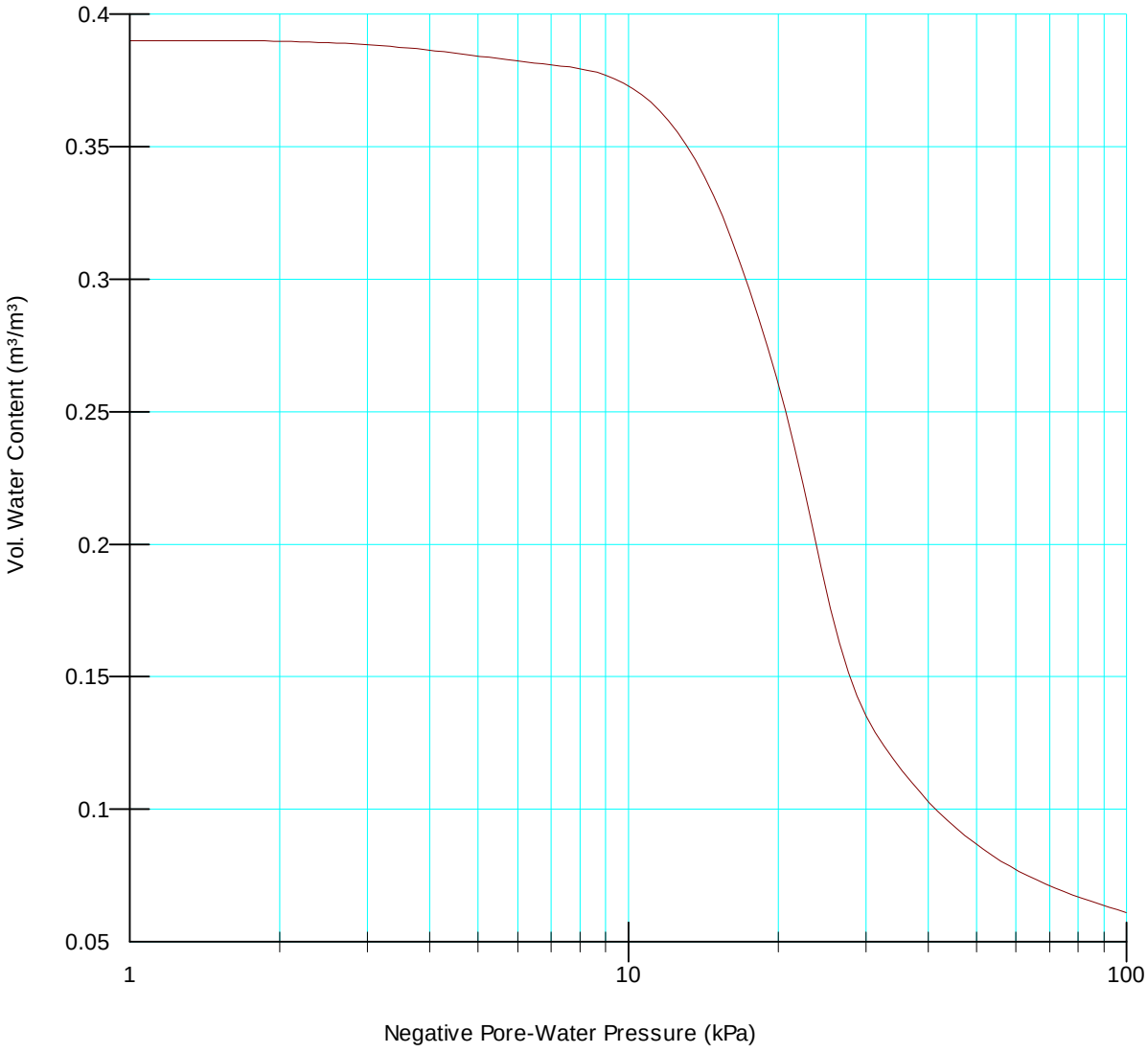


Figure 2 Scavenger Tailings (3) and Cleaner Tailings Volumetric Water Content Function

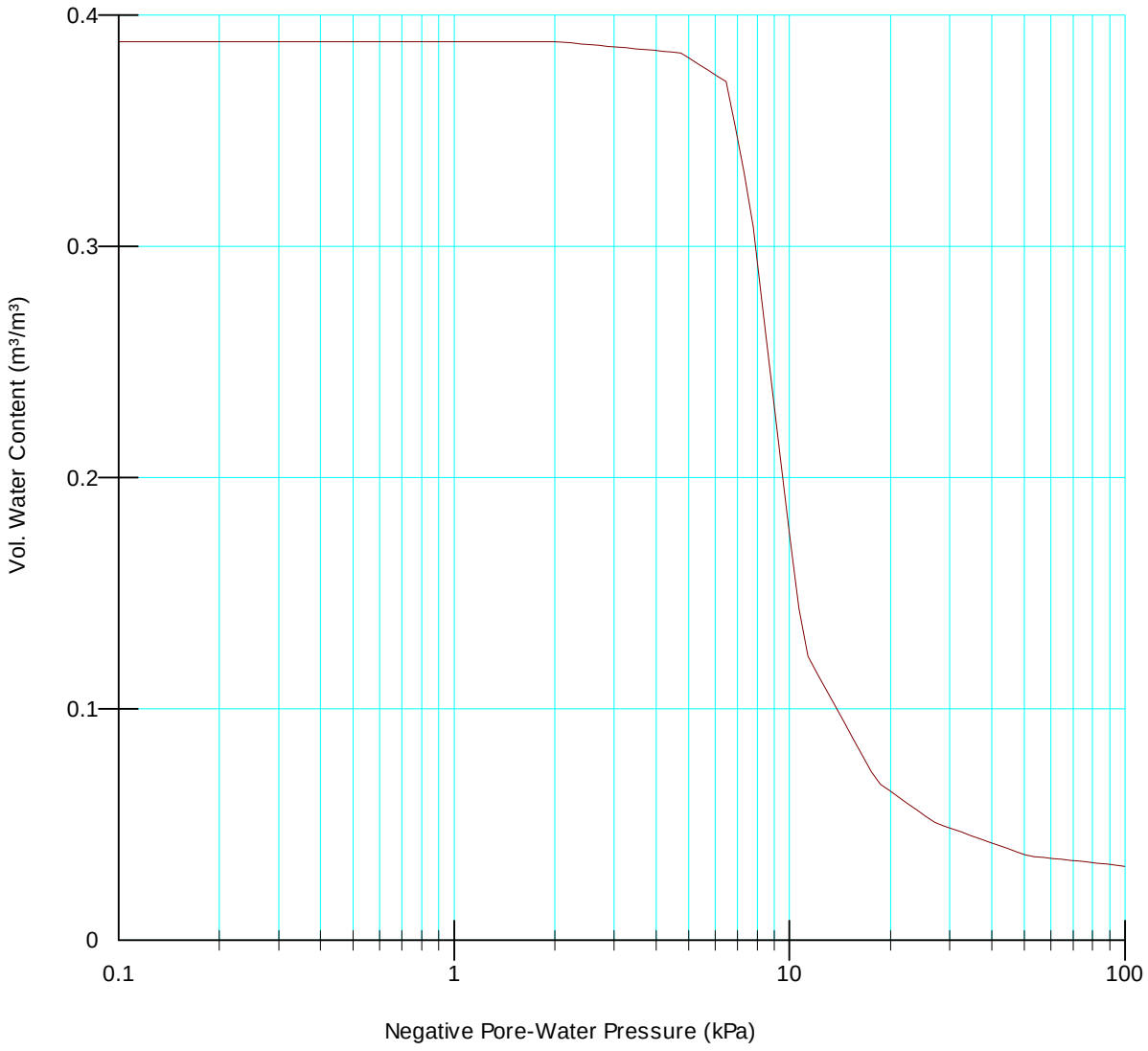


Figure 3 Starter Dam Fill Volumetric Water Content Function

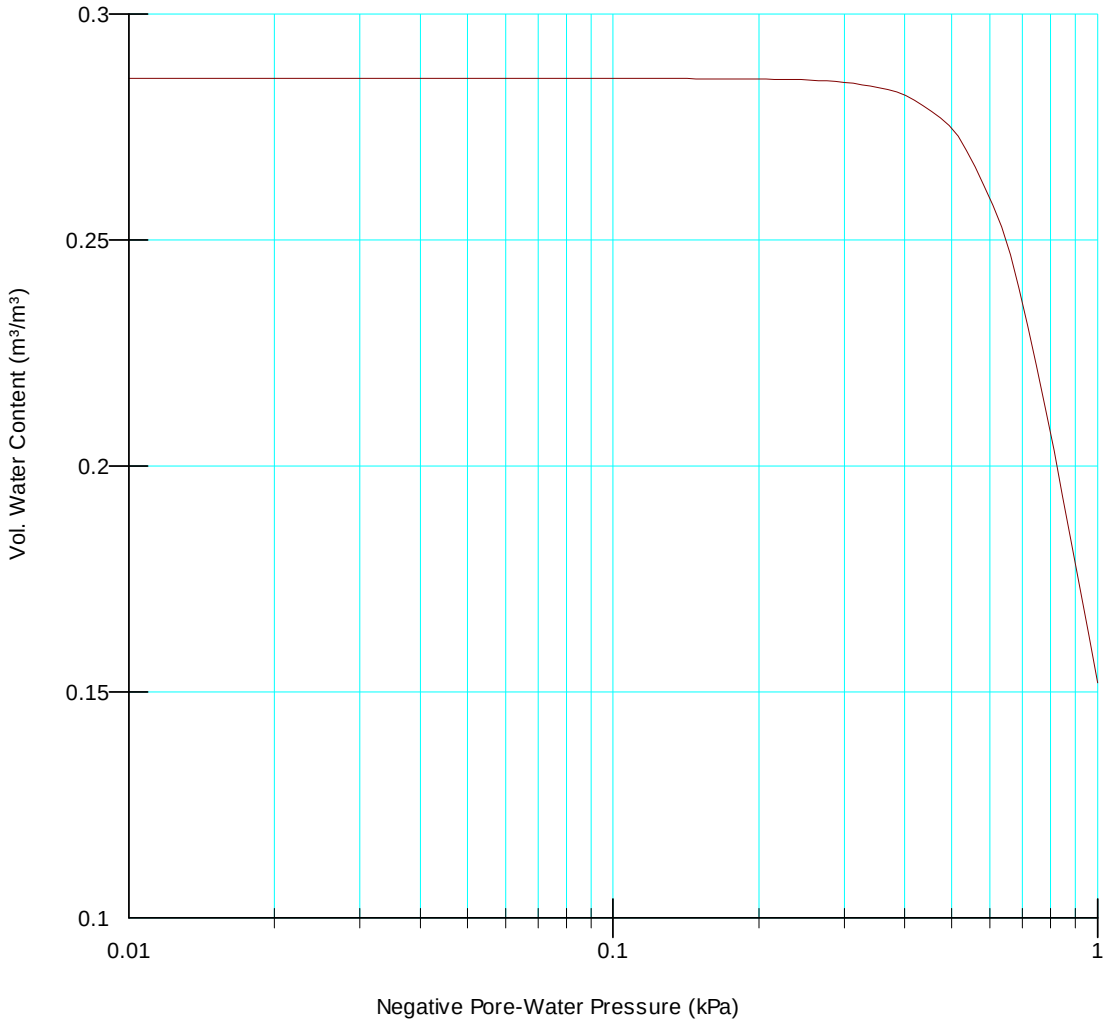


Figure 4 Drain Material Volumetric Water Content Function

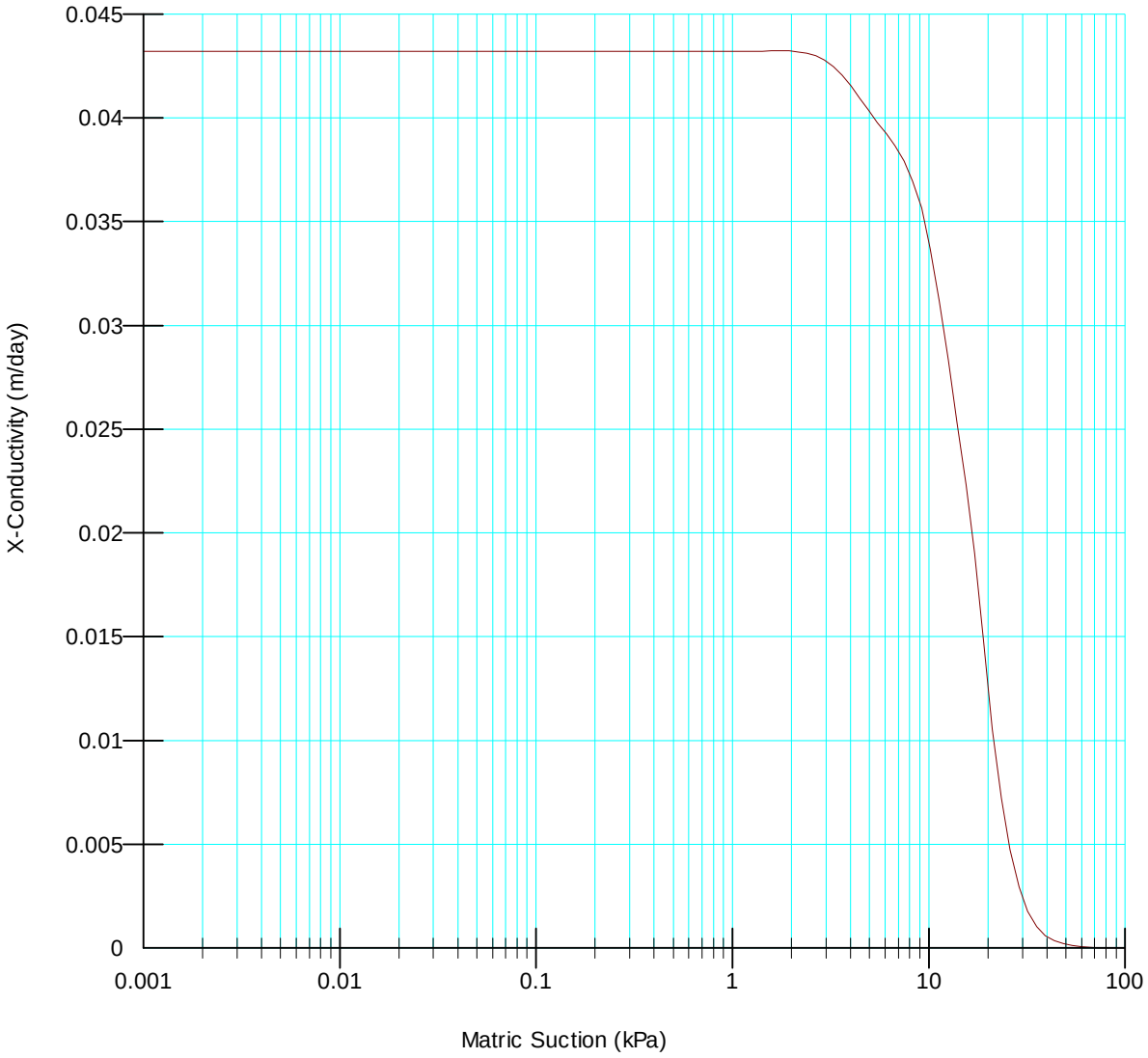


Figure 5 Scavenger Tailings (1) Hydraulic Conductivity Function

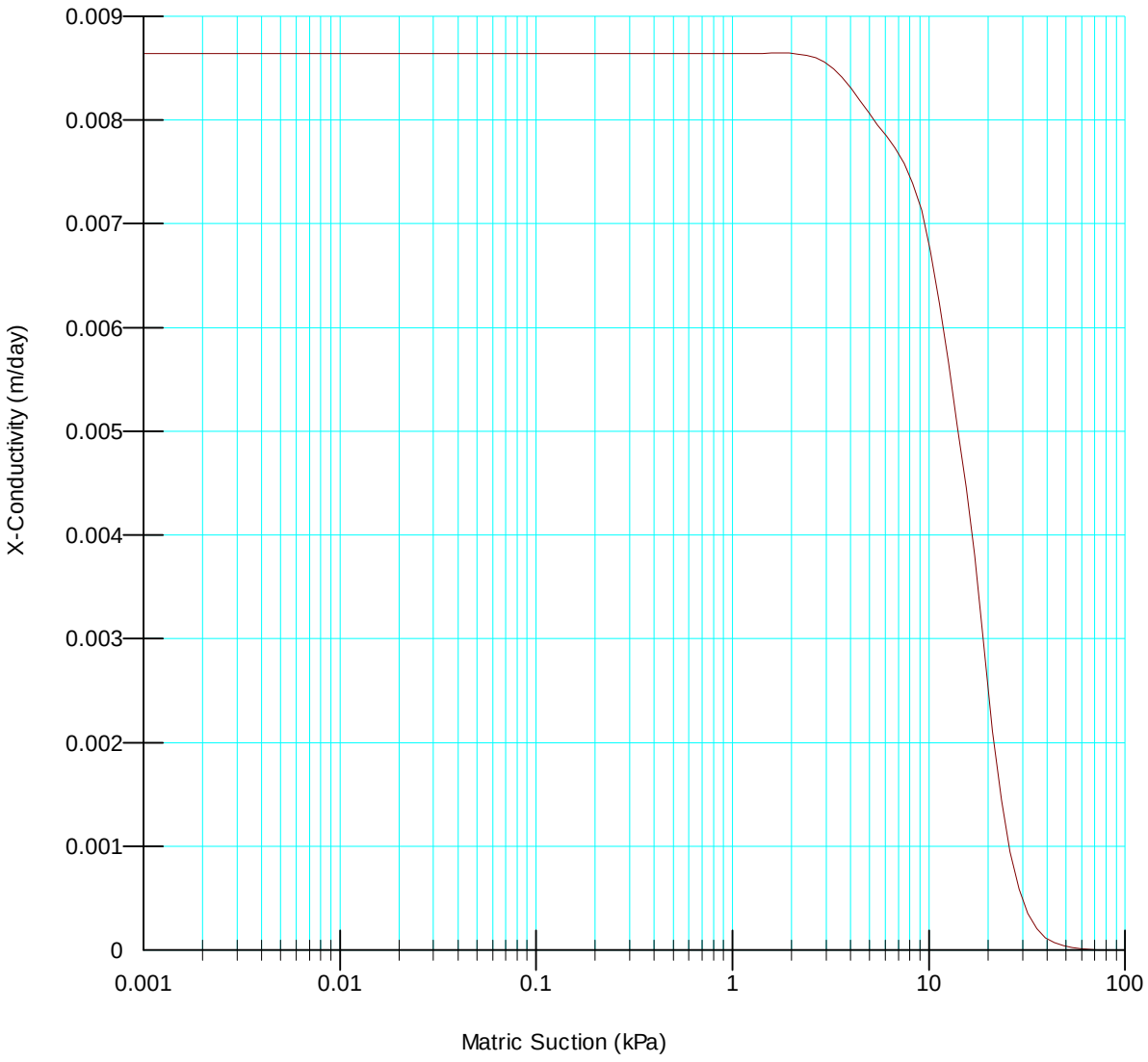


Figure 6 Scavenger Tailings (2) Hydraulic Conductivity Function

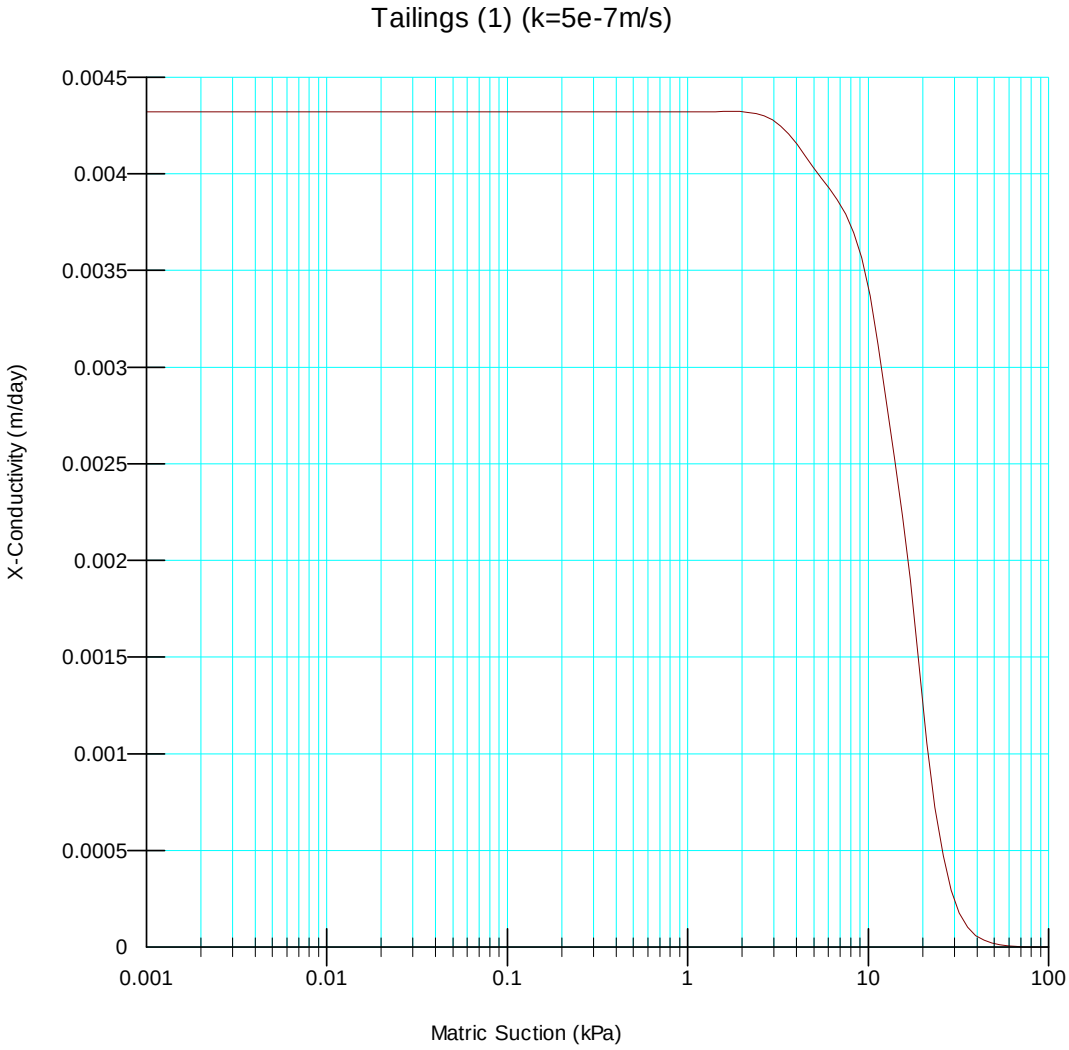


Figure 7 Scavenger Tailings (3) and Cleaner Tailings Hydraulic Conductivity Function

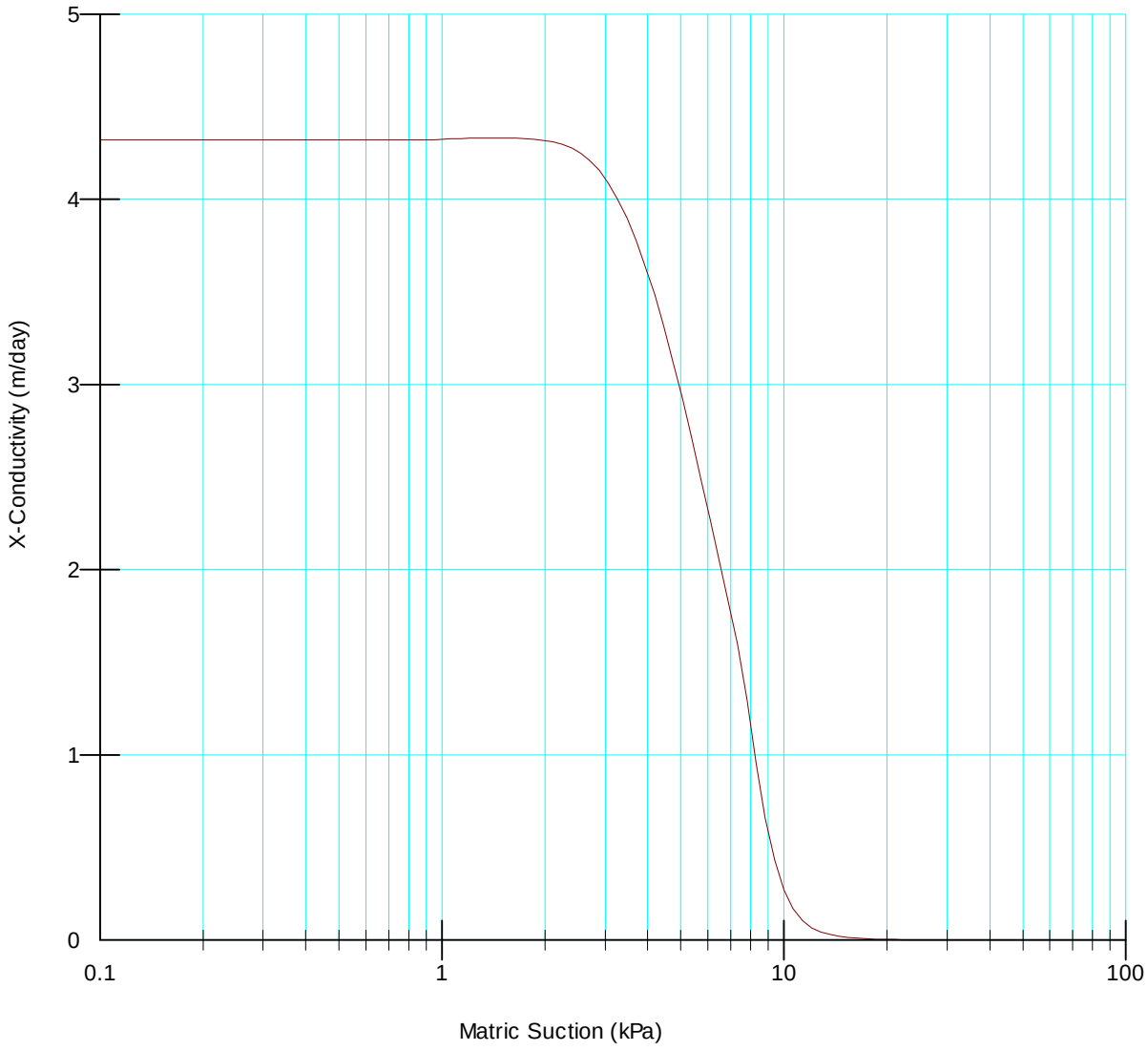


Figure 8 Starter Dam Fill Hydraulic Conductivity Function

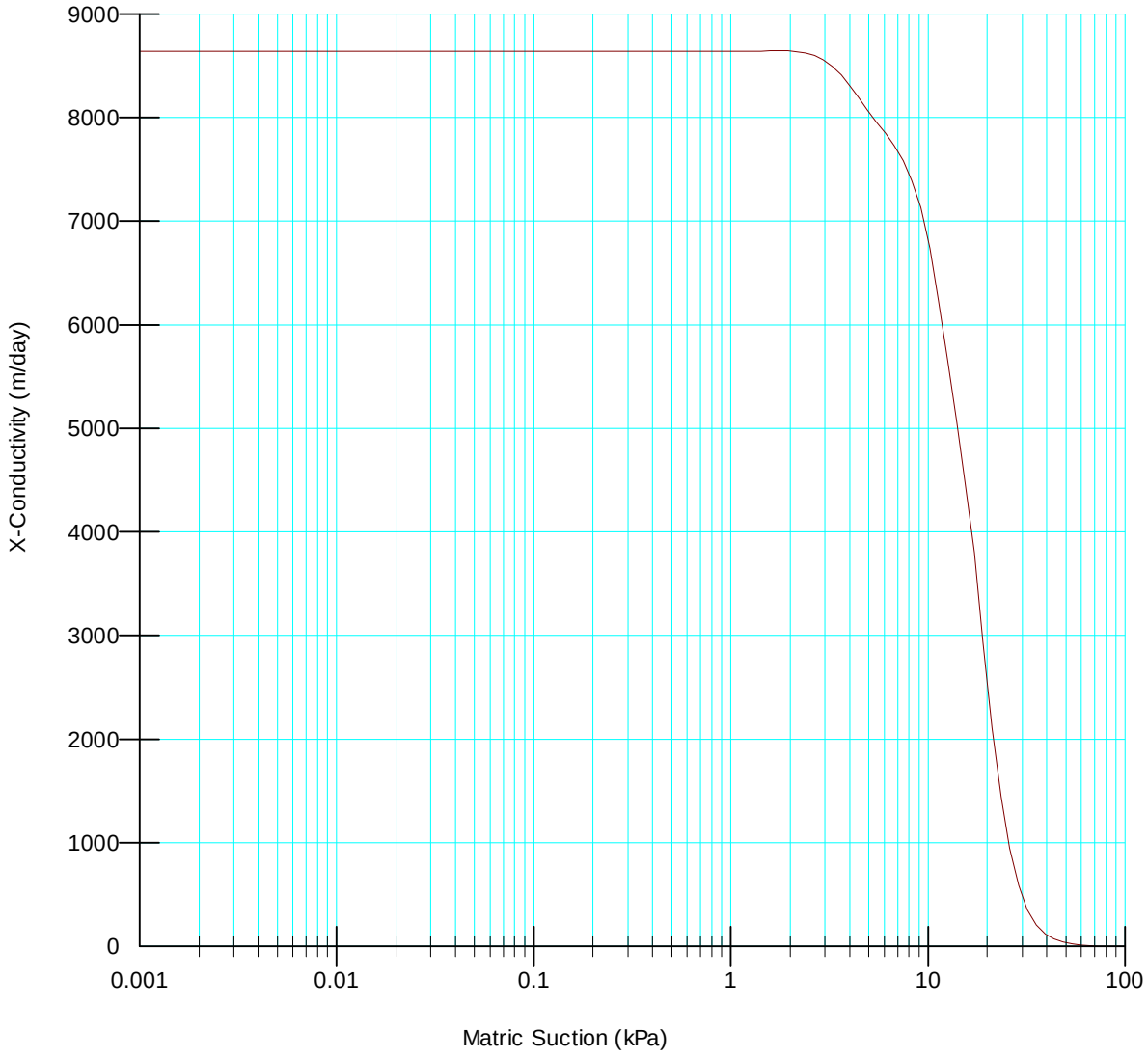


Figure 9 Drain Material Hydraulic Conductivity Function

APPENDIX VII

Static and Pseudo-Static Stability Analysis

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Jim Casey **FILE NO:** M09441A14.730

SUBJECT: Appendix VII - Static and Pseudo-Static Stability Analysis

1 INTRODUCTION

This memorandum presents the results from the static and pseudo-static stability analyses conducted to assess the stability of two representative sections of the Near West Tailings Storage Facility (TSF).

2 SLOPE STABILITY ANALSYSIS

2.1 Design Criteria

Two slope stability cases were considered:

- **Static (Case 1):** This case evaluates stability under static conditions. Pore pressures in the tailings, dam fill and drains are defined by the piezometric surface.
- **Pseudo-Static (Case 2):** The same as Case 1 but with an applied horizontal pseudo-static acceleration to represent seismic loading. The acceleration was taken as 0.07 g, which is 2/3 of the maximum design earthquake peak ground acceleration.

The Factors of Safety (FOS) specified for the two cases are summarized in Table 2.1.

Table 2.1 Design Factors of Safety

Case	Minimum Required FOS
Static	1.5
Pseudo-Static	1.1

Post-earthquake stability was also analyzed, and is presented separately in Appendix V.

2.2 Analysis

Two sections were chosen for stability analysis representing two “typical” configurations on site. Section C is located where the dam is the highest and the dam toe is not confined by topography. Section E is located where the toe is confined by a ridge, and crosses the cleaner tailings deposition area. The location of the section lines is shown on Figure 1.

2.3 Material Parameters

Assumed strengths and unit weights are listed in Table 2.2.

Table 2.2 Material Parameters

Material	Bulk Unit Weight (kN/m^3) *(pcf)*	Friction Angle (degrees)
Tailings (Above Water)	15 *(95.5)*	32°
Tailings (Below Water)	18 *(114.6)*	32°
Cleaner Tailings†	18 *(114.6)*	32°
Starter Dam Fill	19 *(120.9)*	36°
Drain*	22 *(140.0)*	35°

†Cleaner tailings only intersected along Section E
*Local blanket drain only included in Section E

2.4 Piezometric Conditions

The location of the piezometric surface was determined by seepage analysis, which is discussed in Appendix VI.

To be conservative, the piezometric surface from the seepage analysis of Section C without an underdrain was used for the stability analysis. Instead of allowing the water table to be completely drawn down by the starter dam at the dam toe, as it is in the seepage analysis, it was projected parallel to the dam slope, approximately 5 m *(16.4 ft)* below the slope surface.

For Section E, the piezometric surface was taken from the base case seepage analysis which includes a 20 m *(65.6 ft)* wide local blanket drain upstream of the starter dam.

3 RESULTS

The calculated FOS for the stability cases are summarized in Table 3.1. The model sections and analysis results are shown in Figures 2 and 3.

Table 3.1 Analysis Results

Stability Section	Case	Target FOS	Calculated FOS†
C	Static	1.5	1.8
	Pseudo-Static	1.1	1.3
E	Static	1.5	2.3
	Pseudo-Static	1.1	1.7

† The calculated FOS corresponds to the critical slip surface determined by Slope/W.

Both design sections are shown to satisfy the minimum FOS required for static and pseudo-static stability.

FIGURES

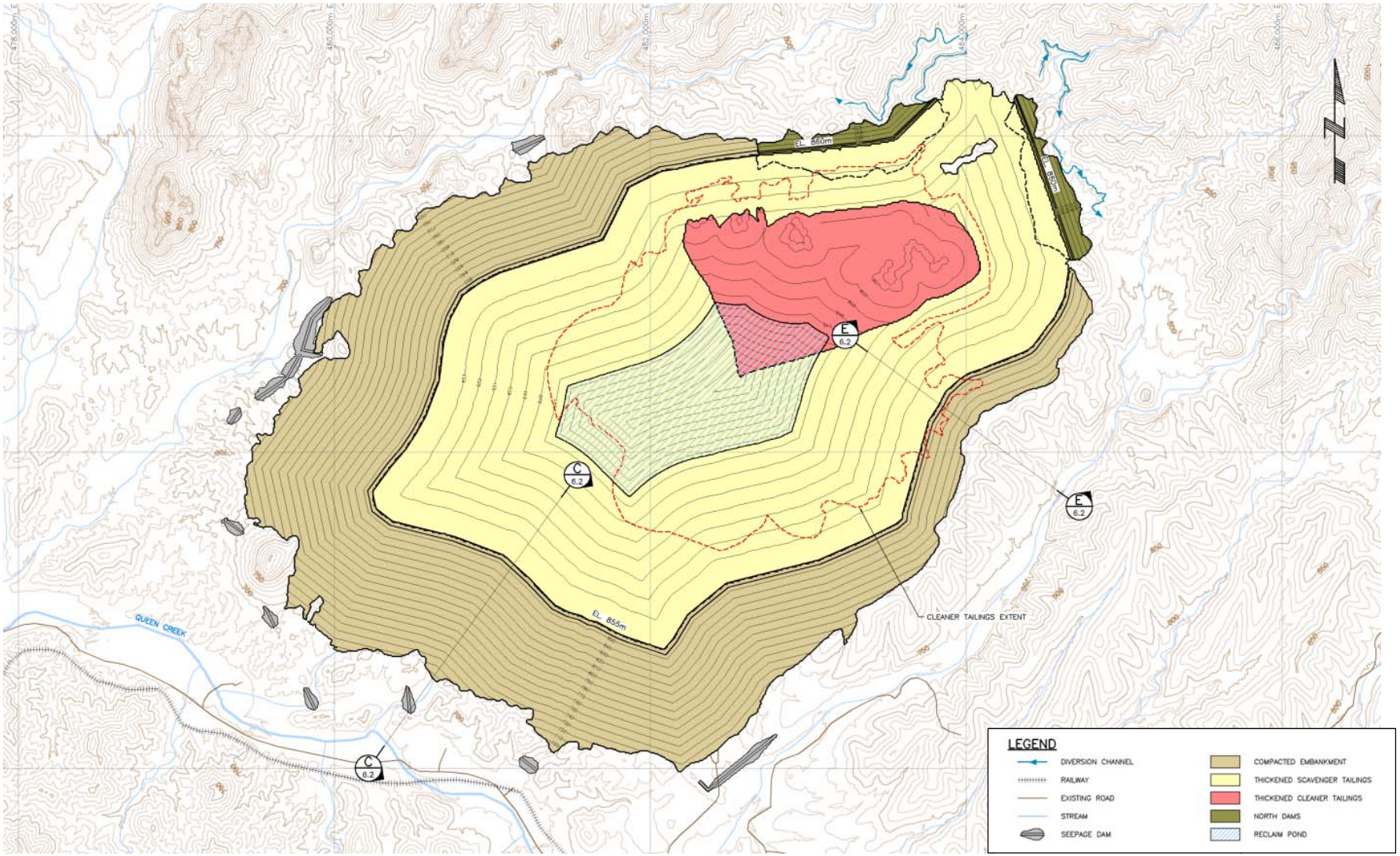


Figure 1 Stability Section Locations

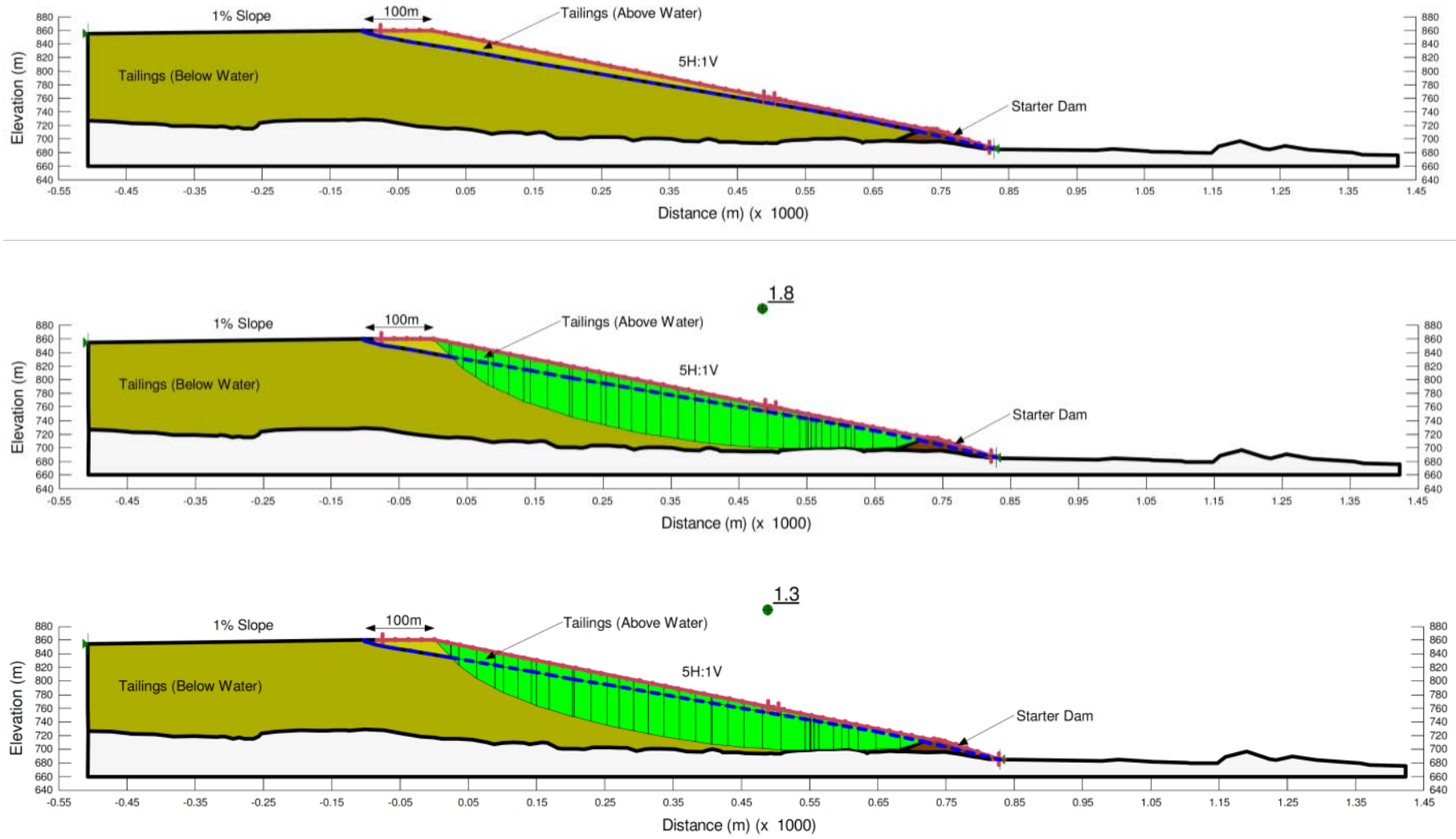


Figure 2 Section C – Model Set-Up (top), Static Analysis (middle) and Pseudo-Static Analysis (bottom)

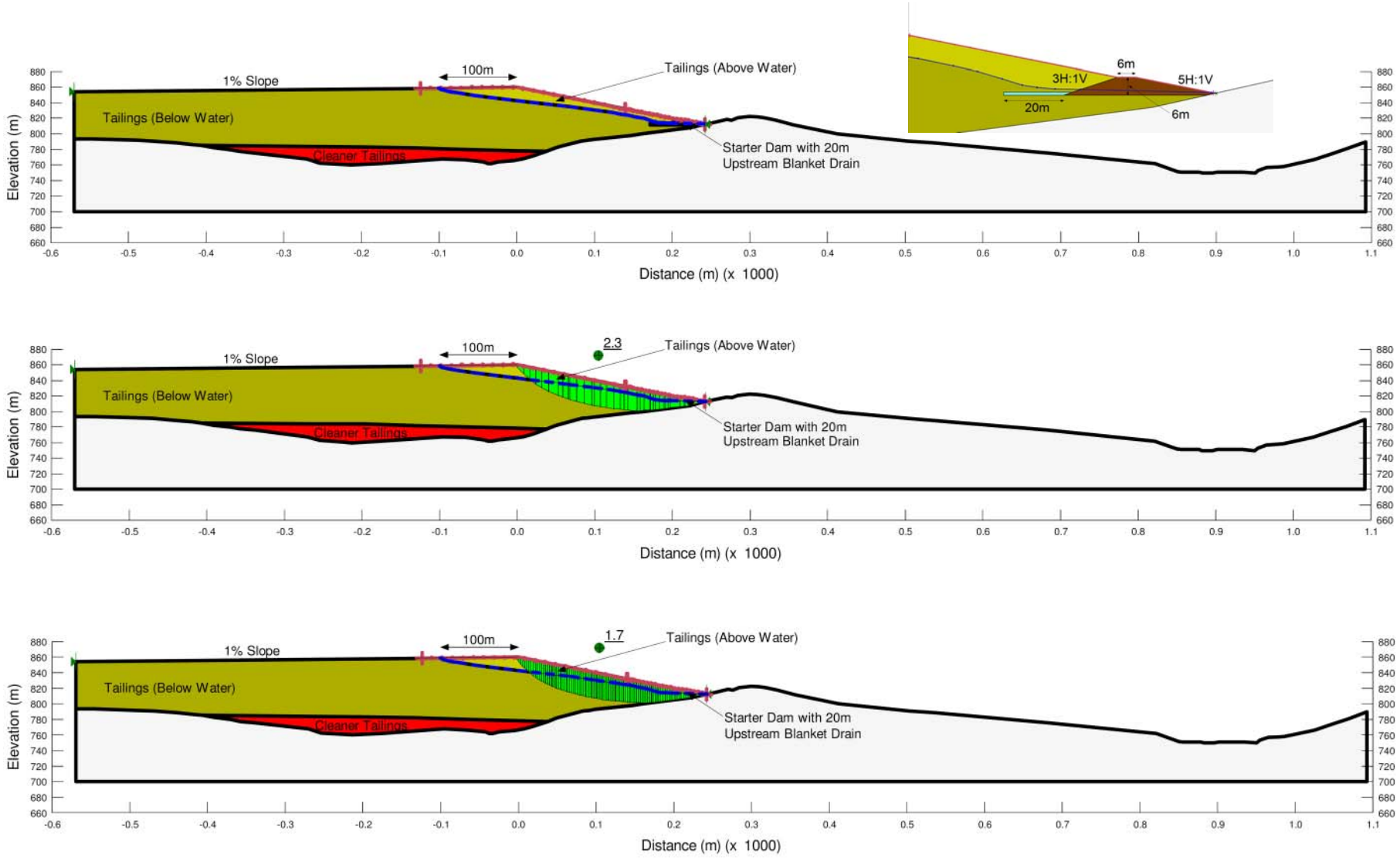


Figure 3 Section E – Model Set-Up (top), Static Analysis (middle) and Pseudo-Static Analysis (bottom)

APPENDIX VIII

Near West Upstream Water Management Diversions Options

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Florian Baltoi **FILE NO:** M09441A14.730

SUBJECT: Appendix VIII - Upstream Water Management Diversions Options

This memorandum presents three options for diversion of non-contact water upstream of the Tailings Storage Facility (TSF) at Resolution Near West site:

- Option 1- Diversion Channels;
- Option 2- Tunnels;
- Option 3- Reservoir Attenuation.

1 DESIGN CRITERIA

The design criteria for the upstream water management structures are presented in Table 1.1.

Table 1.1 Design Criteria

1.0	**Channels**	
1.1	Design event	Probable Maximum Flood (PMF)
1.2	Grade	Min. 1%
1.3	Side Slopes	0.5H:1V in bedrock
1.4	Maximum flow velocity	6 m/s *(19.7 ft/s)*
1.5	Minimum freeboard	1 m *(3.28 ft)*
2.0	**Tunnels**	
2.1	Design event	PMF
2.2	Grade	1.5%
2.3	Width	5 m *(16.4 ft)*
2.4	Height	6.5 m *(21.3 ft)*
2.5	Maximum flow velocity	5.5 m/s *(18.0 ft/s)*
2.6	Minimum freeboard	1 m *(3.28 ft)* at design flow
3.0	**Reservoirs (Spillway)**	
3.1	Design event	PMF
3.2	Minimum freeboard	1.5 m *(4.92 ft)* above peak flood level
4.0	**Dams**	
4.1	Embankment side slopes	3H:1V
4.2	Crest width	10 m *(32.8 ft)*

All structures are designed to route the probable maximum flood (PMF) which occurs from the probable maximum precipitation (PMP). The local storm (6-hr) and general storm (72-hr) PMP

distributed a variety of ways were used in routing calculations to determine the worst case scenario for design.

2 NEAR WEST CATCHMENT AND SUB-CATCHMENTS

The downstream boundary of the Near West Catchment was assumed to be the initial layout of the north dams (See Figure 1). The catchment, which has a total area of 5.2 km^2 *(2.0 sq mi)*, was divided in three sub-catchments as presented in Figure 1. The centroid of the catchment is located at Lat 33.3423^o, Long -111.1597^o and is situated at an elevation of 1020 m *(3,346.5 ft)*.

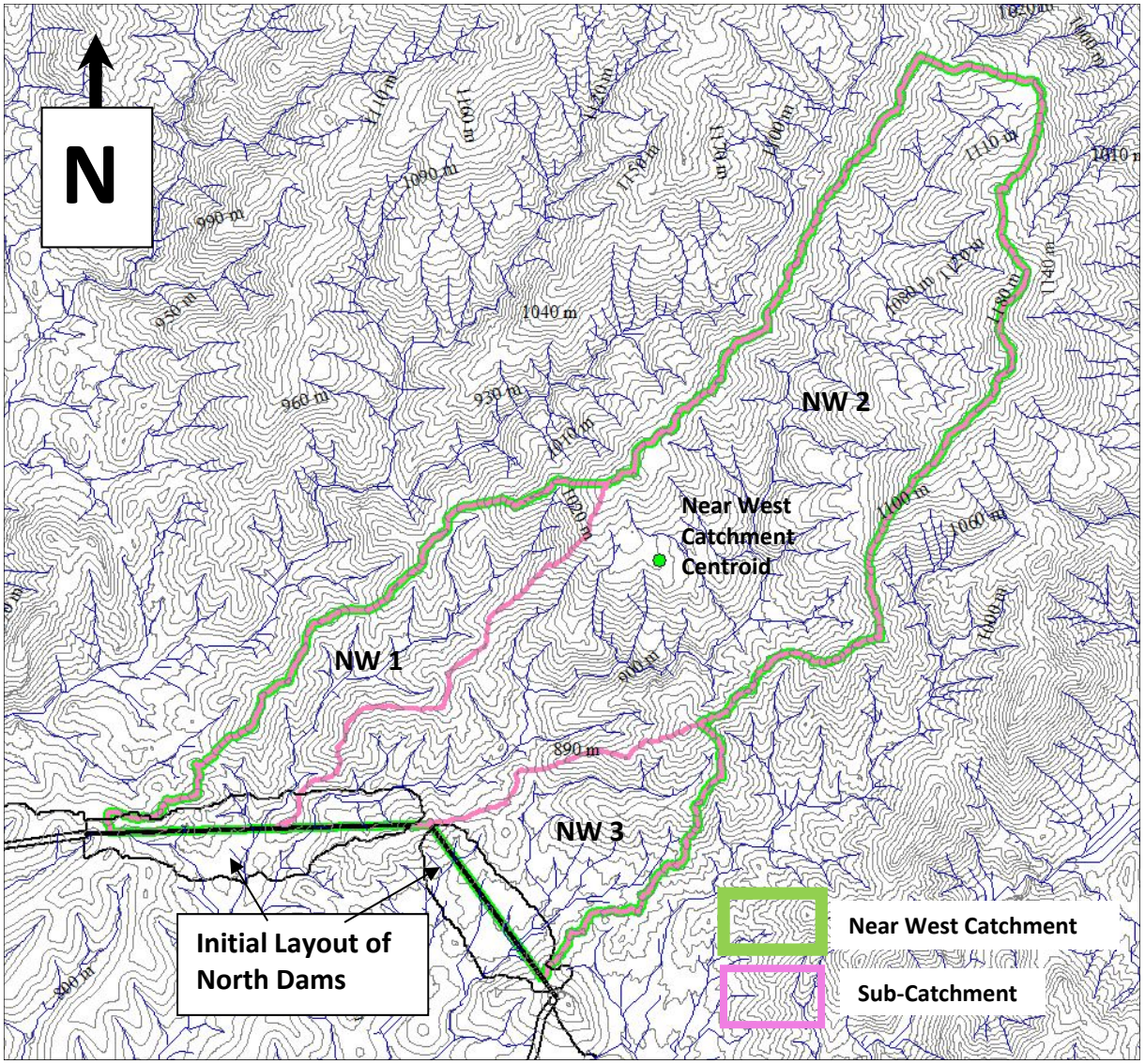


Figure 1 Near West Catchment and Sub-Catchments

For this phase of assessment, the catchment boundaries were not modified for any of the three options to reflect changes due to the layout of proposed structures such as channel, tunnels or dams. However, once an option is selected, the sub-catchment boundaries should be adjusted as necessary for that particular case as designs become refined through NEPA.

3 PROBABLE MAXIMUM PRECIPITATION (PMP)

The PMP values are presented in Table 3.1 and

Table 3.2 and discussed in Appendix III.

Table 3.1 General Storm PMP Estimates

Duration	Precipitation Depth (mm) *(inches)*
6 hr	267 *(10.5)*
12 hr	366 *(14.4)*
18 hr	432 *(17.0)*
24 hr	480 *(18.9)*
48 hr	599 *(23.6)*
72 hr	653 *(25.7)*
30 day	1,575 *(62.0)*

Table 3.2 Local Storm PMP Estimates

Duration	Precipitation Depth (mm) *(inches)*
15 min	132 *(5.2)*
30 min	170 *(6.7)*
45 min	191 *(7.5)*
1 hr	206 *(8.1)*
2 hr	244 *(9.6)*
3 hr	262 *(10.3)*
4 hr	277 *(10.9)*
5 hr	287 *(11.3)*
6 hr	295 *(11.6)*

Storm distributions for the 6-hour period are presented in Table 3.3 based on two recommendations presented in the HMR 49: one from the U. S. Weather Bureau (HMR No. 5), and one from the U. S. Army Corps of Engineers (EM1110-2-1411).

Table 3.3 Local Storm PMP Average Values – Hourly Distribution for 6-hour Storm

Duration	Precipitation Depth (mm) *(inches)*	
	HMR No. 5 Distribution	EM1110-2-1411 Distribution
1 hr	10 *(0.4)*	8 *(0.3)*
2 hr	28 *(1.1)*	23 *(0.9)*
3 hr	234 *(9.2)*	61 *(2.4)*
4 hr	272 *(10.7)*	267 *(10.5)*
5 hr	287 *(11.3)*	285 *(11.2)*
6 hr	295 *(11.6)*	295 *(11.6)*

For the Local Storm PMP, the precipitation distribution for intervals less than 15 minutes was estimated based on the average 15-min storm distribution of NOAA precipitation estimates for return period events up to and including the 1000-year event. This assumption was considered for both, the HMR No. 5 Distribution and the EM1110-2-1411 Distribution.

For the 72-hr General Storm PMP, the precipitation distribution for intervals less than 6 hours was estimated for three cases:

1. Assuming the Local Storm PMP, HMR No. 5 Distribution;
2. Assuming the Local Storm PMP, EM1110-1411 Distribution;
3. Assuming the average 6-hour storm distribution of NOAA precipitation estimates for return period events up to and including the 1000-yr event.

The NOAA precipitation frequency estimates for the watershed centroid are given in Table 3.4.

Table 3.4 Precipitation Depth (in mm) - Duration-Frequency Estimates for the Near West Catchment

Average Recurrence Interval (years)	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr	2-day	3-day	4-day	7-day	10-day	20-day	30-day	45-day	60-day
1	7	10	12	17	21	24	25	31	38	46	54	58	62	71	78	98	118	141	164
2	9	13	16	22	27	31	32	39	47	58	68	73	78	89	99	125	150	179	207
5	11	17	21	29	36	41	42	49	59	73	86	93	101	116	127	160	192	228	262
10	14	21	26	35	43	48	49	57	68	86	101	110	120	138	150	189	226	267	305
25	16	25	31	42	52	58	60	68	81	103	121	134	147	170	184	228	272	318	361
50	19	28	35	47	58	66	68	76	90	116	138	153	168	198	212	259	310	358	401
100	21	32	39	53	66	73	76	85	100	130	155	173	192	227	242	292	348	401	445
200	23	35	43	58	72	81	85	94	110	145	173	195	217	259	274	325	386	442	488
500	26	39	49	66	82	91	97	106	123	165	198	225	252	305	320	371	442	500	546
1000	28	43	53	71	88	99	107	116	133	181	218	250	282	345	358	409	485	544	589

Table 3.5 Precipitation Depth (in inches) - Duration-Frequency Estimates for the Near West Catchment

Average Recurrence Interval (years)	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr	2-day	3-day	4-day	7-day	10-day	20-day	30-day	45-day	60-day
1	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.2	1.5	1.8	2.1	2.3	2.4	2.8	3.1	3.9	4.6	5.6	6.5
2	0.4	0.5	0.6	0.9	1.1	1.2	1.3	1.5	1.9	2.3	2.7	2.9	3.1	3.5	3.9	4.9	5.9	7.0	8.1
5	0.4	0.7	0.8	1.1	1.4	1.6	1.7	1.9	2.3	2.9	3.4	3.7	4.0	4.6	5.0	6.3	7.6	9.0	10.3
10	0.6	0.8	1.0	1.4	1.7	1.9	1.9	2.2	2.7	3.4	4.0	4.3	4.7	5.4	5.9	7.4	8.9	10.5	12.0
25	0.6	1.0	1.2	1.7	2.0	2.3	2.4	2.7	3.2	4.1	4.8	5.3	5.8	6.7	7.2	9.0	10.7	12.5	14.2
50	0.7	1.1	1.4	1.9	2.3	2.6	2.7	3.0	3.5	4.6	5.4	6.0	6.6	7.8	8.3	10.2	12.2	14.1	15.8
100	0.8	1.3	1.5	2.1	2.6	2.9	3.0	3.3	3.9	5.1	6.1	6.8	7.6	8.9	9.5	11.5	13.7	15.8	17.5
200	0.9	1.4	1.7	2.3	2.8	3.2	3.3	3.7	4.3	5.7	6.8	7.7	8.5	10.2	10.8	12.8	15.2	17.4	19.2
500	1.0	1.5	1.9	2.6	3.2	3.6	3.8	4.2	4.8	6.5	7.8	8.9	9.9	12.0	12.6	14.6	17.4	19.7	21.5
1000	1.1	1.7	2.1	2.8	3.5	3.9	4.2	4.6	5.2	7.1	8.6	9.8	11.1	13.6	14.1	16.1	19.1	21.4	23.2

4 HYDROLOGIC MODELING

The hydrologic modeling was conducted using the program HEC-HMS, SCS Curve Number Method. The sub-catchment characteristics assumed in the model are presented in Table 4.1.

Table 4.1 Sub-Catchment Characteristics

Sub-Catchment	Area (km^2) *(sq mi)*	Average Slope (%)	Curve Number[1]	Lag Time[2] (min)
NW1	0.9 *(0.35)*	35	93	10
NW2	3.6 *(1.39)*	35	93	20
NW3	0.7 *(0.27)*	26	93	9
Total	5.2 *(2.00)*			

[1]The Curve Number value was selected assuming that there would be considerable rainfall prior to the PMP event.
[2] The Lag Time was estimated based on a Soil Conservation Service equation.

5 UPSTREAM WATER MANAGEMENT PLAN

The upstream water management plan consists of three diversion channels designed to divert the PMF upstream of the TSF (See Figure 2). The runoff from the NW1 Sub-Catchment would be diverted westerly through the West NW1 Channel. The flow from the NW2 Sub-Catchment would be diverted southeasterly into a natural drainage in the NW3 Catchment, and then discharge into the NW3 Channel. The NW3 Channel would also collect runoff from the NW3 Sub-Catchment and divert it southeasterly.

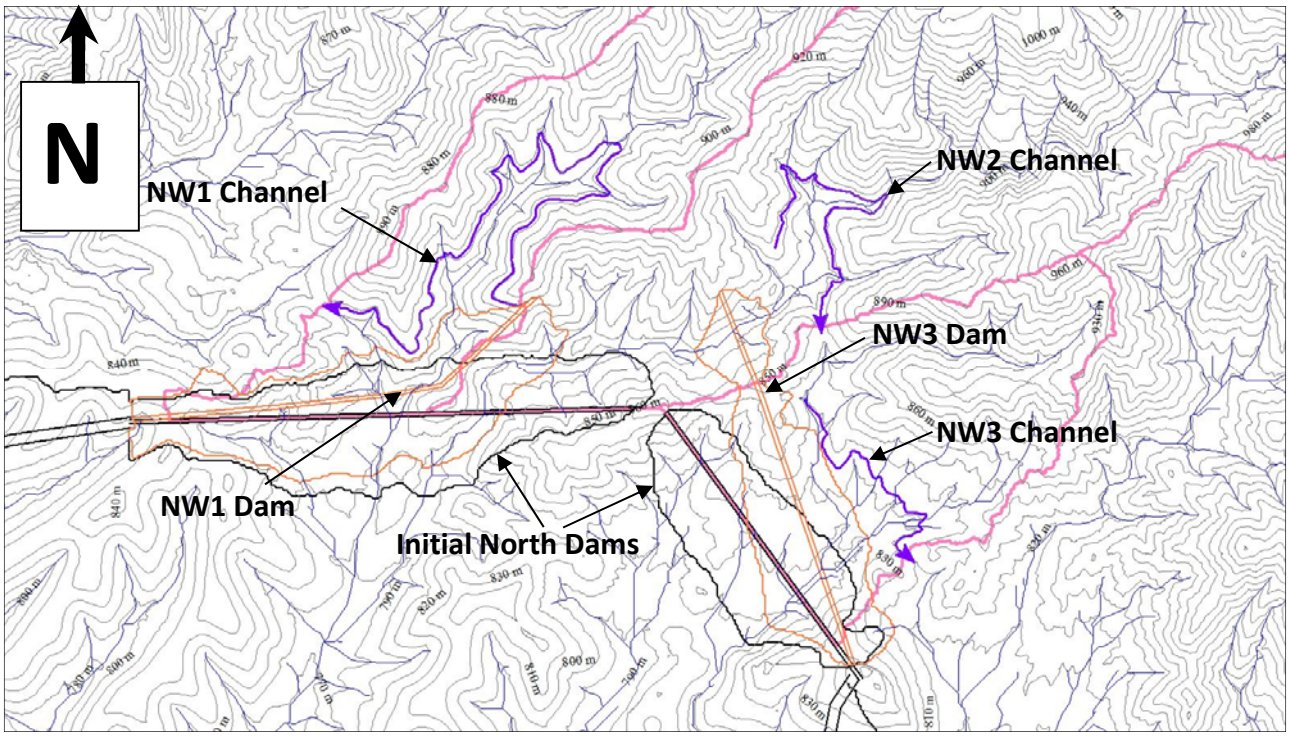


Figure 2 Option 1-Diversion Channels

The proposed design characteristics for the channels and the dams are shown in Table 5.1 and Table 5.2, respectively.

Table 5.1 Channel Characteristics

ID	Length	Slope	Base Width	Side Slopes	Total Depth	Volume of Cut	Design Flow	Flow Velocity
	(m) *(ft)*	(%)	(m)	(xH:1V)	(m)	(m^3) *(acre-ft)*	(m^3/s) *(ft^3/s)*	(m/s) *(ft/s)*
NW1 Channel	2,360 *(7,743)*	1	5 *(16.4)*	0.5	4.5 *(14.8)*	95,000 *(77.0)*	100 *(3,532)*	4.3 *(14.1)*
NW2 Channel	1,225 *(4,019)*	1	15 *(49.2)*	0.5	4.3 *(14.1)*	133,000 *(107.8)*	286 *(10,100)*	5.3 *(17.4)*
NW3 Channel	830 *(2,723)*	1	15 *(49.2)*	0.5	4.7 *(15.4)*	84,000 *(68.1)*	338 *(11,936)*	5.5 *(18.0)*

Table 5.2 Dam Characteristics

ID	Crest Elevation	Embankment Slope	Crest Width	Maximum Dam Height at Centreline	Volume of Fill
	(m) *(ft)*	(xH:1V)	(m) *(ft)*	(m) *(ft)*	(m^3) *(yd^3)*
NW1 Dam	860 *(2,822)*	3	10 *(32.8)*	64 *(210.0)*	7,153,000 *(9,355,770)*
NW3 Dam	860 *(2,822)*	3	10 *(32.8)*	46 *(150.9)*	4,046,000 *(5,291,968)*

REFERENCES

Haan, C. T., et al. 1994. "Design Hydrology and Sedimentology for Small Catchments."

Ponce, V. M. 1989. "Engineering Hydrology. Principles and Practices."

United States Department of Agriculture. Natural Resources Conservation Service. Conservation Engineering Division. 1986. "Urban Hydrology and Sedimentology for Small Watersheds. TR-55."

United States Department of the Interior. Bureau of Reclamation. 1987. "Design of Small Dams."

U.S. Army Corps of Engineers. Institute for Water resources. Hydrologic Engineering Center. 2010. Hydrologic Modeling System (HEC-HMS). Version 3.5.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. U. S. Department of the Army, Corps of Engineers. Reprinted 1984. "Hydrometeorological Report No. 49. Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages."

APPENDIX IX

Seepage Collection Dam Design

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Meredith Kealty **FILE NO:** M09441A14.730

SUBJECT: Appendix IX - Seepage Collection Dam Design

1 INTRODUCTION

This memorandum presents design of the downstream seepage collection dams for the Near West tailings storage facility (TSF).

The design includes dam sizing and dam staging.

2 DESIGN BASIS

Design criteria for the seepage collection dams is as follows:

- maintain a minimum 3 m *(9.8 ft)* deep operating pond for reclaim during operation;
- store the 200-year 24-hr flood; and
- freeboard of 2.0 m *(6.6 ft)* above design storm.

Storm depths were estimated using the Point Precipitation Frequency Estimates from NOAA Atlas 14 (NOAA, 2012). The 200-year 24-hr storm depth is 132 mm *(5.2 inches)*.

3 STAGING

The staging of the seepage collection dams is outlined in Table 3.1.

Table 3.1 Seepage Collection Dam Staging Summary

Stage	Years	Catchments
I	0 – 10	S1 – S4
II	11 – 12	S1 – S10
III	13 – 45	S1 – S11

4 RESULTS

4.1 Dam Sizing

Table 4.1 presents the dam sizing for the eleven seepage collection catchments. The dam crest elevation includes the 2.0 m *(6.6 ft)* design freeboard.

Table 4.1 Seepage Collection Dam Summary

Catchment Name	Catchment Area (m^2) (sq mi)	Dam Crest Elevation (masl) *(fasl)*	Dam Height (m) *(ft)*	Dam Volume (m^3) *(acre-ft)*	200-year 24-hr Flood Volume (m^3) *(acre-ft)*	200-year 24-hr Flood Elevation (masl) *(fasl)*
S1	1,940,472 *(0.75)*	726 *(2381.9)*	11.1 *(36.4)*	109,558 *(88.8)*	256,142 *(207.7)*	723.9 *(2375)*
S2	671,515 *(0.26)*	702 *(2303.2)*	12.3 *(40.4)*	54,017 *(43.8)*	88,640 *(71.9)*	699.4 *(2294.6)*
S3	736,394 *(0.28)*	691 *(2267.1)*	11.5 *(37.7)*	44,862 *(36.4)*	97,204 *(78.8)*	689.4 *(2261.8))*
S4	830,670 *(0.32)*	685 *(2247.4)*	10.6 *(34.8)*	37,288 *(30.2)*	109,648 *(88.9)*	683.2 *(2241.5))*
S5	250,562 *(0.10)*	697 *(2286.8)*	14.3 *(46.9)*	33,701 *(27.3)*	33,074 *(26.8)*	694.7 *(2279.2)*
S6	324,126 *(0.13)*	706 *(2316.3)*	11.5 *(37.7)*	39,512 *(32.0)*	42,785 *(34.7)*	703.6 *(2308.4)*
S7	148,938 *(0.06)*	703 *(2306.4)*	13.5 *(44.3)*	25,831 *(20.9)*	19,660 *(15.9)*	700.6 *(2298.6)*
S8	220,800 *(0.09)*	708 *(2322.8)*	13.3 *(43.6)*	85,884 *(69.6)*	29,146 *(23.6)*	705.5 *(2314.6)*
S9	377,565 *(0.15)*	708 *(2322.8)*	14.5 *(47.6)*	75,458 *(61.2)*	49,839 *(40.4)*	706.2 *(2316.9)*
S10	1,027,424*(0.40)*	715 *(2345.8)*	20.6 *(67.6)*	282,476 *(229.0)*	135,620 *(109.9)*	713.1 *(2339.6)*
S11	645,604 *(0.25)*	751 *(2463.9)*	6.5 *(21.3)*	64,449 *(52.2)*	85,220 *(69.1)*	748.9 *(2457.0)*
Total				833,038 *(675.4)*	-	-

Figure 1 presents the overall plan of all eleven seepage collection dams. Figure 2 presents a typical section of a seepage collection dam. Figure 3 to Figure 13 illustrate the layout of each seepage collection dam.

Figure 14 to Figure 24 present a typical cross section for each of the eleven seepage collection dam (at sections indicated by black lines on Figure 3 to Figure 13).

4.2 Upstream Face Riprap

Armouring of the upstream slopes of the seepage collection dams will be necessary. Table 4.2 details the upstream area inundated with the 200-year 24-hr flood for each seepage collection dam catchment, and the amount of armouring required.

Table 4.2 Riprap Armouring for Embankment Slopes

Catchment	Upstream Area Inundated with the 200-year 24-hr Flood (m^2) *(ft^2)*	Armouring Volume[1] (m^3) *(yd^3)*
S1	5,777 *(62183)*	2,311 *(3023)*
S2	2,527 *(27200)*	1,011 *(1322)*
S3	2,436 *(26221)*	974 *(1274)*
S4	2,216 *(23853)*	886 *(1159)*
S5	1,465 *(15769)*	586 *(766)*
S6	1,698 *(18277)*	679 *(888)*
S7	1,073 *(11550)*	429 *(561)*
S8	2,522 *(27147)*	1,009 *(1320)*
S9	2,853 *(30709)*	1,141 *(1492)*
S10	11,396 *(122666)*	4,558 *(5962)*
S11	3,300 *(35521)*	1,320 *(1726)*
Total		14,905 *(19495)*

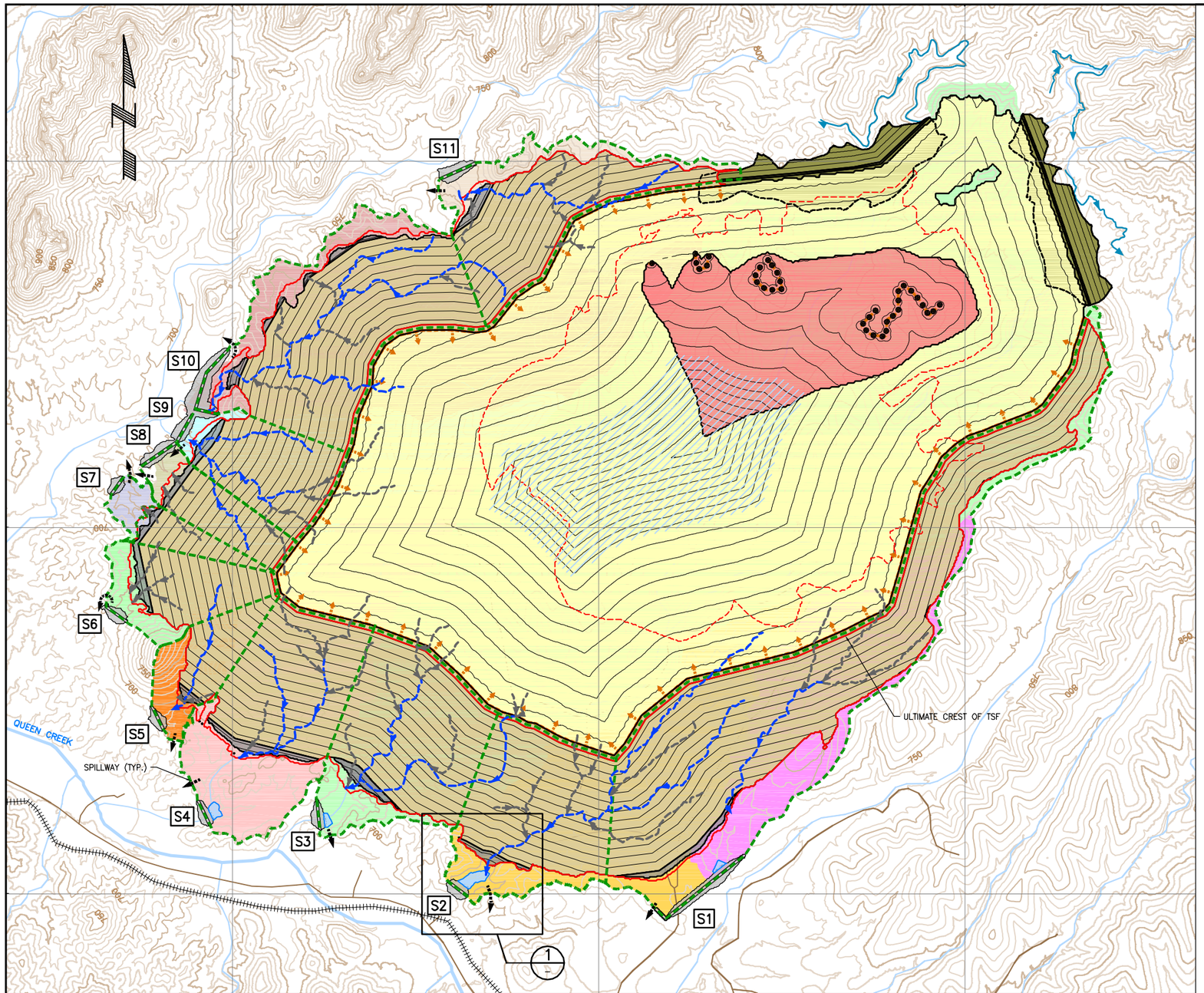
Note: [1]A D_{50} of 200 mm *(7.9 inches)* and a thickness of 400 mm *(15.7 inches)* was assumed based on the Far West PFS study. This should be re-evaluated in the next stage of design.

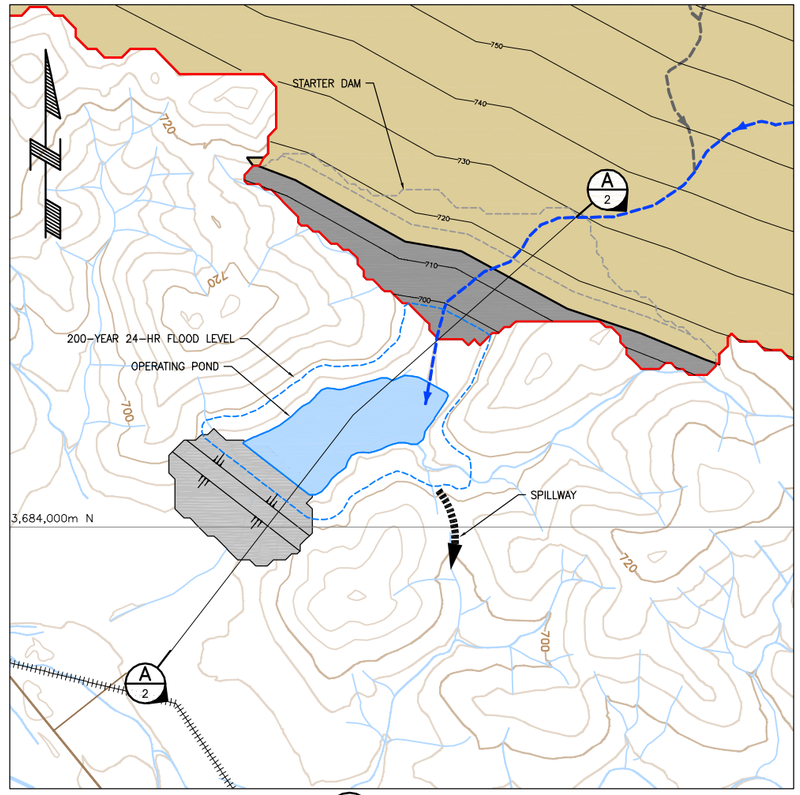
REFERENCE

Bonnin, D. Martin, B. Lin, T. Parzybok, M. Yekta, and D. Riley. 2006. NOAA, National Weather Service, Silver Spring, Maryland.

NOAA. 2012. Point Precipitation Frequency Estimates from NOAA Atlas 14, Volume 1, Version 4 G.M.

FIGURES





DETAIL 1 TYPICAL SEEPAGE DAM
SCALE B

SEEPAGE COLLECTION DAM	CATCHMENT AREA (km^2) (NOTE 3)	DRAINAGE AREA (km^2) (NOTE 4)
S1	1.94	0.96
S2	0.67	1.45
S3	0.74	7.91
S4	0.83	1.36
S5	0.25	0.26
S6	0.32	0.24
S7	0.15	0.07
S8	0.22	0.10
S9	0.38	1.11
S10	1.03	1.99
S11	0.65	0.81

LEGEND

- DIVERSION CHANNEL
- PRIMARY UNDERDRAIN
- SECONDARY UNDERDRAIN
- SPILLWAY
- CATCHMENT BOUNDARY
- RAILWAY
- EXISTING ROAD
- STREAM
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.
3. CATCHMENT AREAS ARE INDICATED BY DASHED BLUE LINES.
4. DRAINAGE AREAS ARE INDICATED BY SHADED AREAS.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE B 0 100m

SCALE A 0 500m

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

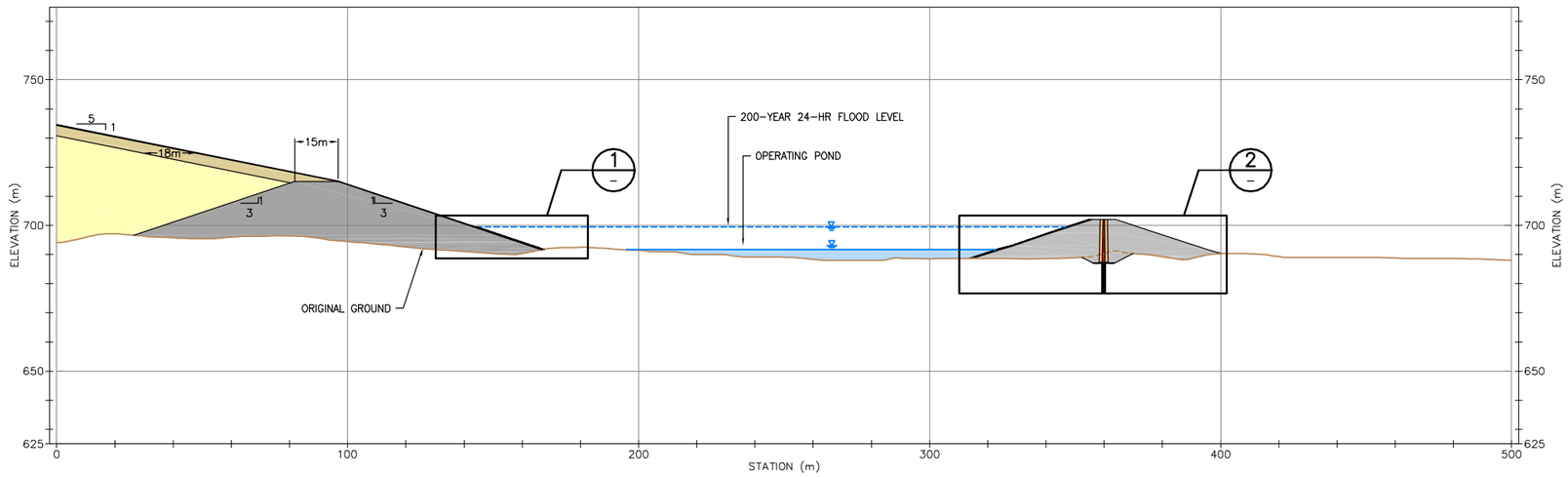
PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: SEEPAGE COLLECTION DAMS PLAN

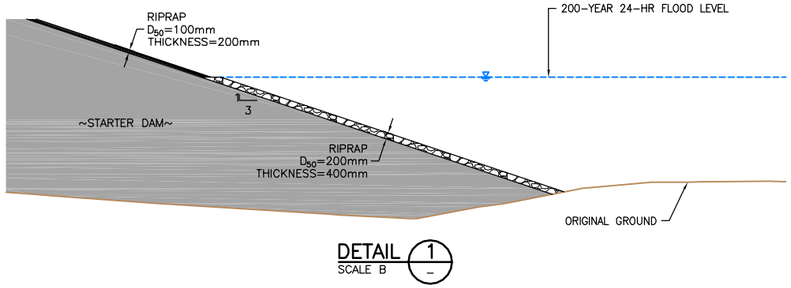
SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	1

K08-FIG-D-L

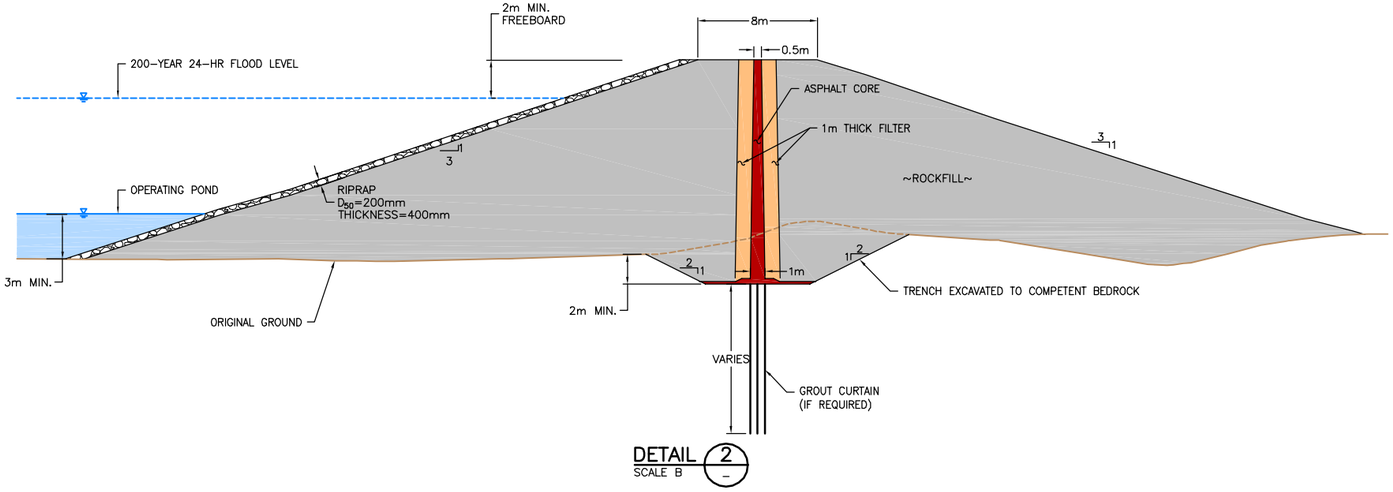
Date: 9/3/2014 Time: 15:43:01 Scale: 1:2,585(PS)
Drawing File: Z:\M_V\CR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\FINAL\Appendix IX - Seepage Collection Dams\Fig1_rA - Seepage Dams.dwg (dhu)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Camp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Camp_Streams_Sep2012
Image File(s):



SECTION A
SCALE A



DETAIL 1
SCALE B



DETAIL 2
SCALE B

LEGEND

- COMPACTED TAILINGS EMBANKMENT
- ROCKFILL
- THICKENED SCAVENGER TAILINGS
- ASPHALT CORE
- FILTER
- STARTER DAM

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE B 0 10 m

SCALE A 0 50 m

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: SEEPAGE COLLECTION DAM
TYPICAL CROSS-SECTION

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	2

KCB-FIG-D-L

Date: 9/3/2014 Time: 15:50:55 Scale: 1:2.585(PS)
Drawing File: Z:\M\VCR\M09441A14 - RES-Near WestGeotech Study\400 Drawings\CAD\Order of Magnitude Study\FINAL\Appendix IX - Seepage Collection Dams\Fig2_rA_Seepage Dam Typ Section.dwg (dhu)
Xref File(s):
Image File(s):

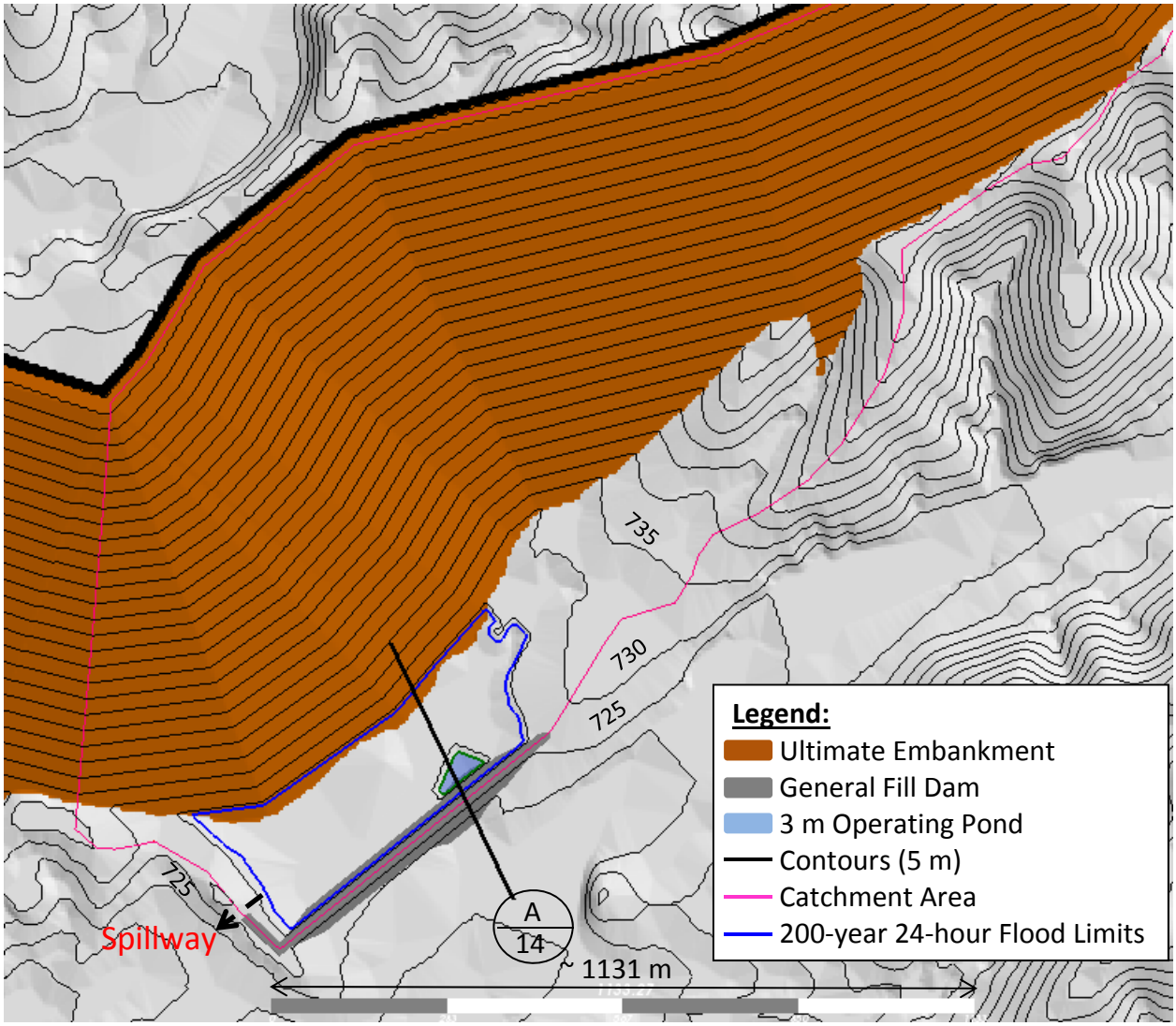


Figure 3 S1 Seepage Collection Dam

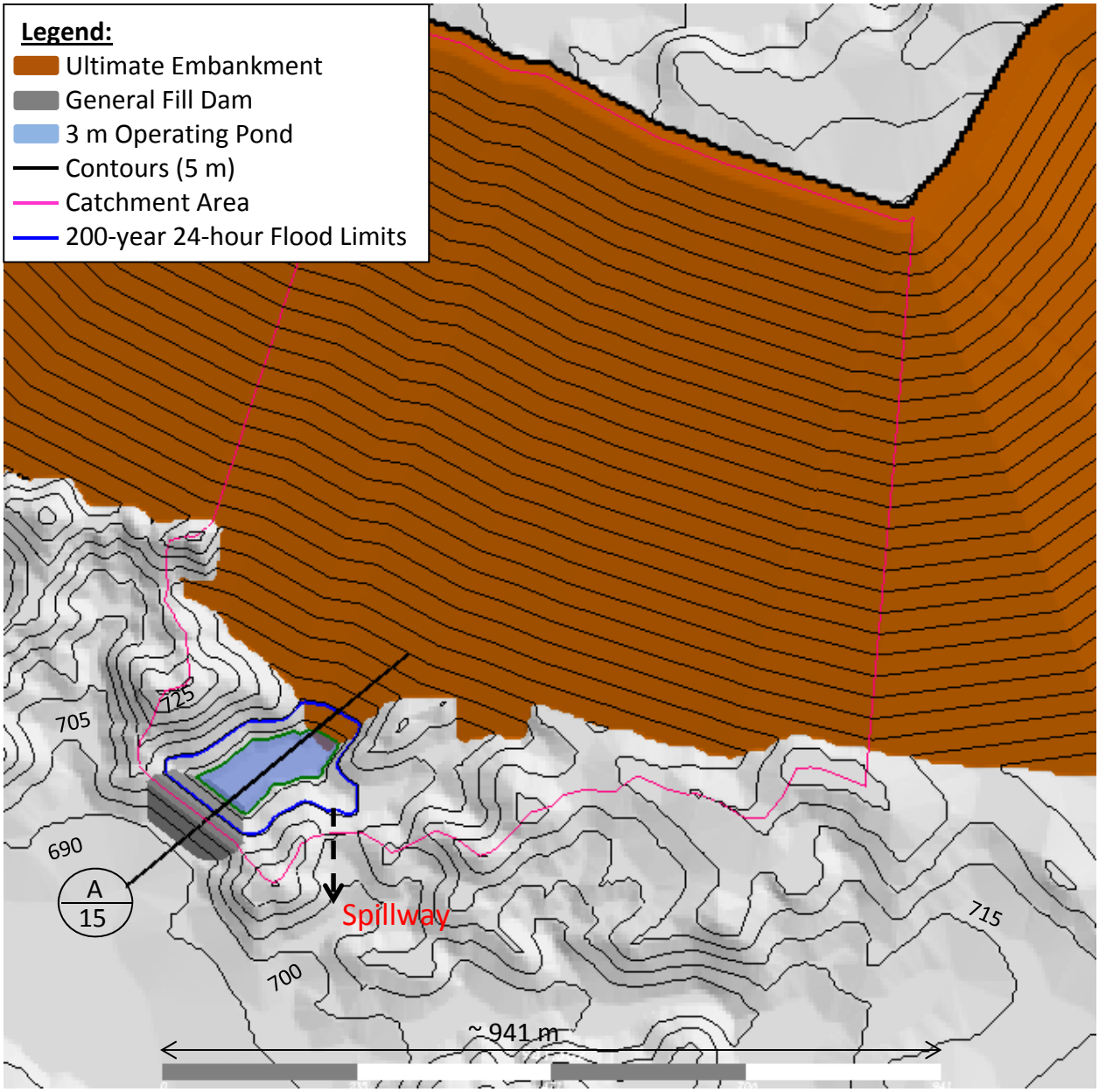


Figure 4 S2 Seepage Collection Dam

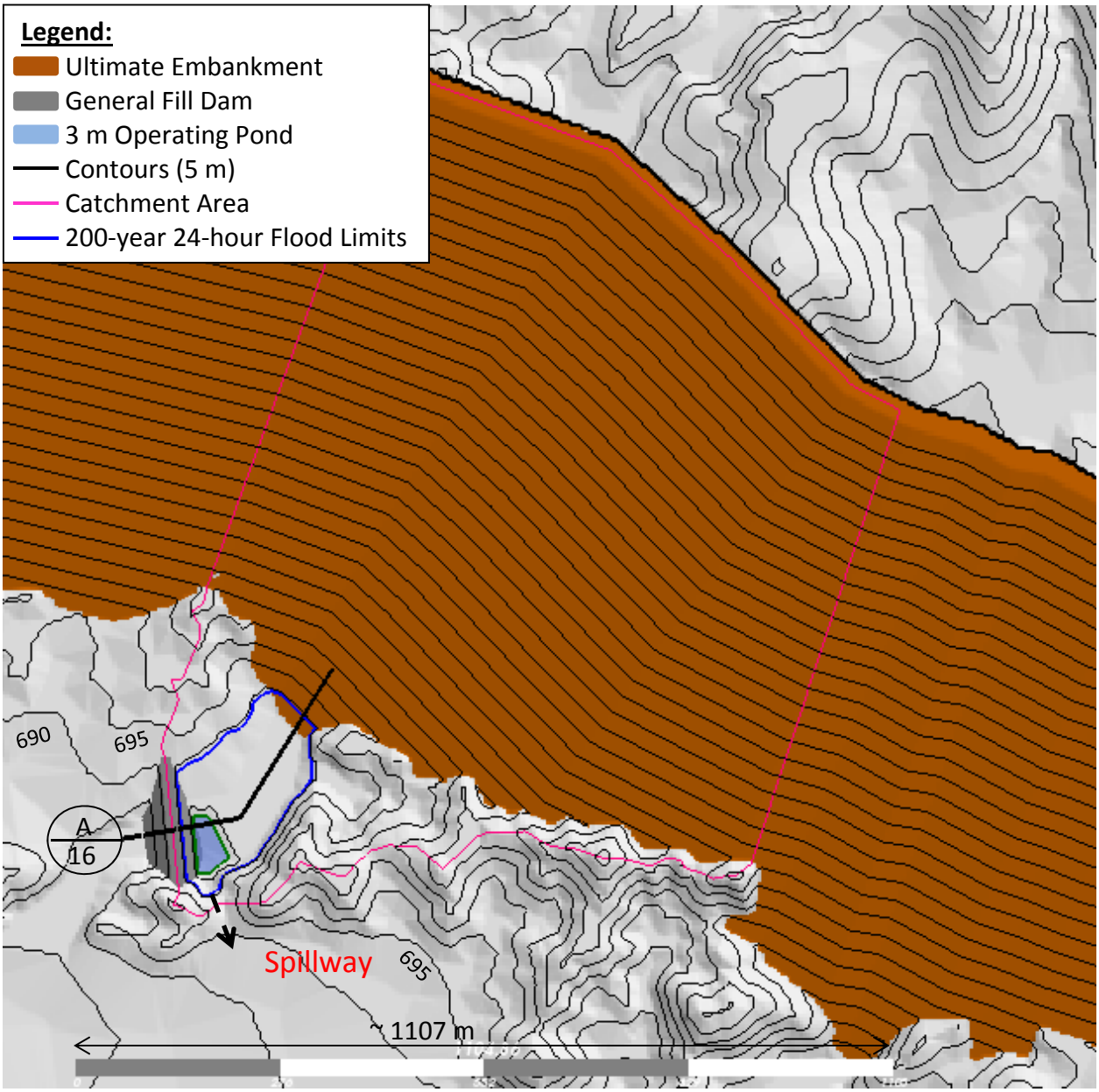


Figure 5 S3 Seepage Collection Dam

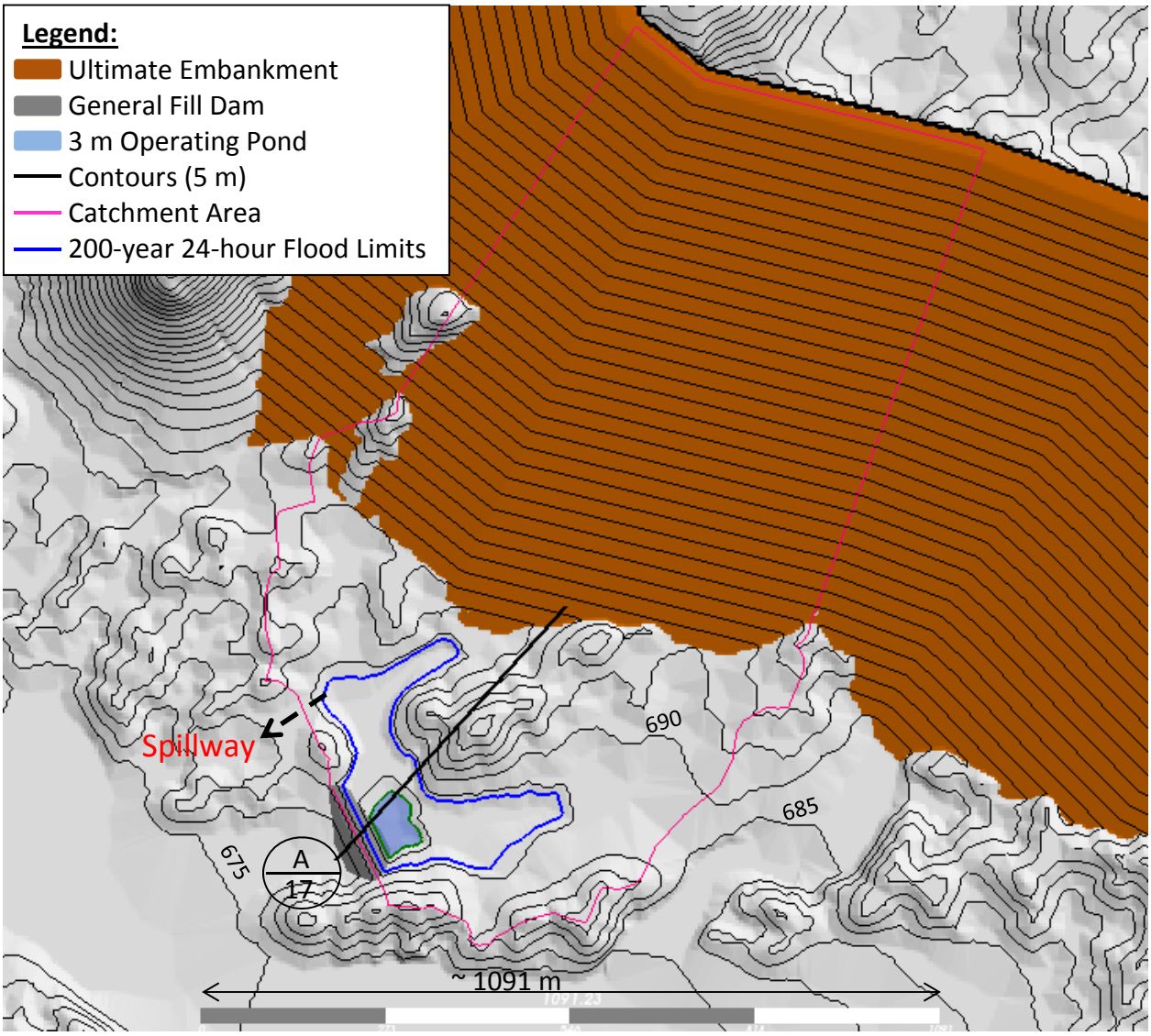


Figure 6 S4 Seepage Collection Dam

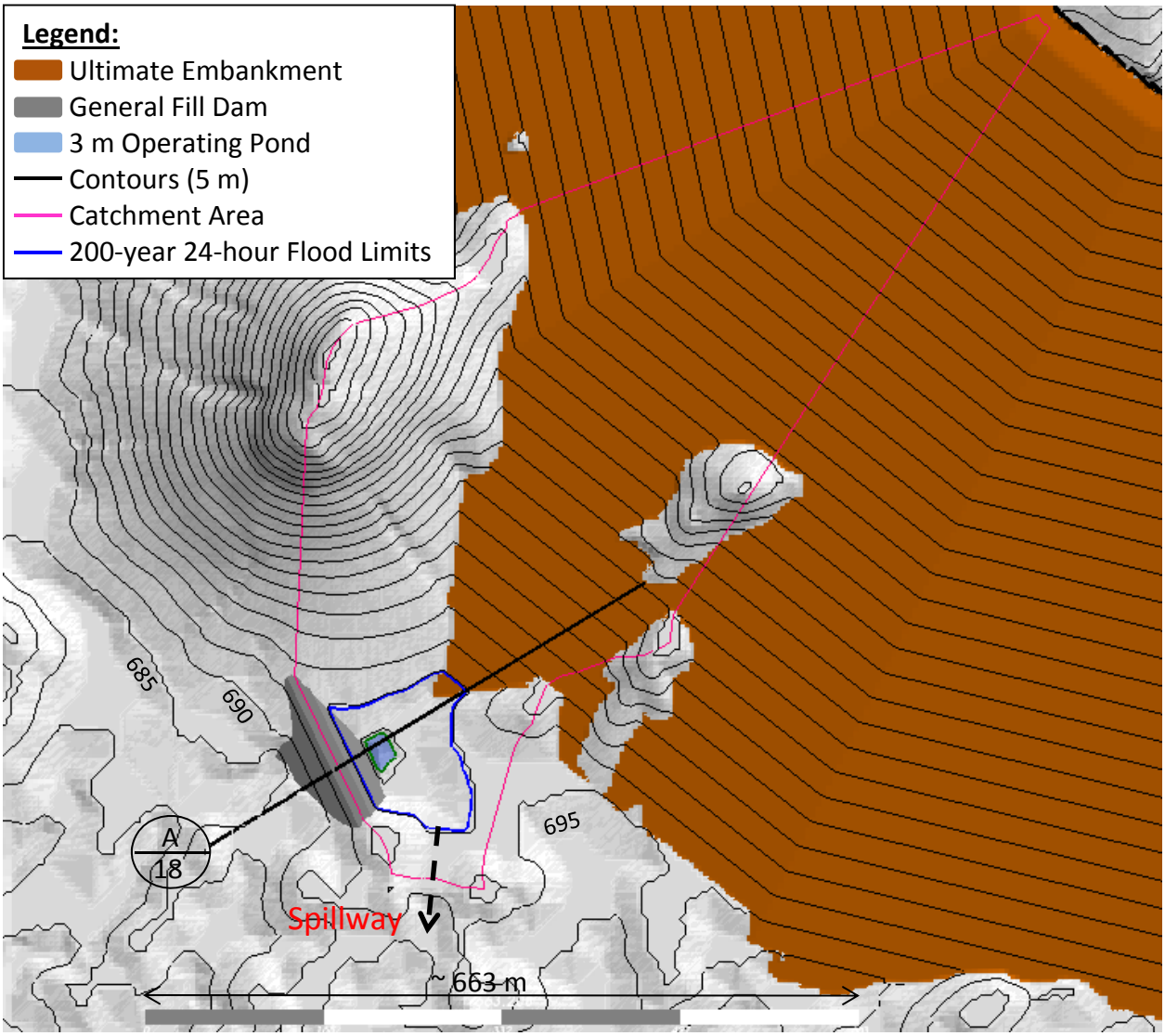


Figure 7 S5 Seepage Collection Dam

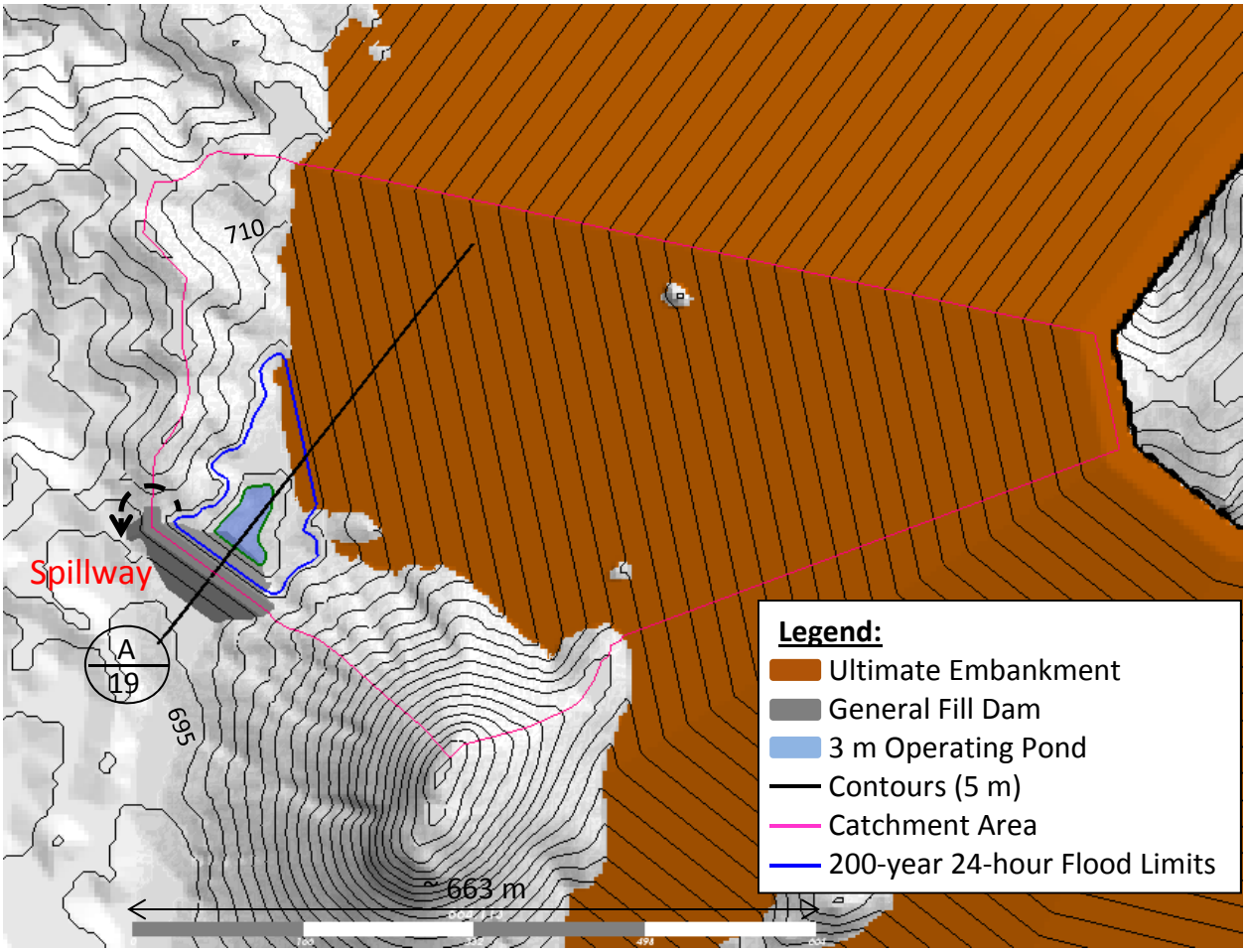


Figure 8 S6 Seepage Collection Dam

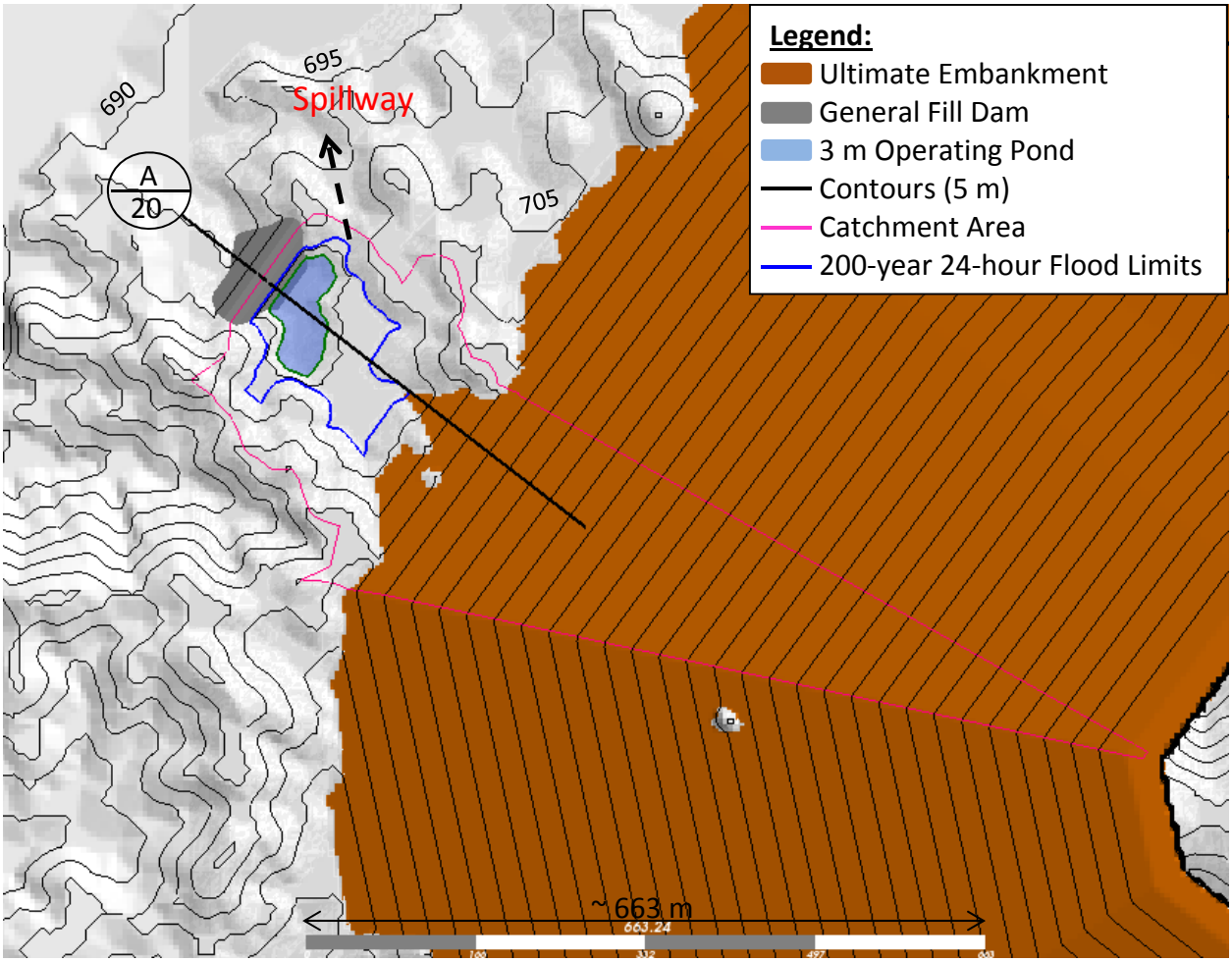


Figure 9 S7 Seepage Collection Dam

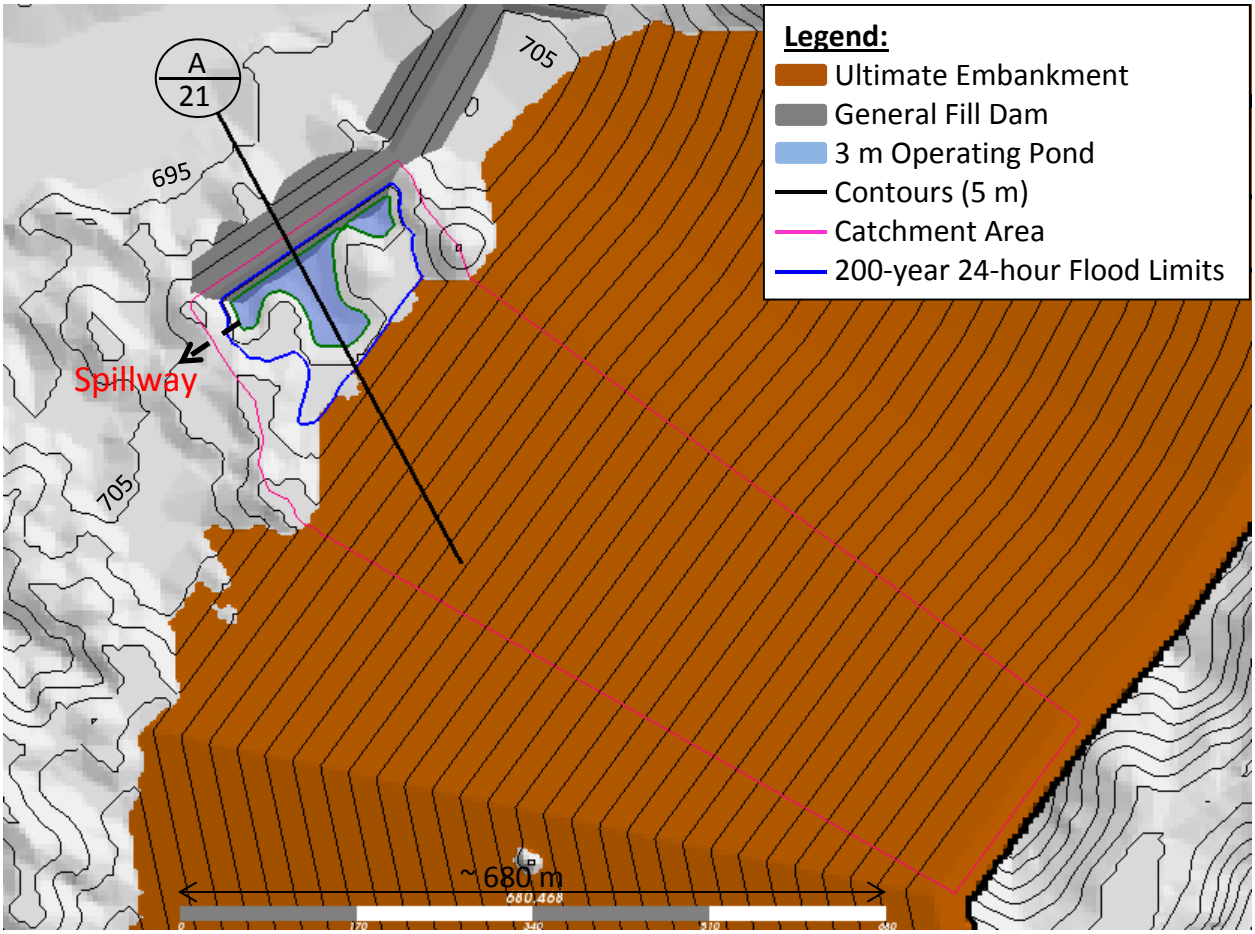


Figure 10 S8 Seepage Collection Dam

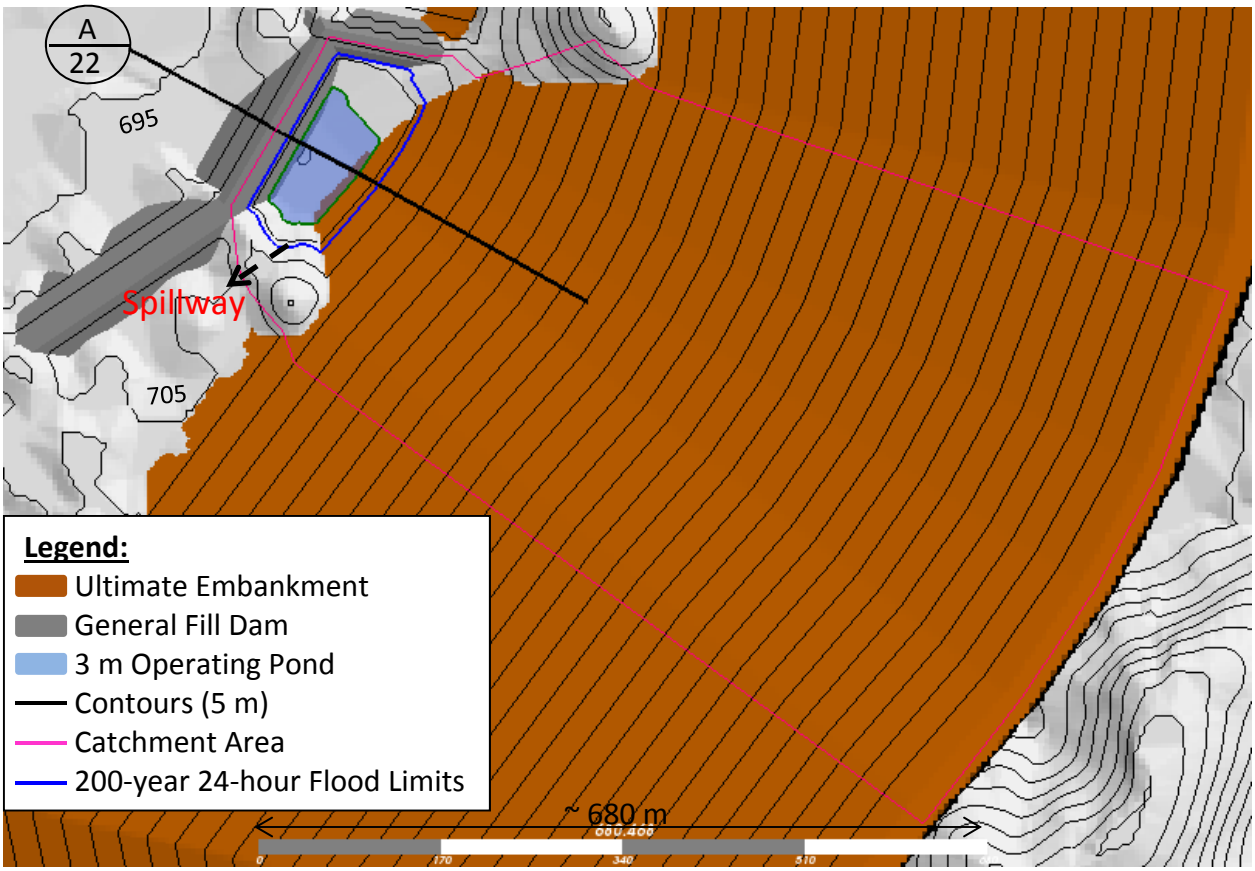


Figure 11 S9 Seepage Collection Dam

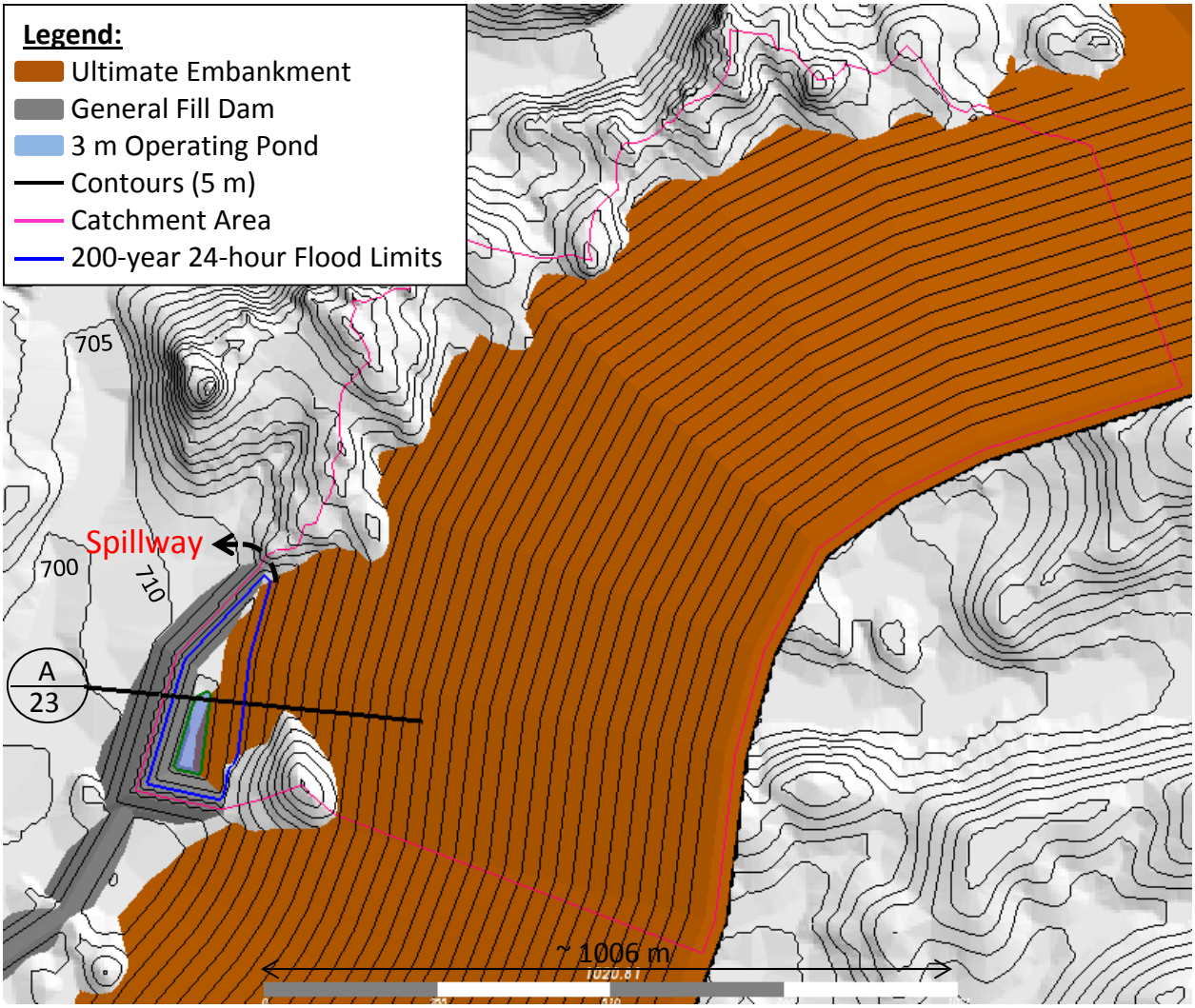


Figure 12 S10 Seepage Collection Dam

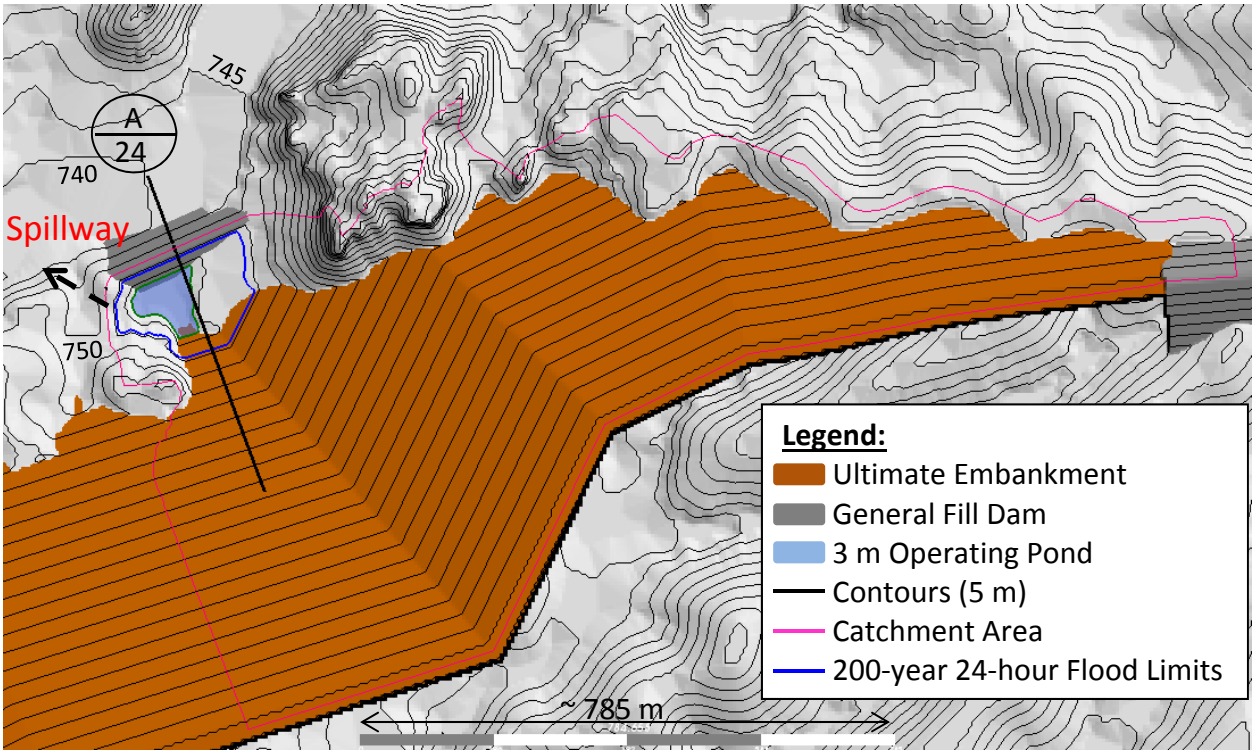


Figure 13 S11 Seepage Collection Dam

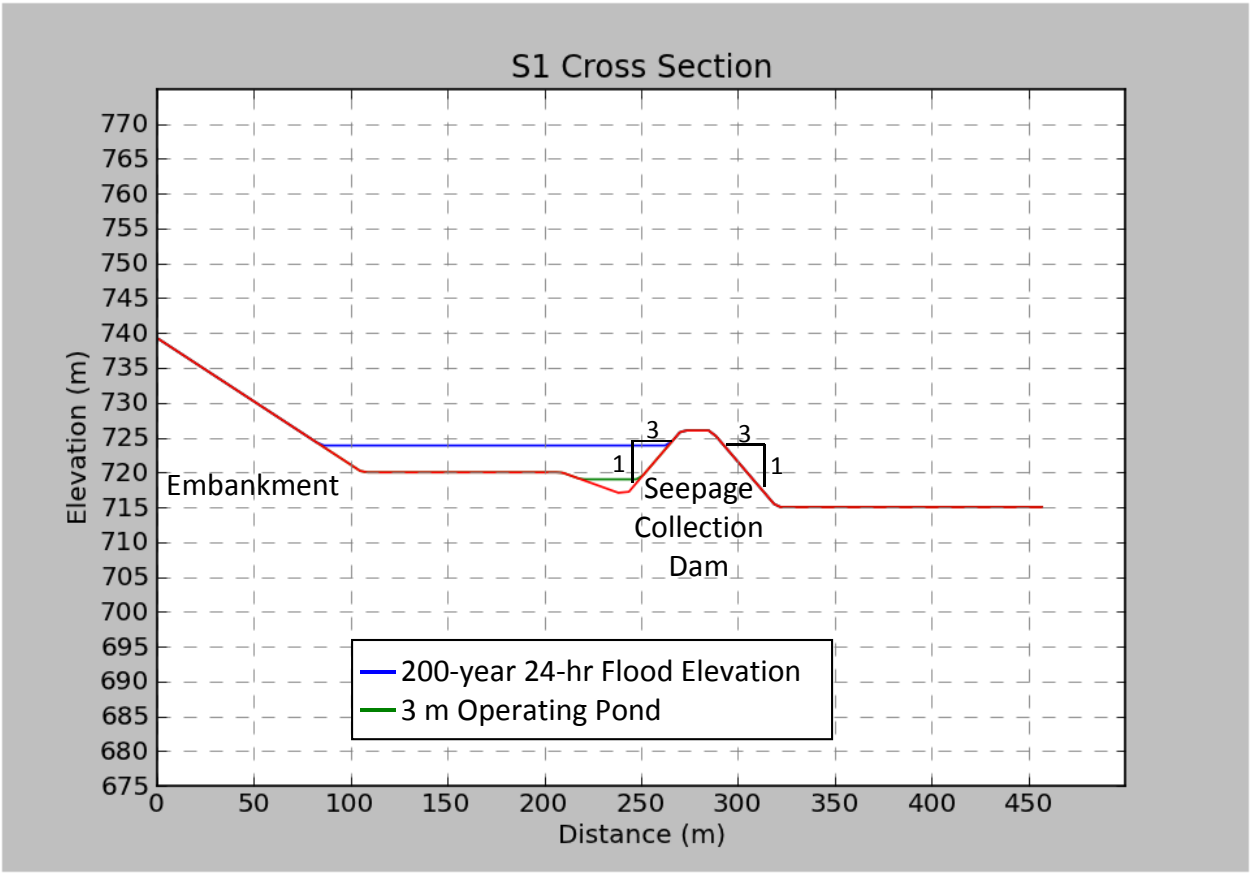


Figure 14 S1 Cross Section (Plan view in Figure 3)

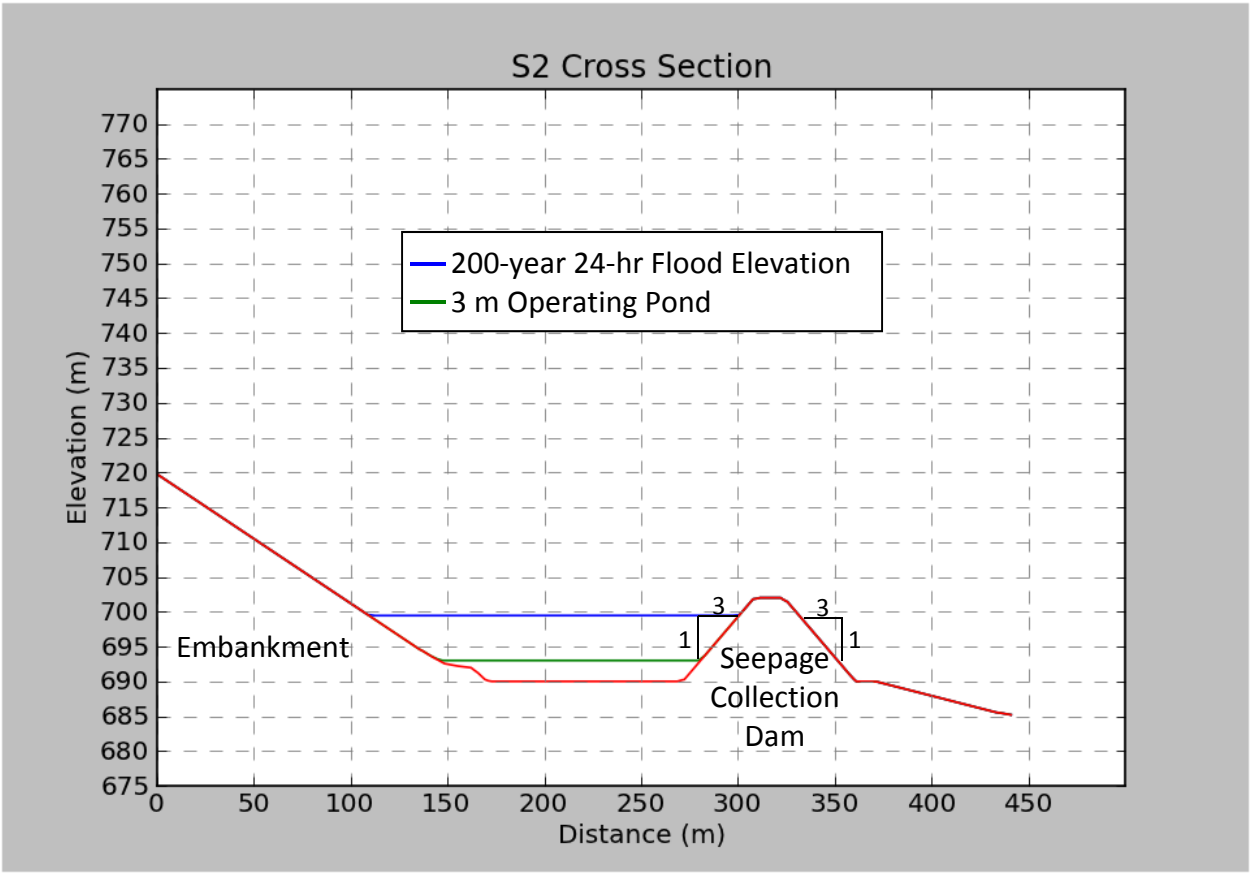


Figure 15 S2 Cross Section (Plan view in Figure 4)

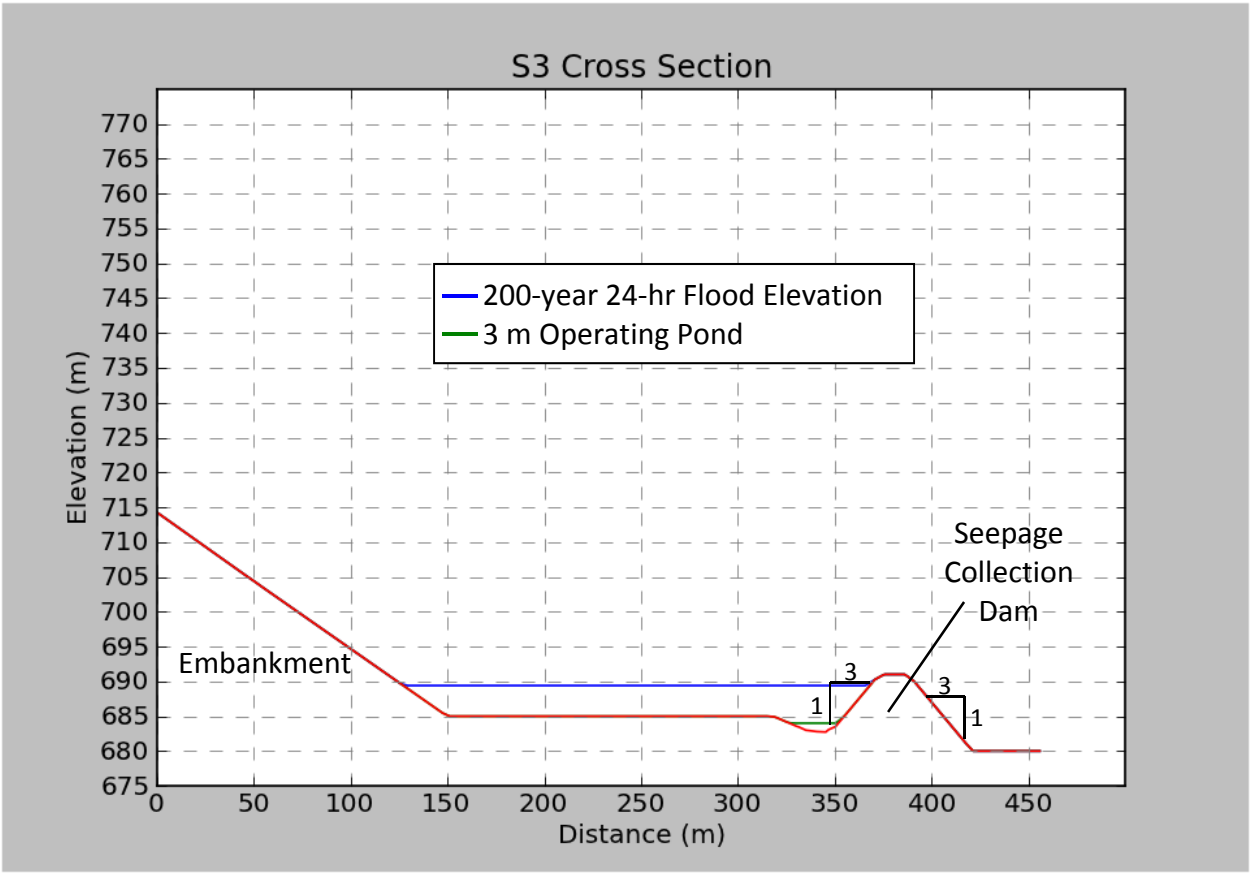


Figure 16 S3 Cross Section (Plan view in Figure 5)

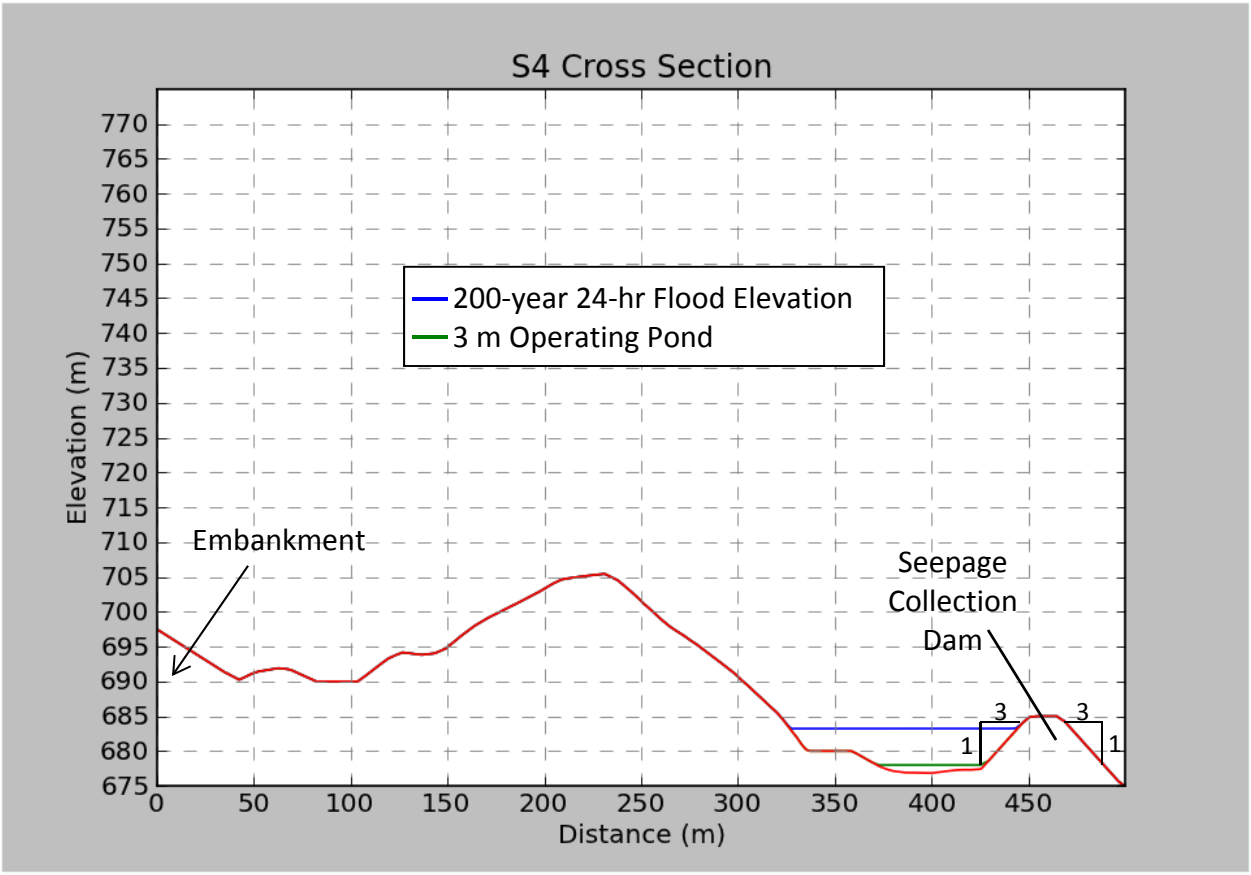


Figure 17 S4 Cross Section (Plan view in Figure 6)

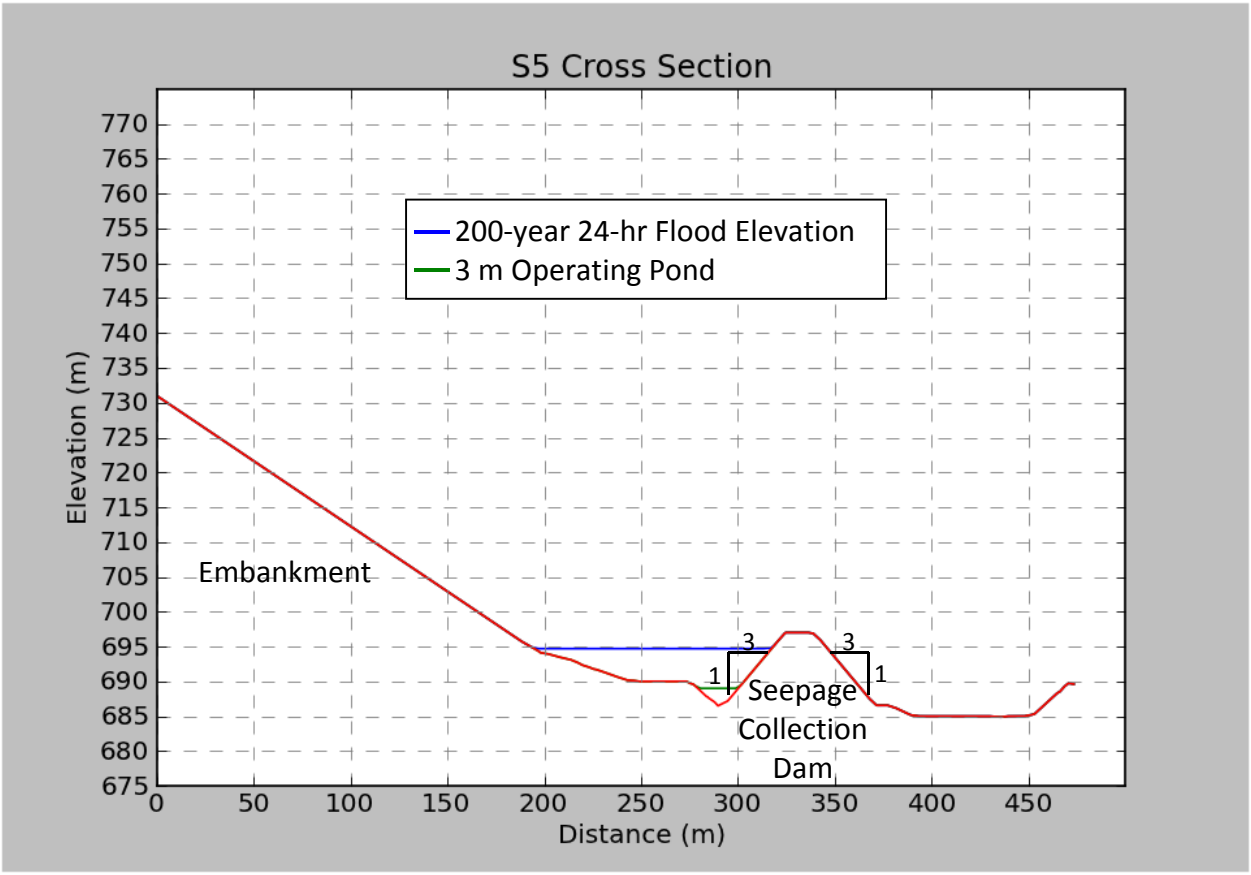


Figure 18 S5 Cross Section (Plan view in Figure 7)



Figure 19 S6 Cross Section (Plan view in Figure 8)

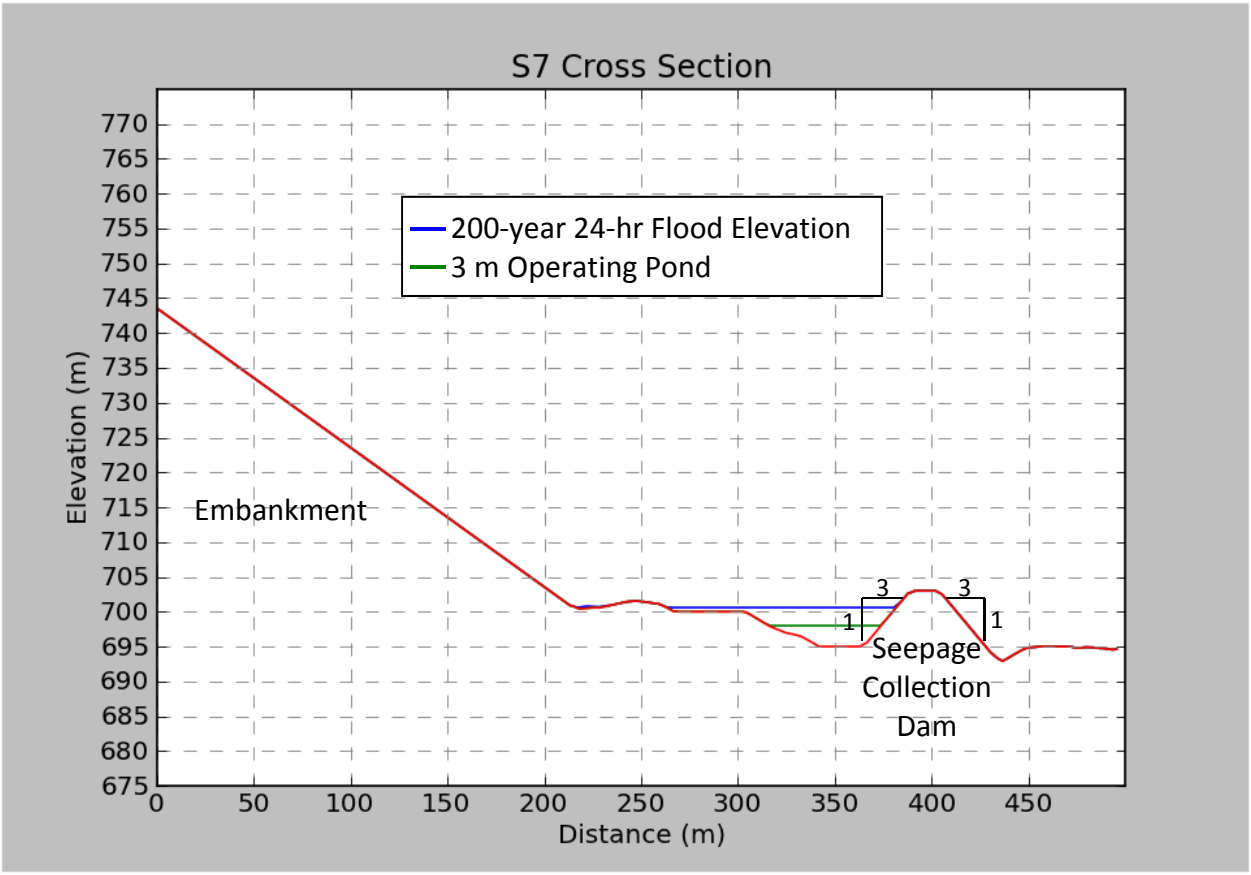


Figure 20 S7 Cross Section (Plan view in Figure 9)

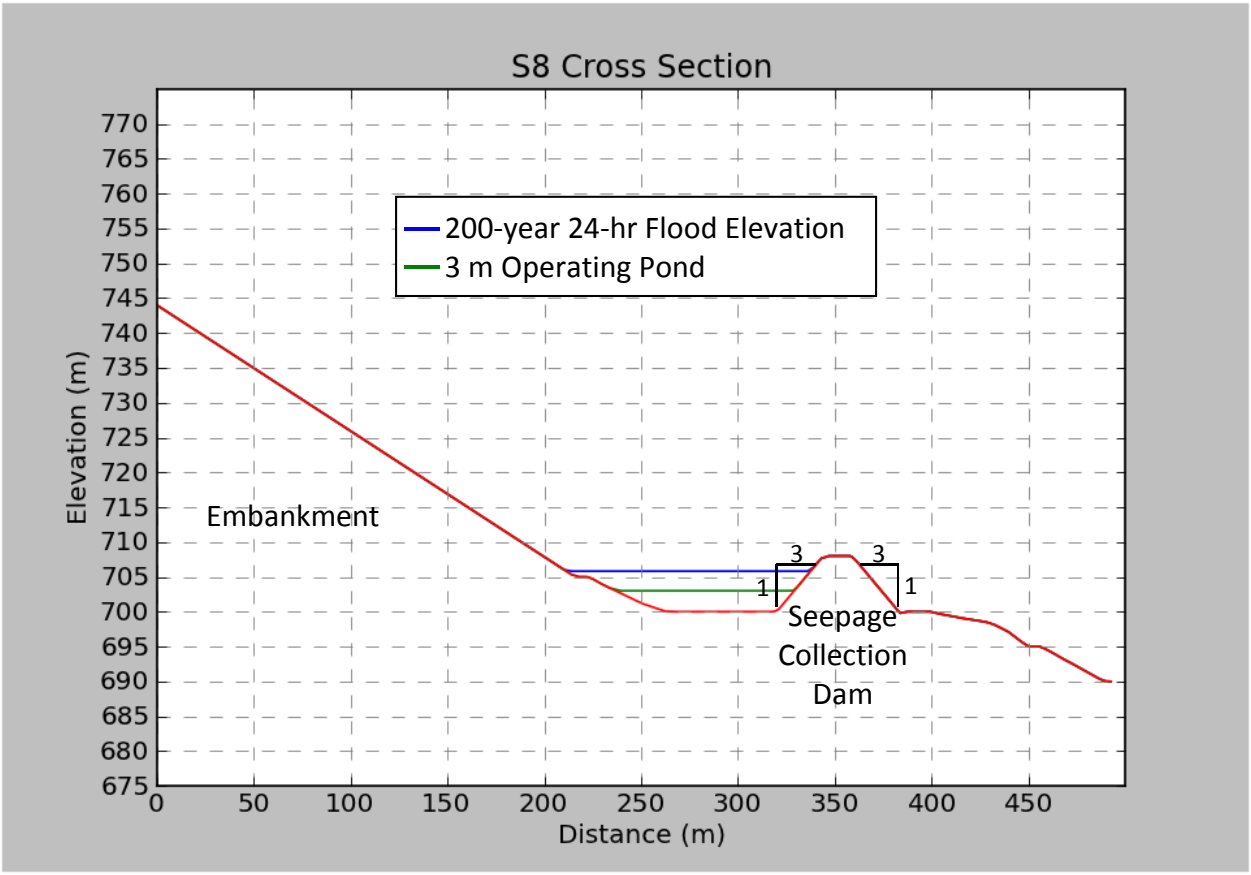


Figure 21 S8 Cross Section (Plan view in Figure 10)

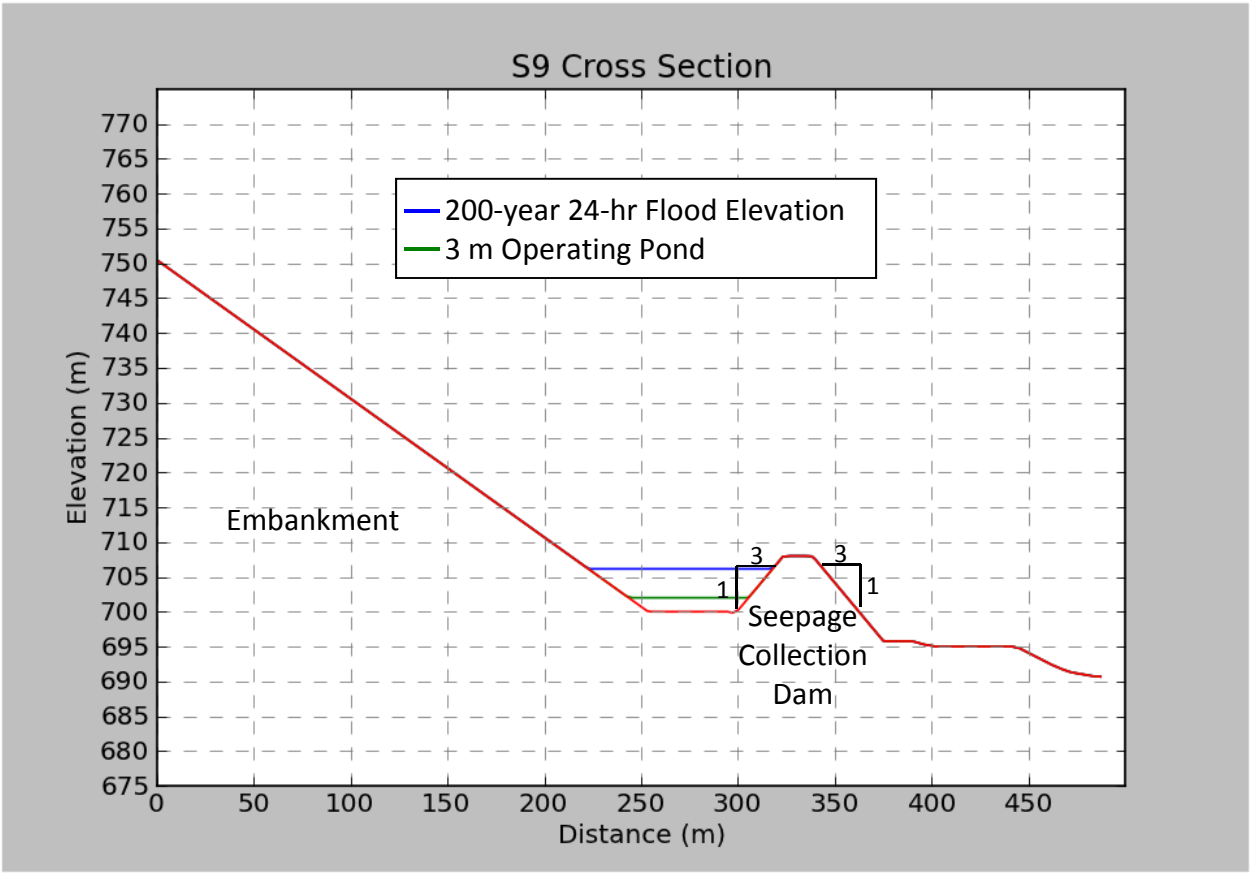


Figure 22 S9 Cross Section (Plan view in Figure 11)

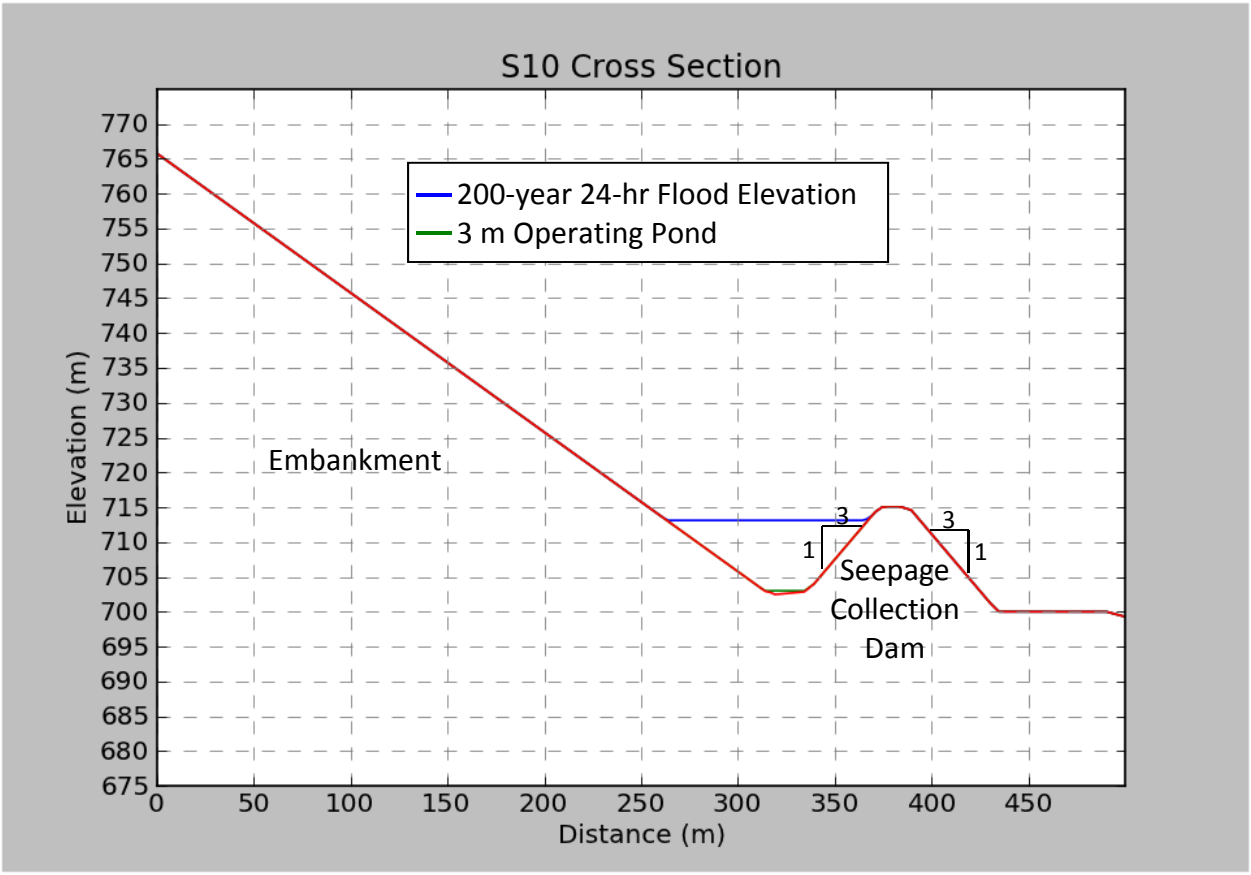


Figure 23 S10 Cross Section (Plan view in Figure 12)

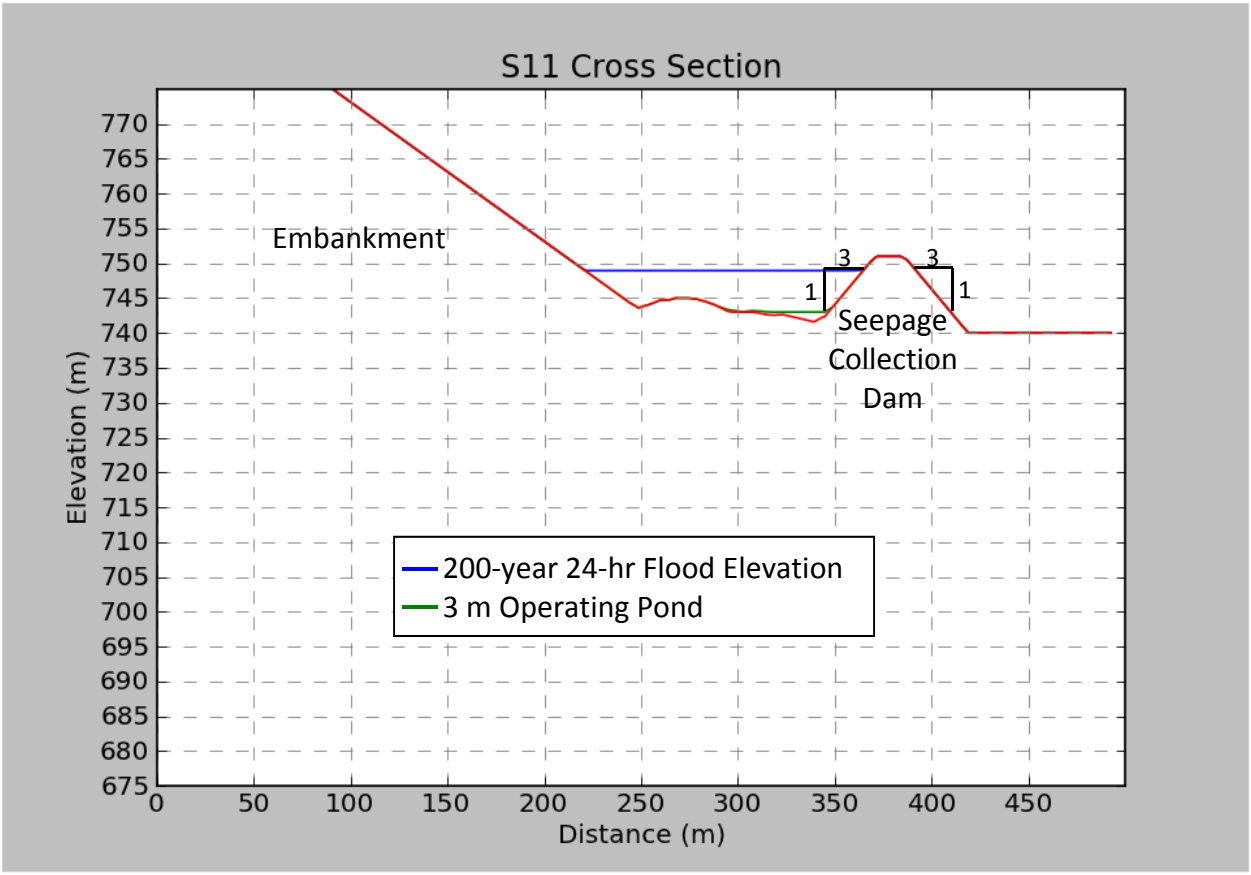


Figure 24 S11 Cross Section (Plan view in Figure 13)

APPENDIX X

Underdrain Design

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Jim Casey **FILE NO:** M09441A14.730

SUBJECT: Appendix X - Underdrain Design

1 INTRODUCTION

Underdrains will be used at the Near West Tailings Storage Facility (TSF) to depress the phreatic surface in the tailings embankment which will aid in tailings consolidation, improve embankment stability and convey seepage water to the seepage collection dams for reclaim. The underdrains will be constructed in existing drainage channels and sized for the expected dam seepage rate with an applied factor of safety.

2 DRAIN DESIGN

The TSF was divided into 11 seepage "catchments", separated by topography. Underdrain locations were identified in each catchment and classified as either "primary" or "secondary" drains depending on the percentage of the total flow each is expected to receive. The catchments, and secondary and primary drain locations, are shown on Figure 2.1.

The drains will be comprised of a high capacity screened rock core (¾ inch to 4 inch) encapsulated by a 18 inch thick ¾" minus sand and gravel filter with D_{15} between 0.6 mm *(0.02 inches)* and 0.2 mm *(0.01 inches)* and less than 5% fines to prevent the migration of soil or tailings into the drain. A typical cross section is shown in Figure 2.2.

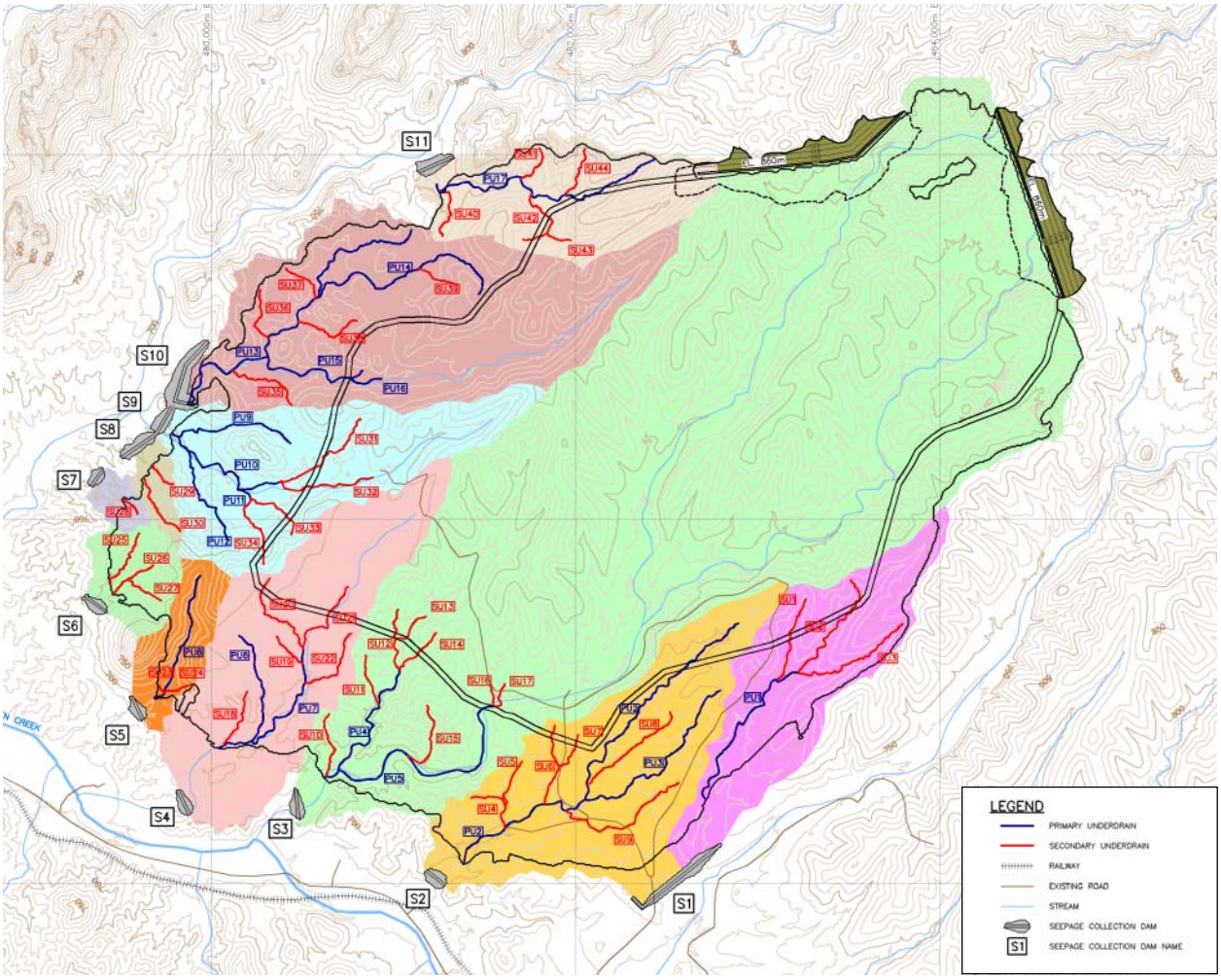


Figure 2.1 Seepage Catchments and Underdrain Locations

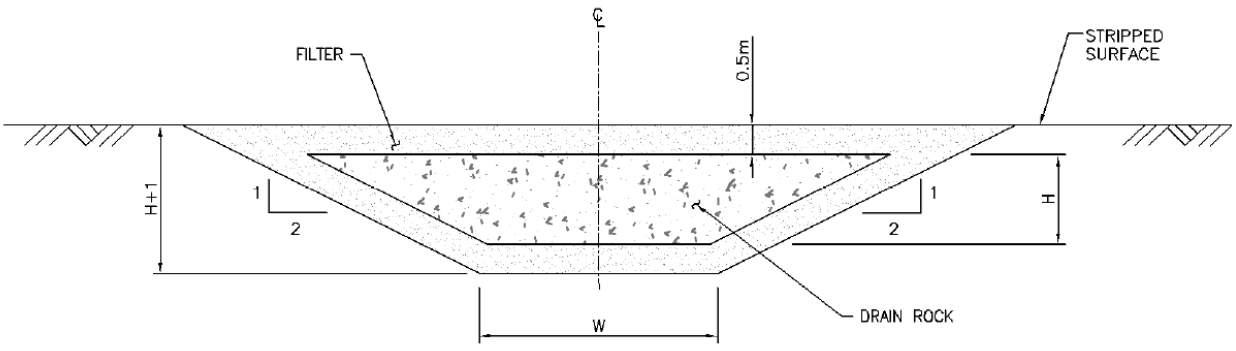


Figure 2.2 Typical Underdrain Section

2.1 Calculation of Design Flow

A two dimensional seepage rate of 0.3 m^3/day/m *(10.6 ft^3/day/m)* was estimated using Seep/W. Details are given in Appendix VI. The total seepage rate was calculated by multiplying the 2-D seepage rate by the dam crest length. The longest crest length, for S10, was used as a conservative estimate. The primary drains were assumed to carry all of the seepage flow and the secondary drains were assumed to carry half of the flow. A factor of safety (FOS) of 20 was applied to the seepage rates to compute the design flow. The calculation inputs are summarized in Table 2.1.

Table 2.1 Design Flow Calculation Inputs

Calculation Input	Value
Dam Seepage Rate (refer to Appendix VI)	0.3 m^3/day/metre *(10.6 ft^3/day/m)* of dam crest length
Dam Crest Length (from Catchment #10)	1500 m *(4921 ft)*
Seepage Flow Rate through Primary Underdrains	5 L/s *(79.3 USgpm)*
Design Flow Rate through Primary Underdrains (FOS=20)	100 L/s *(1585.0 USgpm)*
Seepage Flow Rate through Secondary Underdrains	2.5L/s *(39.6 USgpm)*
Design Flow Rate through Secondary Underdrains (FOS=20)	50 L/s *(792.5 USgpm)*

2.2 Calculation of Flow Capacity

The flow capacity of the drains was calculated by the following formula derived by Wilkins (1956) for non-Darcy turbulent flow in rockfill:

$$Q = Wm^{0.5} i^{0.54} \frac{e}{1+e} A$$

Where: Q = flow in m^3/sec;
W = Wilkins constant;
m = hydraulic mean radius of the rock voids $\cong \frac{eD_{10}}{8.4}$;
i = hydraulic gradient;
e = void ratio; and,
A = cross sectional area of the rockfill (m^2).

Results of the British Columbia Rock Drain Research Program (1999) suggest that Wilkins' constant for end-dumped mine rockfill drains should be 4.2 $m^{0.5}$/s. The void ratio was assumed to be 0.4 and the hydraulic mean radius was calculated to be 0.0013 m *(0.004 ft)* for all drains. These values are consistent with KCB experience with similar materials. Drain hydraulic gradients were calculated by dividing the drop in elevation of the drain by its length. The cross-sectional area of the drain was varied so that the flow capacity of each drain met or exceeded the design flow rate. The calculated flow capacity for each drain is provided in Attachment I.

3 DRAIN DIMENSIONS

The minimum drain dimensions are summarized in Table 3.1. The secondary drains can be constructed with smaller dimensions than the primary drains; however these dimensions represent the minimum and may need to be increased for constructability.

Table 3.1 Minimum Drain Dimensions

	Primary Drains	Secondary Drains
Drain Height (H, refer to Fig. 2.2)	2.5 m *(8.2 ft)*	2 m *(6.6 ft)*
Drain Width (W, refer to Fig. 2.2)	4 m *(13.1 ft)*	2 m *(6.6 ft)*
Filter Area	16 m^2 *(172 ft^2)*	12 m^2 *(129 ft^2)*
Drain Core Area	22.5 m^2 *(242 ft^2)*	12 m^2 *(129 ft^2)*

REFERENCES

British Columbia Rock Drainage Research Program. 1999. "Rock Drain Research Program, Final Report, February 1999", British Columbia Ministry of Mines.

Wilkins, J.K. 1956. "Flow of Water Through Rockfill and its Application to the Design of Dams". Proc. 2nd Aust. N.Z. Soils Conference.

Attachments:

Attachment I – Drain Flow Capacities

ATTACHMENT I

Drain Flow Capacities

Attachment I
Drain Flow Capacities

Flow capacities calculated for each drain are presented in Table 1. Drain flow capacity is plotted against drain gradient for the primary and secondary drains in Figure 1.

Table 1 Drain Flow Capacities

Seepage Catchment	Drain Type	Drain Number	Inlet Elevation (m) *(ft)*	Outlet Elevation (m) *(ft)*	Length (m) *(ft)*	Gradient (dh/dl)	Drain Flow Capacity (L/s) *(USgpm)*
S1	SU	1	767 *(2516)*	745 *(2444)*	505 *(1657)*	4.3%	96 *(1522)*
	SU	2	784 *(2572)*	748 *(2454)*	736 *(2415)*	4.8%	101 *(1601)*
	SU	3	795 *(2608)*	748 *(2454)*	724 *(2375)*	6.4%	118 *(1870)*
	PU	1	748 *(2454)*	722 *(2369)*	1032 *(3386)*	2.5%	133 *(2108)*
S2	SU	4	730 *(2395)*	697 *(2287)*	366 *(1201)*	8.9%	141 *(2235)*
	SU	5	715 *(2346)*	704 *(2310)*	284 *(932)*	3.8%	89 *(1411)*
	SU	6	725 *(2379)*	705 *(2313)*	474 *(1555)*	4.2%	94 *(1490)*
	SU	7	722 *(2369)*	712 *(2336)*	228 *(748)*	4.4%	96 *(1522)*
	SU	8	739 *(2425)*	713 *(2340)*	653 *(2142)*	4.0%	92 *(1458)*
	SU	9	723 *(2372)*	708 *(2323)*	823 *(2700)*	1.8%	60 *(951.0)*
	PU	2	750 *(2461)*	690 *(2264)*	2366 *(7762)*	2.6%	135 *(2140)*
	PU	3	747 *(2451)*	710 *(2329)*	1125 *(3691)*	3.3%	154 *(2441)*
S3	SU	10	713 *(2339)*	684 *(2244)*	385 *(1263)*	7.4%	128 *(2029)*
	SU	11	710 *(2329)*	696 *(2283)*	288 (945)	4.8%	101 *(1601)*
	SU	12	713 *(2339)*	702 *(2303)*	371 *(1217)*	3.0%	78 *(1236)*
	SU	13	712 *(2336)*	705 *(2313)*	236 *(774)*	2.7%	75 *(1189)*
	SU	14	728 *(2388)*	702 *(2303)*	301 *(988)*	8.6%	139 *(2203)*
	SU	15	722 *(2369)*	693 *(2274)*	450 *(1476)*	6.6%	120 *(1902)*
	SU	16	710 *(2329)*	706 *(2316)*	125 *(410)*	3.2%	81 *(1284)*
	SU	17	710 *(2329)*	706 *(2316)*	171 *(561)*	2.3%	69 *(1094)*
	PU	4	702 *(2303)*	683 *(2241)*	909 *(2982)*	2.1%	120 *(1902)*
	PU	5	706 *(2316)*	685 *(2247)*	1362 *(4469)*	1.5%	103 *(1633)*
S4	SU	18	705 *(2313)*	683 *(2241)*	356 *(1168)*	6.4%	118 *(1870)*
	SU	19	710 *(2329)*	700 *(2297)*	214 *(702)*	4.7%	99 *(1569)*
	SU	20	769 *(2523)*	701 *(2300)*	547 *(1795)*	12.4%	168 *(2663)*
	SU	21	712 *(2336)*	701 *(2300)*	488 *(1601)*	2.3%	67 *(1062)*
	SU	22	721 *(2365)*	697 *(2287)*	448 *(1470)*	5.4%	108 *(1712)*
	PU	6	717 *(2352)*	682 *(2238)*	864 *(2835)*	4.1%	173 *(2742)*
	PU	7	701 *(2300)*	687 *(2254)*	718 *(2356)*	1.9%	115 *(1823)*
S5	SU	23	700 *(2297)*	692 *(2270)*	45 *(148)*	18.6%	210 *(3329)*
	SU	24	722 *(2369)*	692 *(2270)*	160 *(525)*	18.4%	209 *(3313)*
	PU	8	740 *(2428)*	689 *(2261)*	782 *(2566)*	6.6%	225 *(3566)*

Seepage Catchment	Drain Type	Drain Number	Inlet Elevation (m) *(ft)*	Outlet Elevation (m) *(ft)*	Length (m) *(ft)*	Gradient (dh/dl)	Drain Flow Capacity (L/s) *(USgpm)*
S6	SU	25	712 *(2336)*	697 *(2287)*	368 *(1207)*	4.1%	93 *(1474)*
	SU	26	719 *(2359)*	697 *(2287)*	288 *(945)*	7.6%	129 *(2045)*
	SU	27	737 *(2418)*	703 *(2306)*	231 *(758)*	14.9%	187 *(2964)*
S7	SU	28	706.97 *(2319.46)*	700 *(2297)*	125.4 *(411.4)*	5.6%	109 *(1728)*
S8	SU	29	731.75 *(2400.75)*	704.41 *(2311.06)*	397.9 *(1305.4)*	6.9%	123 *(1950)*
S9	SU	30	720.28 *(2363.12)*	701.94 *(2302.95)*	173.5 *(569.2)*	10.6%	155 *(2457)*
S10	SU	31	733.14 *(2405.31)*	712.97 *(2339.14)*	634.4 *(2081.4)*	3.2%	81 *(1284)*
	SU	32	735.93 *(2414.47)*	712.97 *(2339.14)*	564.3 *(1851.4)*	4.1%	92 *(1458)*
	SU	33	752.39 *(2468.47)*	710.97 *(2332.58)*	366.6 *(1202.8)*	11.3%	161 *(2552)*
	SU	34	758.86 *(2489.70)*	710.97 *(2332.58)*	426 *(1398)*	11.2%	160 *(2536)*
	PU	9	720.96 *(2365.35)*	697.96 *(2289.90)*	752 *(2467)*	3.1%	149 *(2362)*
	PU	10	712.97 *(2339.14)*	698.96 *(2293.18)*	799.8 *(2624.0)*	1.8%	110 *(1744)*
	PU	11	710.97 *(2332.58)*	709 *(2326)*	79.5 *(260.8)*	2.5%	133 *(2108)*
	PU	12	730.78 *(2397.57)*	699.98 *(2296.52)*	598.7 *(1964.2)*	5.1%	197 *(3123)*
S11	SU	35	731.36 *(2399.48)*	705.94 *(2316.08)*	452.6 *(1484.9)*	5.6%	110 *(1744)*
	SU	36	734.01 *(2408.17)*	712.95 *(2339.07)*	317.4 *(1041.3)*	6.6%	120 *(1902)*
	SU	37	740.88 *(2430.71)*	723.11 *(2372.41)*	268 *(879)*	6.6%	120 *(1902)*
	SU	38	735.97 *(2414.60)*	717.94 *(2355.45)*	397.7 *(1304.8)*	4.5%	98 *(1553)*
	SU	39	777.29 *(2550.16)*	751.61 *(2465.91)*	238 *(781)*	10.8%	157 *(2489)*
	PU	13	755.98 *(2480.25)*	696.97 *(2286.65)*	1995.8 *(6547.9)*	3.0%	146 *(2314)*
	PU	14	782.91 *(2568.60)*	723.97 *(2375.23)*	1246.1 *(4088.3)*	4.7%	188 *(2980)*
	PU	15	724.99 *(2378.58)*	710.29 *(2330.35)*	678.7 (2226.7)	2.2%	123 *(1950)*
	PU	16	725.98 *(2381.82)*	723 *(2372)*	185.4 *(608.3)*	1.6%	105 *(1664)*
S12	SU	40	755.45 *(2478.51)*	740.96 *(2430.97)*	319.4 *(1047.9)*	4.5%	98 *(1553)*
	SU	41	782.86 *(2568.44)*	751.99 *(2467.16)*	248.8 *(816.3)*	12.4%	169 *(2679)*
	SU	42	781.09 *(2562.63)*	756.97 *(2483.50)*	437.78 *(1436.4)*	5.5%	109 *(1728)*
	SU	43	772.18 *(2533.40)*	766 *(2513)*	143.02 *(469.23)*	4.3%	96 *(1521)*
	SU	44	797.36 *(2616.01)*	766.95 *(2516.24)*	315.9 *(1036.4)*	9.6%	147 *(2330)*
	PU	17	831.22 *(2727.10))*	738.99 *(2424.51)*	1518 *(4980)*	6.1%	215 *(3408)*

* Refer to Figure 2.1 in the memorandum main text for drain locations.

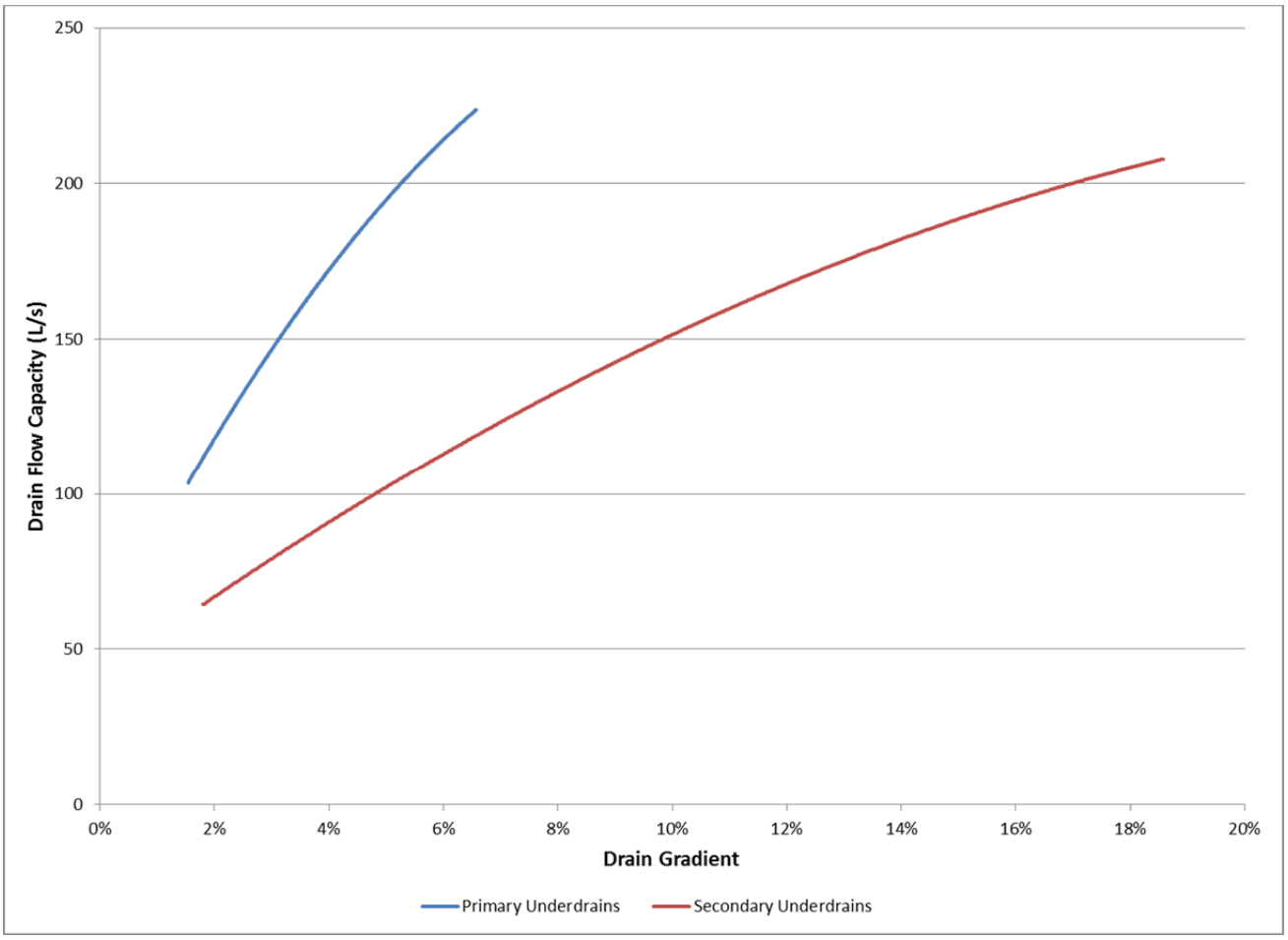


Figure 1 Relationship between Drain Flow Capacity and Drain Gradient

APPENDIX XI

Operational Water Balance

MEMORANDUM

TO: FILE **DATE:** September 5, 2014

FROM: Katty Wang **FILE NO:** M09441A14.730

SUBJECT: Appendix XI - Operational Water Balance

1 INTRODUCTION

This memorandum presents the water balance methodology and results for the Near West Tailings Storage Facility (TSF).

1.1 Model methodology and Assumptions

The water balance was modeled in GoldSim as three facilities, each facility containing its own water balance calculation:

1. West Plant;
2. Tailings Storage Facility (TSF); and
3. Seepage Collection Pond (SCP).

The process flow schematic and the inflows and outflows of each facility are shown in Figure 1.

The TSF was modeled as two cells (East Cell and West Cell) to reflect the tailings deposition plan and to enable independent tracking of water balance inputs and outputs into the two cells.
The tailings deposition plan is summarized as follows:

- From Year 1 to Year 10, thickened scavenger and cleaner tailings will be deposited into the East Cell (regarded as the main facility).
- From Year 11 to Year 17, cleaner tailings will be deposited into the East Cell; while scavenger tailings will be deposited into both the East and West Cells at varying ratios.
- From Year 18 onwards, the East and West Cells are considered to have merged together as one entity; both scavenger and cleaner tailings will be deposited into the merged facility which will maintain the name East Cell.

Excess water from the East Cell will be reclaimed to the West Plant at all times; whereas excess water from the West Cell will be reclaimed to the East Cell.

The SCP is made up of 11 individual seepage collection dams. For model simplicity, the SCP was modeled as one entity with no storage capacity. All runoff and seepage inputs to the SCP will be reclaimed back to the East Cell.

Water requirements for dust management have not been incorporated into the water balance at this stage of design. The dust management plan is shown in Figure 9.3 and discussed in Section 9.5 of the main report; the plan will limit the use of water as a dust suppressant as much as possible. Water usage for suppressing dust is expected to be less than 5% of the total make-up water requirements.

2 MODEL INPUT

The inputs to the water balance model are presented in the following sections.

2.1 Climate and Catchment Data

Table 2.1 presents the monthly average precipitation and evaporation data for the Near West Site. Both the precipitation and pan evaporation data were obtained from the Western Regional Climate Center (WRCC 2013). Monthly average free water surface (FWS) evaporation rates were obtained by multiplying monthly pan evaporation rates by the pan coefficient of 0.7. Details on climate data can be found in Appendix III of this report.

Table 2.1 Monthly Average Precipitation and Evaporation Rates

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation[1] (mm)	55	59	54	16	9	6	50	74	40	23	36	52	474
Pan Evaporation[2] (mm)	62	90	150	219	304	368	365	312	257	172	93	59	2,451
FWS Evaporation (mm)	43	63	105	153	213	258	256	218	180	120	65	41	1,715
Precipitation (inches)	*2.2*	*2.3*	*2.1*	*0.6*	*0.4*	*0.2*	*2.0*	*2.9*	*1.6*	*0.9*	*1.4*	*2.1*	*18.7*
Pan Evaporation (inches)	*2.4*	*3.5*	*5.9*	*8.6*	*12.0*	*14.5*	*14.4*	*12.3*	*10.1*	*6.8*	*3.7*	*2.3*	*96.5*
FWS Evaporation (inches)	*1.7*	*2.5*	*4.1*	*6.0*	*8.4*	*10.2*	*10.1*	*8.6*	*7.1*	*4.7*	*2.6*	*1.6*	*67.5*

Notes:
1. Average precipitation data obtained from Superior station Lat. 33.300° Long. -111.100° (1981-2010)
2. Average evaporation data obtained from Roosevelt 1 WNW station Lat. 33.667° Long. -111.150° (1905-2005)

Table 2.2 presents the percent wetted beach, and runoff coefficients for natural catchment and on dry tailings beach. During operation, 33% of the tailings beach area is assumed to be a wetted surface, receiving 100% of precipitation and evaporation over the area. The remaining 67% of the tailings beach is assumed to be dry beach with a runoff coefficient of 0.15 to calculate runoff. The remaining 85% of precipitation on the dry beach is assumed to be eventually lost to evaporation. Details on the derivation of runoff coefficients can be found in Appendix III of this report.

Table 2.2 Runoff Coefficients and Percent Wetted Beach

Percent Wetted Beach	Natural Catchment	Dry Tailings Beach
33%	0.15	0.15

2.2 Catchment Areas

Table 2.3 presents the catchment areas that contribute runoff to the TSF and SCP.

The site wide water balance contributing areas consist of the tailings beach area, pond area, undiverted natural catchments to the TSF and SCP, and the dam slope area. The total contributing area is 12.2 km^2 *(4.7 sq mi)* from Year 1 to Year 10, and increases to 16.8 km^2 *(6.5 sq mi)* in Year 11 due to the addition of the West Cell. In Year 30, the total contributing area reduces from 16.8 km^2 *(6.5 sq mi)* to 16.3 km^2 *(6.3 sq mi)*, due to the construction of the north dams upstream of the TSF to El. 830 m which allows upstream water to be diverted away.

Table 2.3 TSF Catchment Information

Year	East Cell Catchment Areas (m^2) *(sq ft)*						West Cell Catchment Areas (m^2) *(sq ft)*						Total Contributing Areas (m^2) *(sq ft)*
	Beach Area (Scavenger and Cleaner)	Pond Area (Scavenger and Cleaner)	Natural Catchment to TSF[1]	Dam Slope Area	Natural Catchment to SCP	East Cell Total	Beach Area (Scavenger and Cleaner)	Pond Area (Scavenger and Cleaner)	Natural Catchment to TSF	Dam Slope Area	Natural Catchment to SCP	West Cell Total	East Cell and West Cell Total
0	-	-	-	-	-	-	-	-	-	-	-	-	-
1	194,016 *(2,088,370)*	465,592 *(5,011,591)*	9,524,784 *(102,523,922)*	90,220 *(971,120)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
2	651,284 *(7,010,363)*	527,166 *(5,674,368)*	8,969,958 *(96,551,824)*	126,204 *(1,358,449)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
3	1,009,033 *(10,861,141)*	501,415 *(5,397,186)*	8,587,402 *(92,434,026)*	176,762 *(1,902,650)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
4	1,318,834 *(14,195,811)*	645,193 *(6,944,800)*	8,025,340 *(86,384,041)*	285,245 *(3,070,352)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
5	1,548,988 *(16,673,168)*	752,721 *(8,102,221)*	7,564,013 *(81,418,358)*	408,890 *(4,401,255)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
6	1,749,178 *(18,827,995)*	890,451 *(9,584,735)*	7,044,589 *(75,827,325))*	590,394 *(6,354,948)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
7	1,850,484 *(19,918,444)*	1,005,389 *(10,821,917)*	6,634,261 *(71,410,591)*	784,478 *(8,444,051)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
8	2,464,518 *(26,527,851)*	846,034 *(9,106,634)*	5,978,460 *(64,351,608)*	985,600 *(10,608,910)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
9	2,680,570 *(28,853,415)*	1,057,152 *(11,379,089)*	5,326,495 *(57,333,915)*	1,210,395 *(13,028,583)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
10	3,038,074 *(32,701,556)*	1,010,532 *(10,877,276)*	4,839,143 *(52,088,102)*	1,386,863 *(14,928,069)*	1,894,121 *(20,388,149)*	12,168,733 *(130,983,152)*	-	-	-	-	-	-	12,168,733 *(130,983,152)*
11	2,661,509 *(28,648,244)*	1,540,505 *(16,581,858)*	4,925,834 *(53,021,236)*	641,511 *(6,905,167)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	742,032 *(7,987,166)*	871,474 *(9,380,468)*	3,231,093 *(34,779,196)*	785,313 *(8,453,039)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
12	2,879,305 *(30,992,581)*	1,431,516 *(15,408,710)*	4,948,661 *(53,266,944)*	509,877 *(5,488,270)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	1,374,597 *(14,796,039)*	814,250 *(8,764,514)*	2,361,205 *(25,415,799)*	1,079,860 *(11,623,516)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
13	2,814,653 *(30,296,673)*	1,619,684 *(17,434,133)*	4,956,100 *(53,347,016)*	378,922 *(4,078,682)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	1,656,518 *(17,830,611)*	773,324 *(8,323,990)*	1,782,676 *(19,188,545)*	1,417,394 *(15,256,702)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
14	2,988,103 *(32,163,673)*	1,613,700 *(17,369,722)*	4,918,309 *(52,940,237)*	249,247 *(2,682,872)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	1,845,806 *(19,868,090)*	815,389 *(8,776,774)*	1,196,188 *(12,875,660)*	1,772,529 *(19,079,343)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
15	3,176,572 *(34,192,336)*	1,452,172 *(15,631,049)*	4,946,670 *(53,245,513)*	193,945 *(2,087,607)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	1,796,462 *(19,336,956)*	870,561 *(9,370,641)*	819,796 *(8,824,211)*	2,143,093 *(23,068,061)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
16	3,759,990 *(40,472,196)*	1,284,915 *(13,830,710)*	4,530,509 *(48,765,993)*	193,945 *(2,087,607)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	2,130,863 *(22,936,418)*	847,150 *(9,118,647)*	508,806 *(5,476,742)*	2,143,093 *(23,068,061)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
17	4,115,461 *(44,298,454)*	998,696 *(10,749,874)*	4,543,194 *(48,902,533)*	112,008 *(1,205,644)*	1,364,822 *(14,690,822)*	11,134,181 *(119,847,327)*	2,233,886 *(24,045,349)*	886,811 *(9,545,554)*	145,811 *(1,569,497)*	2,363,404 *(25,439,469)*	-	5,629,912 *(57,370,695)*	16,764,093 *(180,447,195)*
18	5,364,228 *(57,740,070)*	2,501,322 *(26,924,006)*	4,863,169 *(52,346,715)*	2,670,552 *(28,745,582)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
19	5,747,635 *(61,867,028)*	2,719,499 *(29,272,444)*	4,103,651 *(44,171,332)*	2,828,486 *(30,445,570)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
20	6,201,436 *(66,751,702)*	2,387,087 *(25,694,391)*	3,665,143 *(39,451,271)*	3,145,605 *(33,859,010)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
21	6,410,325 *(69,000,164)*	2,357,273 *(25,373,475)*	3,328,067 *(35,823,015)*	3,303,606 *(35,559,719)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
22	6,794,581 *(73,136,261)*	2,278,800 *(24,528,799)*	3,022,284 *(32,531,594)*	3,303,606 *(35,559,719)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
23	6,495,673	2,333,190	2,792,801	3,777,608	1,364,822	16,764,093	-	-	-	-	-	-	16,764,093

Year	East Cell Catchment Areas (m^2) *(sq ft)*						West Cell Catchment Areas (m^2) *(sq ft)*						Total Contributing Areas (m^2) *(sq ft)*
	Beach Area (Scavenger and Cleaner)	Pond Area (Scavenger and Cleaner)	Natural Catchment to TSF[1]	Dam Slope Area	Natural Catchment to SCP	East Cell Total	Beach Area (Scavenger and Cleaner)	Pond Area (Scavenger and Cleaner)	Natural Catchment to TSF	Dam Slope Area	Natural Catchment to SCP	West Cell Total	East Cell and West Cell Total
	(69,918,842)	*(25,114,248)*	*(30,061,460)*	*(40,661,834)*	*(14,690,822)*	*(180,447,195)*							*(180,447,195)*
24	6,655,516 *(26,527,851)*	2,495,919 *(26,865,849)*	2,470,228 *(26,589,313)*	3,777,608 *(40,661,834)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
25	6,539,349 *(70,388,967)*	2,803,076 *(30,172,059)*	2,279,238 *(24,533,514)*	3,777,608 *(40,661,834)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
26	7,378,491 *(79,421,416)*	2,194,720 *(23,623,769)*	2,048,452 *(22,049,354)*	3,777,608 *(40,661,834)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
27	7,558,321 *(81,357,090)*	1,823,097 *(19,623,653)*	1,758,993 *(18,933,643)*	4,258,860 *(45,841,988)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
28	7,734,889 *(83,257,652)*	1,791,245 *(19,280,801)*	1,614,278 *(17,375,944)*	4,258,860 *(45,841,988)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
29	7,984,873 *(85,948,458)*	1,666,905 *(17,942,416)*	1,488,633 *(16,023,512)*	4,258,860 *(45,841,988)*	1,364,822 *(14,690,822)*	16,764,093 *(180,447,195)*	-	-	-	-	-	-	16,764,093 *(180,447,195)*
30	7,493,338 *(80,658,619)*	1,705,360 *(18,356,342)*	950,686 *(10,233,099)*	4,750,077 *(51,129,403)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
31	7,568,021 *(81,461,500)*	1,720,997 *(18,524,658)*	860,366 *(9,260,903)*	4,750,077 *(51,129,403)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
32	7,624,718 *(82,071,782)*	1,743,420 *(18,766,017)*	781,246 *(8,409,262)*	4,750,077 *(51,129,403)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
33	7,739,899 *(83311579)*	1,715,699 *(18,467,630)*	693,786 *(7,467,850)*	4,750,077 *(51,129,403)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
34	7,264,882 *(78,198,539)*	1,704,436 *(18,346,396)*	688,046 *(7,406,066)*	5,242,097 *(56,425,463)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
35	7,358,513 *(79,206,375)*	1,734,885 *(18,674,147)*	563,966 *(6,070,480)*	5,242,097 *(56,425,463)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
36	7,411,499 *(79,776,711)*	1,737,459 *(18,701,853)*	508,406 *(5,472,437)*	5,242,097 *(56,425,463)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
37	7,330,103 *(78,900,572)*	1,566,515 *(16,861,827)*	517,401 *(5,569,258)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
38	7,477,239 *(80,484,331)*	1,450,639 *(15,614,548)*	486,141 *(5,232,778)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
39	7,621,862 *(82,041,040)*	1,331,816 *(14,335,548)*	460,341 *(4,955,069)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	16,264,283 *(175,067,285)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
40	Calculated[2]	Calculated[2]	318,845 *(3,432,019)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	7,169,109 *(77,167,647)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
41	Calculated[2]	Calculated[2]	318,845 *(3,432,019)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	7,169,109 *(77,167,647)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
42	Calculated[2]	Calculated[2]	318,845 *(3,432,019)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	7,169,109 *(77,167,647)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
43	Calculated[2]	Calculated[2]	318,845 *(3,432,019)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	7,169,109 *(77,167,647)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
44	Calculated[2]	Calculated[2]	318,845 *(3,432,019)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	7,169,109 *(77,167,647)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*
45	Calculated[2]	Calculated[2]	318,845 *(3,432,019)*	5,485,442 *(59,044,806)*	1,364,822 *(14,690,822)*	7,169,109 *(77,167,647)*	-	-	-	-	-	-	16,264,283 *(175,067,285)*

Notes: 1. The TSF embankment crest area is accounted under the natural catchment to TSF area.
2. Pond areas are calculated in the model using the ultimate TSF volume-area-elevation curve in Figure 3. Beach areas are calculated by subtracting pond areas from the rest of the contributing areas.

2.3 Tailings Data

This section presents the tailings annual production rates (Figure 2), tailings properties (Table 2.4) and tailings mill water requirement (Table 2.5).

Table 2.4 Tailings Properties

Tailings	Transport % solids	Dry Density (t/m^3) *(pcf)*	Specific Gravity	In Situ Saturated Water Content
Thickened Scavenger	65% (Note 1)	1.4 *(87.4)*	2.67	0.34
Thickened Cleaner	55% (Note 1)	1.7 *(106.1)*	3.54	0.31

Notes:
1. Minor changes in the % solids will affect the magnitude of the internal flows for the water balance, but will not significantly affect the overall water balance. The scavenger tailings slurry density will be between 58% to 65% solids. The cleaner tailings slurry density will be between 50% to 60% solids.

Table 2.5 Tailings Mill Water Requirement

Tailings Mill Water Requirement[1] (% solids)
30%

Note:
1. The assumed water required to process tailings at the mill.

2.4 Operating Pond Volume

Table 2.6 presents the operating pond volumes at the east and west TSF. The operating pond volumes were calculated based on providing 20 day retention time for the incoming tailings slurry water to the TSF.

Table 2.6 Operating Pond Volumes

Year	East TSF (m^3) *(acre-ft)*	West TSF (m^3) *(acre-ft)*
0	1,000,000 *(810.7)*	0
1	1,000,000 *(810.7)*	0
2	1,039,800 *(843.0)*	0
3	1,052,500 *(853.3)*	0
4	2,015,100 *(1,633.7)*	0
5	2,959,900 *(2,399.6)*	0
6	3,905,400 *(3,166.2)*	0
7	4,632,300 *(3,755.5)*	0
8	5,280,300 *(4,280.8)*	0
9	5,267,800 *(4,270.7)*	0
10	5,290,000 *(4,288.7)*	0
11	3,000,000* *(2,432.1)*	4,540,600 *(3,681.1)*

Year	East TSF (m^3) *(acre-ft)*	West TSF (m^3) *(acre-ft)*
12	3,000,000* *(2,432.1)*	4,598,800 *(3,728.3)*
13	3,000,000* *(2,432.1)*	4,503,200 *(3,650.8)*
14	3,000,000* *(2,432.1)*	4,737,800 *(3,841.0)*
15	3,000,000* *(2,432.1)*	4,762,700 *(3,861.2)*
16	3,000,000* *(2,432.1)*	4,729,200 *(3,834.0)*
17	3,000,000* *(2,432.1)*	4,678,300 *(3,792.8)*
18	5,350,300 *(4,337.6)*	0
19	5,361,500 *(4,346.6)*	0
20	5,373,500 *(4,356.4)*	0
21	5,384,800 *(4,365.5)*	0
22	5,383,300 *(4,364.3)*	0
23	5,363,800 *(4,348.5)*	0
24	5,351,400 *(4,338.5)*	0
25	5,351,300 *(4,338.4)*	0
26	5,363,700 *(4,348.4)*	0
27	5,378,500 *(4,360.4)*	0
28	5,379,600 *(4,361.3)*	0
29	5,368,800 *(4,352.6)*	0
30	5,365,500 *(4,349.9)*	0
31	5,378,600 *(4,360.5)*	0
32	5,397,400 *(4,375.7)*	0
33	5,397,400 *(4,375.7)*	0
34	5,397,400 *(4,375.7)*	0
35	5,397,400 *(4,375.7)*	0
36	5,397,400 *(4,375.7)*	0
37	3,797,600 *(3,078.8)*	0
38	2,947,200 *(2,389.3)*	0
39	2,161,400 *(1,752.3)*	0
40	2,000,000* *(1,621.4)*	0
41	2,000,000* *(1,621.4)*	0
42	2,000,000* *(1,621.4)*	0
43	2,000,000* *(1,621.4)*	0
44	2,000,000* *(1,621.4)*	0
45	2,000,000* *(1,621.4)*	0

Note:
* Extra pond volume was provided for the East TSF from Year 11 to Year 17 and from Year 40 to Year 45 to maintain saturation of cleaner tailings.

2.5 Ultimate TSF

Figure 3 presents the ultimate volume-area-elevation curves for the TSF pond. This is used after Year 40 to determine the actual pond area instead of Table 2.3.

2.6 Seepage Rate

Table 2.7 presents the annual seepage rate from the TSF to the SCP which was calculated proportionally to the TSF dam crest length. The seepage rate (calculated from a seepage flux of 0.3 m^3/day/m) was obtained from steady state seepage analysis of the TSF at ultimate configuration, and assumes the tailings beach is saturated 100 m upstream of the dam crest. Details of the seepage analysis can be found in Appendix VI of this report.

Table 2.7 Seepage Rate from the TSF to the SCP

Year	Total Seepage (L/s) *(USgpm)*	Year	Total Seepage (L/s) *(USgpm)*
0	0.0	23	32.4 *(513.6)*
1	6.9 *(109.4)*	24	32.4 *(513.6)*
2	6.9 *(109.4)*	25	32.4 *(513.6)*
3	9.5 *(150.6)*	26	32.4 *(513.6)*
4	11.0 *(174.4)*	27	32.4 *(513.6)*
5	12.5 *(198.1)*	28	32.4 *(513.6)*
6	12.7 *(201.3)*	29	32.4 *(513.6)*
7	13.8 *(218.7)*	30	33.8 *(535.7)*
8	14.2 *(225.1)*	31	33.8 *(535.7)*
9	15.1 *(239.3)*	32	33.8 *(535.7)*
10	15.7 *(248.9)*	33	33.8 *(535.7)*
11	10.3 *(163.3)*	34	33.8 *(535.7)*
12	10.2 *(161.7)*	35	33.8 *(535.7)*
13	10.1 *(160.1)*	36	33.8 *(535.7)*
14	10.1 *(160.1)*	37	33.9 *(537.3)*
15	10.0 *(158.5)*	38	33.9 *(537.3)*
16	10.0 *(158.5)*	39	33.9 *(537.3)*
17	10.0 *(158.5)*	40	33.9 *(537.3)*
18	27.6 *(437.5)*	41	33.9 *(537.3)*
19	28.0 *(443.8)*	42	33.9 *(537.3)*
20	28.5 *(451.7)*	43	33.9*(537.3)*
21	28.5 *(451.7)*	44	33.9 *(537.3)*
22	28.5 *(451.7)*	45	33.9 *(537.3)*

3 MODEL RESULTS

This section presents the water balance results at the TSF, SCP and West Plant. Reclaim and makeup water rates were calculated assuming average climate conditions.

3.1 Tailings Storage Facility

The TSF annual pond volume is shown in Figure 4. From Year 1 to Year 40, the TSF pond is generally in a water surplus condition due to the large slurry water inflow. After Year 40, as slurry water inflow declines and evaporative losses continue, some additional water is required to maintain an operating pond volume of 2.0 Mm^3 *(1621.4 acre-ft)*. This water will likely be sent to the TSF as additional slurry water. The total monthly reclaim rates from the TSF over the years are shown in Figure 5.

East Cell (Total TSF) reclaim to West Plant:

- maximum monthly rate = 767 L/s *(12157 USgpm)*
- average rate = 141 L/s *(2234.9 USgpm)*

3.2 Seepage Collection Pond

Runoff and TSF seepage collected at the SCP is reclaimed back to the East Cell. The SCP reclaim rate to the TSF over the years is illustrated in Figure 6.The SCP reclaim rate increases over time due to increasing dam slope runoff and increasing seepage from the TSF.

Seepage reclaim to East Cell:

- maximum monthly rate = 63 L/s (*998.6 USgpm)*
- average rate = 37 L/s *(586.5 USgpm)*

3.3 West Plant

Figure 7 shows the water balance inflows and outflows at the West Plant. The West Plant processes scavenger and cleaner tailings slurry (to 30% solids) using water recovered from the plant thickeners and water reclaimed from the TSF. The tailings slurry is then pumped to the plant thickeners, where the scavenger tailings slurry is thickened to 65% solids, and the cleaner tailings slurry to 55% solids. Water shortage at the plant is supplemented by makeup water from an external source.

Water recovery from plant thickeners (this is internal water recovery):

- maximum monthly rate = 2357 L/s (*37,359.2 USgpm)*
- average rate = 1745 L/s *(27,658.8 USgpm)*

Total reclaim from TSF:

- maximum monthly rate = 772 L/s *(12,236.4 USgpm)*
- average rate = 141 L/s *(2,234.9 USgpm)*

Required external makeup water to process ore at 30% solids (not including water required with concentrate):

- maximum monthly rate = 772 L/s *(12,236.4 USgpm)*
- average rate = 427 L/s *(6,768.1 USgpm)*

3.4 Site Wide Makeup Water

Figure 8 illustrates the monthly site wide external makeup water requirements during mine operation. The TSF is predicted to require 640 Mm^3 *(518,856 acre-ft)* of makeup water during the entire mine operation. The breakdown of makeup water requirement at the TSF and West Plant are listed below:

- TSF – 20 Mm^3 *(16,214.3 acre-ft)* to maintain TSF pond volume from Year 40 to Year 45 (3% of total makeup water).
- West Plant – 620 Mm^3 *(502,642.2 acre-ft)* (97% of total makeup water).

3.5 Monthly Results – Year 35

To show monthly flow variation, a flow sheet diagram for a typical operational year (Year 35) is presented in Figure 9. The figure gives a snapshot of the flows; the flows will vary with the tailings production rate and TSF surface areas overtime.

3.6 Overall Water Balance

Table 3.1 summarizes the cumulative volumes for the various water balance inflows and outflows over 45 years of mine operation, as well as their relative contribution to the water balance represented by the percent total.

Overall, the system experiences a water deficit over the mine life. Evaporative loss accounts for 36% of the water balance outflow, while entrainment in tailings accounts for the remaining 64% of outflow. The system only receives 15% of its inflow from precipitation and runoff. The remaining 85% of inflow has to be obtained from makeup water from an external source.

Table 3.1 Site Wide Water Balance Cumulative Volumes over 45 years of Mine Operation

Water Balance Components		Cumulative Volume (Mm^3) *(acre-ft)*	% total
Inflows			
East Cell	East Cell pond precipitation	31.4 *(25,456.4)*	4.2%
	East Cell wetted beach precipitation	38.3 *(31,050.3)*	5.1%
	East Cell dry beach runoff	11.7 *(9,485.3)*	1.6%
	East Cell natural catchment runoff	10.5 *(8,512.5)*	1.4%
West Cell	West Cell pond precipitation	2.8 *(2,270.0)*	0.4%
	West Cell wetted beach precipitation	1.8 *(1,459.3)*	0.2%

Water Balance Components		Cumulative Volume (Mm^3) *(acre-ft)*	% total
	West Cell dry beach runoff	0.6 *(486.4)*	0.1%
	West Cell natural catchment runoff	0.7 *(567.5)*	0.1%
SCP	Dam slope runoff to SCP	10.5 *(8,512.5)*	1.4%
	Natural catchment runoff to SCP	4.7 *(3,810.4)*	0.6%
Makeup water	TSF makeup water	19.6 *(15,890.0)*	2.6%
	West Plant makeup water	620.0 *(502642.2)*	82.3%
Pond Volume	Initial pond volume	1.0 *(810.7)*	0.1%
Total Inflows		753.6 *(610,953.5)*	100%
Outflows			
East Cell	East Cell pond evaporation	113.5 *(92,015.9)*	15.1%
	East Cell wetted beach evaporation	138.3 *(112,121.6)*	18.3%
	East Cell scavenger entrainment	345.9 *(280,425.7)*	45.9%
	East Cell cleaner entrainment	54.5 *(44183.9)*	7.2%
West Cell	West Cell pond evaporation	10.1 *(8188.2)*	1.3%
	West Cell wetted beach evaporation	6.7 *(5,431.8)*	0.9%
	West Cell scavenger entrainment	82.6 *(66,964.9)*	11.0%
Pond Volume	Final pond volume	2.1 *(1,702.5)*	0.3%
Total Outflows		753.7 *(611,034.5)*	100%

Note:
1. Seepage from the TSF is assumed to be 100% reclaimed at the SCP. It is considered an internal flow and is therefore not listed here as a site wide water balance component.

4 CONCLUSION

The reclaim and makeup rates for the TSF system, assuming average climate conditions, are presented in Table 4.1.

Table 4.1 Flow Rate Summary

Flow Description	Maximum Monthly Rate (L/s) *(USgpm)*	Average Annual Rate (L/s)
TSF reclaim to West Plant	767 *(12,157.2)*	141 *(2,234.9)*
SCF reclaim to TSF	63 *(998.6)*	37 *(586.5)*
Makeup water at West Plant	772 *(12,236.4)*	427 *(6,768.1)*
Makeup water at TSF (after Year 40)	307 *(4,866.0)*	63 *(998.6)*

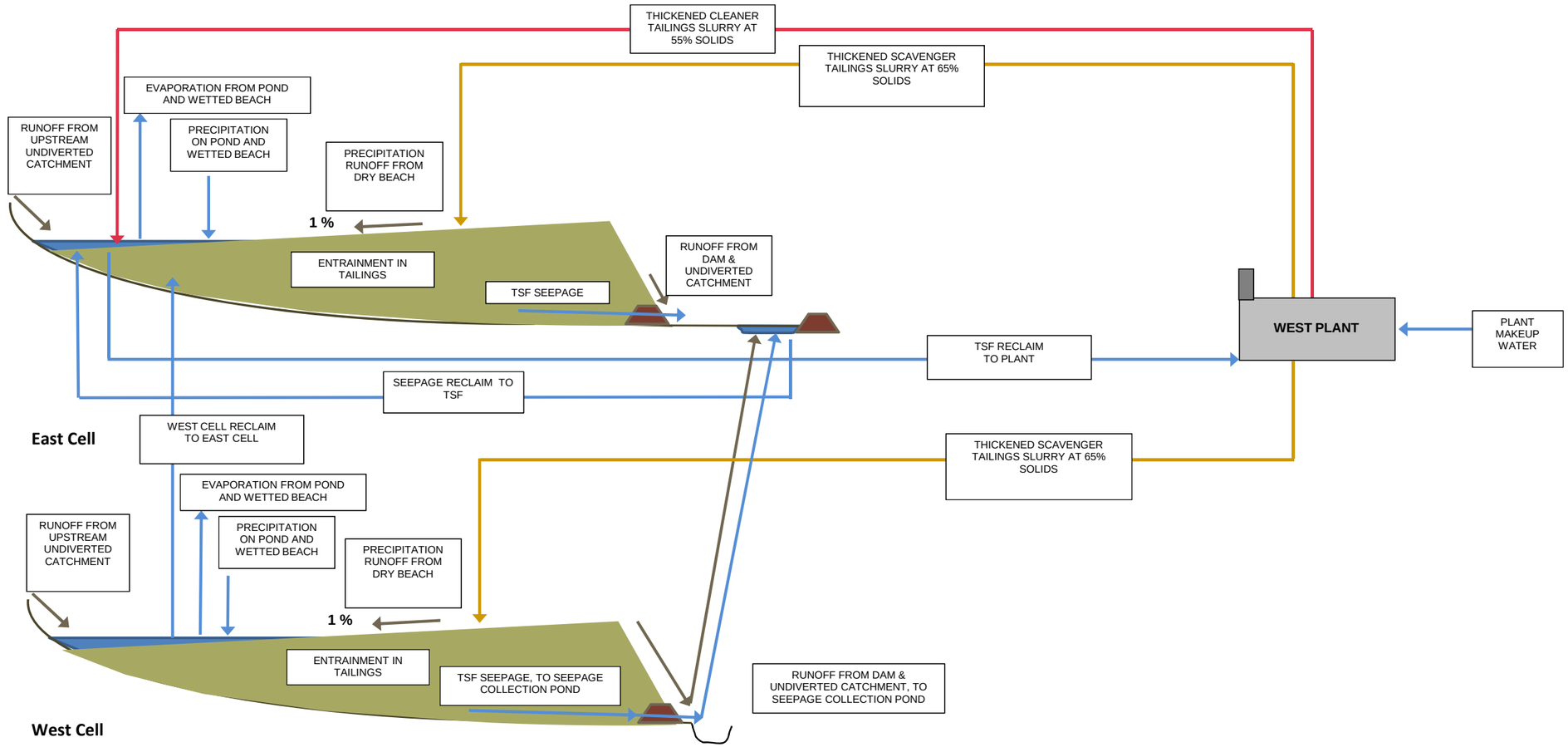
According to the model results, the system is predicted to require 640 Mm^3 *(518,856.4 acre-ft)* of makeup water during the entire mine operation, with 97% of the makeup water going to the West Plant and the remaining 3% to the TSF. Rather than supplying water to the TSF directly, the % solids of the tailings can be adjusted to increase the water in the slurry reporting to the TSF.

REFERENCES

Weather Service. 1982. NOAA Technical Report NWS 34. Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States.

Western Regional Climate Center (WRCC). 2013. "Climate Summaries." Accessed April 16, 2013. http://www.wrcc.dri.edu/summary/Climsmaz.html

FIGURES



East and West Cells Tailings Storage Facility (TSF)
Water Balance

Input
Precipitation over pond area
Precipitation over wetted tailings beach (33% of tailings beach)
Precipitation runoff over dry tailings beach (0.15 runoff coefficient on 67% of tailings beach)
Runoff from upstream undiverted catchment (0.15 runoff coefficient)
Thickened scavenger tailings slurry water
Thickened cleaner tailings slurry water
Seepage reclaim to TSF

Output
Evaporation over pond area
Evaporation over wetted tailings beach (33% of tailings beach)
Entrainment in scavenger tailings
Entrainment in cleaner tailings
TSF reclaim to West Plant
TSF seepage (max 34 L/s, collected at seepage collection pond)

Seepage Collection Pond (Note 1)
Water Balance

Input
TSF Seepage (max 34 L/s)
Runoff from dam and undiverted catchment

Output
Seepage reclaim to TSF

West Plant
Water Balance

Input
TSF reclaim to West Plant
Plant makeup water

Output
Thickened scavenger tailings slurry to East and West Cells (at 65% solids)
Thickened cleaner tailings slurry to East Cell (at 55% solids)

Figure 1 Near West Operational Water Balance Schematic

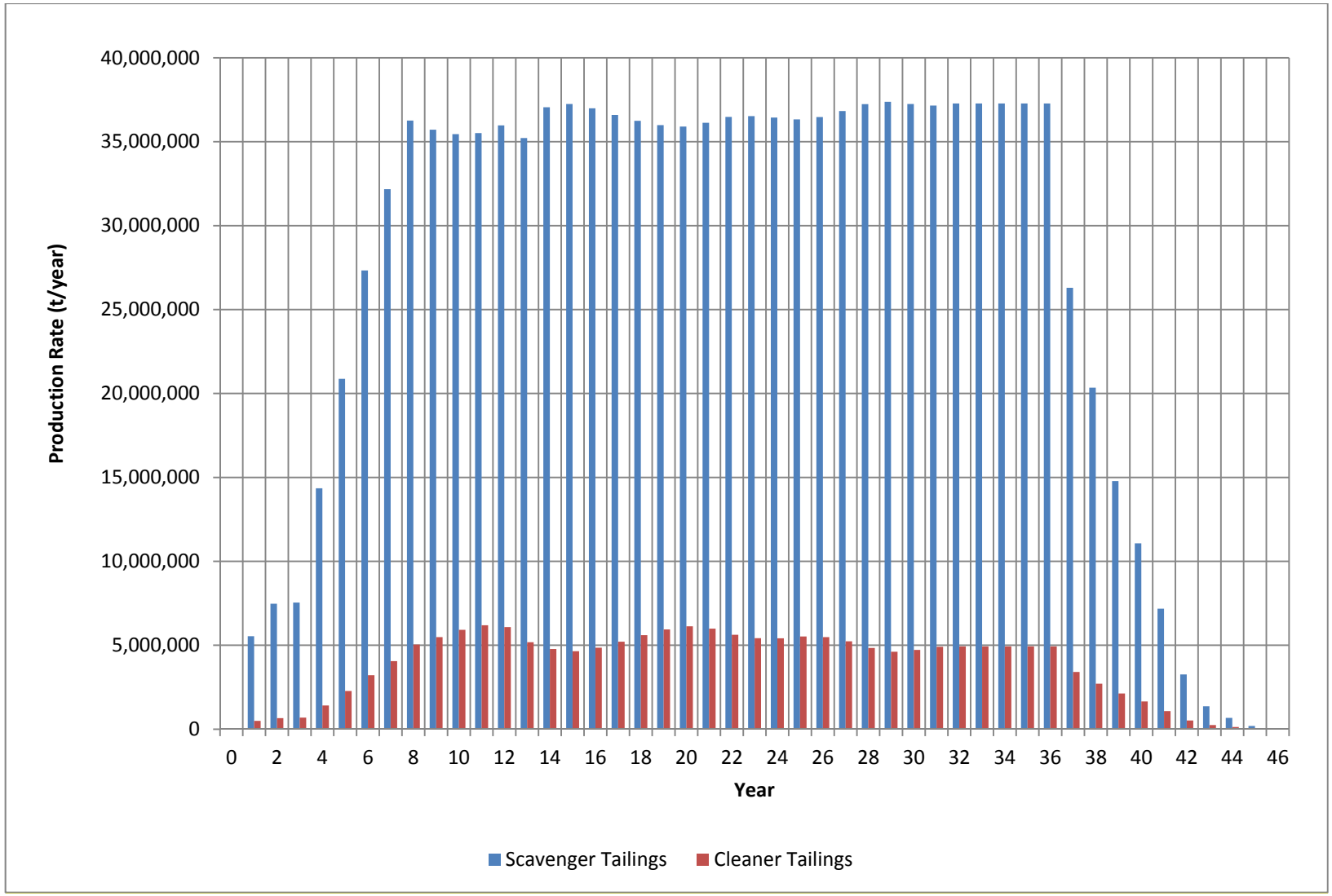


Figure 2 Tailings Annual Production Rates

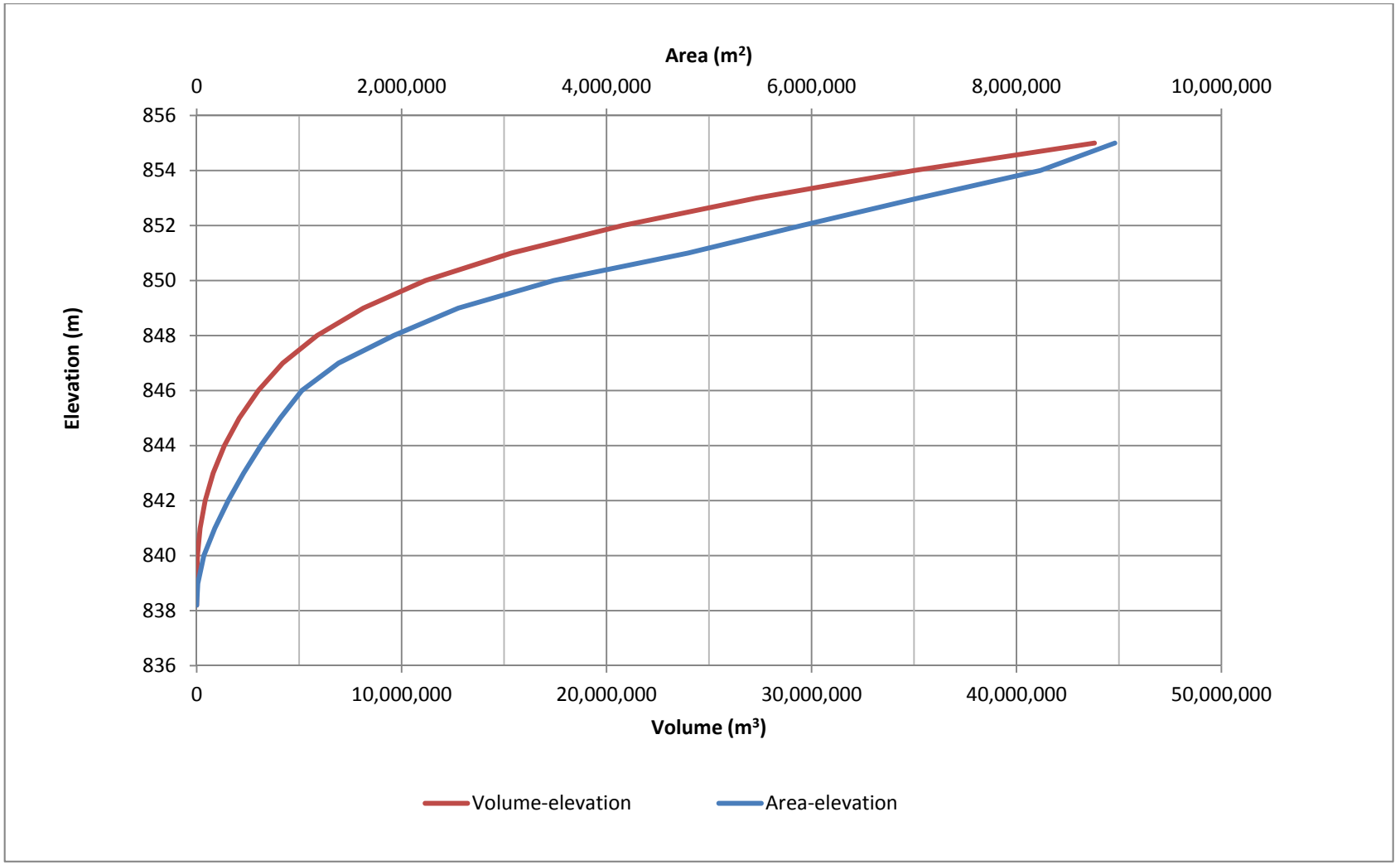


Figure 3 Ultimate TSF Pond Volume-Area-Elevation Curves

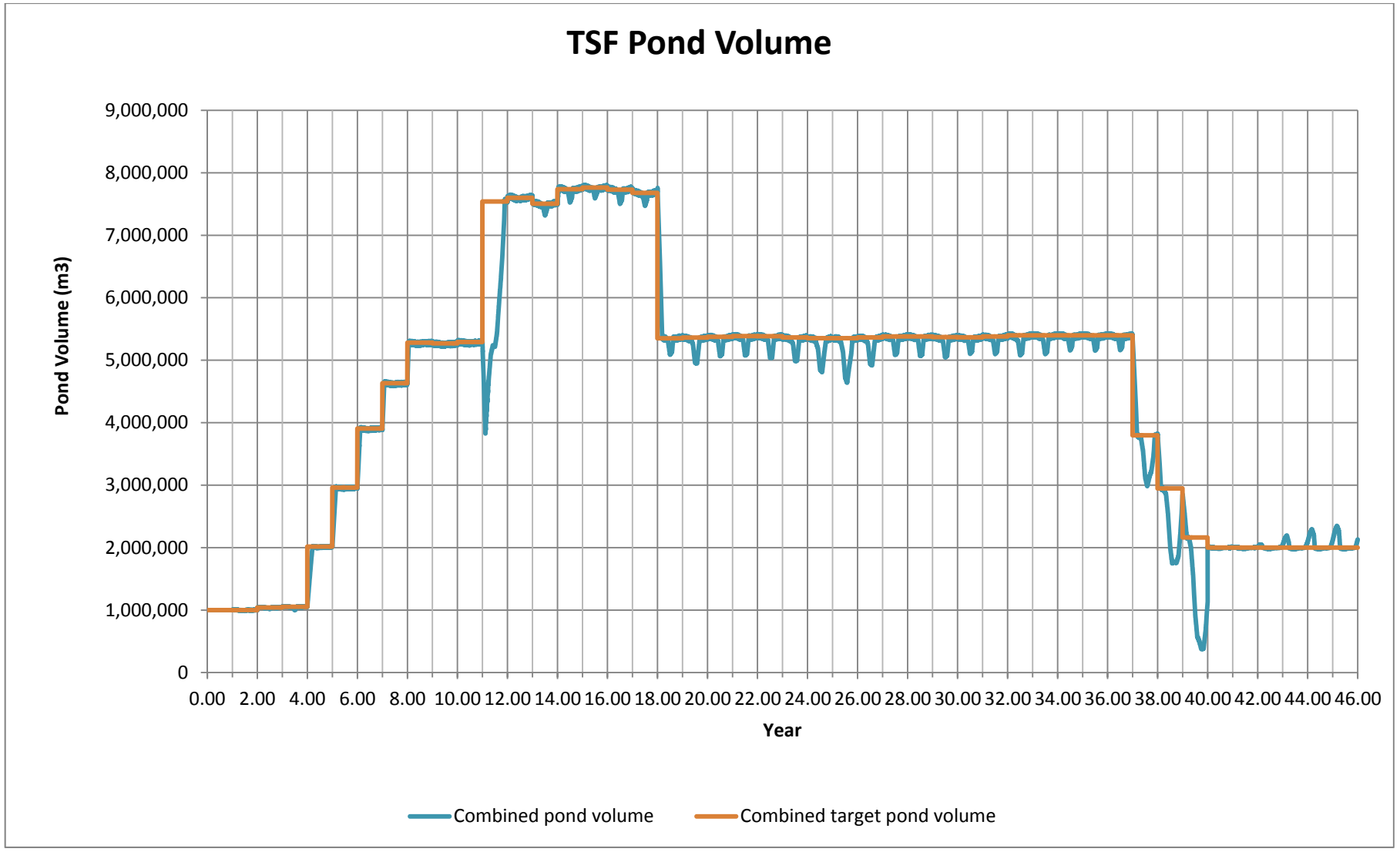


Figure 4 East and West Cell Combined Pond Volume

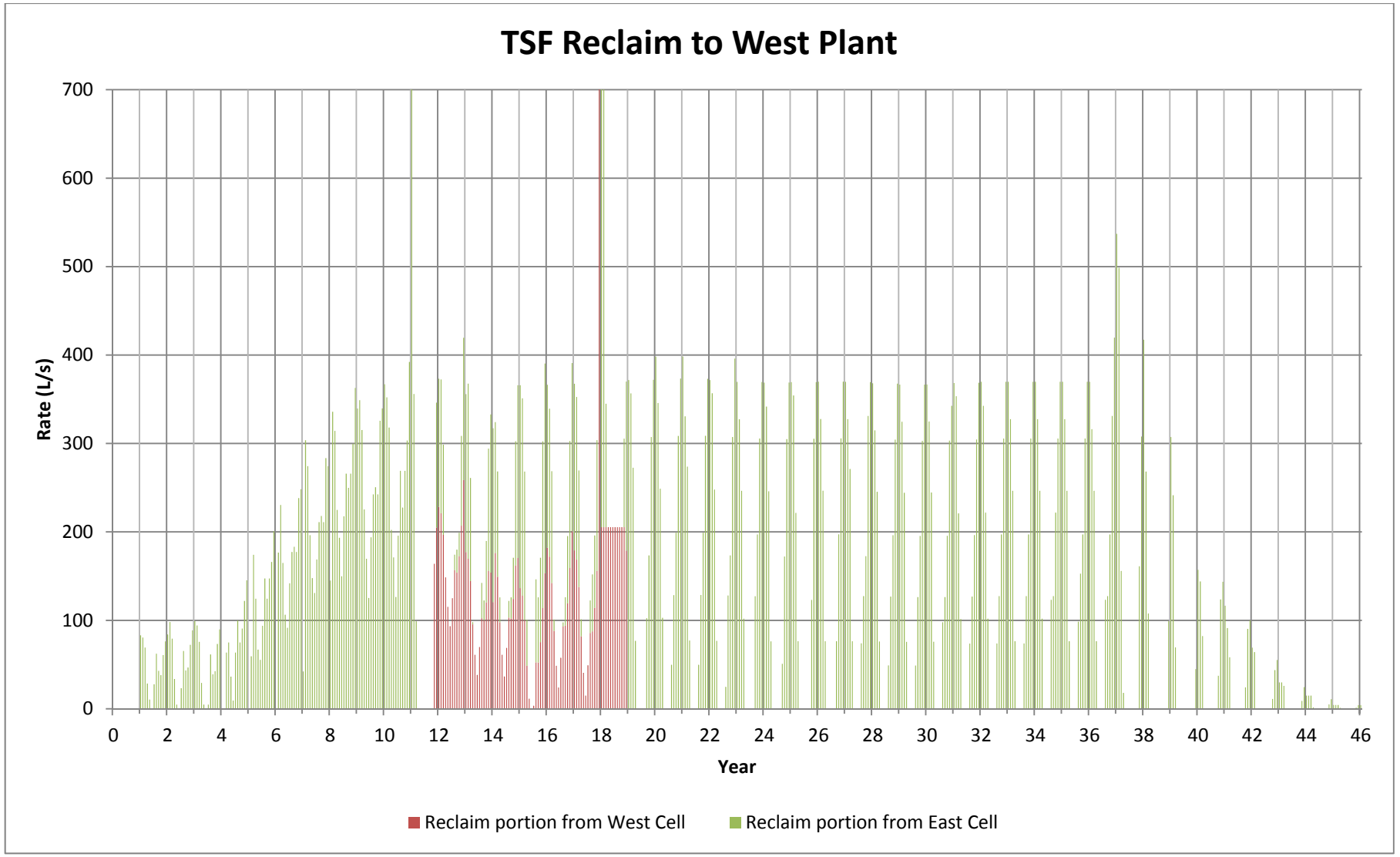


Figure 5 Total TSF reclaim to the West Plant

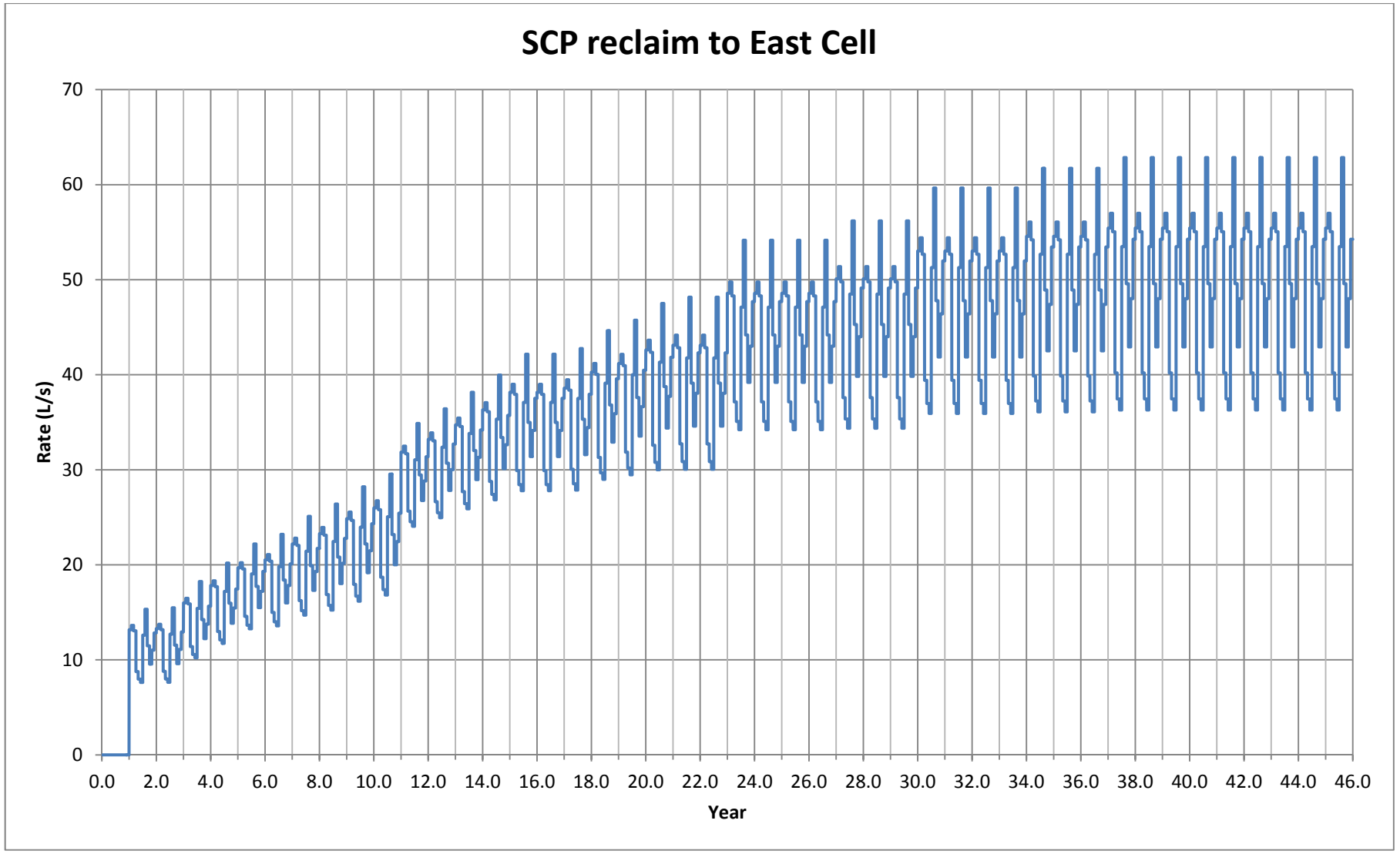


Figure 6 SCP Reclaim to East Cell

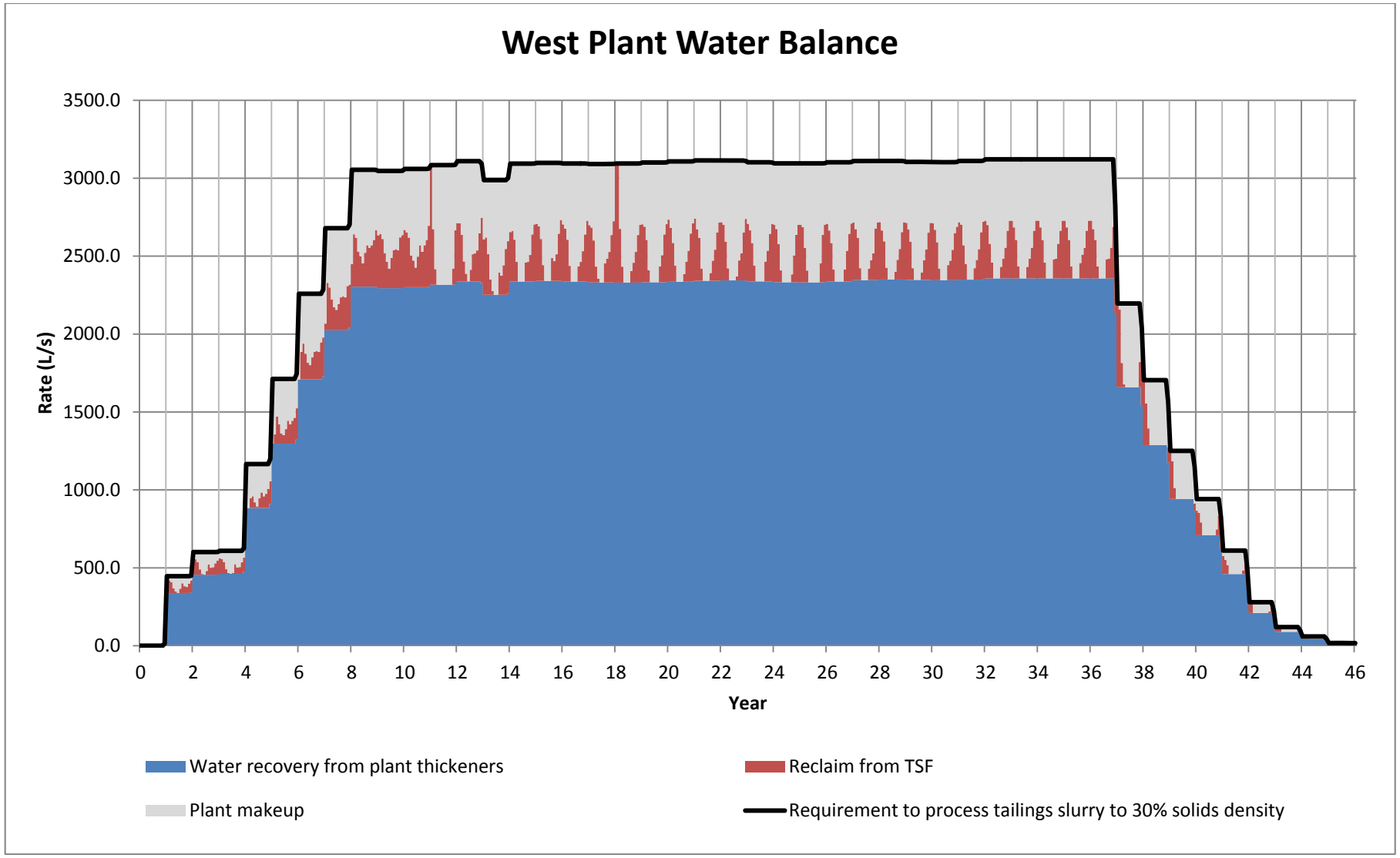


Figure 7 West Plant Water Balance

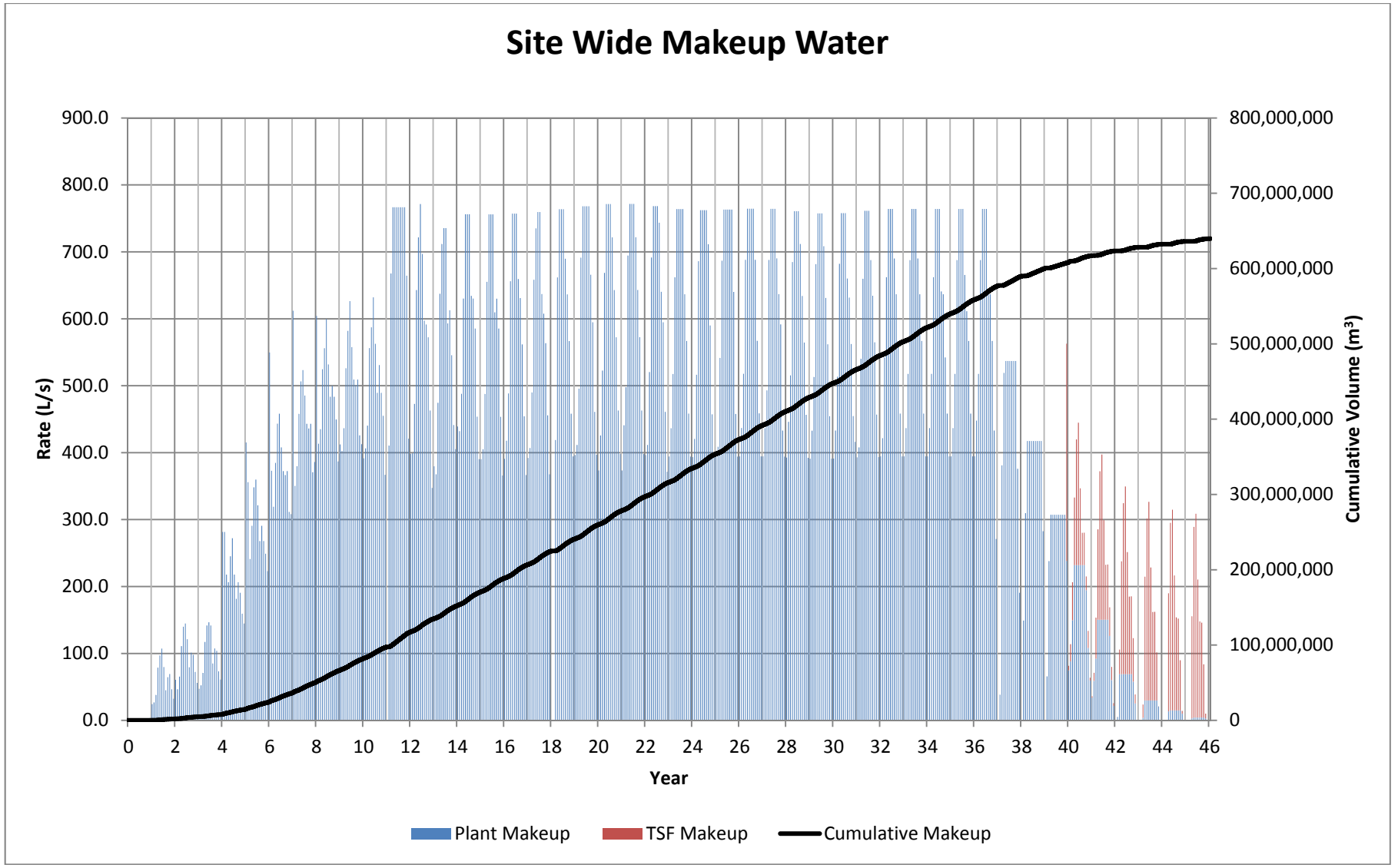
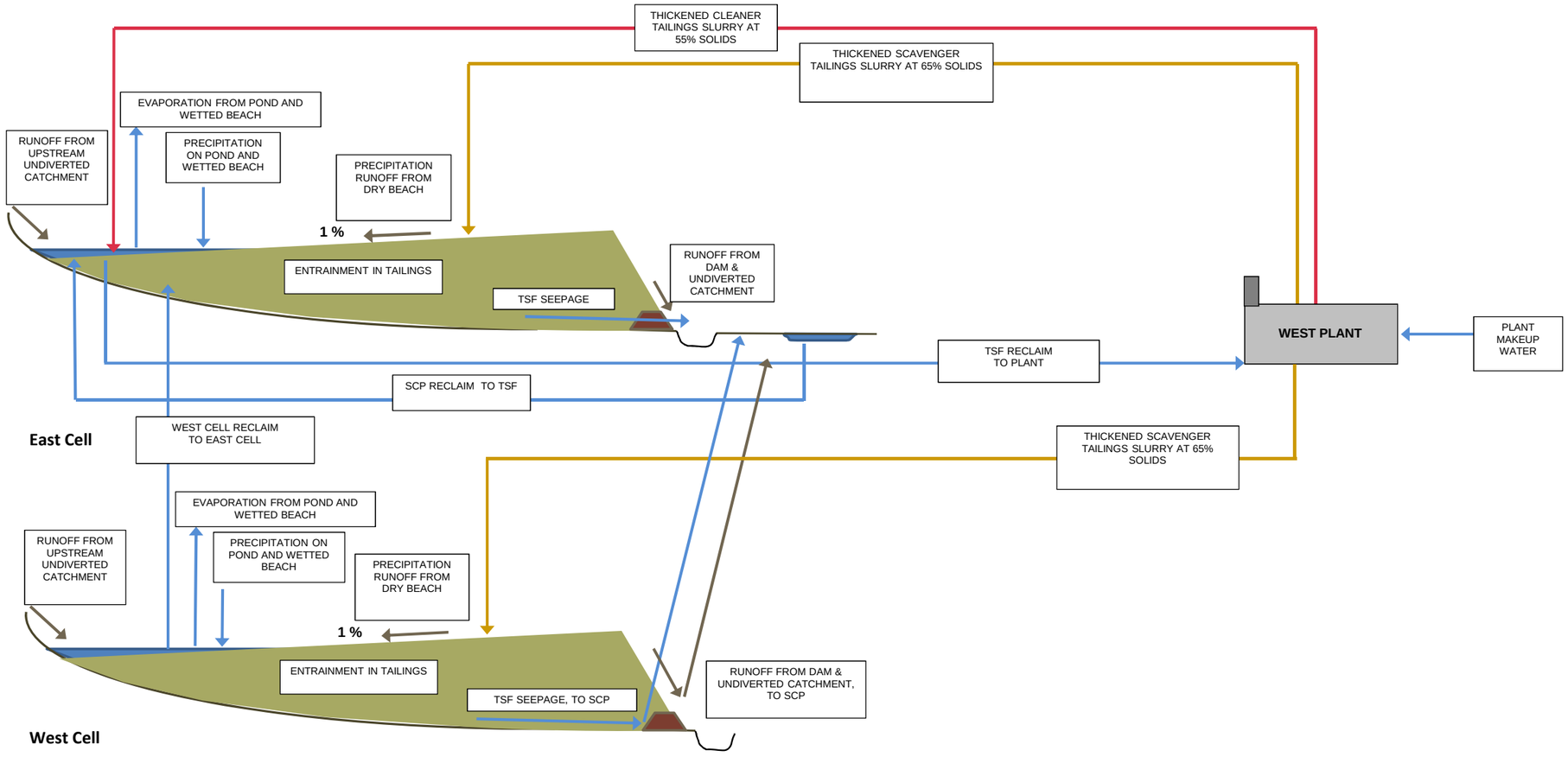


Figure 8 Site Wide Makeup Water



Year 35, Monthly Minimum, Maximum and Average Rates (L/s)

East and West Cells TSF[1]		Min	Max	Average
Input	Precipitation over pond area	5.5	43	26
	Precipitation over wetted tailings beach	7.7	60	37
	Precipitation runoff over dry tailings beach	2.3	18	11
	Runoff from upstream undiverted catchment	0.3	2.1	1.3
	Thickened scavenger tailings slurry water	636	636	636
	Thickened cleaner tailings slurry water	128	128	128
	SCP reclaim to TSF	37	59	49
	TOTAL			**888**
Output	Evaporation over pond area	27	170	94
	Evaporation over wetted tailings beach	38	238	132
	Entrainment in scavenger tailings	401	401	401
	Entrainment in cleaner tailings	48	48	48
	TSF reclaim to West Plant	0	370	179
	TSF seepage	34	34	34
	TOTAL			**887**

Seepage Collection Pond (SCP)		Min	Max	Average
Input	TSF Seepage	34	34	34
	Runoff from dam and undiverted catchment	3.1	25	15
	TOTAL			**49**
Output	SCP reclaim to TSF	37	59	49
	TOTAL			**49**

West Plant		Min	Max	Average
Input	TSF reclaim to West Plant	0	370	179
	Plant makeup water	394	764	585
	TOTAL			**764**
Output	Thickened scavenger tailings slurry	636	636	636
	Thickened cleaner tailings slurry	128	128	128
	TOTAL			**764**

Note:
1. The difference between total inflow and outflow (1 L/s) is due to the slight increase in pond volume in Year 35

Figure 9 Flow Sheet Diagram for Year 35

APPENDIX XII

Mechanical Designs

CLIENT: RESOLUTION

PROJECT: RESOLUTION – NEAR WEST

Near West Seepage System Memorandum

	SIGNATURE	DATE
PREPARED BY:	Tyler Campbell	September 5, 2014
REVIEWED BY:		September 5, 2014
APPROVED BY:		September 5, 2014
APPROVED BY:		

ISSUE/REVISION INDEX

Issue Code	Revision					Revision Details
	No.	By	Rev'd	App.	Date	
RR	A	TC	SC	HP	2013-05-01	
RR	B	TC	SC	HP	2013-05-13	Pond Flow and Head Table Added.
RR	1	TC	SC	HP	2014-09-05	Final

Issue Codes: RC = Released for Construction, RD = Released for Design, RF = Released for Fabrication, RI = Released for Information, RP = Released for Purchase, RQ = Released for Quotation, RR = Released for Review and Comments.

TABLE OF CONTENTS

1. INTRODUCTION 1
2. DESIGN BASIS 1
3. RESULTS 2
4. PIPE QUANTITIES 3
5. DISCLAIMER 4

TABLES

Table 2.1 Design Basis 1
Table 2.2 Seepage System Design Flow and Head Difference 2
Table 3.1 Calculation Results 2
Table 4.1 Pipe Quantities 3

APPENDICES

Appendix I Pipeline Plan and Profile Drawings

Appendix II Hydraulic Grade Lines

Appendix III Seepage Pump Datasheet

1. INTRODUCTION

This memorandum is a concept selection study of the Seepage Transport Systems for the Near West Tailings Facility (TSF). The seepage pipelines extend from the eleven seepage collection ponds up the embankment and discharge onto the tailings beach. Barge pumps will be required at each collection pond. The pipelines will be constructed and extended as required by the increasing height of the TSF. A typical seepage pipeline route for Years 2, 10, 25, and 45 (Ultimate) is shown in Appendix I. Note that the Year 2 route is representative of the start-up condition for Year 0.

2. DESIGN BASIS

Design Basis information for this study is listed in Table 2.1 below. Seepage pond S2 has been selected as a typical representative of the seepage ponds. The Year 45 plan on figure M06 in Appendix I identifies the eleven seepage collection ponds. Design flow rate is based on pumping out the 100-year 24-hour storm event in a period of 14 days, in addition to average seepage and catchment runoff flows.

Table 2.1 Design Basis

Description	Seepage
Solids Concentration by Weight	1%
Specific Gravity	1.01
S2 Pond Grade Elevation	675 m *(2214.57 ft)*
Year 2 Discharge Elevation	740 m *(2427.82 ft)*
Year 10 Discharge Elevation	788 m *(2585.30 ft)*
Year 25 Discharge Elevation	816 m *(2677.17 ft)*
Year 45 Discharge Elevation	855 m *(2805.12 ft)*
Design Flow Rate (Note 1)	324 m^3/hr *(11442 ft^3/hr)*
HDPE Pipe Roughness	.02 mm *(0.00079 inches)*
Steel Pipe Roughness	.05 mm *(0.0020 inches)*
Friction Design Factor (allowance for valves and fittings)	10%

Notes:
1. The design flow rate was chosen to be 90 L/s *(1426.53 USGPM)*, rather than 72 L/s *(1141.23 USGPM)* as shown Table 2.2, to be conservative for "typical" seepage collection pipe design.

Specific flow rate and head requirements by year for each seepage pond are listed in Table 2.2 below. Note these values were not used to design a seepage system for each pond.

Table 2.2 Seepage System Design Flow and Head Difference

SCD	Design Pumping Rate (L/s) *(USGPM)*	Head Difference in Year 2 (m) *(ft)*	Head Difference in Year 10 (m) *(ft)*	Head Difference in Year 25 (m) *(ft)*	Head Difference in Year 45 (m) *(ft)*
S1	213 *(3376.13)*	6 *(19.69)*	72 *(236.22)*	100 *(328.08)*	139 *(456.04)*
S2	72 *(1141.23)*	32 *(104.99)*	98 *(321.52)*	126 *(413.39)*	165 *(541.34)*
S3	79 *(1252.18)*	41 *(134.51)*	107 *(351.05)*	135 *(442.91)*	174 *(570.87)*
S4	87 *(1378.98)*	47 *(154.20)*	113 *(370.74)*	141 *(462.60)*	180 *(590.55)*
S5	26 *(412.11)*	n/a	102 *(334.65)*	130 *(426.51)*	169 *(554.46)*
S6	34 *(538.91)*	n/a	93 *(305.12)*	121 *(396.98)*	160 *(524.93)*
S7	15 *(237.76)*	n/a	93 *(305.12*	121 *(396.98)*	160 *(524.93)*
S8	23 *(364.56)*	n/a	88 *(288.71)*	116 *(380.58)*	155 *(508.53)*
S9	41 *(649.87)*	n/a	88 *(288.71)*	116 *(380.58)*	155 *(508.53)*
S10	110 *(1743.54)*	n/a	88 *(288.71)*	116 *(380.58)*	155 *(508.53)*
S11	72 *(1141.23)*	n/a	48 *(157.48)*	76 *(249.34)*	115 *(377.30)*

3. RESULTS

Each Seepage System consists of a pump barge located on a seepage pond. From the barge a single pipeline heads directly up the embankment to the crest. On the crest the pipeline discharges the seepage water onto the tailings beach where it flows into the Reclaim Pond. HDPE pipe was selected for the pipeline except for a short steel section required in Year 45 which exceeded the pressure rating of HDPE.

Hydraulic grade lines for a typical Seepage Transport System are presented in Appendix II. Calculation results are summarized Table 3.1 below.

Table 3.1 Calculation Results

Description	Result
HDPE Pipeline Size	12” DR6.3 HDPE
HDPE Flow Velocity	2.48 m/s *(8.14 ft/s)*
HDPE Friction Gradient	23.7 m/km *(23.7 ft/1000ft)*
HDPE Maximum Allowable Working Pressure	1666 kPa *(241.63 PSI)*
Steel Pipeline Size	8” SCH 40
Steel Flow Velocity	2.78 m/s *(9.12 ft/s)*
Steel Friction Gradient	31.2 m/km *(31.2 ft/1000ft)*
Steel Maximum Allowable Working Pressure	7838 kPa *(1136.81 PSI)*
Year 2 Pump Head	55 m *(180.45 ft)*
Year 10 Pump Head	130 m *(426.51 ft)*
Year 25 Pump Head	162 m *(531.50 ft)*
Year 45 Pump Head	208 m *(682.42 ft)*

We note that in the next stage of design the pipe wall thickness should be optimized for cost and local availability. Specifically DR7 pipe could be considered instead of DR6.3.

The working pressure for HDPE pipe is specified per the manufacturer's temperature de-rating factors. A PE 4710 HDPE pipe at 50°C *(122^{o}F)* (the assumed summertime maximum) should operate at no more than 73% of the published pressure rating. The MAWP of HDPE pipe was selected to be 25 m *(82.02 ft)* below the de-rated pressure to ensure sufficient margin between the system pressure and de-rated pipe pressure.

The maximum allowable working pressure (MAWP) was calculated for ASME B31.3. API 5L Grade B Electrical Resistance Welded steel pipe.

4. PIPE QUANTITIES

To assist Resolution Copper in estimating CAPEX, we have listed the pipe quantities and pumping power in Table 4.1 below. This table is assumes all eleven seepage pipelines are similar to the S2 pipeline. The number of systems required for Years 2, 10, 25, and 45 are listed.

Table 4.1 Pipe Quantities

Description	Quantity
Maximum Pipe Length	985 m *(3231.63 ft)*
Year 2 Number of Systems	4
Year 2 Pipe HDPE (Length)	54,000 kg *(59.52 tons)* (4 x 300 m *(984.25 ft)*)
Year 10 Number of Systems	4
Year 10 Pipe HDPE (Length)	116,000 kg *(127.87 tons)* (4 x 640 m *(2099.74 ft)*)
Year 25 Number of Systems	11
Year 25 Pipe HDPE (Length)	393,000 kg *(433.21 tons)* (11 x 790 m *(2591.86 ft)*)
Year 45 Number of Systems	11
Year 45 Pipe Steel (Length)	141,000 kg *(155.43 tons)* (11 x 300 m *(984.25 ft)*)
Year 45 Pipe HDPE (Length)	341,000 kg *(375.89 tons)* (11 x 685 m *(2247.38 ft)*)
Pumps	11 x Floway 14JKM

The pumps will require a variable frequency drive (VFD) to accommodate the increasing head in the system as the TSF increases in height.

5. DISCLAIMER

This report is an instrument of service of KCB. The report has been prepared for the exclusive use of Resolution Copper for the specific application to the Resolution Near West project. The report's contents may not be relied upon by any other party without the express written permission of KCB. In this report, KCB has endeavoured to comply with generally-accepted professional practice common to the local area. KCB makes no warranty, express or implied.

KLOHN CRIPPEN BERGER LTD.



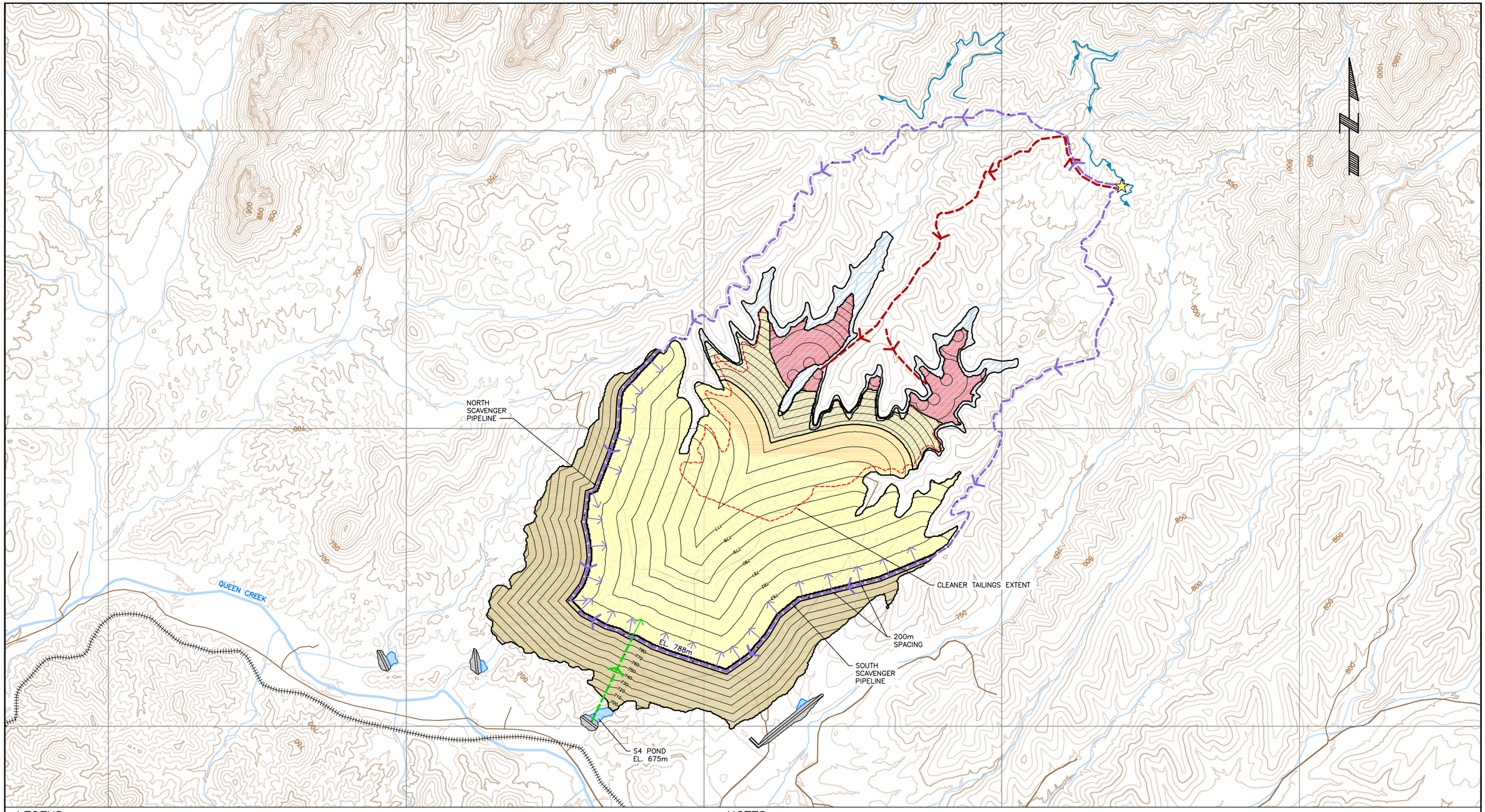
Prepared By: Tyler Campbell, E.I.T.



Senior Review By: Scott Crozier, P.Eng.

APPENDIX I

Pipeline Plan and Profile Drawings



LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE-IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

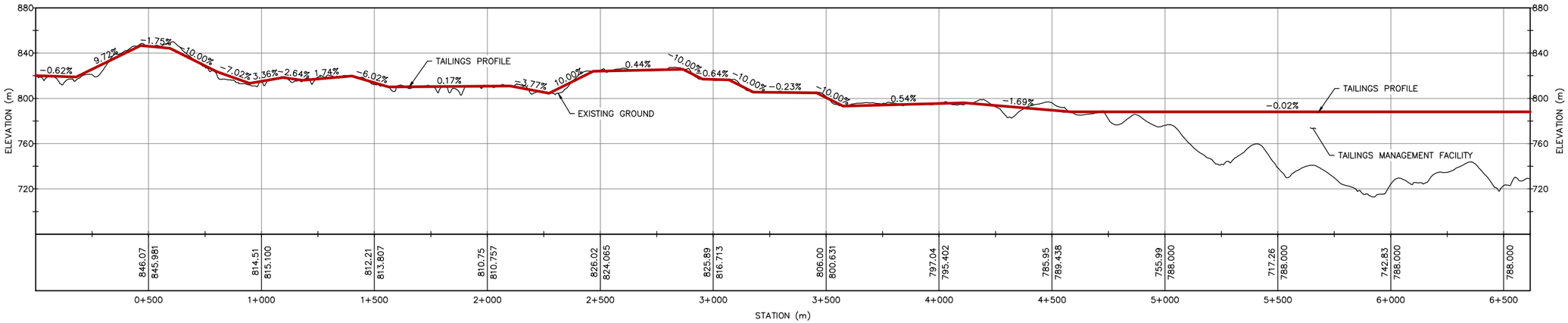
TITLE: PLAN
YEAR 10

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M02

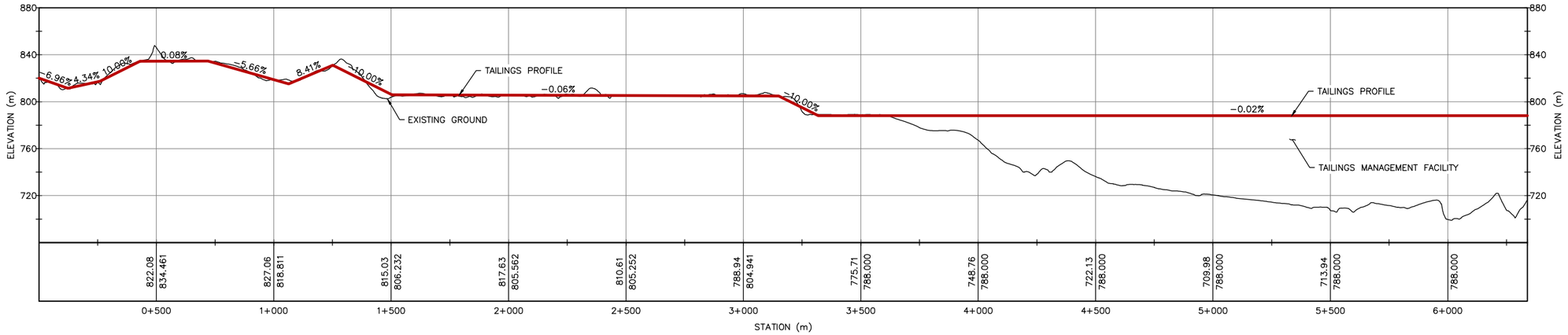
KCB-FIG-D-L

Date: 7/23/2013 Time: 09:54:53 Scale: 1:2,585(PS)
Drawing File: Z:\WVCR\M09441A14 - RES-Near WestGeotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M02.dwg (dacson)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Comp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Comp_Streams_Sep2012
Image File(s):



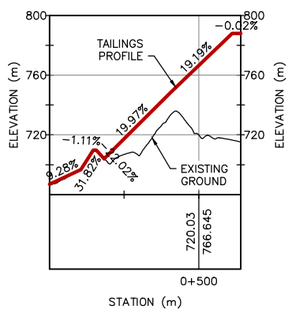
PROFILE ALONG NORTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



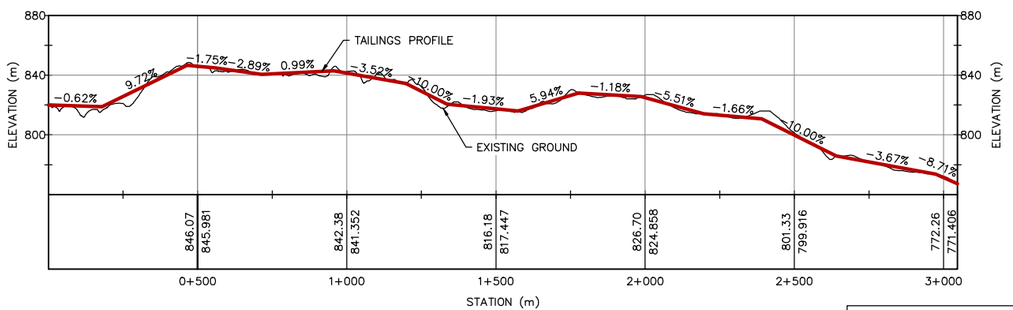
PROFILE ALONG SOUTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

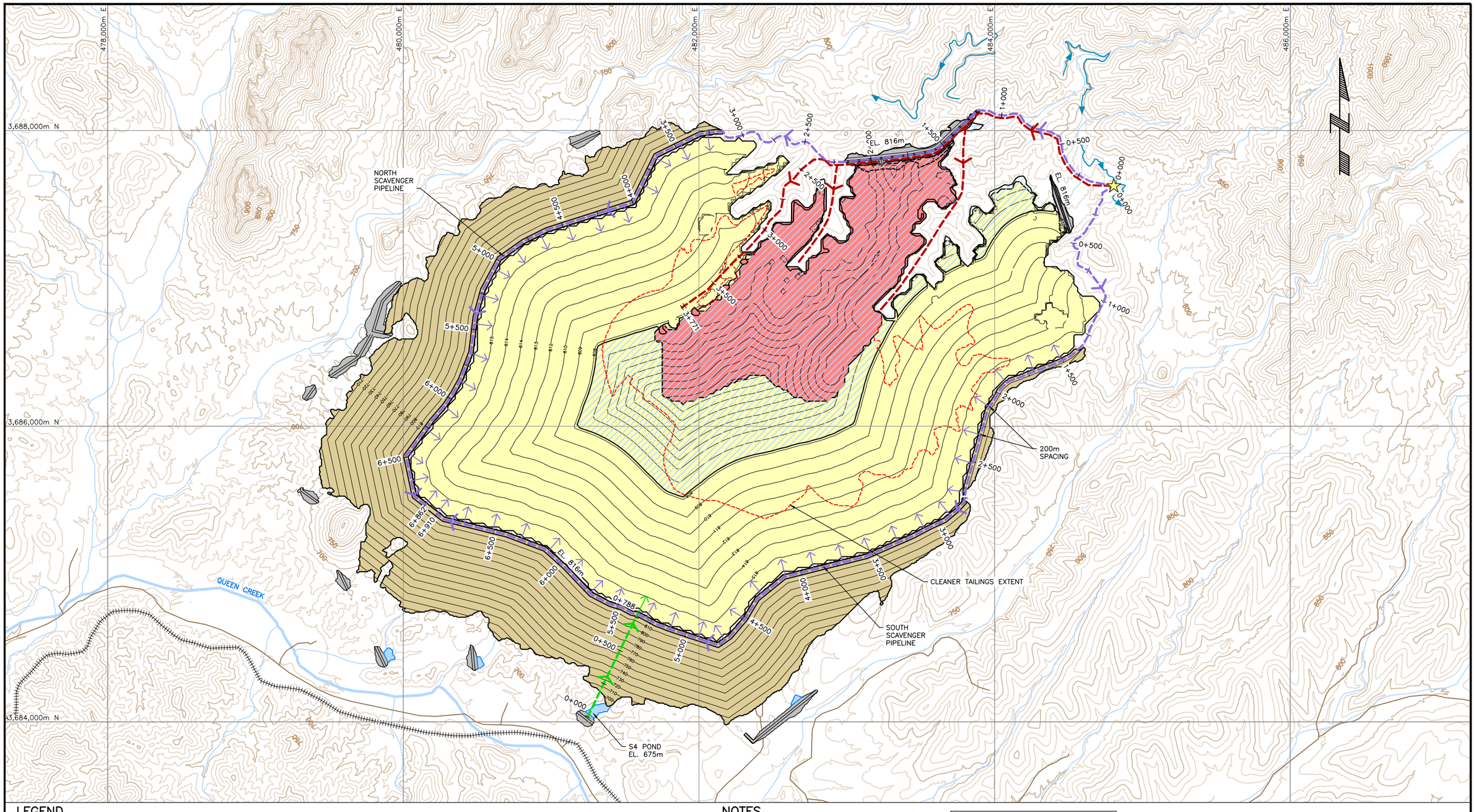
TITLE: PROFILES
YEAR 10

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A12	M03

KCB-FIG-D-L

Date: 7/23/2013 Time: 09:57:06 Scale: 1:32.524(PS)
Drawing File: Z:\M\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M03.dwg (olarson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):



LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE–IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

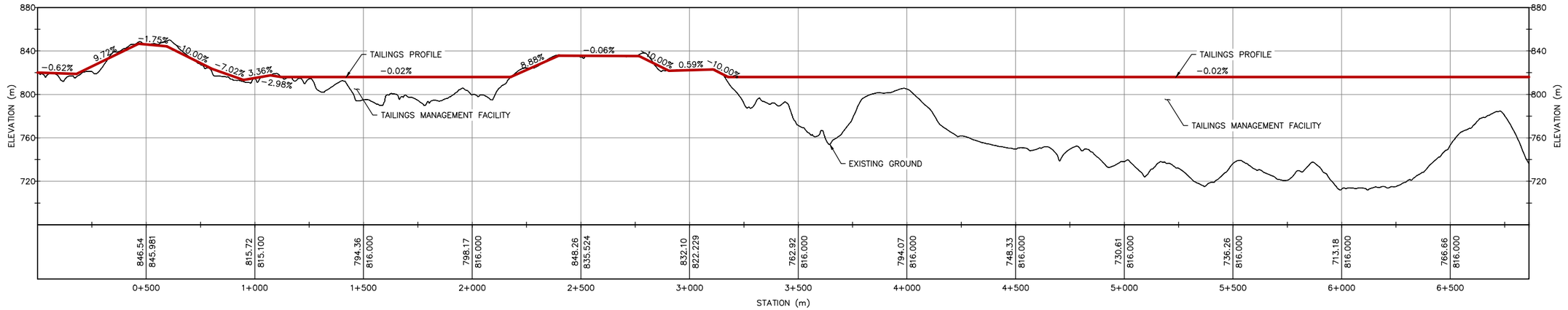
PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: PLAN
YEAR 25

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M04

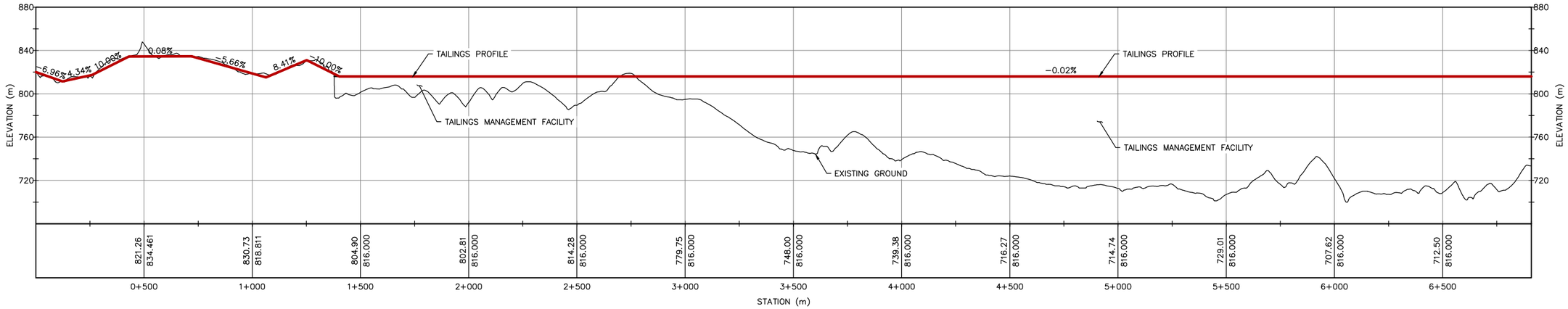
KCB-FIG-D-L

Date: 7/23/2013 Time: 09:55:17 Scale: 1:2,585(PS)
Drawing File: Z:\MVCAD\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M04.dwg (olacson)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Comp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Comp_Streams_Sep2012
Image File(s):



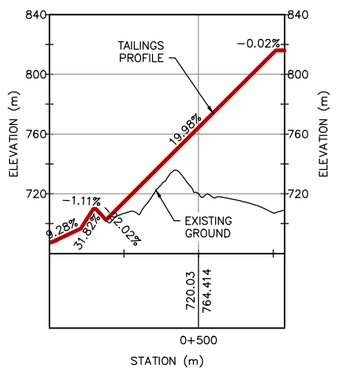
PROFILE ALONG NORTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



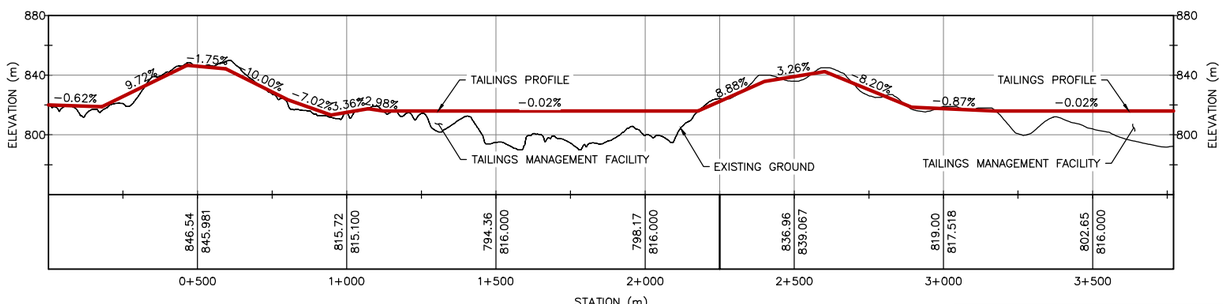
PROFILE ALONG SOUTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

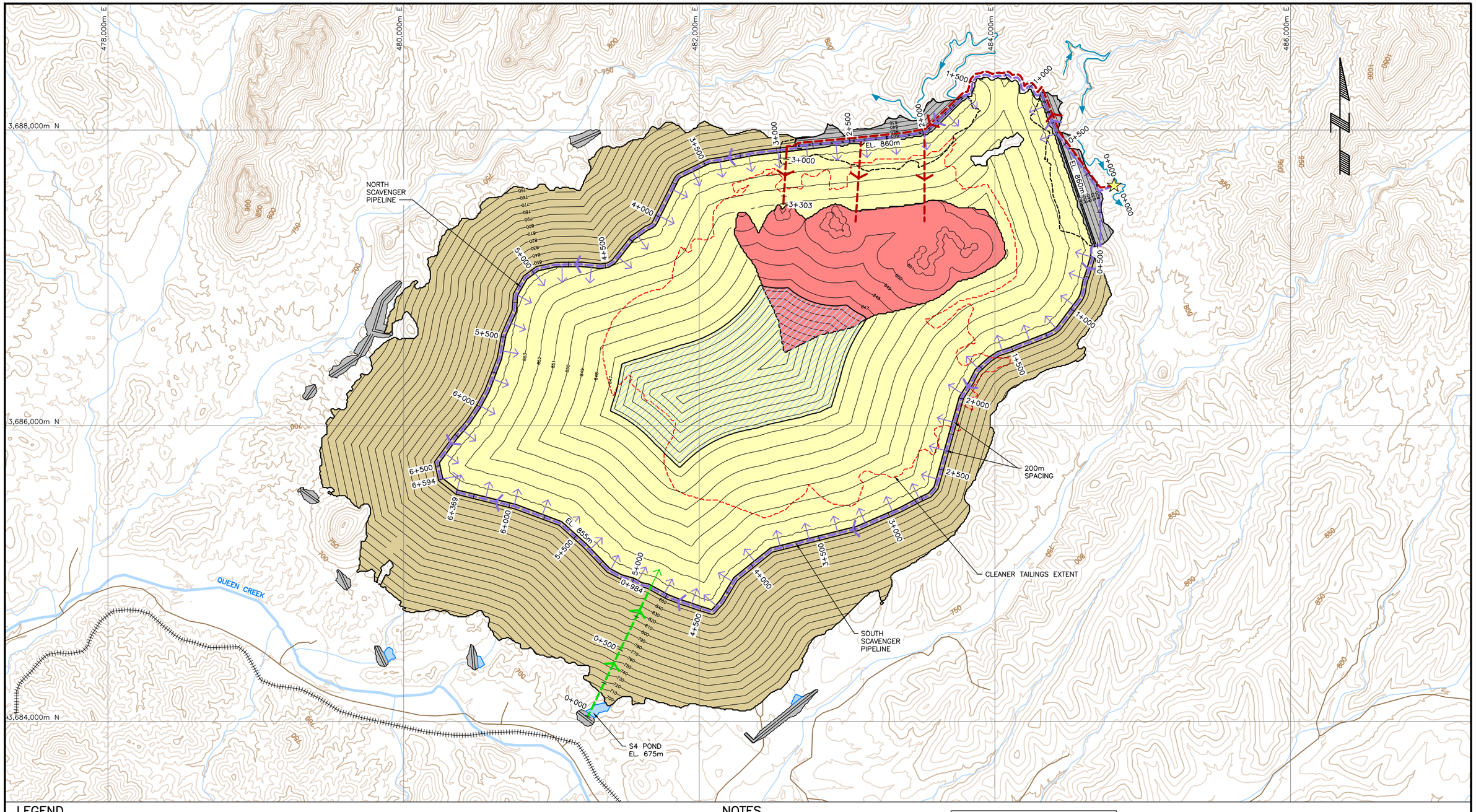
TITLE: PROFILES
YEAR 25

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A12	M05

KCB-FIG-D-L

Date: 7/23/2013 Time: 09:55:53 Scale: 1:32.524(PS)
Drawing File: Z:\M\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M05.dwg (olarson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):



LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE–IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

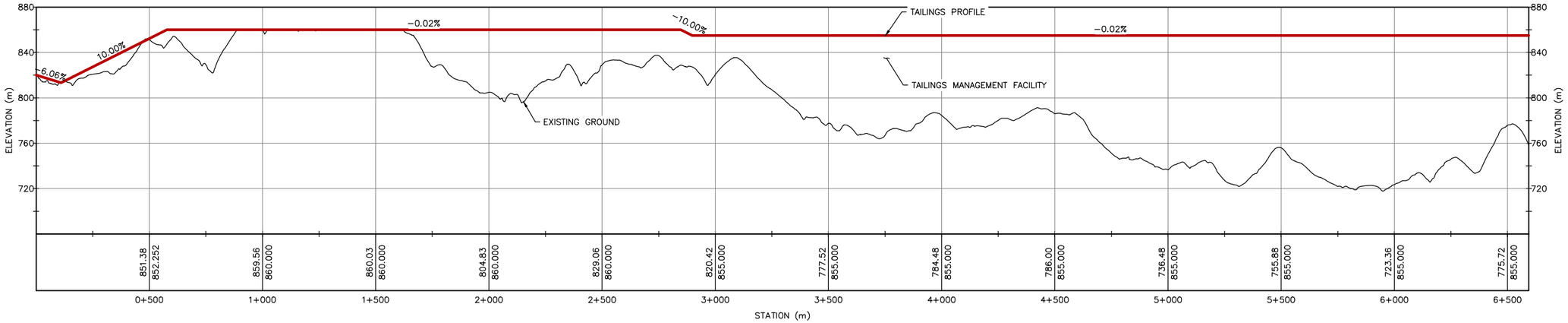
TITLE: ULTIMATE PLAN

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M06

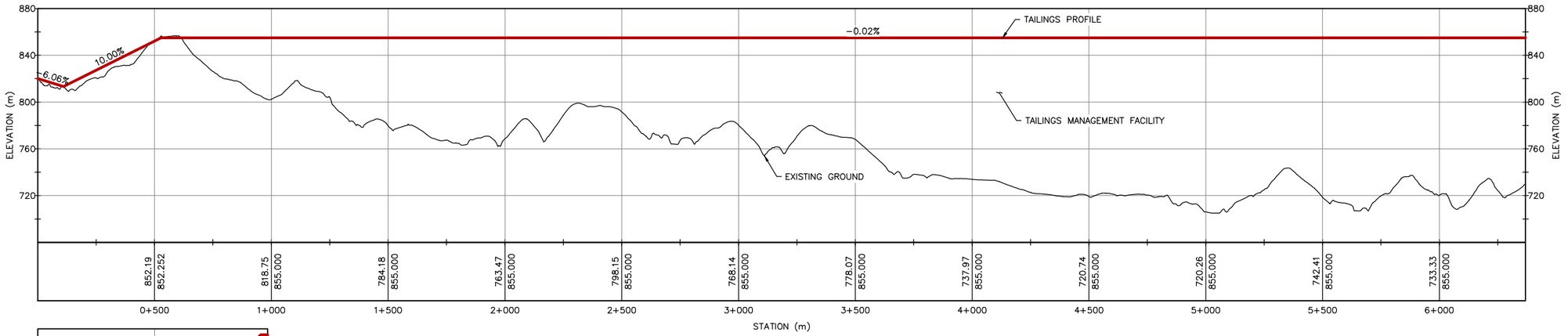
KCB-FIG-D-L

Date: 9/3/2014 Time: 17:07:51 Scale: 1:2,585(PS)
Drawing File: Z:\MA\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M06.dwg (dhu)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Camp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Camp_Streams_Sep2012
Image File(s):



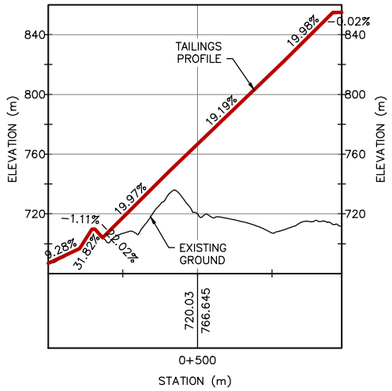
PROFILE ALONG NORTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



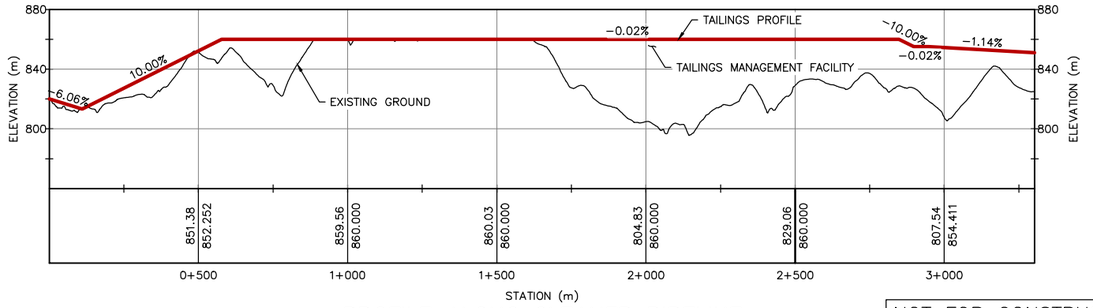
PROFILE ALONG SOUTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining	PROJECT: RESOLUTION PROJECT NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY
Klohn Crippen Berger	TITLE: PROFILES YEAR 45 (ULTIMATE)
	SCALE: AS SHOWN · PROJECT No.: M09441A12 · FIG. No.: M07

KCB-FIG-D-L

Date: 7/23/2013 Time: 09:56:07 Scale: 1:32.524(PS)
Drawing File: Z:\M\VOR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M07.dwg (olacson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):

Date: 9/3/2014 Time: 17:07:49 Scale: 1:2,585(PS)
Drawing File: Z:\M\VCR\M09441A14 – RES–Near WestGeotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14–M08.dwg (dhu)
Xref File(s): FOR INSERT_NEAR WEST – APRIL 2013; Happy_Camp_Facilities_Sep2012; bm–near west–5mtopo; Happy_Camp_Streams_Sep2012
Image File(s):

478,000m E
480,000m E
482,000m E
484,000m E
486,000m E
3,688,000m N
3,686,000m N
3,684,000m N

QUEEN CREEK

0+000
0+500
1+000
1+500
2+000
2+500
3+000
3+500
4+000
4+500
4+819
5+000
5+500
6+000
6+500
7+000
7+293
7+500
8+000
8+500
8+554

EL. 768m
EL. 722m
EL. 722m
EL. 722m
EL. 675m
S4 POND

200m SPACING

LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE–IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

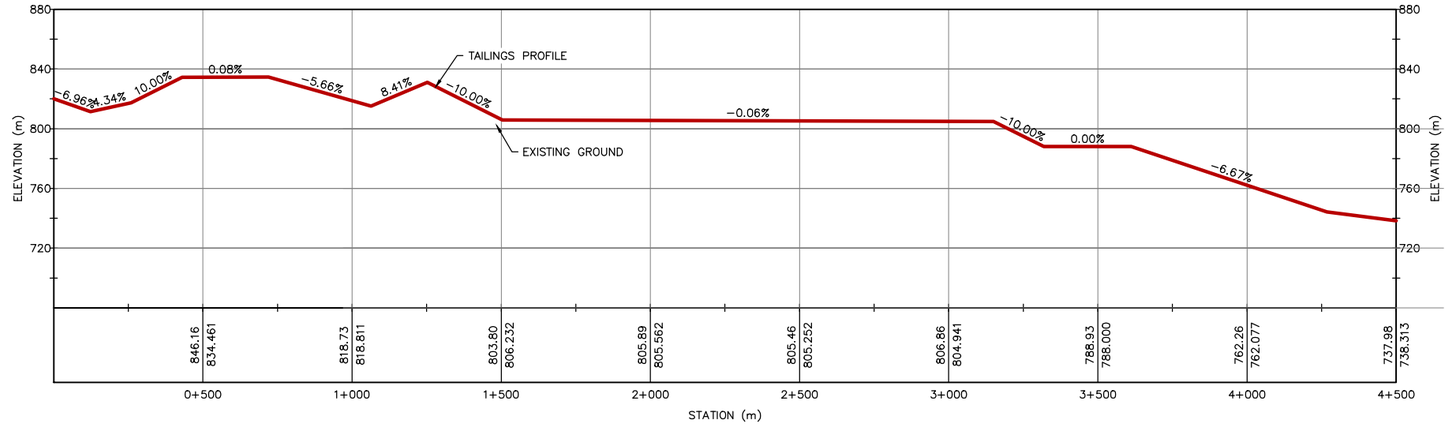
Klohn Crippen Berger

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

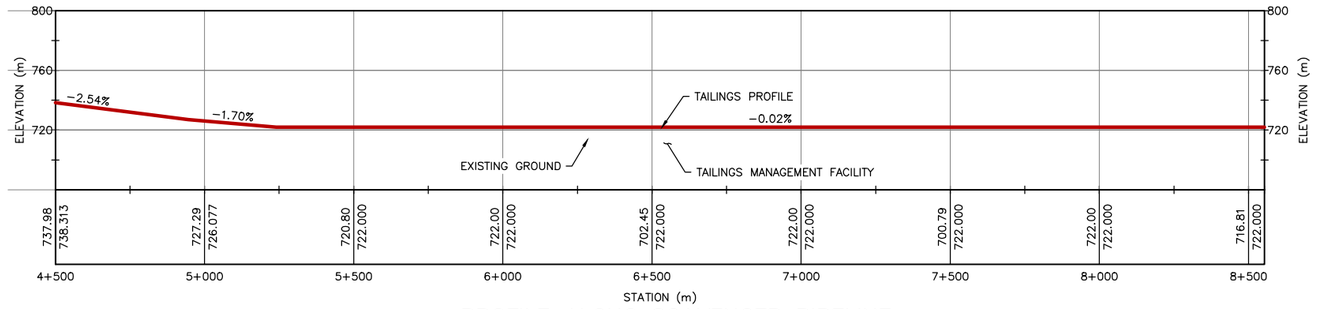
TITLE: STARTUP PLAN

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M08

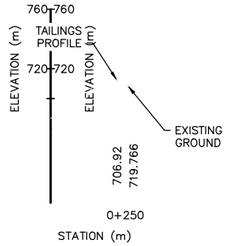
KCB-FIG-D-L



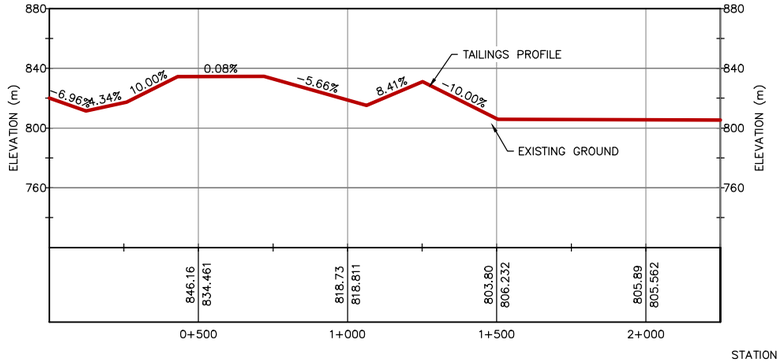
PROFILE ALONG SCAVENGER PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



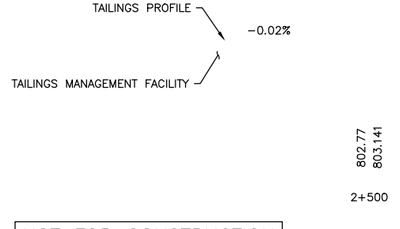
PROFILE ALONG SCAVENGER PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: PROFILES
YEAR 2

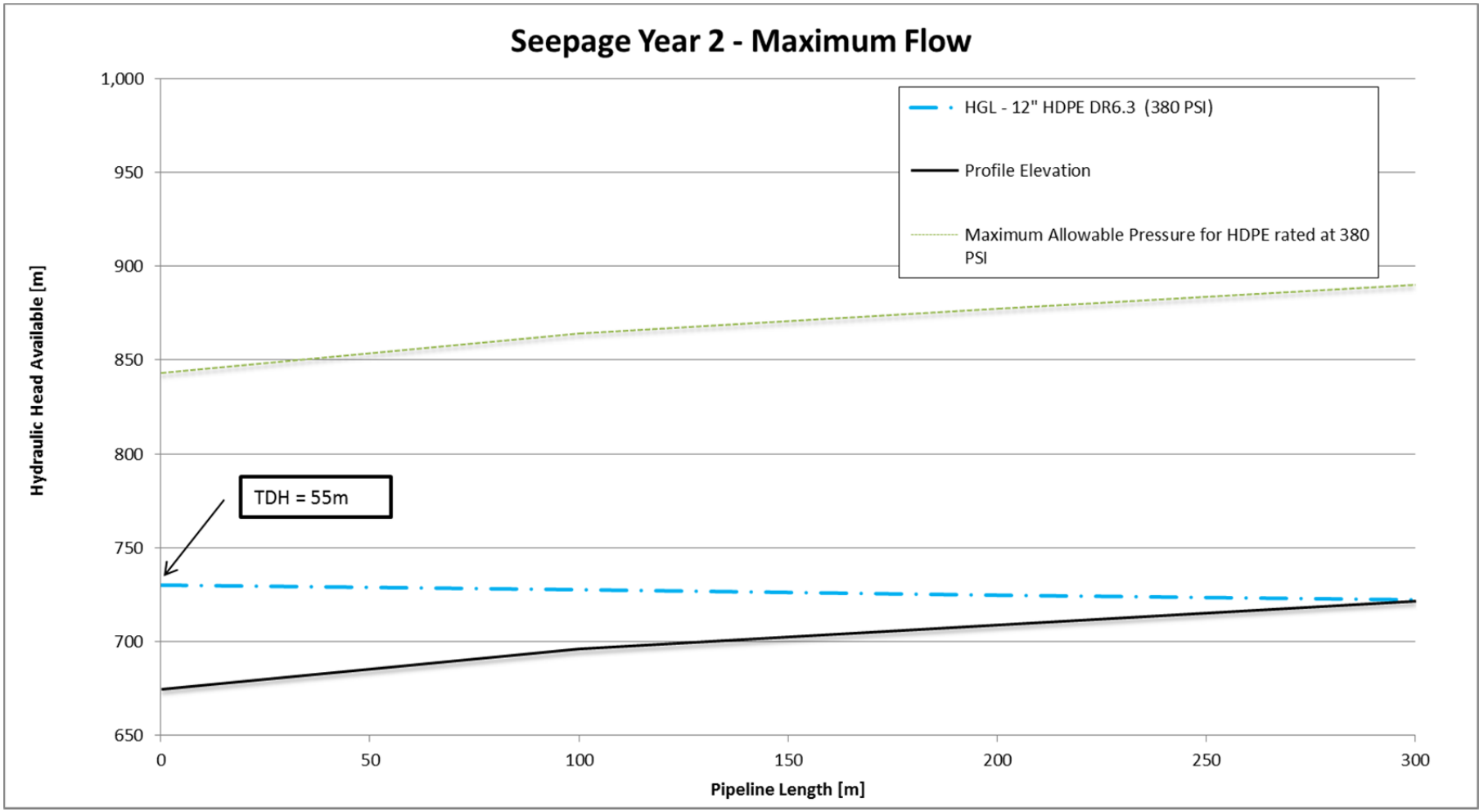
SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A12	M09

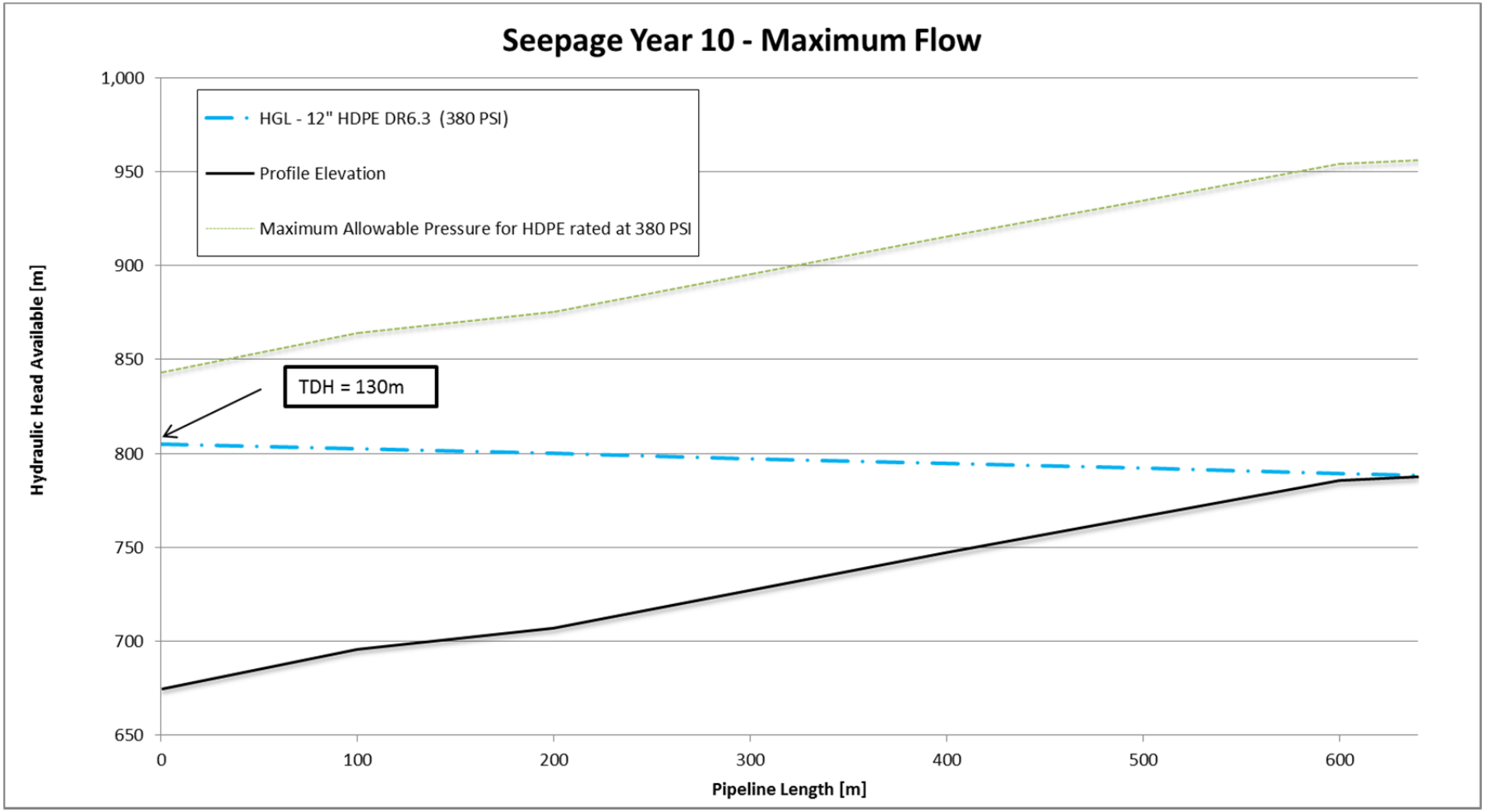
KCB-FIG-D-L

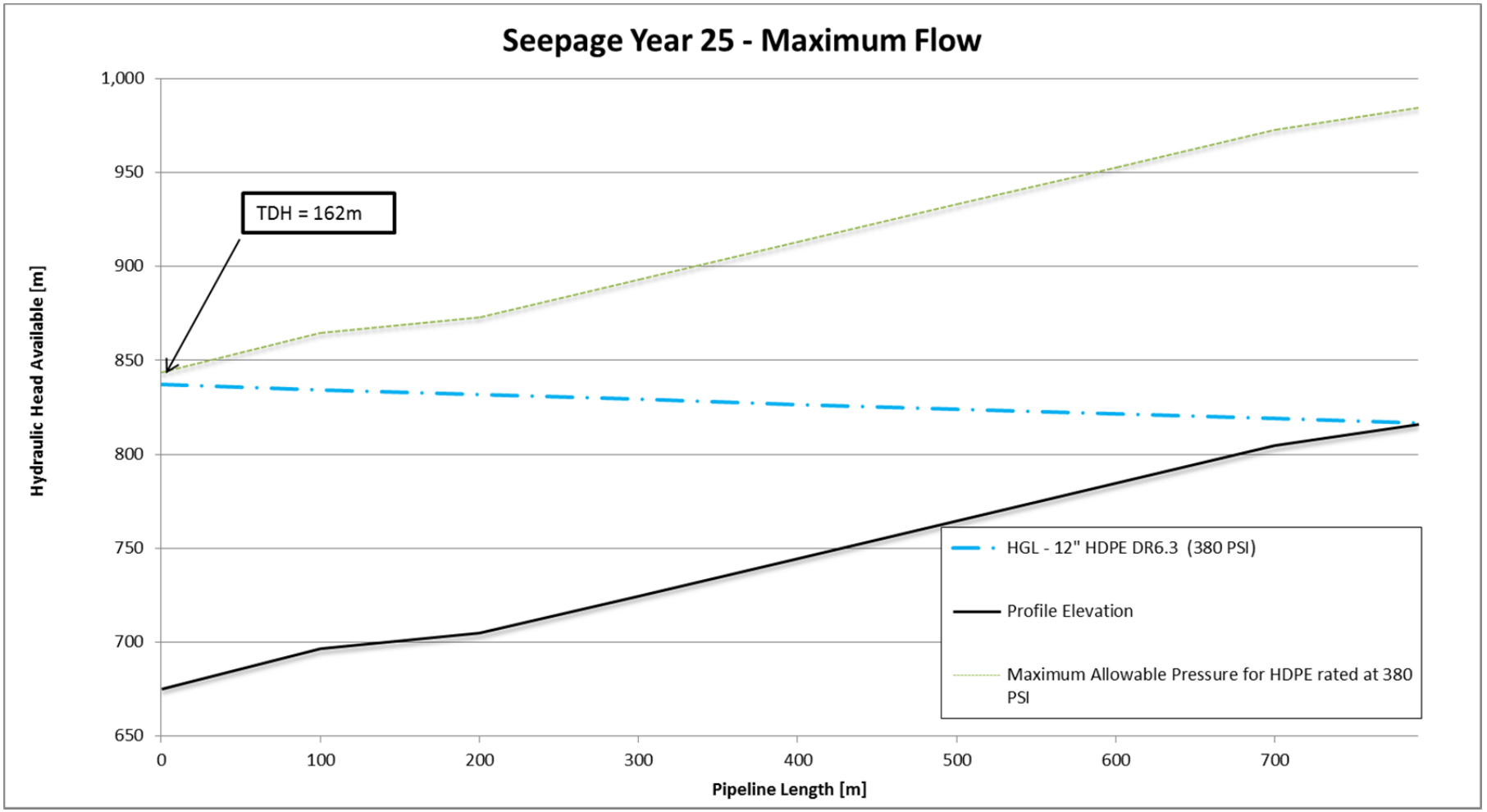
Date: 7/23/2013 Time: 09:54:48 Scale: 1:32.524(PS)
Drawing File: Z:\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M09.dwg (olarson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):

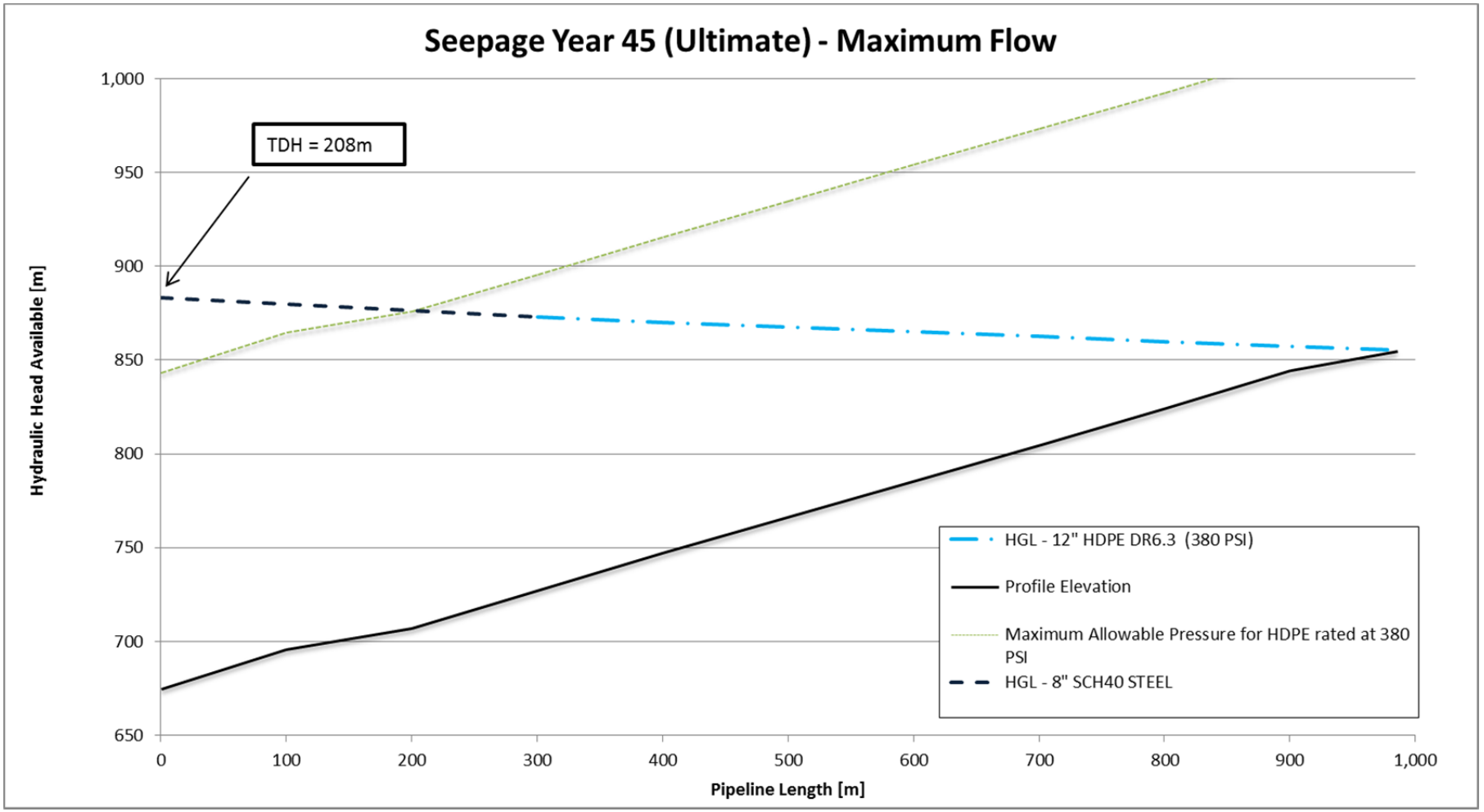
APPENDIX II

Hydraulic Grade Lines


Seepage Year 2 - Maximum Flow
Hydraulic Head Available [m]
1,000
950
900
850
800
750
700
650
0
50
100
150
200
250
300
Pipeline Length [m]
HGL - 12" HDPE DR6.3 (380 PSI)
Profile Elevation
Maximum Allowable Pressure for HDPE rated at 380 PSI
TDH = 55m


Seepage Year 10 - Maximum Flow
HGL - 12" HDPE DR6.3 (380 PSI)
Profile Elevation
Maximum Allowable Pressure for HDPE rated at 380 PSI
TDH = 130m
Hydraulic Head Available [m]
Pipeline Length [m]
1,000
950
900
850
800
750
700
650
0
100
200
300
400
500
600


Seepage Year 25 - Maximum Flow
Hydraulic Head Available [m]
1,000
950
900
850
800
750
700
650
TDH = 162m
0
100
200
300
400
500
600
700
Pipeline Length [m]
HGL - 12" HDPE DR6.3 (380 PSI)
Profile Elevation
Maximum Allowable Pressure for HDPE rated at 380 PSI


Seepage Year 45 (Ultimate) - Maximum Flow
Hydraulic Head Available [m]
Pipeline Length [m]
TDH = 208m
1,000
950
900
850
800
750
700
650
0
100
200
300
400
500
600
700
800
900
1,000
HGL - 12" HDPE DR6.3 (380 PSI)
Profile Elevation
Maximum Allowable Pressure for HDPE rated at 380 PSI
HGL - 8" SCH40 STEEL

APPENDIX III

Seepage Pump Data Sheet

Pump Performance Datasheet

Customer	:	Quote number	: 143156
Customer reference	:	Size	: 14JKM
Item number	: 144	Stages	: 7
Service	:	Based on curve number	: 14JKM 1770 Rev. 0
Quantity	: 1	Date last saved	: 25 Apr 2013 12:20 PM

Operating Conditions

Flow, rated	: 90.00 l/s
Differential head / pressure, rated (requested)	: 208.0 m
Differential head / pressure, rated (actual)	: 209.1 m
Suction pressure, rated / max	: 0.00 / 0.00 bar.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 1,770 rpm
Impeller diameter, rated	: 255 mm
Impeller diameter, maximum	: 268 mm
Impeller diameter, minimum	: 229 mm
Efficiency (bowl / pump)	: 82.91 / 82.36 %
NPSH required / margin required	: 3.70 / 0.00 m
nq (imp. eye flow) / S (imp. eye flow)	: 47 / 187 Metric units
MCSF	: 30.85 l/s
Head, maximum, rated diameter	: 247.5 m
Head rise to shutoff	: 18.72 %
Flow, best eff. point (BEP)	: 107.6 l/s
Flow ratio (rated / BEP)	: 83.65 %
Diameter ratio (rated / max)	: 95.07 %
Head ratio (rated dia / max dia)	: 90.09 %
Cq/Ch/Ce [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

Liquid type	: --Other
Additional liquid description	:
Solids diameter, max	: 1.00 mm
Solids concentration, by volume	: 1.00 %
Temperature, max	: 20.00 deg C
Fluid density, rated / max	: 0.999 / 0.999 kg/dm3
Viscosity, rated	: 1.00 cSt
Vapor pressure, rated	: 0.00 bar.a

Material

Material selected	: Cast Iron/Bronze

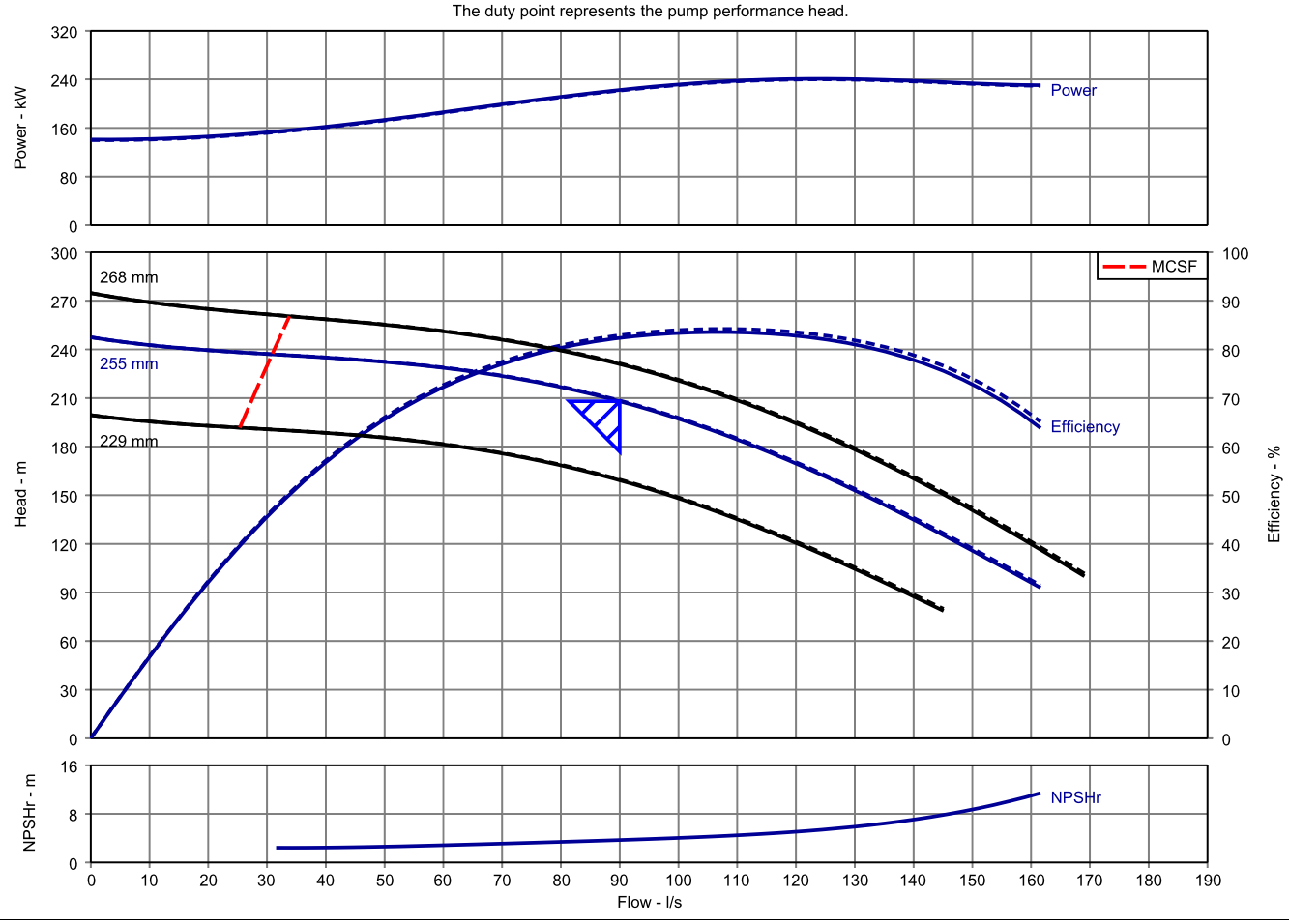
Pressure Data

Maximum working pressure	: See the Additional Data page
Maximum allowable working pressure	: See the Additional Data page
Maximum allowable suction pressure	: N/A
Hydrostatic test pressure	: See the Additional Data page

Driver & Power Data

Driver sizing specification	: Max power + 5%
Margin over specification	: 20.00 %
Service factor	: 1.15 (used)
Power, hydraulic	: 184 kW
Power (bowl / pump)	: 222 / 223 kW
Power, maximum, rated diameter	: 241 kW
Minimum recommended motor rating	: 298 kW / 400 hp

Pump and bowl (dashed) performance. Bowl adjusted for construction and viscosity.
Pump further adjusted for friction and power losses of lineshaft and thrust bearings. Pump is not adjusted for any static lift.
The duty point represents the pump performance head.



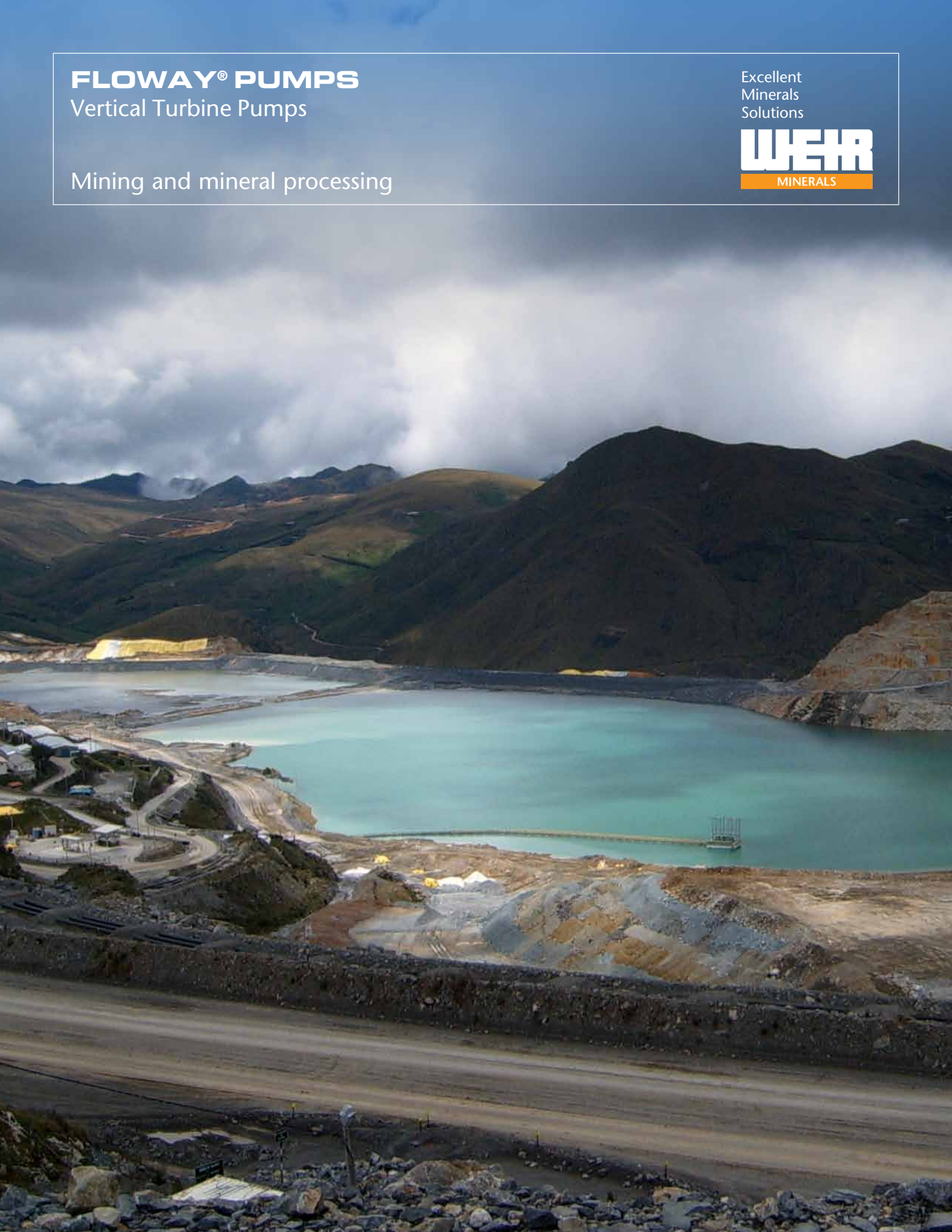
FLOWAY® PUMPS

Vertical Turbine Pumps

Mining and mineral processing

Excellent
Minerals
Solutions

WEIR
MINERALS



Meeting customer specifications is simply the first step in delivering whole life cycle performance. From design and installation, through service, maintenance and upgrade, we ensure continuity of excellence.

Weir Minerals Floway Pumps are committed to providing a **strong technological and engineering resource** dedicated to minimizing downtime and preventing disruption to the customer's operation.

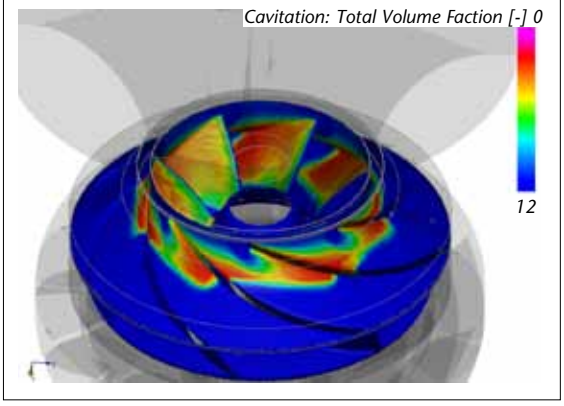
Floway® Pump's product reliability reduces downtime and keeps the routine replacement of parts to a minimum. Our qualified staff ensures the design and manufacturing quality is accurate to specifications. Our global service capability allows us, upon request, to put someone on site. These are some of the key benefits of Weir Minerals Floway Pumps.

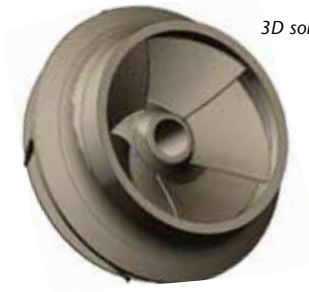
The heart of your operation

When designing and manufacturing the Floway® vertical turbine pump we keep in mind that the pump is the heart of the mining operation and the entire project depends on it. This is why the Floway® pump product line is designed to be the most versatile, reliable and long lasting on the market.

Unlike our competitors, Floway® Pumps are manufactured all under one roof. That means that every step from designing to manufacturing and the finished product is controlled in our state of the art facility in Fresno, California, USA.

CFD Analysis





3D solid modeling

Lateral and Torsional Rotordynamic Analysis



Commitment to extending operating life

Floway® Pumps is dedicated to pumping excellence. That means using our experience in the industry to produce products with long life cycles and unparalleled performance.

Excellent engineering solutions

Floway® Pumps utilizes an in-house staff of licensed professional engineers to ensure maximum control over design specifications. Engineering capabilities include:

- 3D solid modeling
- In-house hydraulic design
- Products engineered to customer specifications
- Computational Fluid Dynamics (CFD) analysis
- Stress and deflection analysis using Finite Element Analysis (FEA)
- Lateral and torsional rotor dynamic analysis
- Structural natural frequency analysis (using FEA) and design for VFD operation
- Design for low vibration

We can increase that benefit by offering a range of complementary products conducive to our portfolio of branded pumps. By using Weir Minerals valves, mill-liners and cyclones in conjunction with pumps, customers can consolidate maintenance and service programmes, reducing the frequency of interruptions to production.

- Entire manufacturing process controlled at our facility
- Commitment to extending operating life and efficiency
- Customer-focused product development
- Worldwide network of support

Typical Services

Process Pumps — Pumps that move solutions throughout the mining processes such as raffinate, pregnant leach solution (PLS), thickener, acid water, cooling water, organic solvent, electrolyte, and dump leach

Water Supply — Typically well pumps that supply the mine with their primary source of water

Tailings Pumps — Post-processed solution is collected and pumped into a treatment facility and recycled back into the process

RO Treatment Pumps — Reverse osmosis water treatment facilities. Feed pumps, low pressure RO feed pumps, filter backwash pumps, recycle pumps, sea water RO pumps, and spray/flush pumps.

Dewatering Pumps — Sump pump design or deep well turbine design

Seepage Water Pumps — Sump pump design or can/booster design

Reclaim Water Pumps — Sump pump design

Overflow Water Pumps — Sump pump design

Barge Mounted Pumps — Pumps that are used for dewatering or water supply from ponds and/or reservoirs



2000 HP raffinate pumps



Tailing water pumps



Reclaim water pumps

Floway® Pumps is dedicated to manufacturing pumps with industry leading low vibration levels.

Optional features:

- Premium machined and balanced motor
- Specially toleranced motor coupling machined by Floway® Pumps
- Jacking posts for precise motor/pump shaft alignment
- Impellers balanced per API 610
- Reduced run-out on motor base

Minimum downtime, minimum disruption to process

1: Machining discharge head

2: Super duplex impellers



1


2

Through continuous improvements to materials, product design, engineering and manufacturing, we minimize downtime and reduce the risk of disruption to our customers' operations.

Wear/corrosion resistant materials

To increase pump longevity and enhance efficiency, Floway® pumps are constructed with wear/corrosion resistant materials such as duplex and super duplex stainless steels.

Materials:

- Austenitic-304L (J92500)
- 316L (J92800)
- Super Austenitic-904L (N08925)
- AL6XN (J94651)
- 317LM (J93000)
- Duplex SS-2205 (J92205)
- 255 (J32250)
- CD4MCu (J93370)
- Super Duplex SS-2507 (J93380)
- Alloy 20 (N08020)
- Super Austenitic 254SM0 (J31254)
- Compatible wrought alloys are available for above cast materials

Manufactured to meet global certifications and standards:

Electrical standards

- NEMA
- IEEE
- IEC

Construction standards

- ANSI B16.5 Class 150 through 1500 flange ratings
- Welding to ASME section IX on all listed materials
- ASTM standards met for all materials supplied - castings, forgings, and wrought materials
- Stress relief carbon steel to ASME Section VIII
- DIN
- BS
- Hydraulic Institute
- CE Marking
- API 610

Quality assurance

Quality control never ends at Floway® Pumps. It begins with the quotation phase and continues throughout the order process, manufacturing phase, warranty period, customer follow-up and service. This dedication to quality has given us the reputation for having one of the finest products in the vertical turbine pump industry. Certifications include:

- ISO 9001:2008 Quality Management Systems
- ISO 14001:2004 Environmental Management Systems
- OHSAS: 18001:2007 Occupational Health and Safety Management Systems

Welding and fabrication

Weir Minerals Floway Pumps utilizes in-house fabrication staffed with welders certified to ASME Code Section IX on all listed materials.

Performance testing

A major engineering function of any pump manufacturer is hydraulic performance testing under a variety of operational conditions. Testing ensures that pump performance matches specifications and that all components are operating properly.

Testing and analysis capabilities include:

- Three testing pits for flows to 45,000 GPM (10,220 m^3/hr)
- Hydrostatic testing equipment for pressures to 5,000 PSI (345 Bars)
- NPSH testing equipment available for flows to 30,000 GPM (6,814 m^3/hr)
- Pressures to 2,500 PSI (172 Bars)
- Electrical power through 3,000 HP (2,235 KW)
- All measuring equipment calibrated on a scheduled basis with traceability to National Institute of Standards and Technology (NIST)
- Vibration testing available including spectrum analysis (FFT) with multiple simultaneous channels. Proximity probes available for measuring dynamic shaft vibration
- Impact testing available to determine the structural natural frequencies (Reed Critical Frequency) of the pump/motor structure
- Capable of testing a complete engine driven pump
- Both 50 Hz and 60 Hz power available
- Pump testing using a Variable Frequency Drive (VFD) available upon request
- Coating spark test (low voltage/high voltage)
- Pump thrust testing
- Noise testing

Non-Destructive Testing (NDT)

- Dye Penetrant (LP)
- Magnetic Particle Inspection (MP)
- Radiography Exam (RT)
- Ultrasonic Testing (UT)
- Positive Material Identification (PMI)
- Hardness Testing (Rockwell and Brinell)
- CMTR upon request
- AWS Certified Welding Inspection (CWI)


1


2


3

1: Test lab

2: Fabrication of stainless steel discharge head

3: The manufacturing facility is ISO 9001 and 14001 certified

Weir Minerals is at the forefront of the industry in developing a truly global supply capability.

This enables us to provide major minerals producers worldwide with consistent products and standards of service.

For customers with operations in diverse regions, the operational advantages of **global supply** are clear. Standardized processes permit the transfer of best practice. Efficiencies realized on one site can be repeated elsewhere. As customers move their people around the world, they will encounter familiar equipment and processes, and be able to call on the same team for technical support.

Global supply, local support

- Application expertise
- Installation supervision and support
- Ease of maintenance
- 24 hour availability of support
- Understanding the customers' processes
- Local aftercare and engineering service
- Local solutions backed by global design resource



Closer to the customer

Clearly, local engineering support and the ability to have someone on site are vital for our customers' process efficiency. Weir is synonymous with engineering expertise, and our close customer relationships are based on the fact that we have historically delivered that expertise locally, on site, day or night.

None of this has been discarded in our drive for globalization. On the contrary, we have expanded the offering of local operations, providing access to a global product portfolio and the pooled engineering expertise of the entire Weir Group. In this way, we can support our customers' ambitions worldwide.

Emerging markets

Weir Minerals has operations across North America, South America, Europe, Africa, Australia and Asia. By working closely with our customers, we are able to mirror their movements into emerging markets with our own. Our strategy for global expansion in China, India, and Eastern Europe is already under way.

At the same time, all our customers require **rapid response, on-site support** from someone who understands the local conditions. Weir Minerals' geographical footprint plays a major role in establishing our closeness with customer operations.

Our business model allows us to service **global and local** customers simultaneously, effectively. By centralizing shared functions such as materials research, testing, purchasing, marketing and administration, we are able to support regional and local engineering.

"The mining industry is characterized by large scale, complex operations in remote and inaccessible locations Through our companies around the world we have responded to the challenge by offering tailored solutions to their problems and a basket of Weir products, including vertical turbine, slurry, and clear liquid pumps, and other handling equipment."


1


2

"In 1997 the first integrated package was offered to Minera Collahuasi. This developed into the supply of most of the slurry and clear water equipment required, and was extended into a full maintenance service contract, under which Weir engineers remain on site 24 hours a day, 7 days a week. We also supply and maintain all the rubber linings, cyclones and related products. The same concept has been duplicated and repeated in mining operations throughout the world."

"For the customer, the arrangement offers real benefits in terms of reduced downtime, increased plant life and improved throughput. The key elements of this success are a very close relationship with our customers and the 'can-do' attitude of all Weir people."

Ricardo Garib
Weir Vulco SA, Chile


3


4


5

1: Installing two vertical turbine pumps in the field

2: Vulco® service facility in Chile

3: A Weir Minerals on site service facility

4: Installing Floway® vertical turbine pump on a Multiflo® barge

5: Service and support is available 24 hours a day

Weir Minerals has an advanced product range incorporating market leading brands covering virtually any application, in any environment. Our products account for 19% of market share worldwide.

We own a valuable portfolio of intellectual property, which is continually being expanded through research and development in materials and technology to enhance the wear life of our products. As a result, our global leadership in mining pump applications is combined with innovative designs in an extensive product range of mill liners, hydrocyclones and slurry valves.

Meeting the needs of customers worldwide

Geographical Footprint

Weir Minerals has the geographical presence to service all the major minerals markets around the world. This global supply capability provides a competitive advantage in this relatively fragmented market.

We support customer operations worldwide with consistent products and local engineering expertise. As part of The Weir Group, we have the reach and resource to grow into emerging markets alongside our customers. This includes specific plans for expansion in Asia.

Weir Minerals has operations across:

- North America
- South America
- Africa
- Europe & UK
- Australia
- Former Soviet Union







1: Weir Minerals has the global capabilities to service all customer operations

2: Reclaim water pumps

WARMAN® Centrifugal Slurry Pumps
GEHO® PD Slurry Pumps
LINATEX® Rubber Products
VULCO® Wear Resistant Linings
CAVEX® Hydroclones
FLOWAY® PUMPS Vertical Turbine Pumps

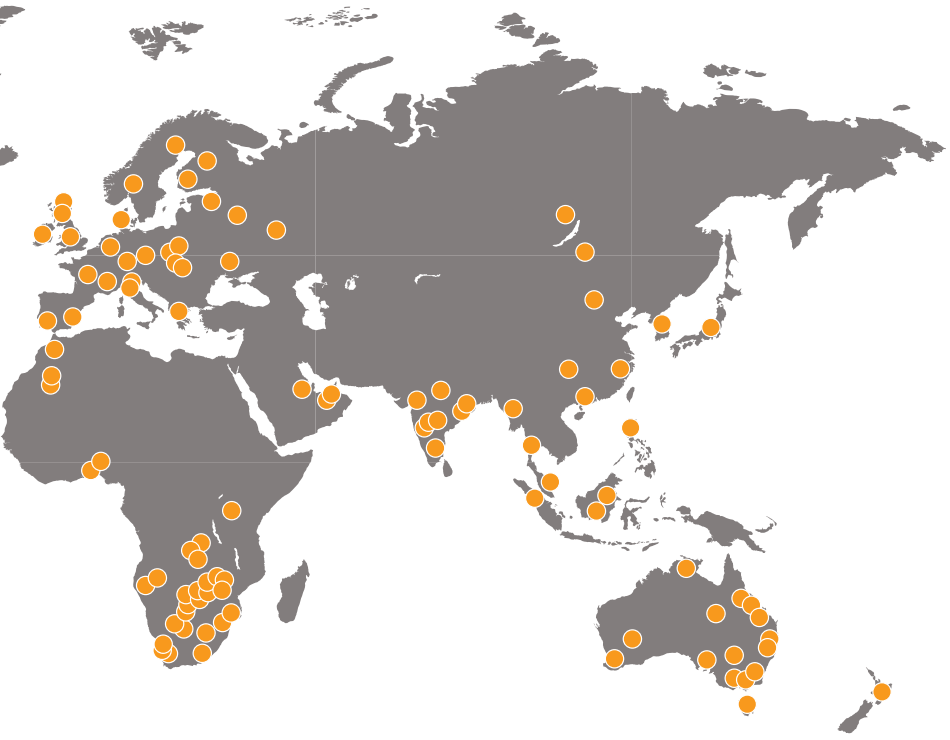
ISOGATE® Slurry Valves
MULTIFLO® Mine Dewatering Solutions
HAZLETON® Specialty Slurry Pumps
LEWIS® PUMPS Vertical Chemical Pumps
WEIR MINERALS SERVICES™

Customer Profile

Our customers range from the world's largest minerals and mining multinationals to single site coal producers.

Weir Minerals capability supports an array of customer specifications with products easily adaptable to meet specific process requirements.

We build close, long term partnerships through which we are able to help customers achieve process efficiencies.



Our customers include:

- Alcoa
- Barrick
- BHP-Billiton
- Newmont
- Rio Tinto Alcan
- CVRD
- Grupo Mexico
- WMC
- Freeport McMoran
- Anglo American
- Xstrata
- IAMGOLD
- Codelco
- SQM Salar
- Teck Comico
- Gold Fields
- Dofasco
- Iron Ore
- Consolidated Thompson
- Kennecott Copper



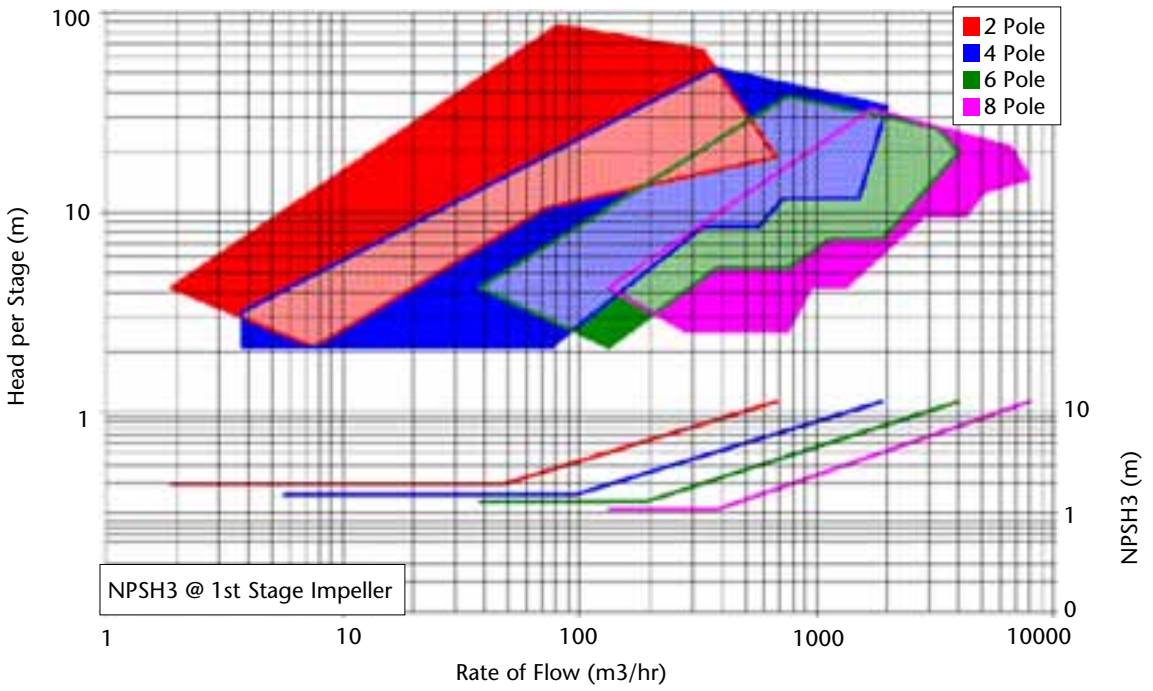
Reclaim water pumps

The Floway® Vertical Mining Pump - VMP Series

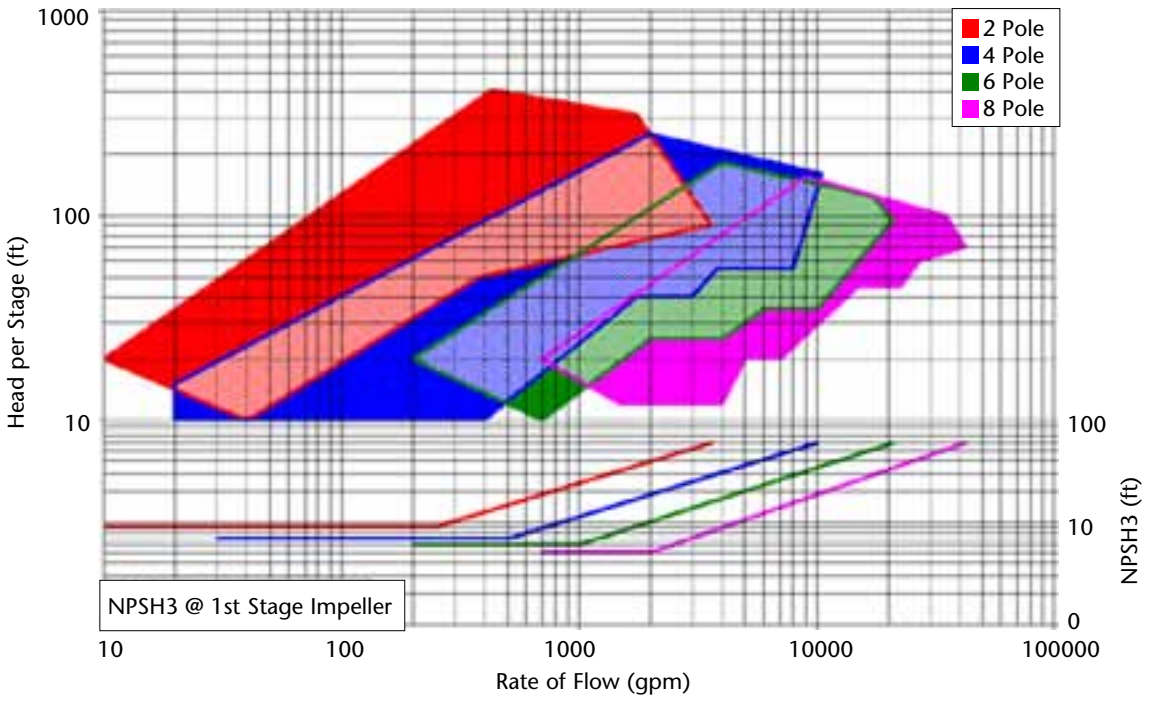
VMP Wet Pit and Barrel Can design features

- Pump configuration - vertically suspended close coupled single or multi- staged turbine within a closed suction system.
- Capacity - to 35,000 USGPM (8,000 M3/HR)
- Pressure - Wet Pit to 1,500 PSI (100 bars) and Barrel Can to 3,000 PSI (200 Bars)
- Liquid Handled - Water, Raffinate, PLS, Thickener, Tailings, Brine, & Other Various Mining Applications
- Temperature range - to 175 Deg F (80 Deg C)
- HP range - to 2,500 HP (1,850 KW)
- Drivers - Engine and gear drive, electric motor with or without thrust pot, used with or without a VFD

Floway® Coverage Chart 50Hz



Floway® Coverage Chart 60Hz



Performance data shown is approximate. For actual pump performance contact your local Floway® representative or visit the online pump selector website at www.weirminerals.com.

The Floway® vertical turbine pump is specially designed to reduce vibration levels and improve corrosive and abrasive resistance.

VMP - Wet Pit (VS1)



VMP - Barrel/Can (VS6)





Vertical motor with solid shaft medium thrust construction

Flexible coupling spacer for ease of thrust bearing and mechanical seal removal

Coupling guards

Thrust Bearing - Tandem DB angular contact for continuous up and down extends mechanical seal life

Constant level oil and guard

Discharge head

Sleeve mounted mechanical seal

Shaft lateral adjusting nut for impeller lift

Oil temperature gauge.

Throttle bearing provides shaft support and allows higher operating pressures

Precision shaft straightness. Surface turned, ground, and polished the entire length

Threaded or keyed type lineshaft couplings

Corrosion & abrasion resistant lineshaft bearings

Flange face, metal-to-metal contact with close tolerance register for precision alignment

Radial hydraulic forces equalized by multi- vane bowl diffuser, reduces rotor loading and provides exceptional sleeve bearing life. Low energy per stage bowl assembly allows broad range of hydraulic stability

Optional Low NPSHR 1st stage impeller available

Maintenance free, permanently grease packed suction bearing

Impeller Wear Ring

Bowl Wear Ring

Intermediate Bowl

Bowl Bearing

Impeller

Suction Bell

Clip-on Basket Strainer

Geographical footprint

Weir Minerals has the geographical presence to service all the major minerals markets around the world. This global supply capability provides a competitive advantage in this relatively fragmented market.

Weir Minerals has operations across:

- North America
- Latin America
- Africa
- Former Soviet Union
- Europe
- Australia
- Asia

Customer profile

Our customers range from the world's largest minerals and mining multinationals to single pumpset operators.

We support customer operations worldwide with consistent products and local engineering expertise. As part of The Weir Group, we have the reach and resource to build close, long term relationships with all our customers, helping them to achieve ...

The Lowest Cost of Ownership

Service and support

This global capability with our own dedicated service teams combined with the service centres of our sister companies within the Weir Group and those of our strategic partners provide support in virtually every developed market.

WARMAN® Centrifugal Slurry Pumps
GEHO® PD Slurry Pumps
LINATEX® Rubber Products
VULCO® Wear Resistant Linings
CAVEX® Hydrocyclones
FLOWAY® PUMPS Vertical Turbine Pumps
ISOGATE® Slurry Valves
MULTIFLO® Mine Dewatering Solutions
HAZLETON® Specialty Slurry Pumps
LEWIS® PUMPS Vertical Chemical Pumps
WEIR MINERALS SERVICES™



For further information on any of these products, service or support services contact your nearest sales office or visit:

www.weirminerals.com

Weir Floway, Inc. dba Weir Minerals Floway Pumps

2494 S Railroad Avenue
PO Box 164
Fresno, CA 93707 USA

Tel: +1 559 442 4000
Fax: +1 559 442 3098
Email: floway@weirminerals.com

Excellent Minerals Solutions

WEIR MINERALS

Copyright © 2012 Weir Floway, Inc. All rights reserved.
WARMAN is a registered trademark of Weir Minerals Australia Ltd and Weir Group African IP Ltd; CAVEX, HAZLETON, MULTIFLO are registered trademarks of Weir Minerals Australia Ltd; LEWIS PUMPS is a registered trademark of Envirotech PumpSystems Inc; GEHO is a registered trademarks of Weir Minerals Netherlands bv; FLOWAY is a registered trademark of Weir Floway Inc.; VULCO is a registered trademark of Vulco SA; ISOGATE is a registered trademark of Weir do Brasil Ltda. LINATEX is a registered trademark of Linatex, Ltd.

CLIENT: RESOLUTION

PROJECT: RESOLUTION – NEAR WEST

Near West Tailings System Memorandum

	SIGNATURE	DATE
PREPARED BY:	Tyler Campbell	September 5, 2014
REVIEWED BY:		September 5, 2014
APPROVED BY:		September 5, 2014
APPROVED BY:		

ISSUE/REVISION INDEX

Issue Code	Revision					Revision Details
	No.	By	Rev'd	App.	Date	
RR	A	TC	SC	HP	2013-05-01	
RR	1	TC	SC	HP	2014-09-05	Final

Issue Codes: RC = Released for Construction, RD = Released for Design, RF = Released for Fabrication, RI = Released for Information, RP = Released for Purchase, RQ = Released for Quotation, RR = Released for Review and Comments.

TABLE OF CONTENTS

1. INTRODUCTION 1
2. DESIGN BASIS 1
3. RESULTS 2
4. PIPE QUANTITIES 4
5. AREAS FOR FUTURE STUDY 4
6. DISCLAIMER 5

REFERENCES 6

TABLES

Table 2.1 Design Basis 2
Table 3.1 Calculation Results 3
Table 4.1 Pipe Quantities 4

APPENDICES

Appendix I Pipeline Plan and Profile Drawings

Appendix II Hydraulic Grade Lines

1. INTRODUCTION

This memorandum is a concept selection study of the tailings transport systems for the Near West Tailings Storage Facility (TSF). Tailings will be delivered from the plant to a "Tie-in Point" at the North East corner of the TSF. The tailings delivery system to the toe of the North Dam is designed by others, whereas KCB's scope starts downstream of a pumphouse. We identified the pipelines and the pumping head requirements for the tailings in our study for the design of the pumphouse. These requirements are defined for both Scavenger and Cleaner Tailing systems.

The Scavenger pipeline extends from the Tie-in Point at the pumphouse to follow the North and South crests of the tailings embankment. Where possible the pipelines have been routed to stay 10 m below the ridge crests and within the ridge lines to the north and south of the TSF, such that any leak will drain into the TSF pond. The pipeline will be constructed in Year 0 and will be adjusted to account for the growth of the TSF.

The Cleaner pipeline extends from the Tie-in Point at the pumphouse to the center area of the TSF. The pipeline will be constructed in Year 0 and will be adjusted to deposit the Cleaner Tailings at the desired locations.

The Scavenger and Cleaner pipeline routes and profiles for Years 2, 10, 25, and 45 (Ultimate) are shown in Appendix I. The pipeline routes follow topography; no regrading or excavations were designed. The routes were not optimized to avoid low spots. The pipeline profile was selected to keep the slopes at 10% or less. Note that the Year 2 route is representative of the start-up condition for Year 0.

2. DESIGN BASIS

Design Basis information for this study is listed in Table 2.1 below. Throughput is based on an assumed nominal 120,000 MTPD *(132,277.36 STPD)* and a 92% availability factor (M3, 2012).

Table 2.1 Design Basis

Description	Scavenger Tailings	Cleaner Tailings
Design Throughput	123,288 MTPD *(135,901.76 STPD)*	24,308 MTPD *(26,794.98 STPD)*
Solids SG	2.67	3.54
Solids Concentration by Weight	65%	55%
Slurry Specific Gravity	1.69	1.65
Pumphouse Tie-in (Start) Elevation	820 m *(2690.29 ft)*	820 m *(2690.29 ft)*
Year 2 Discharge Elevation	740 m *(2427.82 ft)*	768 m *(2519.69 ft)*
Year 10 Discharge Elevation	788 m *(2585.30 ft)*	775 m *(2542.65 ft)*
Year 25 Discharge Elevation	816 m *(2677.17 ft)*	810 m *(2657.48 ft)*
Year 45 Discharge Elevation	855 m *(2805.12 ft)*	855 m *(2805.12 ft)*
Plastic Viscosity	40 mPa-sec	18 mPa-sec
Yield Stress	9.4 Pa *(0.0014 PSI)*	8.5 Pa *(0.0012 PSI)*
Design Flow Rate	4690 m^3/hr *(165,625.80 ft^3/hr)*	1115 m^3/hr *(39,375.85 ft^3/hr)*
HDPE Pipe Roughness	.02 mm *(0.00079 inches)*	.02 mm *(0.00079 inches)*
Steel Pipe Roughness	.05 mm *(0.0020 inches)*	.05 mm *(0.0020 inches)*
Friction Design Factor (allowance for valves and fittings)	15%	15%

Our assumptions for the rheology were based on previous site selection studies, specifically the Far West site (KCB, 2013). As noted in that report we recommend further testing of the slurries in the next stage of design.

3. RESULTS

The Tailings Transport System incorporates dual pipelines for each of the Scavenger and Cleaner systems. Flow is split equally between dual lines to keep the pipe size manageable and accommodates a larger range of flow rates. Due to the lower startup production rates Year 2 requires only single Scavenger and Cleaner pipelines. HDPE pipe was selected for all pipelines except for a short steel section of the Year 45 Scavenger line which exceeded the pressure rating of HDPE. Choke stations will be required to dissipate excess line pressure for both Scavenger and Cleaner lines.

Discharge valve junctions are spaced every 200 m *(656.17 ft)* on the main lines. Moveable discharge hoses will connect to the valves to allow spigotting anywhere along the embankment crest.

The Cleaner pipeline route travels to the center area of the TSF. The Cleaner Tailings discharge pattern requires the pipeline to shift often.

The pipeline friction losses have been calculated using Saskatchewan Research Council (SRC) Bingham Fluid Model for slurries with yield stresses. The SRC model uses the pipe diameter, wall

roughness, fluid density, Bingham yield stress, and Bingham plastic viscosity to predict a transition velocity and a pressure gradient. Using these hydraulic parameters hydraulic grade lines for the Scavenger and Cleaner lines were generated. The hydraulic grade lines are presented in Appendix II. The HGLs were used to define pumping head and energy dissipation requirements. Calculation results are summarized in Table 3.1 below.

Table 3.1 Calculation Results

Description	Scavenger Tailings	Cleaner Tailings
HDPE Pipeline Size	32" DR9 HDPE	18" DR6.3 HDPE
HDPE Flow Velocity	2.15 m/s *(7.05 ft/s)*	2.14 m/s *(7.02 ft/s)*
HDPE Friction Gradient	6.94 m/km *(6.94 ft/1000ft ft/mi)*	13.74 m/km *(13.74 ft/10000ft)*
HDPE Maximum Allowable Working Pressure	845 kPa *(122.56 PSI)*	1508 kPa *(218.72 PSI)*
Steel Pipeline Size	26" SCH 20	NA
Steel Flow Velocity	2.06	NA
Steel Friction Gradient	6.27 m/km *(6.27 ft/1000ft)*	NA
Steel Maximum Allowable Working Pressure	3998 kPa *(579.86 PSI)*	NA
Year 2 Pump Head	18 m *(59.06 ft)*	25 m *(82.02 ft)*
Year 2 Dissipation	58 m *(190.29 ft)*	10 m *(32.81 ft)*
Year 10 Pump Head	30 m *(98.43 ft)*	36 m *(118.11 ft)*
Year 10 Dissipation	16 m *(52.49 ft)*	46 m *(150.92 ft)*
Year 25 Pump Head	44 m *(144.36 ft)*	59 m *(193.57 ft)*
Year 25 Dissipation	NA	11 m *(36.09 ft)*
Year 45 Pump Head	81 m *(265.75 ft)*	79 m *(259.19 ft)*

The maximum allowable working pressure (MAWP) was calculated for ASME B31.3. API 5L Grade B Electrical Resistance Welded steel pipe.

The working pressure for HDPE pipe is specified per the manufacturer's temperature de-rating factors. A PE 4710 HDPE pipe at 50°C *(122^{o}F)* (the assumed summertime maximum) should operate at no more than 73% of the published pressure rating. The MAWP of HDPE pipe was selected to be 25 m *(82.02 ft)* below the de-rated pressure to ensure sufficient margin between the system pressure and de-rated pipe pressure.

We note in the next stage of design, KCB would be available to size the pumps and pumphouse required to distribute the tailings. This way a complete system could be designed and quantities could be defined along with operating power requirements.

As mentioned above the pipeline alignment and profiles are defined in Appendix I on figures M02 to M09. The corresponding hydraulic grade lines (HGLs) are defined in Appendix II.

4. PIPE QUANTITIES

To assist Resolution Copper in estimating CAPEX, we have listed the pipe quantities are listed in Table 4.1 below. HDPE pipe quantities are for pipe meeting the PE4710 specification.

Table 4.1 Pipe Quantities

Description	Scavenger Tailings	Cleaner Tailings
Number of Pipelines	2	2
Maximum Pipe Length	8,560 m *(28,083.99 ft)*	4,820 m *(15,813.65 ft)*
Year 2 Pipe HDPE (Length)	1,810,000 kg *(1995.18 tons)* (1 x 8560 m *(28,083.99 ft)*)	434,000 kg *(478.40 tons)* (1 x 4820 m *(15,813.65 ft)*)
Year 10 Pipe HDPE (Length)	2,810,000 kg *(3097.49 tons)* (2 x 6618 m *(21,712.60 ft)*)	550,000 kg *(606.27 tons)* (2 x 3050 m *(10,006.56 ft)*)
Year 25 Pipe HDPE (Length)	2,920,000 *(3218.75 tons)* kg (2 x 6910 m *(22,670.60 ft)*)	680,000 kg *(749.57 tons)* (2 x 3770 m *(12,368.77 ft)*)
Year 45 Pipe Steel (Length)	245,000 kg *(270.07 tons)* (2 x 600 m *(1968.50 ft)*)	0
Year 45 Pipe HDPE (Length)	2,540,000 kg *(2799.87 tons)* (2 x 6000 m *(19,685.04 ft)*)	684,000 kg *(753.98 tons)* (2 x 3300 m *(10,826.77 ft)*)
Total Number of Distribution Valves	140 - 26” Knife Gate Valves	12 - 14” Knife Gate Valves

5. AREAS FOR FUTURE STUDY

In the next stage of design the pipelines should be optimized to minimize pump head, pipeline length, and other factors affecting capital and operating costs. Specifically the pipe chosen for each section should be optimized for cost, pressure rating, and local availability. The system design presented does not include any redundancy. Requirements for additional pipelines to improve system reliability should be investigated. System performance under low flow conditions (during mine ramp up and ramp down) should be analyzed.

The results of our analysis depend heavily on accurate rheology for the tailings. We recommend that additional definition of the rheology is done as the project develops. Rheology testing should define the shape, size, density, hardness and abrasivity of the tailings particles. This will assist in final selection of the pumps and pipelines.

6. DISCLAIMER

This report is an instrument of service of KCB. The report has been prepared for the exclusive use of Resolution Copper for the specific application to the Resolution Near West project. The report's contents may not be relied upon by any other party without the express written permission of KCB. In this report, KCB has endeavoured to comply with generally-accepted professional practice common to the local area. KCB makes no warranty, express or implied.

KLOHN CRIPPEN BERGER LTD.



Prepared By: Tyler Campbell, E.I.T.



Senior Review By: Scott Crozier, P.Eng.

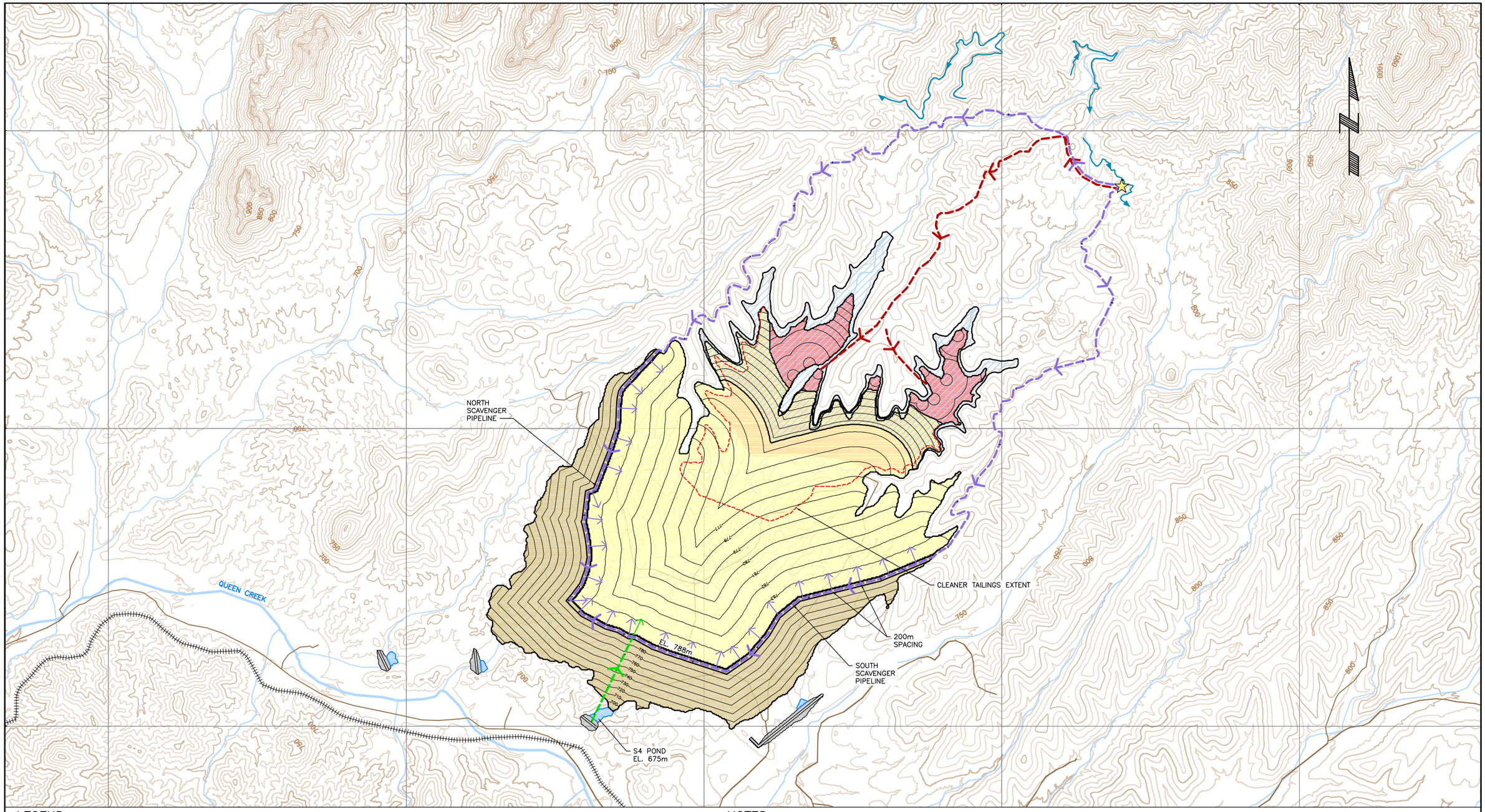
REFERENCES

4000 Process Design Criteria, Resolution Project: Pre-feasibility Study, Milling at West Site Tailing at Near East Sites: Option F – 600, M3 Project No.: M3-PN110036, December 2012.

Technical Memorandum Scavenger Tailings, Klohn Crippen Berger Report No.: M09441A12-01-07-0001, April 2013.

APPENDIX I

Pipeline Plan and Profile Drawings



LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE-IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

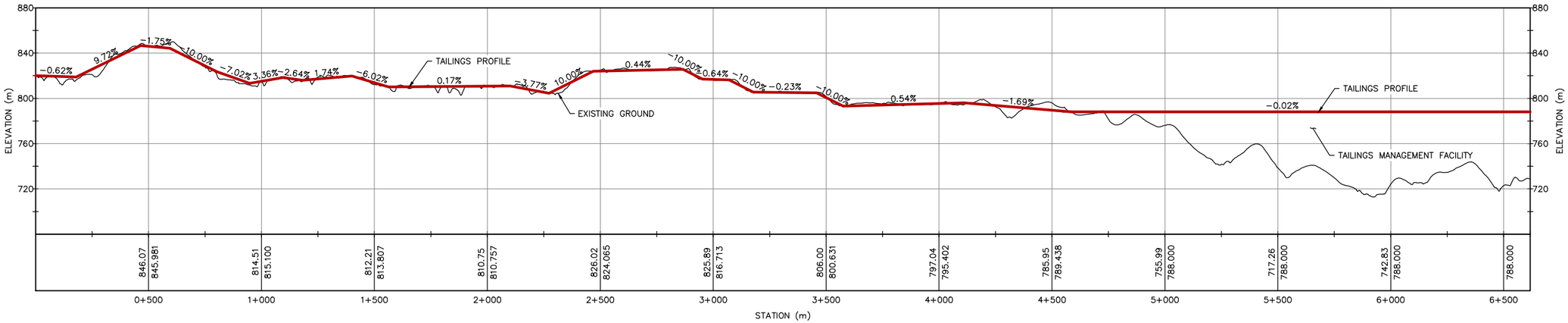
TITLE: PLAN
YEAR 10

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M02

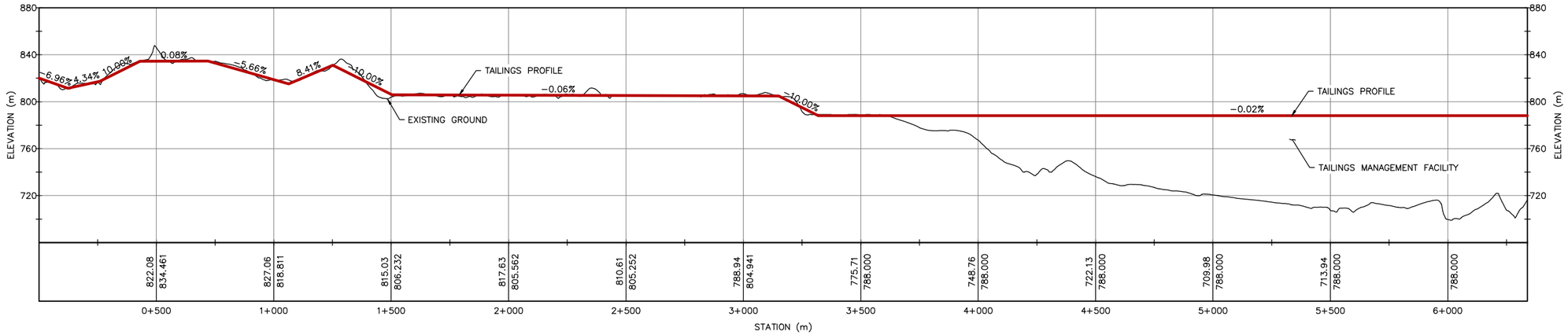
KCB-FIG-D-L

Date: 7/23/2013 Time: 09:54:53 Scale: 1:2,585(PS)
Drawing File: Z:\WVCR\M09441A14 - RES-Near WestGeotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M02.dwg (dacson)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Comp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Comp_Streams_Sep2012
Image File(s):



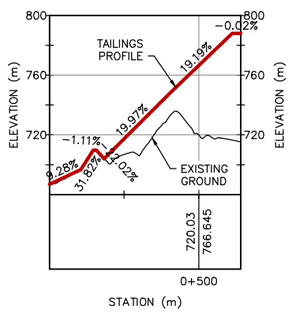
PROFILE ALONG NORTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



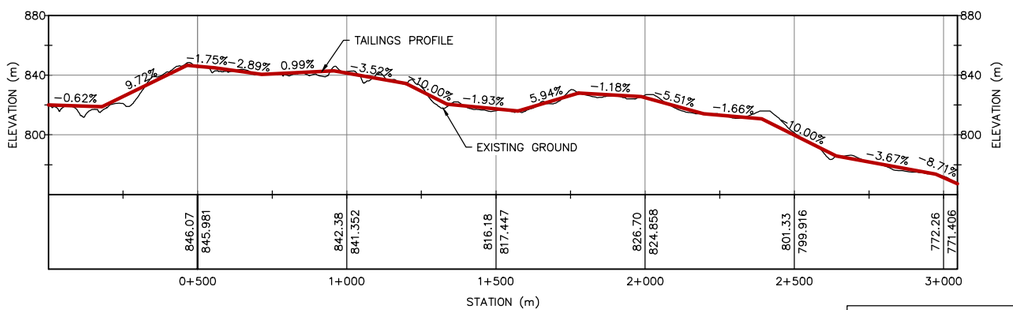
PROFILE ALONG SOUTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

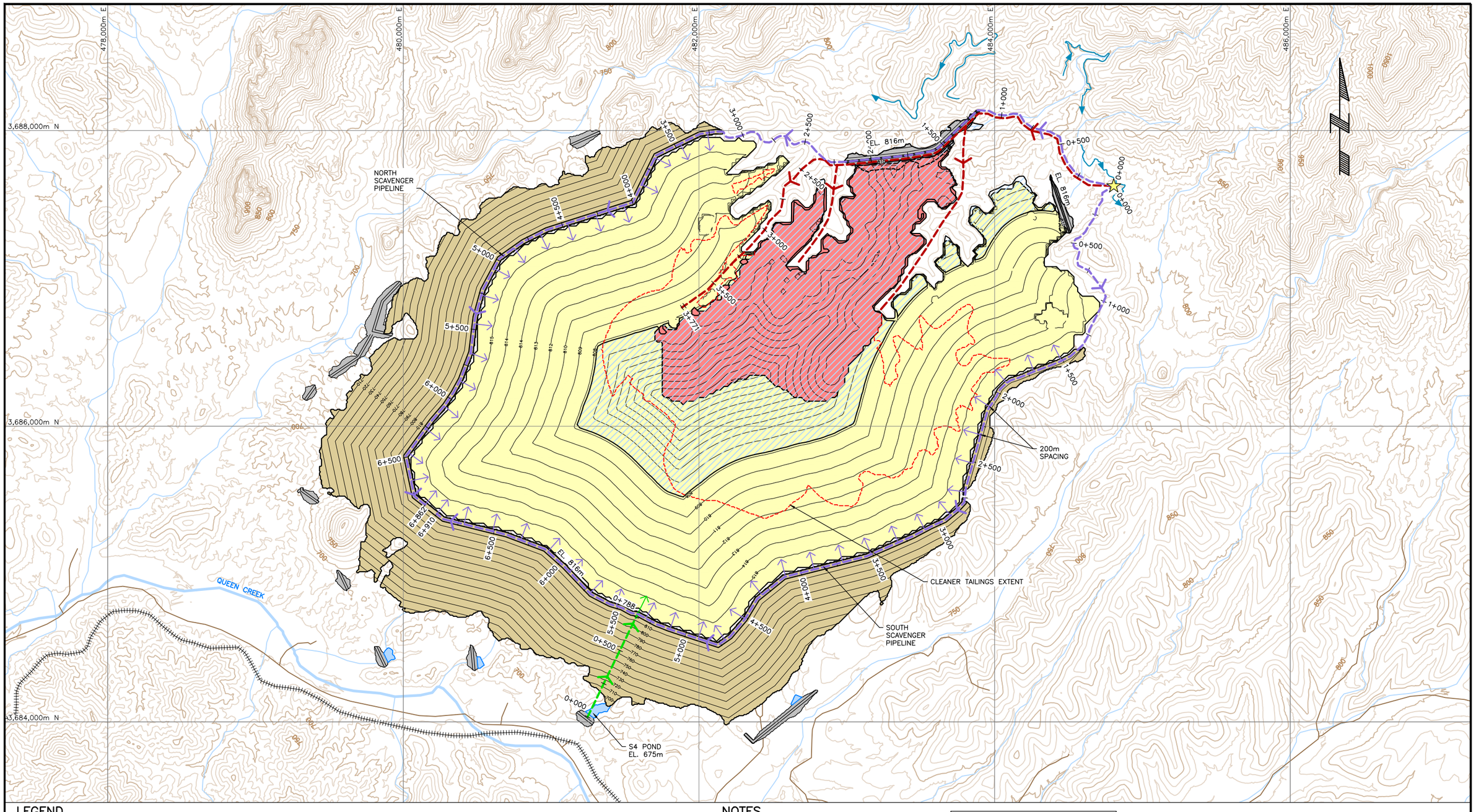
TITLE: PROFILES
YEAR 10

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A12	M03

KCB-FIG-D-L

Date: 7/23/2013 Time: 09:57:06 Scale: 1:32.524(PS)
Drawing File: Z:\M\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M03.dwg (olarson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):



LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE–IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

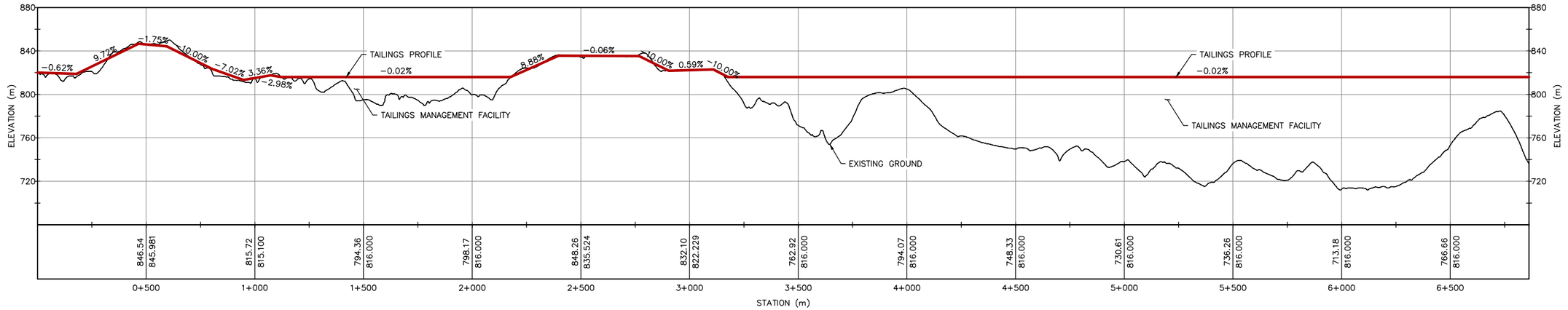
PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: PLAN
YEAR 25

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M04

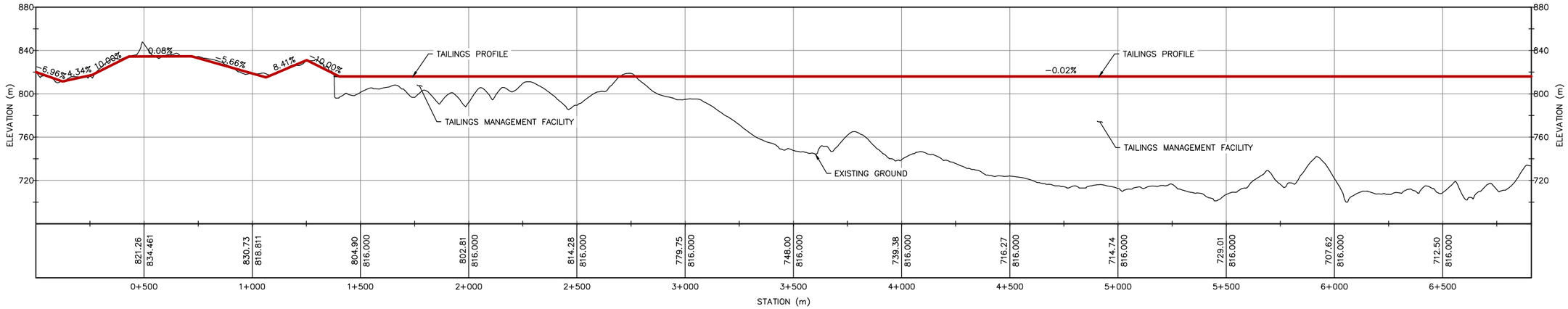
KCB-FIG-D-L

Date: 7/23/2013 Time: 09:55:17 Scale: 1:2,585(PS)
Drawing File: Z:\MVCAD\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M04.dwg (olacson)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Comp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Comp_Streams_Sep2012
Image File(s):



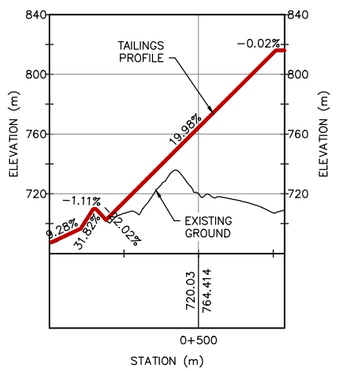
PROFILE ALONG NORTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



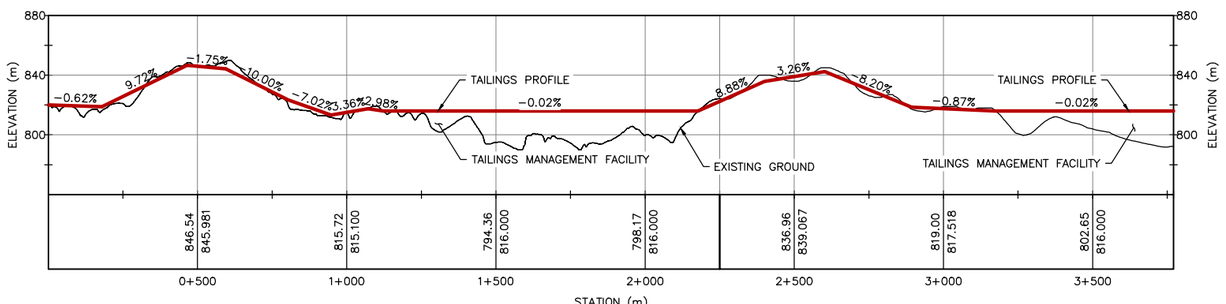
PROFILE ALONG SOUTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

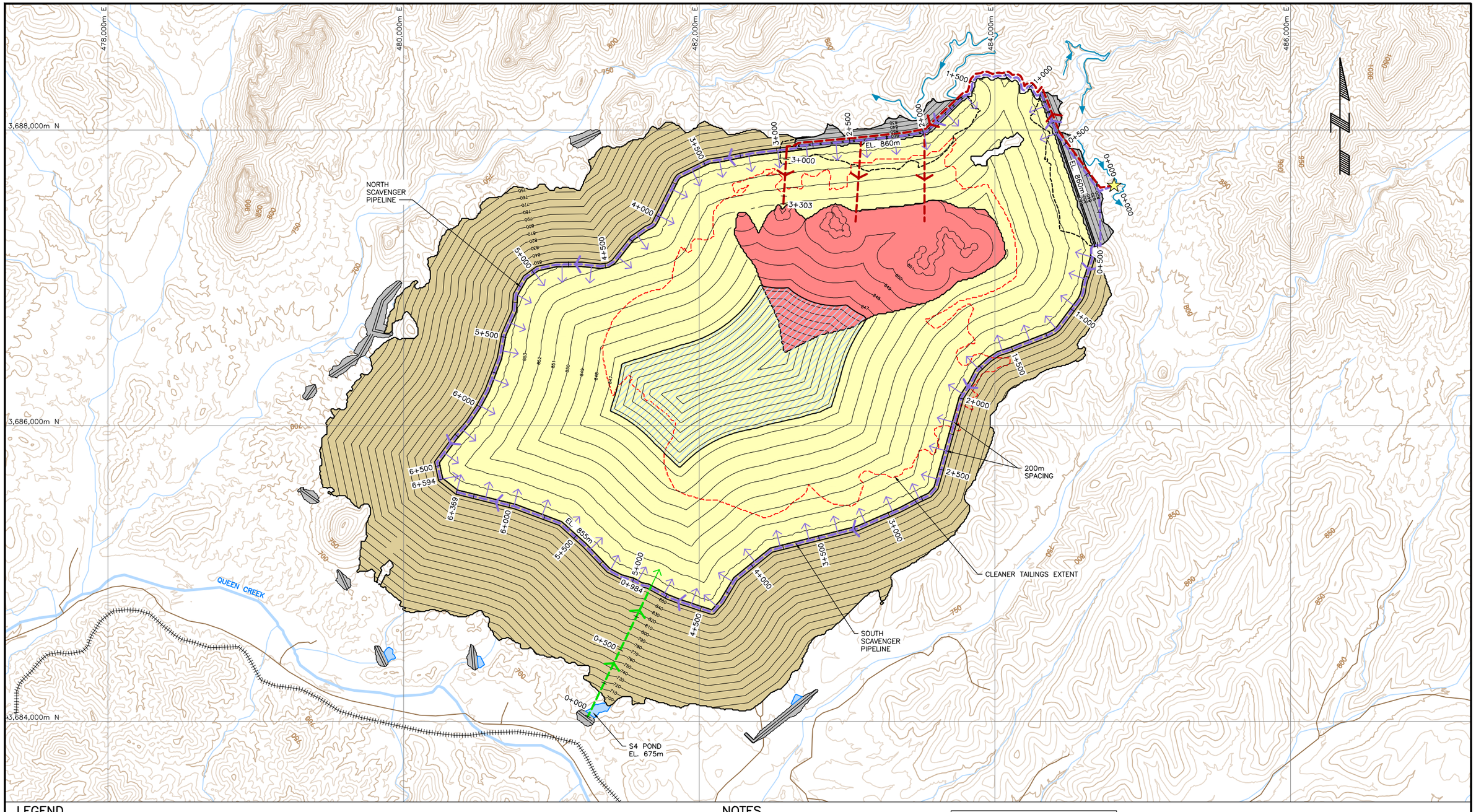
TITLE: PROFILES
YEAR 25

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A12	M05

KCB-FIG-D-L

Date: 7/23/2013 Time: 09:55:53 Scale: 1:32.524(PS)
Drawing File: Z:\M\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M05.dwg (olarson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):



LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE–IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

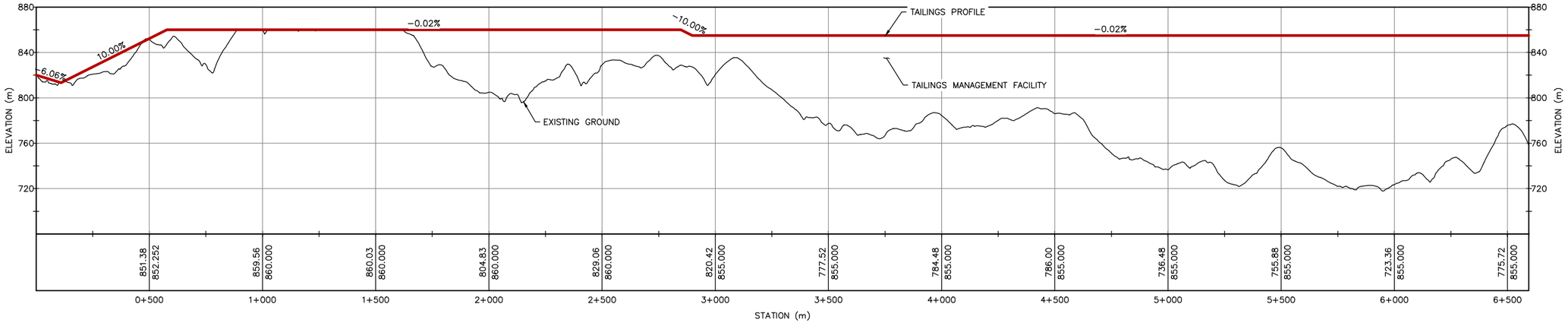
TITLE: ULTIMATE PLAN

Klohn Crippen Berger

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M06

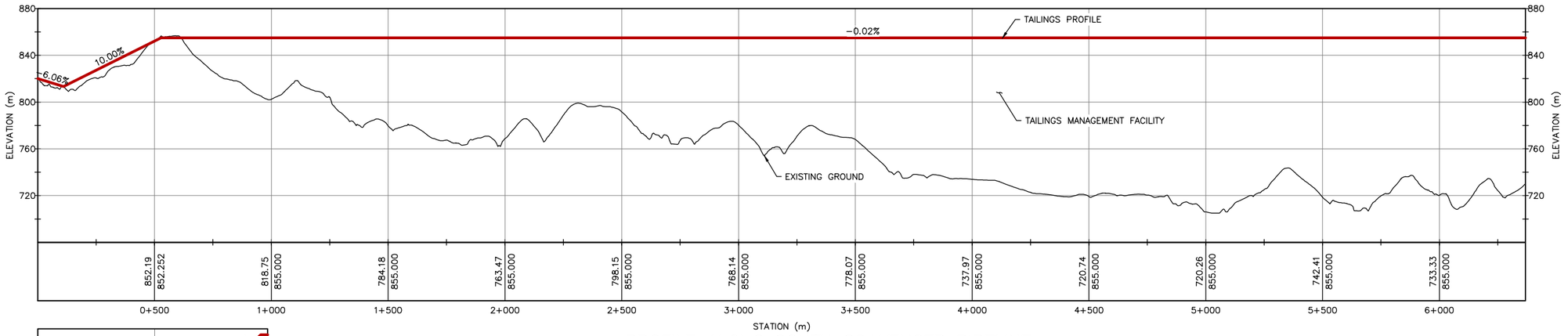
KCB-FIG-D-L

Date: 9/3/2014 Time: 17:07:51 Scale: 1:2,585(PS)
Drawing File: Z:\MA\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M06.dwg (dhu)
Xref File(s): FOR INSERT_NEAR WEST - APRIL 2013; Happy_Camp_Facilities_Sep2012; bm-near west-5mtopo; Happy_Camp_Streams_Sep2012
Image File(s):



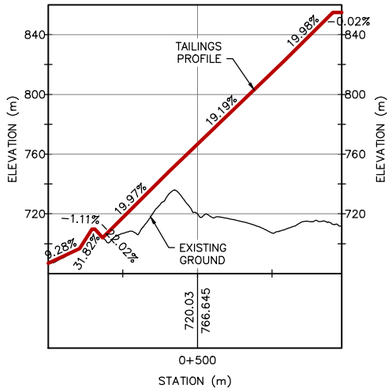
PROFILE ALONG NORTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



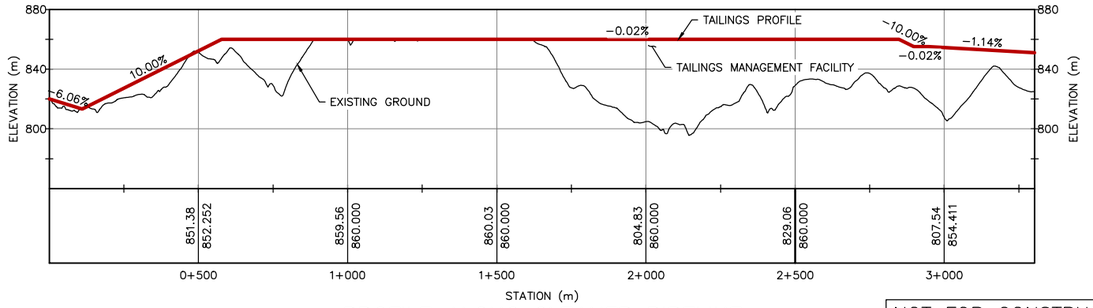
PROFILE ALONG SOUTH SCAVENGER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE

SCALE HOR 1:10000
SCALE VER 1:2000

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining	PROJECT: RESOLUTION PROJECT NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY
Klohn Crippen Berger	TITLE: PROFILES YEAR 45 (ULTIMATE)
	SCALE: AS SHOWN · PROJECT No.: M09441A12 · FIG. No.: M07

KCB-FIG-D-L

Date: 7/23/2013 Time: 09:56:07 Scale: 1:32.524(PS)
Drawing File: Z:\M\VOR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M07.dwg (olacson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):

Date: 9/3/2014 Time: 17:07:49 Scale: 1:2,585(PS)
Drawing File: Z:\M\VCR\M09441A14 – RES–Near WestGeotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14–M08.dwg (dhu)
Xref File(s): FOR INSERT_NEAR WEST – APRIL 2013; Happy_Camp_Facilities_Sep2012; bm–near west–5mtopo; Happy_Camp_Streams_Sep2012
Image File(s):

478,000m E
480,000m E
482,000m E
484,000m E
486,000m E
3,688,000m N
3,686,000m N
3,684,000m N

QUEEN CREEK

0+000
0+500
1+000
1+500
2+000
2+500
3+000
3+500
4+000
4+500
4+819
5+000
5+500
6+000
6+500
7+000
7+293
7+500
8+000
8+500
8+554

EL. 768m
EL. 722m
EL. 722m
EL. 722m
EL. 675m
S4 POND

200m SPACING

LEGEND

- RAILWAY
- EXISTING ROAD
- STREAM
- TIE–IN POINT
- SCAVENGER PIPELINE
- CLEANER PIPELINE
- SEEPAGE WATER PIPELINE (TYPICAL)
- COMPACTED EMBANKMENT
- THICKENED SCAVENGER TAILINGS
- THICKENED CLEANER TAILINGS
- STARTER DAM
- RECLAIM POND
- SEEPAGE DAM

NOTES

1. PROJECTION AND DATUM: UTM ZONE 12N, NAD 27
2. 1m INTERVAL CONTOURS RECEIVED FROM RESOLUTION JANUARY, 2013.

NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

SCALE 0 500m

CLIENT: Resolution Copper Mining

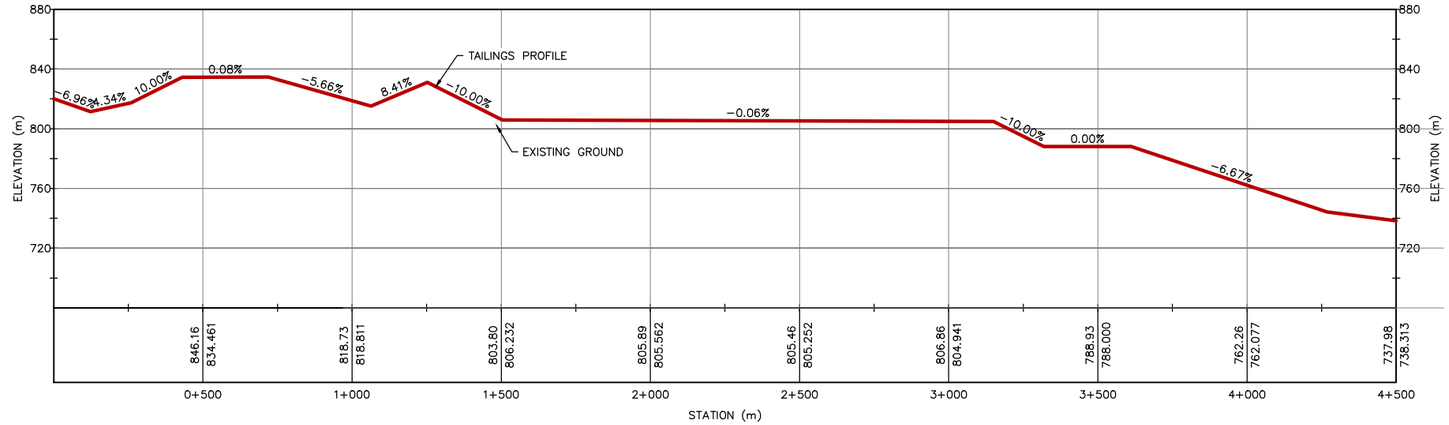
Klohn Crippen Berger

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

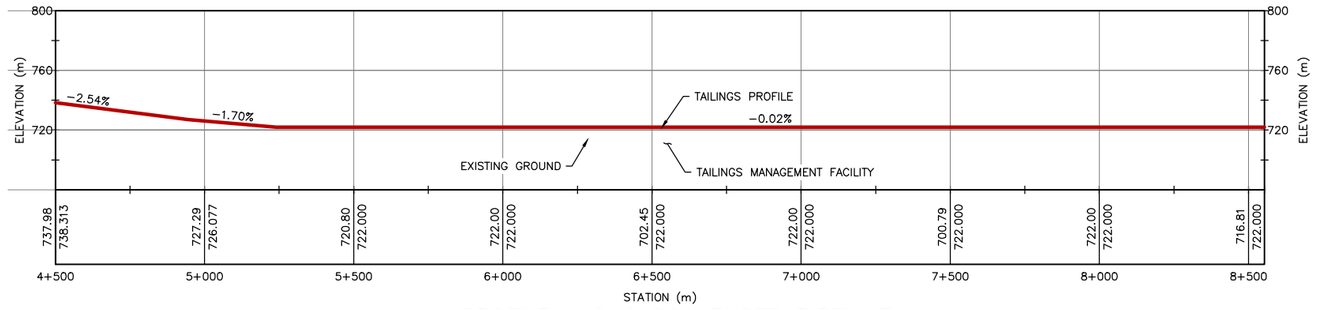
TITLE: STARTUP PLAN

SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A14	M08

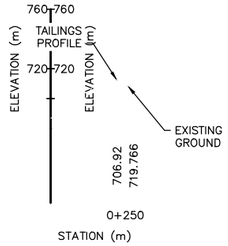
KCB-FIG-D-L



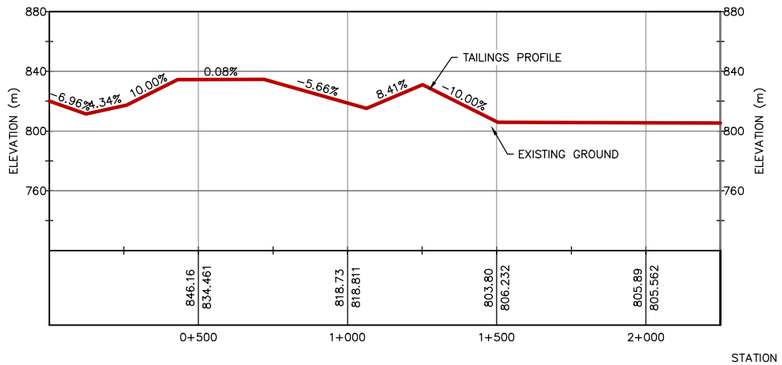
PROFILE ALONG SCAVENGER PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



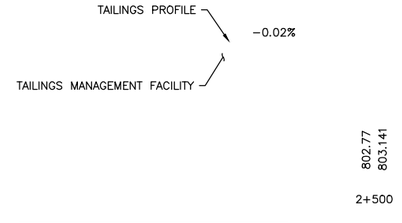
PROFILE ALONG SCAVENGER PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG WATER SEEPAGE PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



PROFILE ALONG CLEANER PIPELINE
SCALE HOR 1:10000
SCALE VER 1:2000



NOT FOR CONSTRUCTION

To be read with Klohn Crippen Berger report dated SEPT. 2014

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: PROFILES
YEAR 2

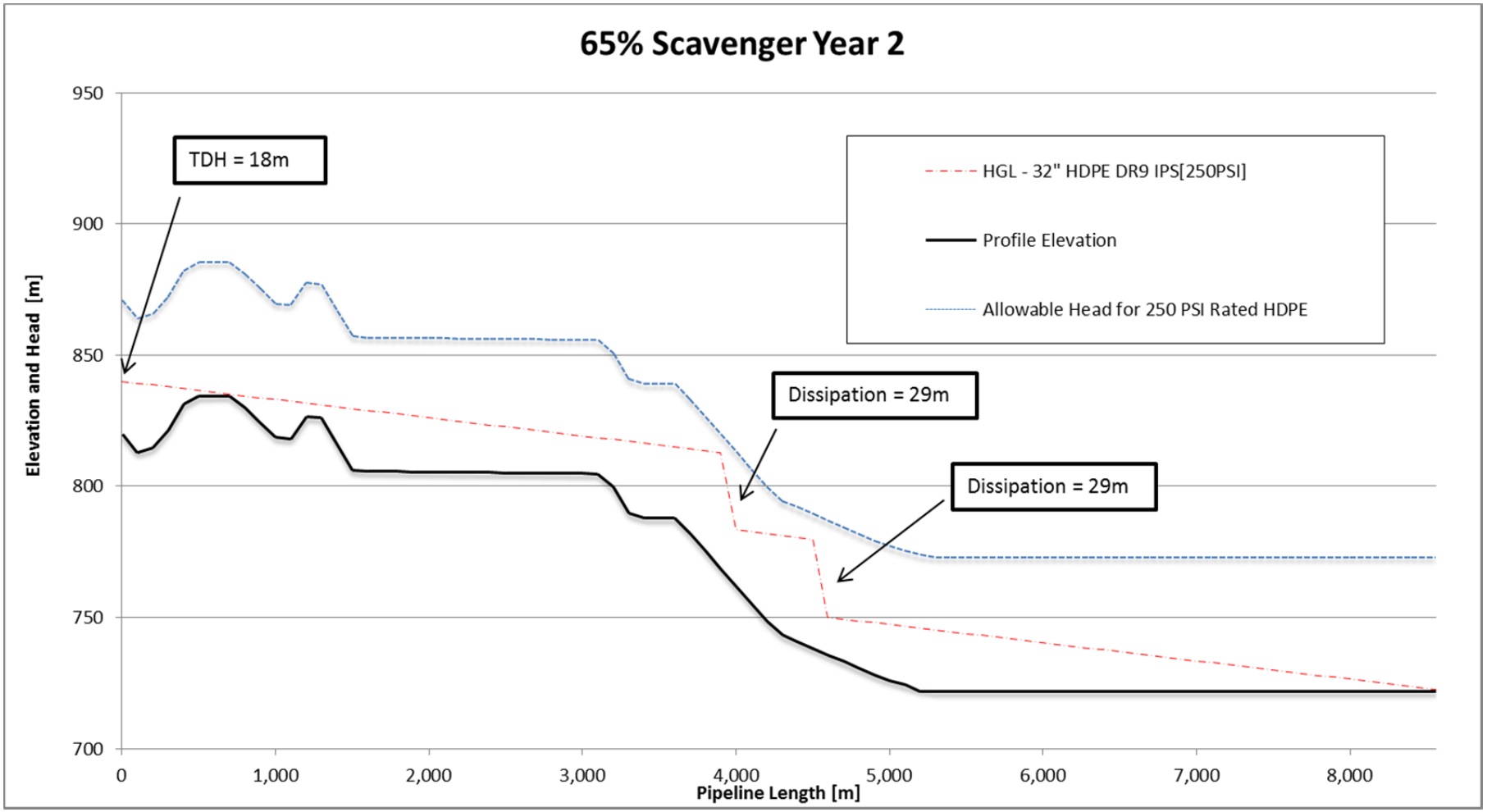
SCALE	PROJECT No.	FIG. No.
AS SHOWN	M09441A12	M09

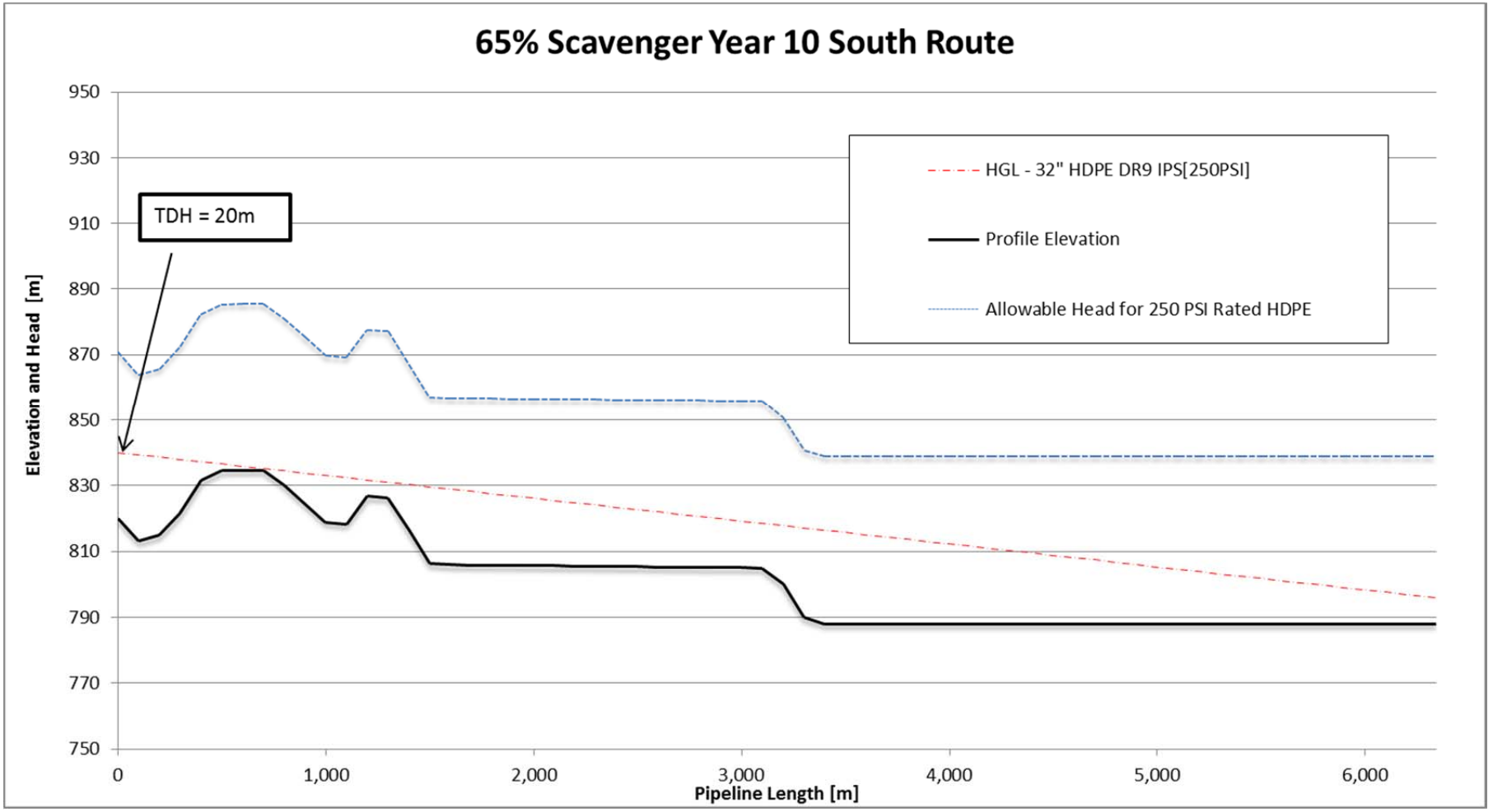
KCB-FIG-D-L

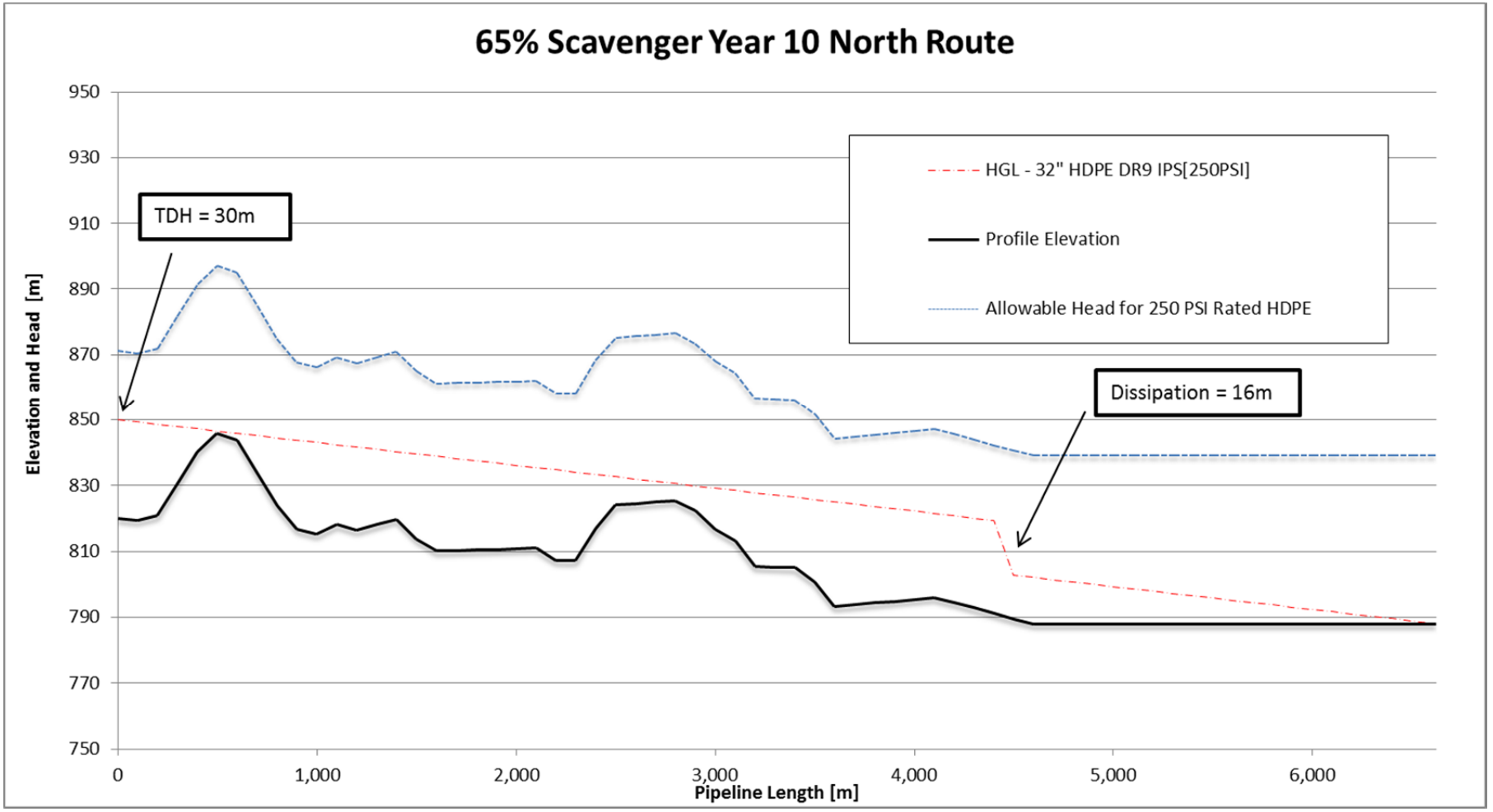
Date: 7/23/2013 Time: 09:54:48 Scale: 1:32.524(PS)
Drawing File: Z:\VCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\CAD\Order of Magnitude Study\Study Memorandum\M09441A14-M09.dwg (olarson)
Xref File(s): Near west_profiles_Apr2013
Image File(s):

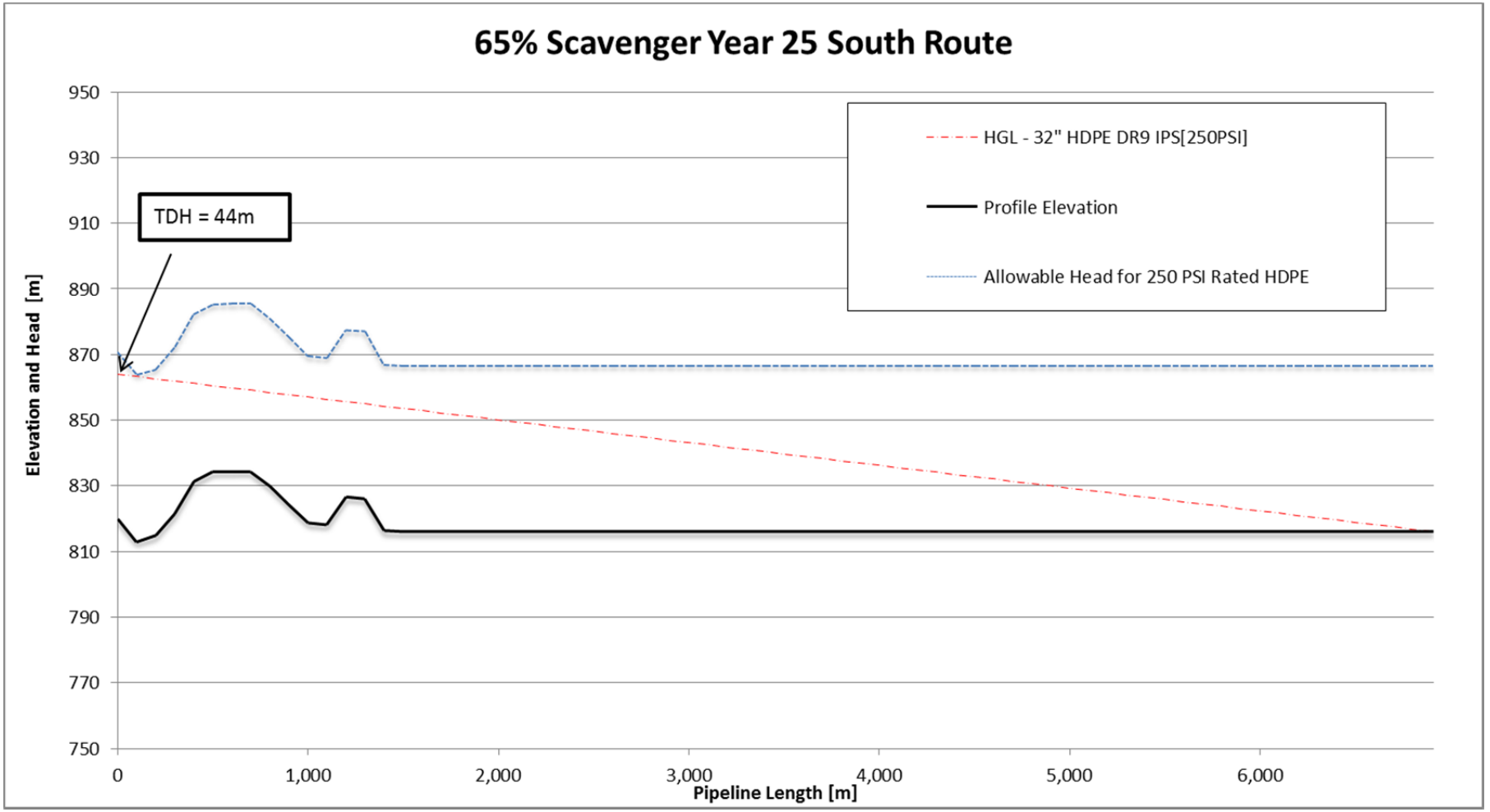
APPENDIX II

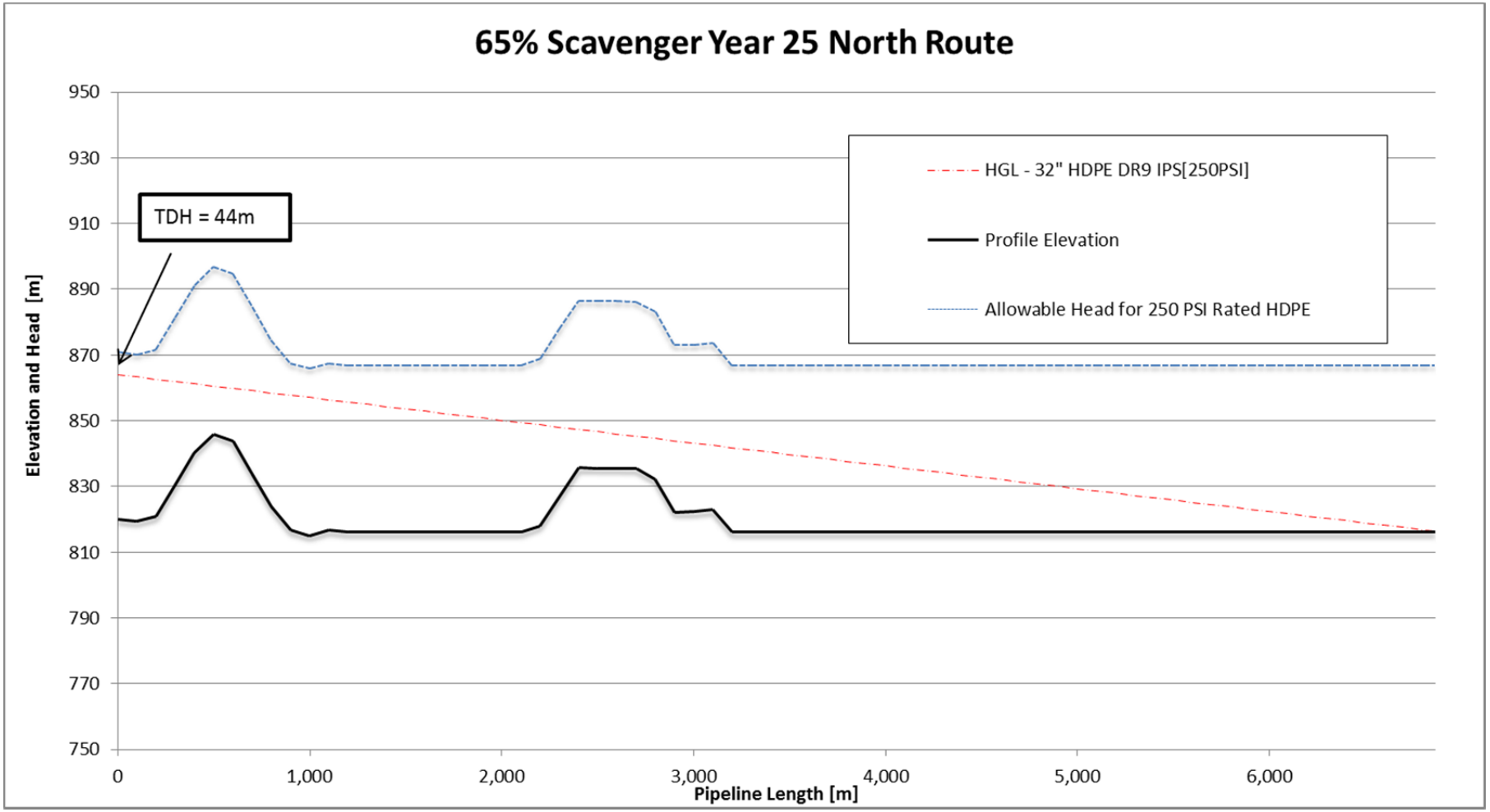
Hydraulic Grade Lines

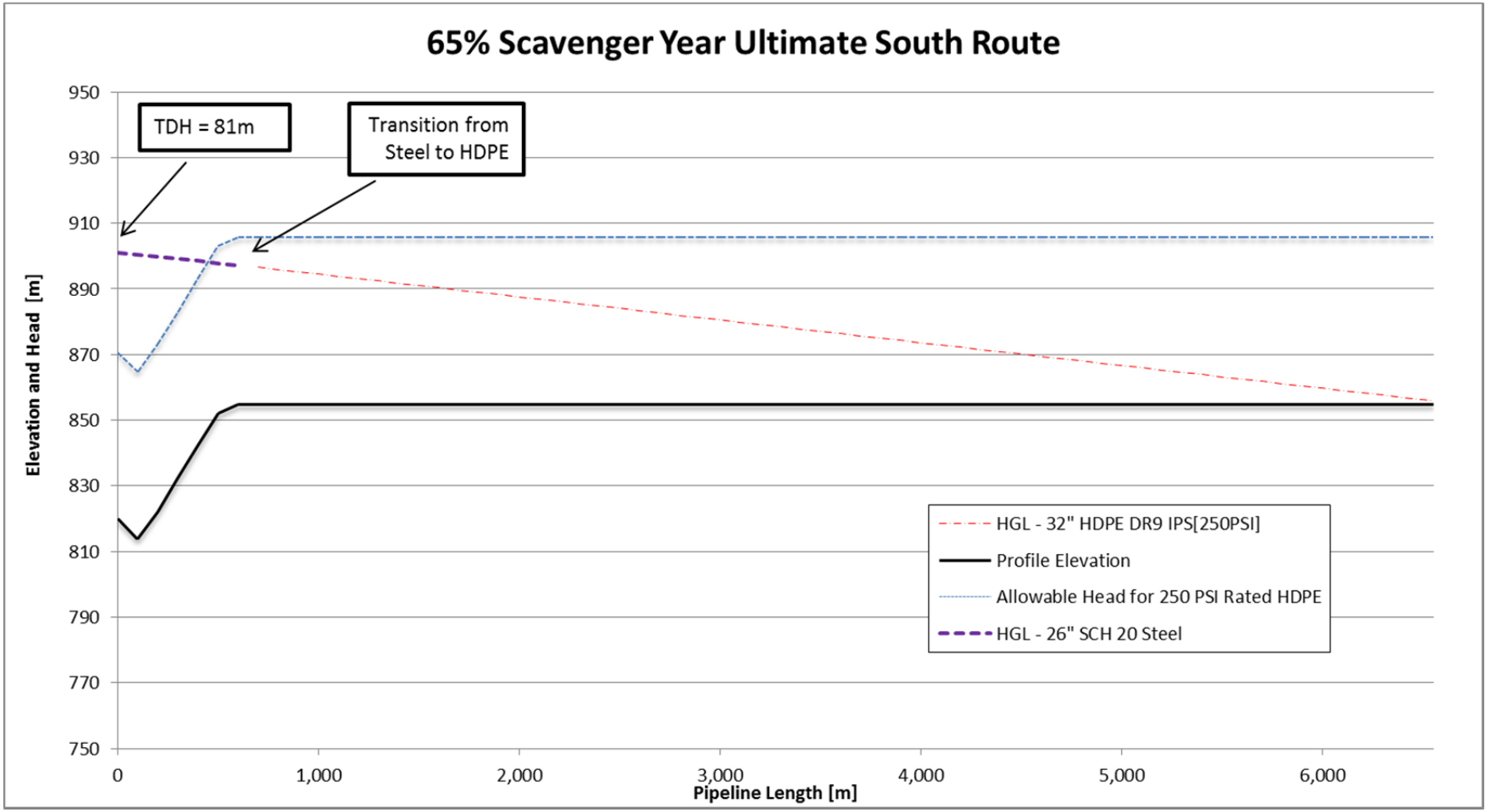

65% Scavenger Year 2
950
900
850
800
750
700
Elevation and Head [m]
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Pipeline Length [m]
TDH = 18m
Dissipation = 29m
Dissipation = 29m
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE

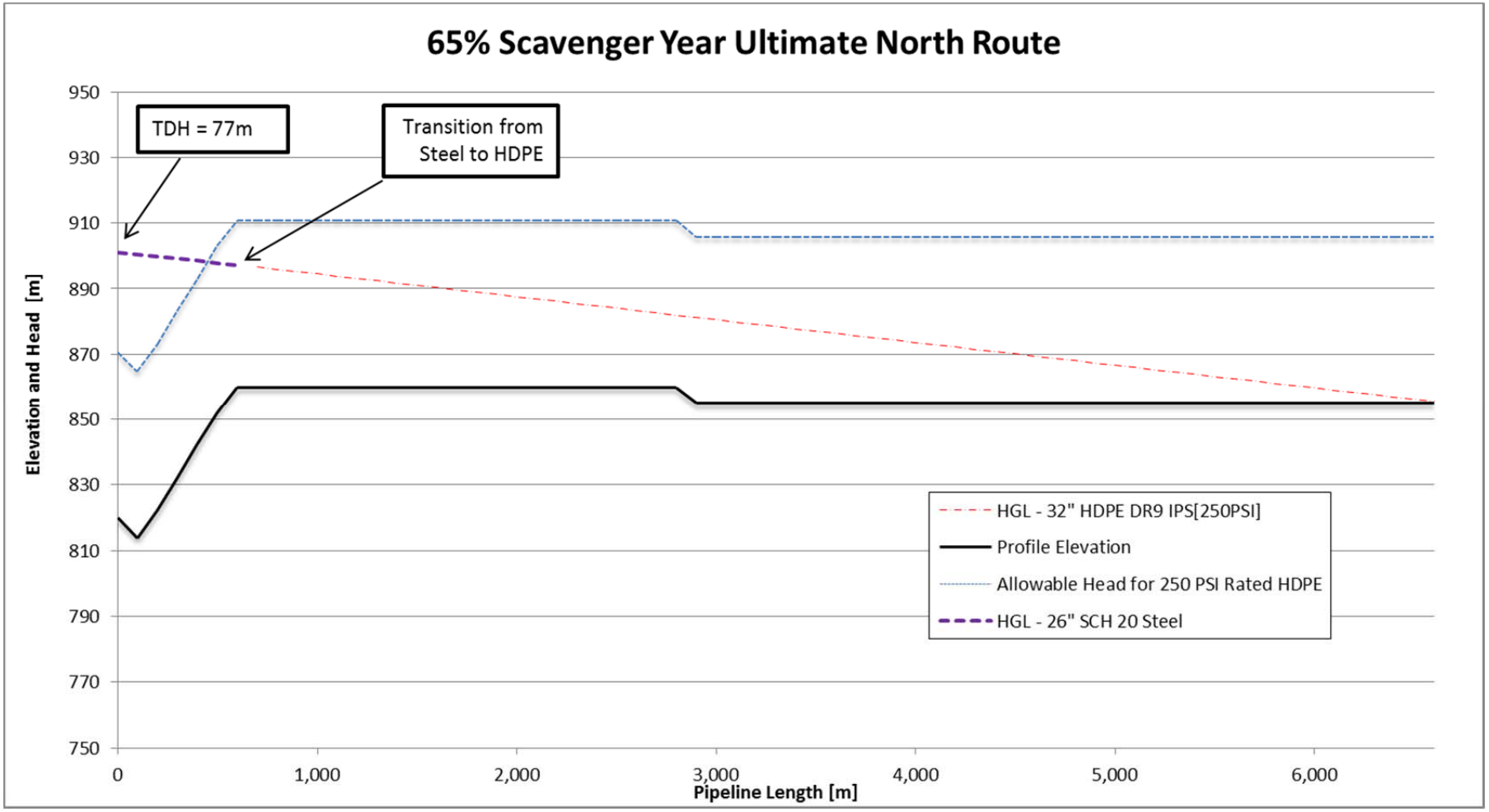

65% Scavenger Year 10 South Route
950
930
910
890
870
850
830
810
790
770
750
Elevation and Head [m]
TDH = 20m
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE
0
1,000
2,000
3,000
4,000
5,000
6,000
Pipeline Length [m]

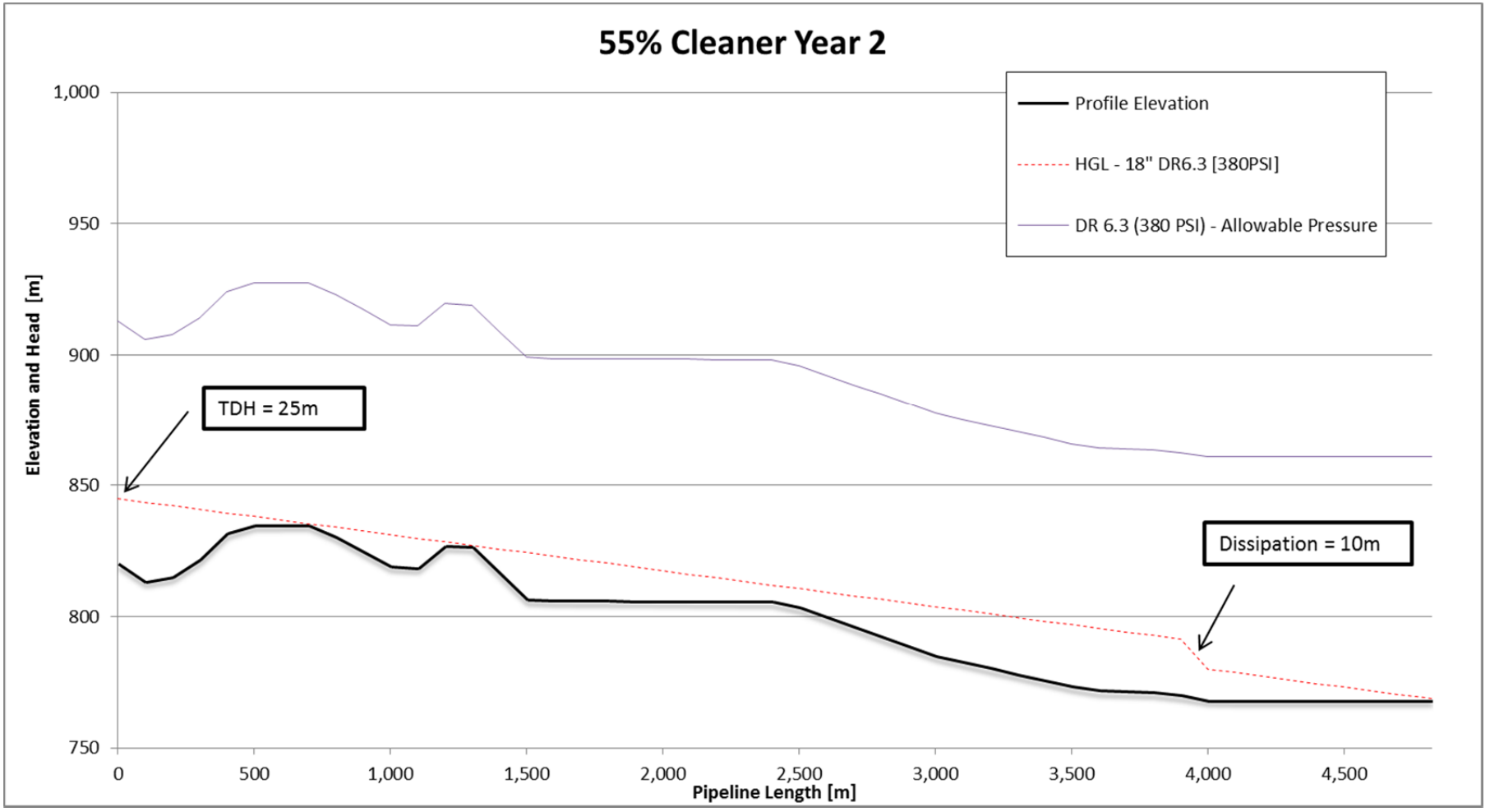

65% Scavenger Year 10 North Route
Elevation and Head [m]
950
930
910
890
870
850
830
810
790
770
750
0
1,000
2,000
3,000
4,000
5,000
6,000
Pipeline Length [m]
TDH = 30m
Dissipation = 16m
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE

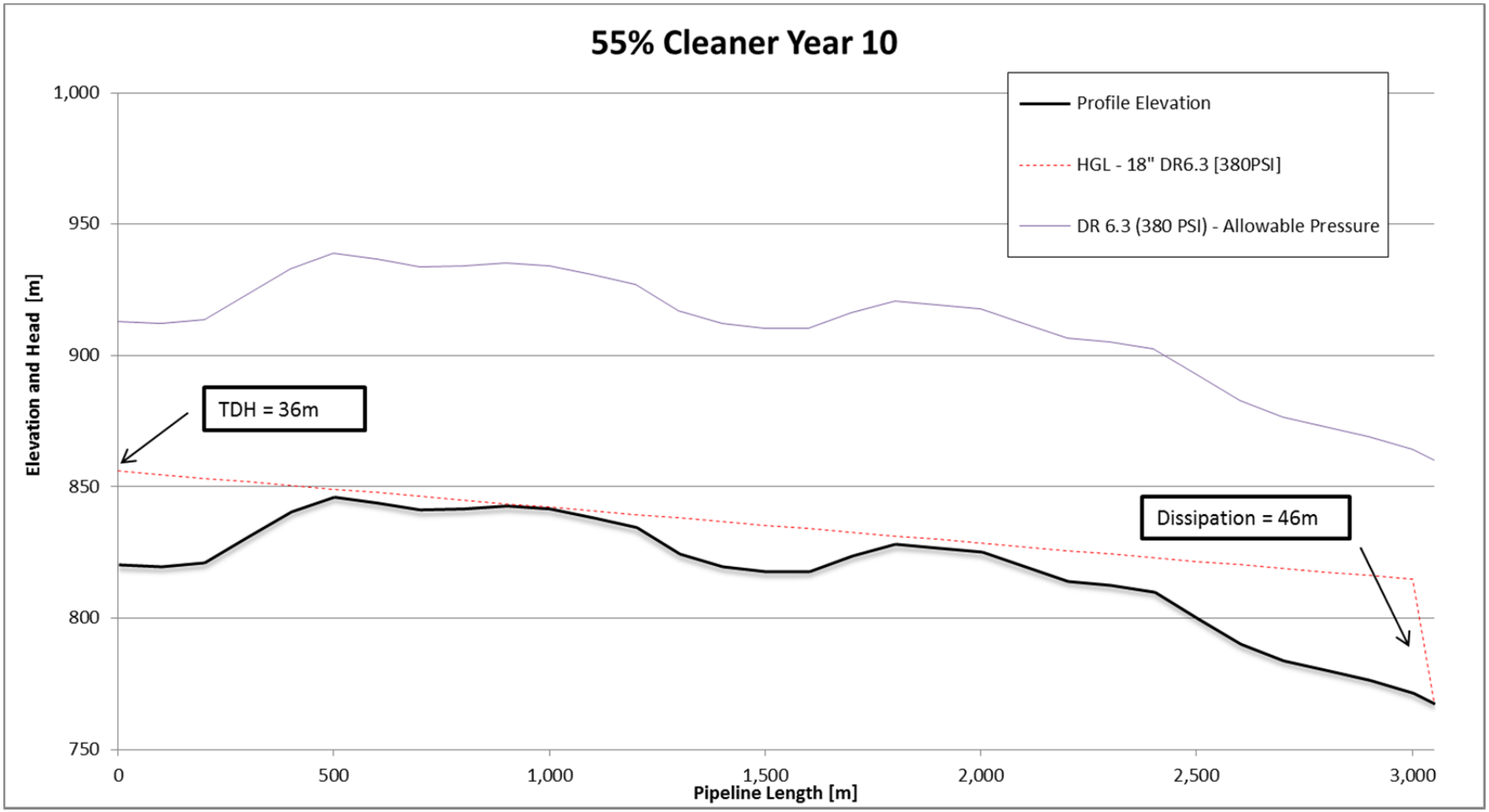

65% Scavenger Year 25 South Route
Elevation and Head [m]
950
930
910
890
870
850
830
810
790
770
750
0
1,000
2,000
3,000
4,000
5,000
6,000
Pipeline Length [m]
TDH = 44m
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE

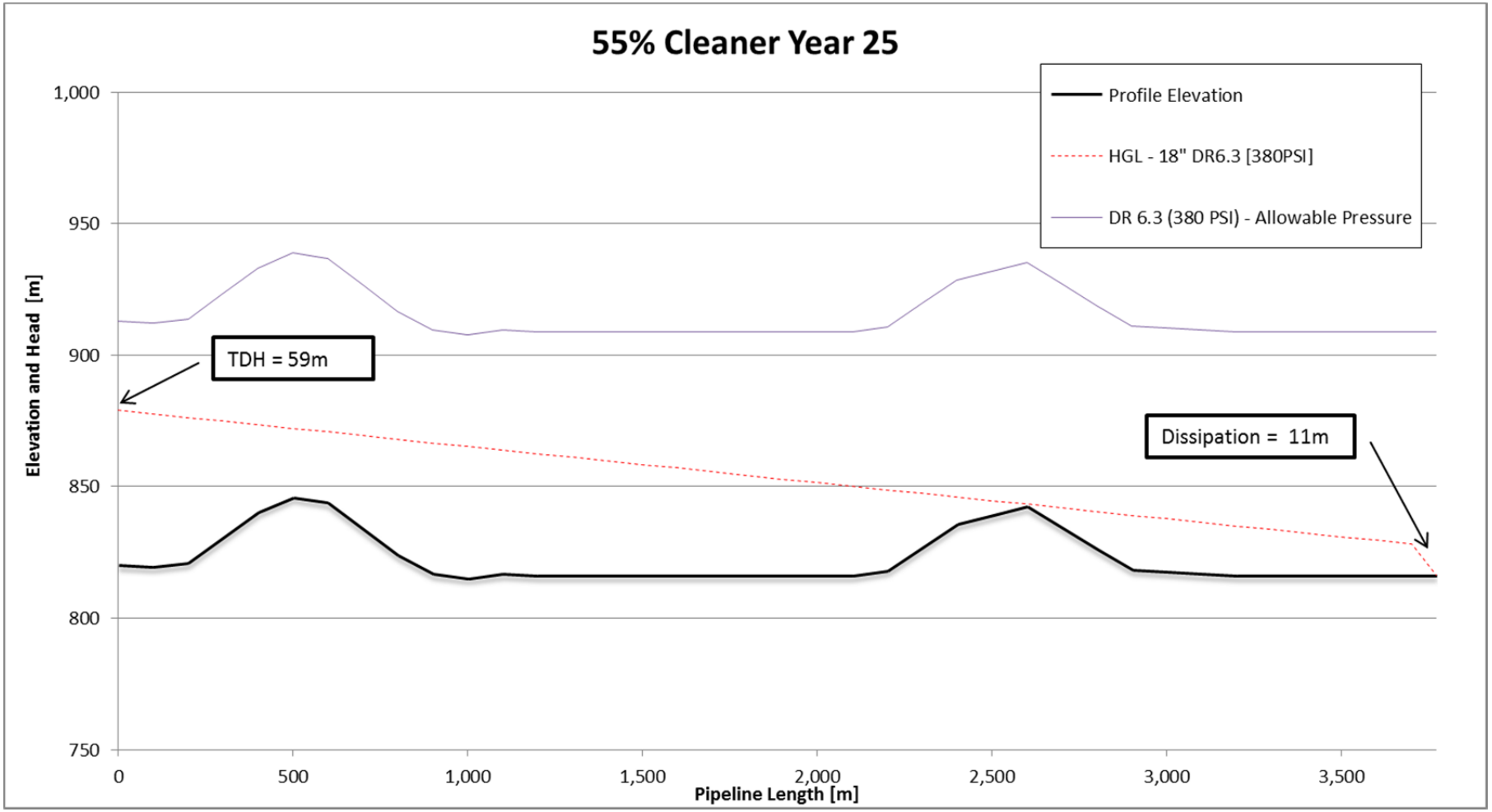

65% Scavenger Year 25 North Route
950
930
910
890
870
850
830
810
790
770
750
Elevation and Head [m]
TDH = 44m
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE
0
1,000
2,000
3,000
4,000
5,000
6,000
Pipeline Length [m]

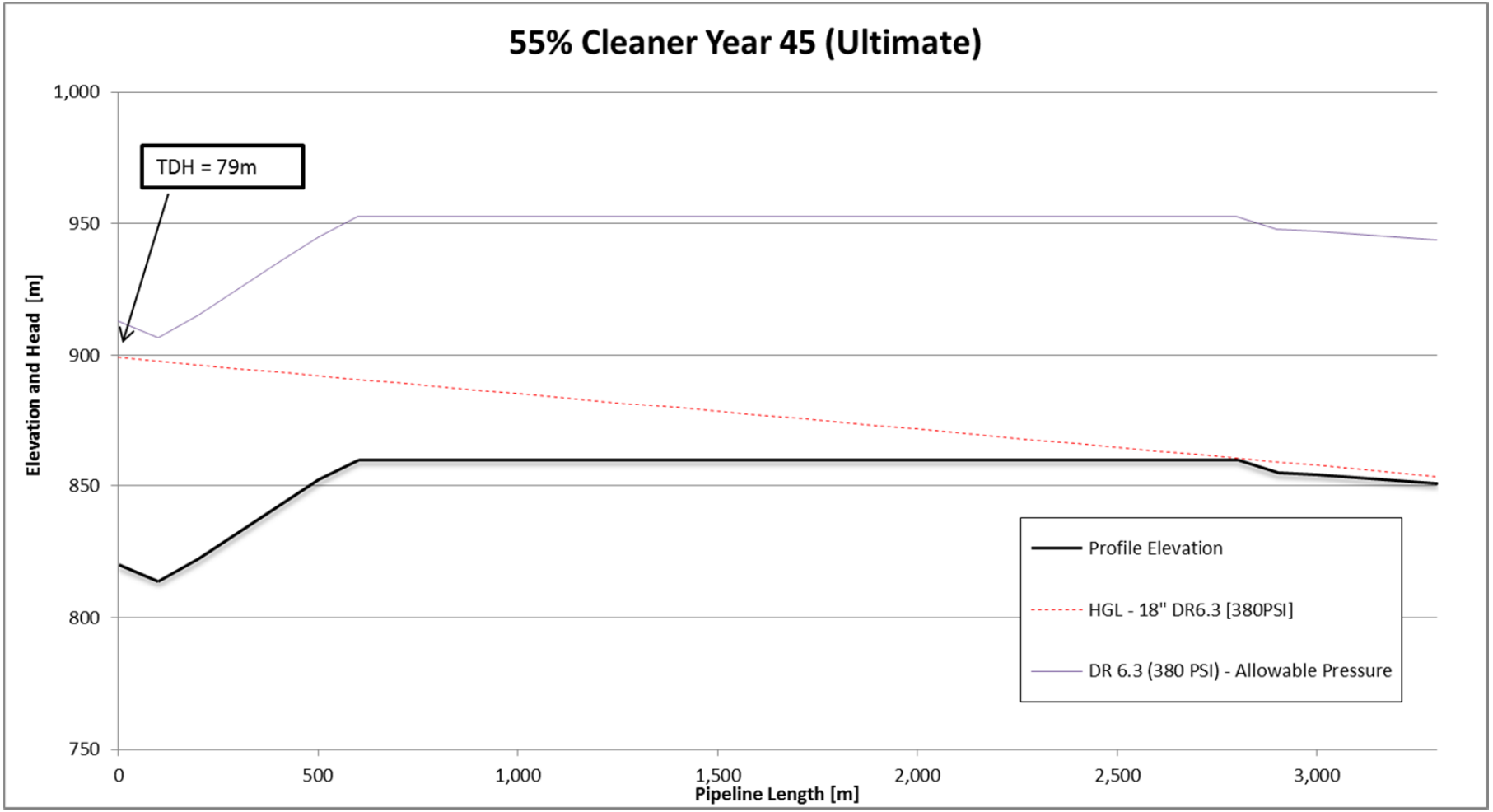

65% Scavenger Year Ultimate South Route
TDH = 81m
Transition from Steel to HDPE
Elevation and Head [m]
950
930
910
890
870
850
830
810
790
770
750
0
1,000
2,000
3,000
4,000
5,000
6,000
Pipeline Length [m]
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE
HGL - 26" SCH 20 Steel


65% Scavenger Year Ultimate North Route
TDH = 77m
Transition from Steel to HDPE
Elevation and Head [m]
950
930
910
890
870
850
830
810
790
770
750
0
1,000
2,000
3,000
4,000
5,000
6,000
Pipeline Length [m]
HGL - 32" HDPE DR9 IPS[250PSI]
Profile Elevation
Allowable Head for 250 PSI Rated HDPE
HGL - 26" SCH 20 Steel


55% Cleaner Year 2
Profile Elevation
HGL - 18" DR6.3 [380PSI]
DR 6.3 (380 PSI) - Allowable Pressure
TDH = 25m
Dissipation = 10m
Elevation and Head [m]
Pipeline Length [m]
1,000
950
900
850
800
750
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500


55% Cleaner Year 10
Profile Elevation
HGL - 18" DR6.3 [380PSI]
DR 6.3 (380 PSI) - Allowable Pressure
TDH = 36m
Dissipation = 46m
Elevation and Head [m]
Pipeline Length [m]
1,000
950
900
850
800
750
0
500
1,000
1,500
2,000
2,500
3,000


55% Cleaner Year 25
Profile Elevation
HGL - 18" DR6.3 [380PSI]
DR 6.3 (380 PSI) - Allowable Pressure
TDH = 59m
Dissipation = 11m
Elevation and Head [m]
1,000
950
900
850
800
750
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Pipeline Length [m]


55% Cleaner Year 45 (Ultimate)
TDH = 79m
Elevation and Head [m]
1,000
950
900
850
800
750
0
500
1,000
1,500
2,000
2,500
3,000
Pipeline Length [m]
Profile Elevation
HGL - 18" DR6.3 [380PSI]
DR 6.3 (380 PSI) - Allowable Pressure

APPENDIX XIII

Borrow Estimates for Near West TSF

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Adrian Lee, Jim Casey **FILE NO:** M09441A14.730

SUBJECT: Appendix XIII - Borrow Estimate for Near West TSF

1 INTRODUCTION

This memorandum presents the estimated available and required borrow quantities for the Near West Tailings Storage Facility (TSF). Borrow areas were sized to meet material requirements for the alternative North Dam design which reflects the upper bound of expected fill quantities.

The quantities are organized by material types:

- Drain and Filter Material;
- General Fill;
- Riprap; and
- Asphalt Core

Google Earth (Google Inc.), Muck3D (Wruffware Ltd.) and observations from site mapping were used to locate the material sources and estimate available volumes. The suitability of all materials will need to be confirmed with laboratory testing. A bulking factor of 25% was applied to all bank volumes, except when noted, to calculate loose fill volume.

2 REQUIRED MATERIAL QUANTITIES

The required fill quantities are from the bill of quantities (Appendix XIV) and are listed in Table 2.1. It is assumed that material for the asphalt dam cores will be purchased, and is not included in the borrow estimates.

Table 2.1 Fill Requirements

Material Type	Structural Component	Material Specification	Borrow Requirement for Base Case North Dam Design (Mm^3) *(acre-ft)*	Borrow Requirement for Alternative North Dam Design (Mm^3) *(acre-ft)*
Drains and Filters	Seepage Dam Cores (asphalt filter)	60 mm *(2.36 inches)* minus gravel	0.06 *(48.64)*	0.06 *(48.64)*
	North Dam Cores (asphalt filter)	60 mm *(2.36 inches)* minus gravel	0.02 *(16.21)*	0.2 *(162.14)*
	Underdrains (drain core)	100 mm *(3.94 inches)* to 20 mm *(0.79 inches)*	0.7 *(567.50)*	0.6 *(486.43)*
	Local Blanket Drains (drain core)	100 mm *(3.94 inches)* to 20 mm *(0.79 inches)*	0.08 *(64.86)*	0.06 *(48.64)*
	Underdrains (filter zone)	19 mm *(0.75 inches)* minus sand and gravel, 0.2 mm *(0.0079 inches)* < D_{15} < 0.6 mm *(0.024 inches)*, max. 5% fines	0.6 *(486.43)*	0.5 *(405.36)*
	Local Blanket Drains (filter zone)		0.08 *(64.86)*	0.06 *(48.64)*
		TOTAL	**1.5 *(1216.07)***	**1.5 *(1216.07)***
General Fill	Scavenger Starter Dams	max. particle size = 300 mm *(11.82 inches)*, max. fines = 15%	3.3 *(2675.35)*	3.0 *(2432.14)*
	Deposition Berms and Causeways		3.2 *(2594.28)*	2.7 *(2188.93)*
	Cleaner Starter Dam		1.7 *(1378.21)*	1.7 *(1378.21)*
	North Dams		0.6 *(486.43)*	11.2*(9079.99)*
	Seepage Dams	max. particle size = 300 mm *(11.82 inches)*	0.9 *(729.64)*	0.9 *(729.64)*
	Closure Cover for Tailings Beaches			
	Erosion Resistant Material	sand and gravel	1.3 *(1053.93)*	1.3 *(1053.93)*
	Uncompacted Fill	max. particle size = 150 mm *(5.91 inches)*	3.2 *(2594.28)*	3.2 *(2594.28)*
	Compacted Fill		1.4 *(1135.00)*	1.4 *(1135.00)*
		TOTAL	**15.6 *(12647.13)***	**25.4 *(20592.12)***
Riprap	Seepage Dam Armouring	D_{50} = 200 mm *(7.87 inches)*	0.02 *(16.21)*	0.02 *(16.21)*
	North Dam Armouring (Closure)	D_{50} = 200 mm *(7.87 inches)*	0.01 *(8.11)*	0.09 *(72.96)*
	Tailings Embankment Toe Armouring (Before Year 10)	D_{50} = 200 mm *(7.87 inches)*	0.08 *(64.86)*	0.08 *(64.86)*
	Tailings Embankment Toe Armouring (After Year 10)	D_{50} = 200 mm *(7.87 inches)*	0.16 *(129.71)*	0.12 *(97.29)*
	Tailings Embankment Slope Armouring (Before Year 10)	D_{50} = 100 mm *(3.94 inches)*, 200 mm *(7.87 inches)*	0.2 *(162.14)*	0.2 *(162.14)*
	Tailings Embankment Slope Armouring (After Year 10)	D_{50} = 100 mm *(3.94 inches)*, 200 mm *(7.87 inches)*	1.0 *(810.71)*	0.9 *(729.64)*
	Embankment Closure Diversion Channels	D_{50} = 200 mm *(7.87 inches)*	0.02 *(16.21)*	0.02 *(16.21)*
		TOTAL	**1.5 *(1216.07***	**1.4 *(1135.00)***
Asphalt Core	Asphalt Concrete	-		
		TOTAL	**0.03 *(24.32)***	**0.1 *(81.07)***

Note: Volume requirements are neat-line estimates.

3 BORROW SOURCES FOR STARTER FACILITIES AND DURING OPERATIONS

Borrow material will be sourced from within the TSF footprint before start-up and during operations to minimize ground disturbance in the surrounding area. The location of each borrow area is shown on Figure 1.

3.1 Drainage Channels (Drains and Filters)

The best source of drain and filter material is clean, well graded sands and gravels present in existing channels since they would likely require the least processing. It was observed during mapping that drainage channels often contain both "active channel" sediments as well as "older alluvium" sediments. Where traverse logs were available, the two were differentiated. The older alluvium requires processing due to its higher fines content. Field mapping details are given in Appendix I.

Eight drainage channels were identified as potential material sources as shown on Figure 2. Google Earth imagery and field mapping logs were used to estimate width and length of sediment deposits. A nominal sediment depth of 1.5 m *(4.92 ft)* was assumed. Assuming 75% of the active channel sediments and 50% of the older alluvium can be utilized after screening, the available volume is 167,000 m^3 *(218,000 yd^3)*. No bulking factor was used for these unconsolidated sediments. The usable volume available in each channel is shown in Table 3.1.

Processed Gila Conglomerate and Apache Leap Tuff are also potential sources for drains and filters, if sourcing material from the drainage channels is not practical.

Table 3.1 Drainage Channel Sediment Volumes

Drainage Channel	Segment	Segment Length	Active Channel Sediments		Older Alluvium Sediments	
			Width (m) *(ft)*	Usable Volume (m^3) *(yd^3)*	Width (m) *(ft)*	Usable Volume (m^3) *(yd^3)*
1	A	578	4 *(13.12)*	2,601 *(3401.98)*	0 *(0)*	0 *(0)*
	B	506	2 *(6.56)*	1,139 *(1489.76)*	6 *(19.69)*	2,277 *(2978.20)*
	C	489	3 *(9.84)*	1,650 *(2158.12)*	0 *(0)*	0 *(0)*
2	A	300	3 *(9.84)*	1,013 *(1324.95)*	32 *(104.99)*	7,200 *(9417.24)*
	B	544	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
	C	551	6 *(19.69)*	3,719 *(4864.27)*	0 *(0)*	0 *(0)*
	D	832	3 *(9.84)*	2,808 *(3672.73)*	0 *(0)*	0 *(0)*
3	A	324	10 *(32.81)*	3,645 *(4767.48)*	30 *(98.43)*	7,290 *(9534.96)*
	B	649	12 *(39.37)*	8,762 *(11460.26)*	30 *(98.43)*	14,603 *(19,100.00)*
	C	694	9 *(29.53)*	7,027 *(9190.97)*	50 *(164.04)*	26,025 *(34,039.41)*
	D	533	8 *(26.25)*	4,797 *(6274.24)*	10 *(32.81)*	3,998 *(5229.19)*
	E	346	19 *(62.34)*	7,396 *(9673.60)*	0 *(0)*	0 *(0)*
4	-	1776	7 *(22.97)*	14,021 *(18338.78)*	0 *(0)*	0 *(0)*
5	A	315	9 *(29.53)*	3,189 *(4171.05)*	0 *(0)*	0 *(0)*
	B	700	3 *(9.84)*	2,363 *(3090.69)*	0 *(0)*	0 *(0)*
	C	421	3 *(9.84)*	1,421 *(1858.60)*	0 *(0)*	0 *(0)*
	D	506	3 *(9.84)*	1,708 *(2233.98)*	0 *(0)*	0 *(0)*
6	-	1502	5 *(16.40)*	7,650 *(10,005.82)*	0 *(0)*	0 *(0)*

Drainage Channel	Segment	Segment Length	Active Channel Sediments		Older Alluvium Sediments	
			Width (m) *(ft)*	Usable Volume (m^3) *(yd^3)*	Width (m) *(ft)*	Usable Volume (m^3) *(yd^3)*
7	-	2534	8 *(26.25)*	22,756 *(29,763.72)*	0 *(0)*	0 *(0)*
8	-	1475	5 *(16.40)*	8,318 *(10,879.53)*	0 *(0)*	0 *(0)*
			TOTAL	**106,000 *(138,642.77)***	**TOTAL**	**61,000 *(79,784.99)***

3.2 Gila Conglomerate (General Fill, Drains and Filters)

General fill was assumed to come from Gila Conglomerate in the center of the facility. One specific ridge in the middle of the east cell was selected since excavation in that area will not affect the tailings deposition plan between the east and west cells. The borrow area was assumed to have a horizontal base with 20% side slopes. The volume of fill from the cut is 37 Mm^3 *(29996.39 acre-ft)* which exceeds the maximum base case requirements for the scavenger and cleaner starter dams, seepage dams and north dams by 50%. It also satisfies the volume required for drains and filters, assuming that 50% of the material is lost during processing. The maximum excavation surface is shown on Figure 3.

3.3 Apache Leap Tuff (Riprap, Drains and Filters)

Riprap material for the first 10 years of operation is assumed to come from the Apache Leap Tuff ridges near the south end of the TSF. A quarry was modeled in the side of the one of the ridges. The volume available from the quarry is 2.6 Mm^3 *(2107.85 acre-feet)* which exceeds the requirements for armouring before Year 10 and total drain and filter requirements by 50%. A loss of 5% was assumed during processing of the mined tuff for drains and filters. The excavation surface is shown on Figure 4.

4 BORROW SOURCES FOR OPERATIONS AND CLOSURE

Once the TSF is operating, borrow sources from outside of the TSF footprint will be used to satisfy material requirements during operations and closure. The location of each borrow area is shown on Figure 1.

4.1 Gila Conglomerate (Cover for Tailings Beaches)

Closure cover for tailings beaches was assumed to be unprocessed Gila Conglomerate from within the Happy Camp area, east of the TSF. Two possible excavation locations were reviewed; B3 is near to the TSF but close to Potts Canyon, B4 is further east from the TSF but less visible to the public. Both excavations were sized to yield 10 Mm^3 *(8107.13 acre-ft)* of loose fill which is 70% greater than the requirement for the tailings beach closure cover. This was done to account for additional General Fill that may be needed during operations to raise the north dams under the base case scenario. The two excavation options are shown on Figure 5 and Figure 6.

4.2 Pinal Schist (Riprap)

Riprap is required during operations and at closure for armouring embankment slopes and closure diversion channels. Once the west cell is commissioned, and the Apache Leap Tuff is no longer available, Pinal Schist from outside of the TSF footprint will be used. Two possible borrow locations were modeled; B5 at the north end of site, between the diversion ditches and B6 at the southwest corner of the TSF. For this estimate, the volume of the northern option was calculated using horizontal cuts, however in practice the borrow area should be graded so that run-off water is directed south to the toe of the north dam. The southern excavation was modeled with 10% side slopes, with a base elevation higher than that of Queen Creek, to prevent the excavation from acting as a seepage collection point. Both excavation options were sized to exceed the riprap requirements by 50%. Excavations for the north and south options are shown on Figure 7 and Figure 8, respectively.

5 BORROW SUMMARY

Table 5.1 summarizes the borrow sources and the material requirements that each satisfies.

Table 5.1 Borrow Summary

Staging	Geology Unit	Material Type	Structural Component	Borrow Area	Fill Volume Available (Mm^3) *(acre-ft)*[1]
Starter Facility & Operations	Alluvial Sediments	Drains and Filters	Drain Rock and Drain Filters Seepage Dam Filters North Dam Filters	-	0.17 *(137.82)*
	Gila Conglomerate	General Fill	Starter Dams North Dams Seepage Collection Dams	B1	36.6 *(29,672.10)*
		Drains and Filters	Underdrain Drain Rock and Filters Seepage Dam Filters North Dam Filters	B1	
	Apache Leap Tuff	Riprap	Seepage Dam Armouring Tailings Embankment Slope Armouring (before Year 10) Tailings Embankment Toe Armouring (before Year 10)	B2	2.6 *(2107.85)*
		Drains and Filters	Underdrain Drain Rock and Filter Seepage Dam Filters North Dam Filters	B2	
Operations & Closure	Gila Conglomerate	General Fill	Closure Cover for Tailings Beaches North Dams	B3 or B4	10.0 *(8107.13*
	Pinal Schist	Riprap	Tailings Embankment Slope Armouring (after Year 10) Tailings Embankment Toe Armouring (after Year 10) North Dam Armouring Embankment Closure Diversion Channels	B5 or B6	2.2 *(1783.57)*

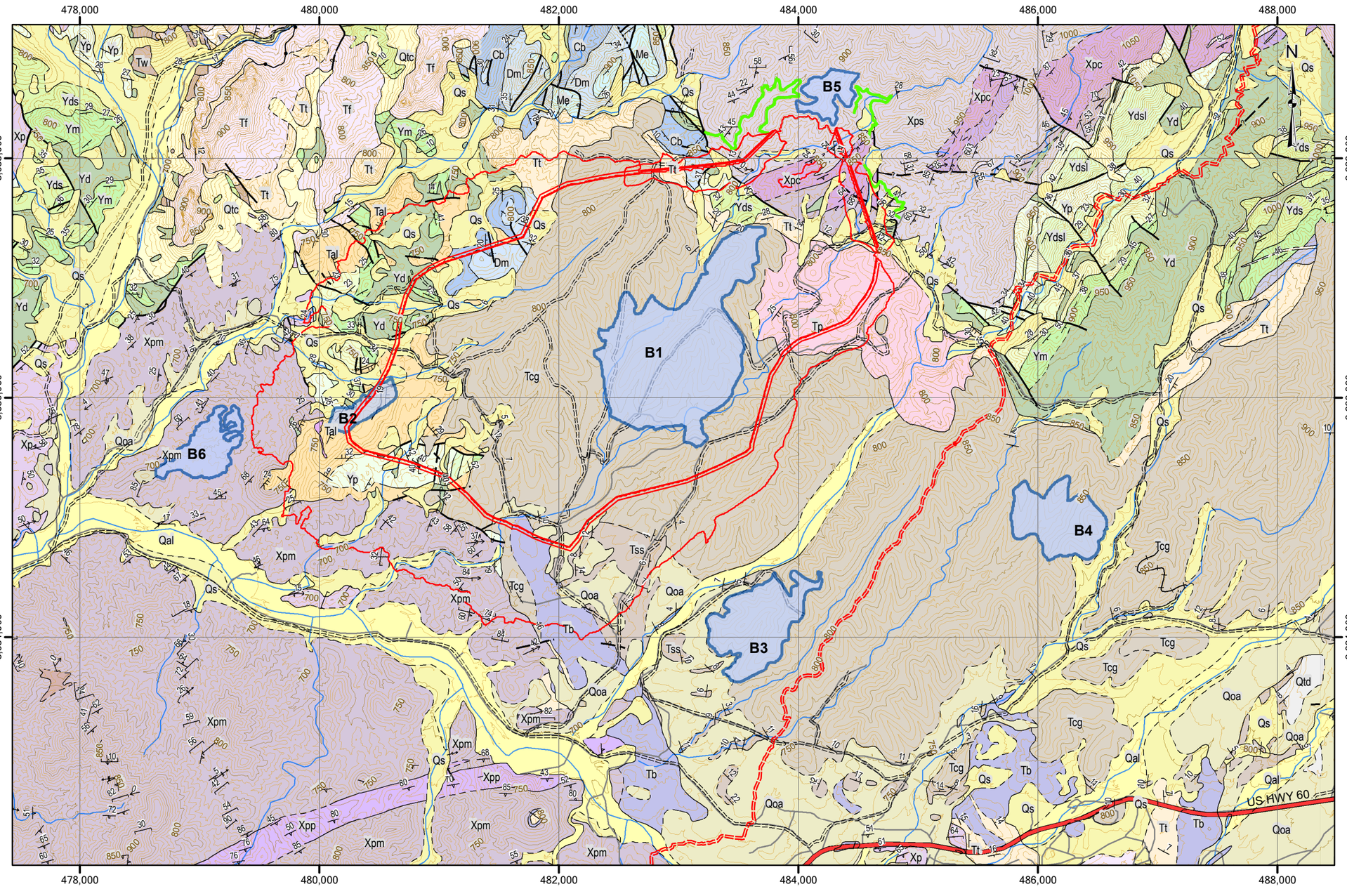
Note 1: Fill volume is based on cut volume +25%.

6 CONCLUSIONS

Based on this analysis, the following conclusions can be made:

- There is insufficient alluvium in the drainage channels to meet the filter and drain rock requirements.
- There is sufficient material available in the Gila Conglomerate borrow area within the TSF footprint to meet General Fill requirements. Drain and filter material may also be sourced from this area with additional processing.
- Starter facility and operational requirements for riprap before Year 10 can be satisfied by quarrying Apache Leap Tuff within the TSF footprint. Drain and filter material may also be sourced from this area with additional processing. After Year 10, riprap will be sources from Pinal Schist either north or south of the TSF to meet operational and closure requirements.
- There is sufficient Gila Conglomerate available east of the TSF to satisfy requirements for the tailings beach closure cover and north dam raises during operations.

FIGURES



Qs Undivided Surficial Deposits (Quaternary)
Qtd Disturbed Surficial Deposits (Holocene)
Qtc Talus and Colluvium (Quaternary)
Qal Unconsolidated Alluvium (Quaternary)
Qoa Old Alluvium (Quaternary)
QTs Older Alluvium (Early Quaternary to Late Tertiary)
Tcg Conglomerate (Pliocene to Late Miocene)
Tss Sandstone (Pliocene to late Miocene)
Tb Basalt (Mid-Miocene to Early Miocene)
Tp Perlitic Aphyric Rhyolite (Middle Tertiary)
Tal Apache Leap Tuff (Early Miocene)
Tt Tuff (poorly welded) (Miocene)
Tf Felsic Volcanic Rocks, undivided (Middle Tertiary)
Tbl Lower Basalt (Middle Tertiary)
Tx Rock Avalanche or Talus Brecchia (Middle Tertiary)
Tw Whitetail Conglomerate
Tdb Basaltic Dikes (Middle Tertiary)
Kd Quartz Diorite (Latest Cretaceous)
Me Escabrosa Limestone (Mississippian)
Dm Martin Limestone (Devonian)
Cb Bolsa Quartzite (Cambrian)
Yd Diabase (Middle Proterozoic)
Ym Mescal Limestone (Middle Proterozoic)
Yds Dripping Spring Quartzite, undivided (Middle Proterozoic)
Ydsu Dripping Spring Quartzite, Upper Unit (Middle Proterozoic)
Ydsl Dripping Spring Quartzite, Lower Unit (Middle Proterozoic)
Yp Pioneer Shale (Middle Proterozoic)
Ypt Pioneer Shale, Tuff Unit (Middle Proterozoic)
YXd Diorite (Early or Middle Proterozoic)
Xp Pinal Schist, undivided (Early Proterozoic)
Xpc Pinal Schist, Calc-silicate Facies (Early Proterozoic)
Xpcs Pinal Schist, Calc-silicate and Schist Facies (Early Proterozoic)
Xpm Pinal Schist, Psammite Facies (Early Proterozoic)
Xpp Pinal Sctist, Phyllite Facies (Early Proterozoic)
Xpq Pinal Schist, Quartzite Layers (Early Proterozoic)
Xps Pinal Schist, Pelitic Schist (Early Proterozoic)

LEGEND

DIVERSION
NEAR WEST TAILINGS SITE
ARIZONA TRAIL
HIGHWAY
ROAD (FROM RESOLUTION)
ROAD (FROM STATE)
STREAM
FELSIC DYKE
FAULT
FAULT - APPROXIMATE
FAULT - CONCEALED
MARKER HORIZON (LOCAL)
CONTACT (BETWEEN GEOLOGIC UNITS)
CONTACT - APPROXIMATE
CONTACT - INFERRED
CONTACT BETWEEN PINAL SCHIST *CLAST-RICH CONGOMERATE BELOW AND DRIPPING SPRING QUARTZITE CLAST-RICH CONGLOMERATE ABOVE*
BORROW AREA

Notes:
1. NAD27 UTM12N
2. Refer to main report for source of geologic data.

NOT FOR CONSTRUCTION

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED SEPT 2014

0 1,000 m

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

CLIENT: Resolution Copper Mining

Klohn Crippen Berger

PROJECT: RESOLUTION PROJECT
NEAR WEST TAILINGS MANAGEMENT MINE PLAN OF OPERATIONS STUDY

TITLE: BORROW LOCATIONS

PROJECT No. M09441A14

FIG No. 1

CB
Z:\MVCR\M09441A14 - RES-Near West\Geotech Study\400 Drawings\MXD\Mine_Plan_Operations_Study\Appendix_XIII\Borrow_Locations.mxd 02/09/2014 12:04:45 PM

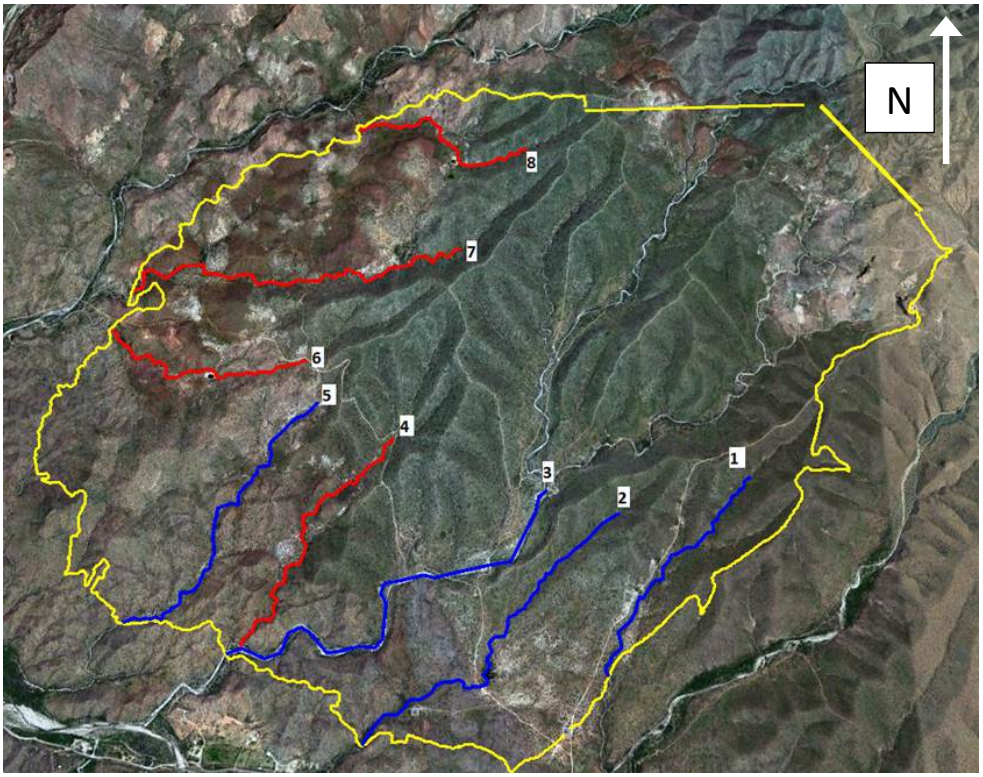


Figure 2 **Location of Drainage Channels for Filter and Drain Material Estimate**

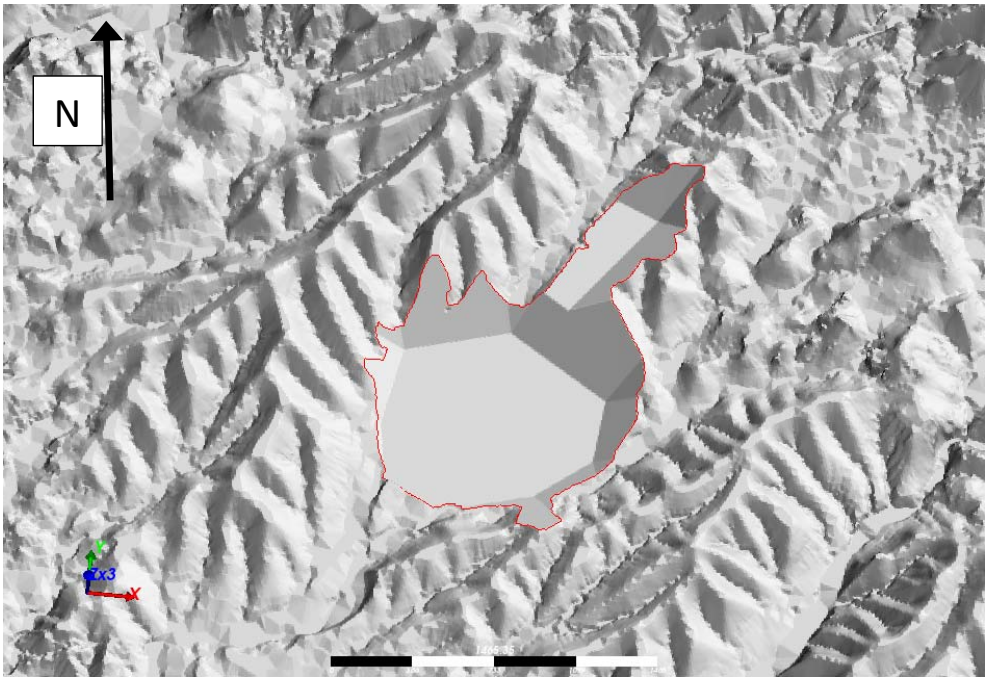


Figure 3 **B1 Gila Conglomerate Borrow Excavation inside TSF**

Note: 3x Vertical Exaggeration

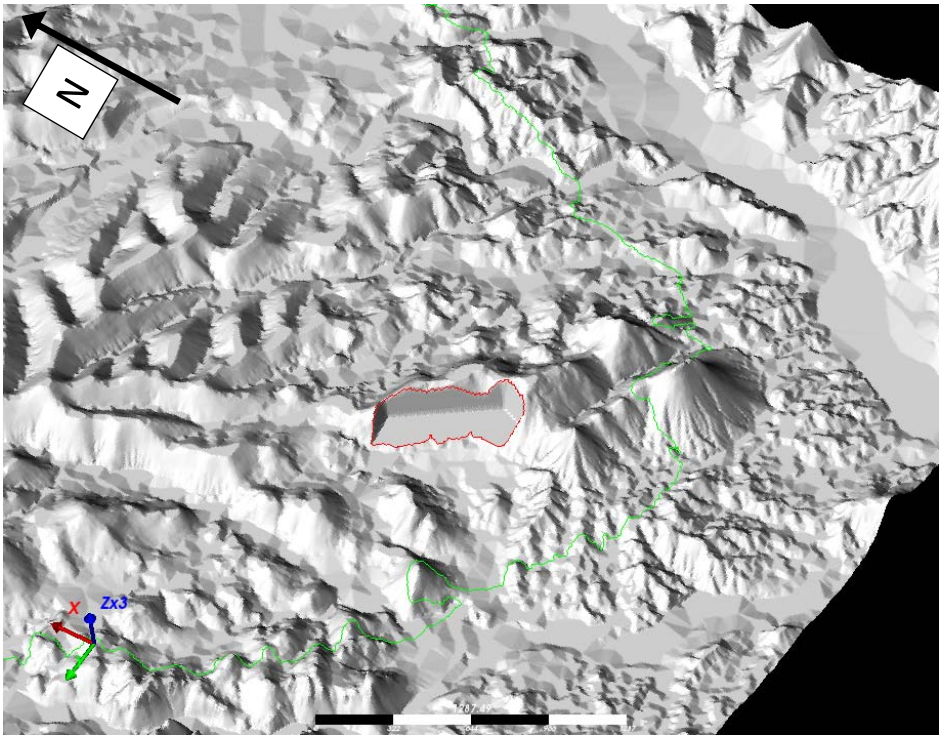


Figure 4 B2 Apache Leap Tuff Borrow Excavation

Note: 3x Vertical Exaggeration

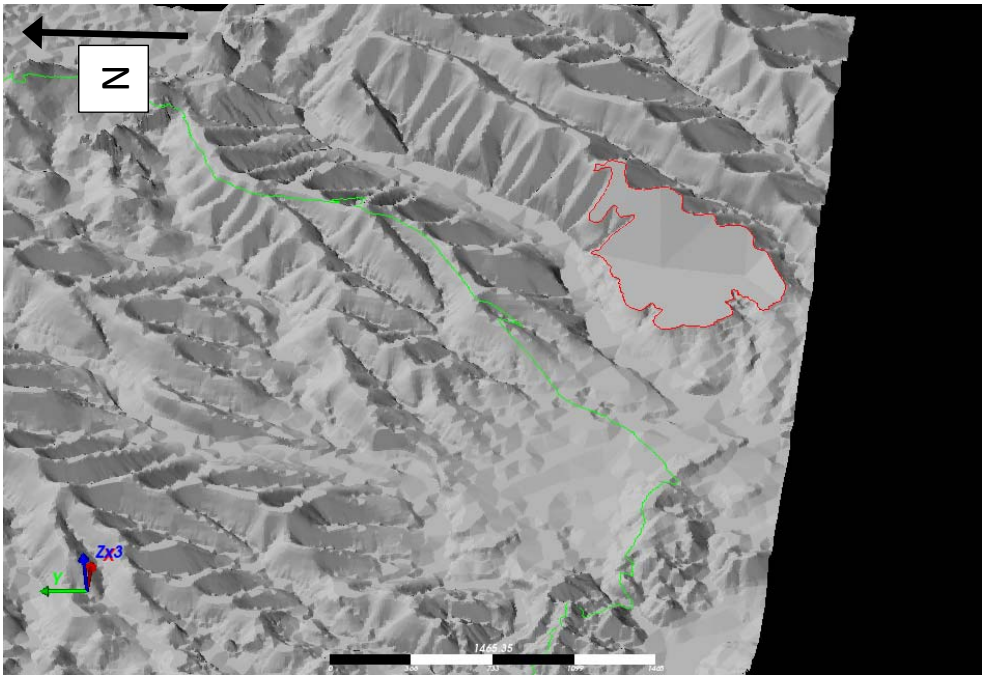


Figure 5 B3 Gila Conglomerate Borrow Excavation – Happy Camp Option 1

Note: 3x Vertical Exaggeration

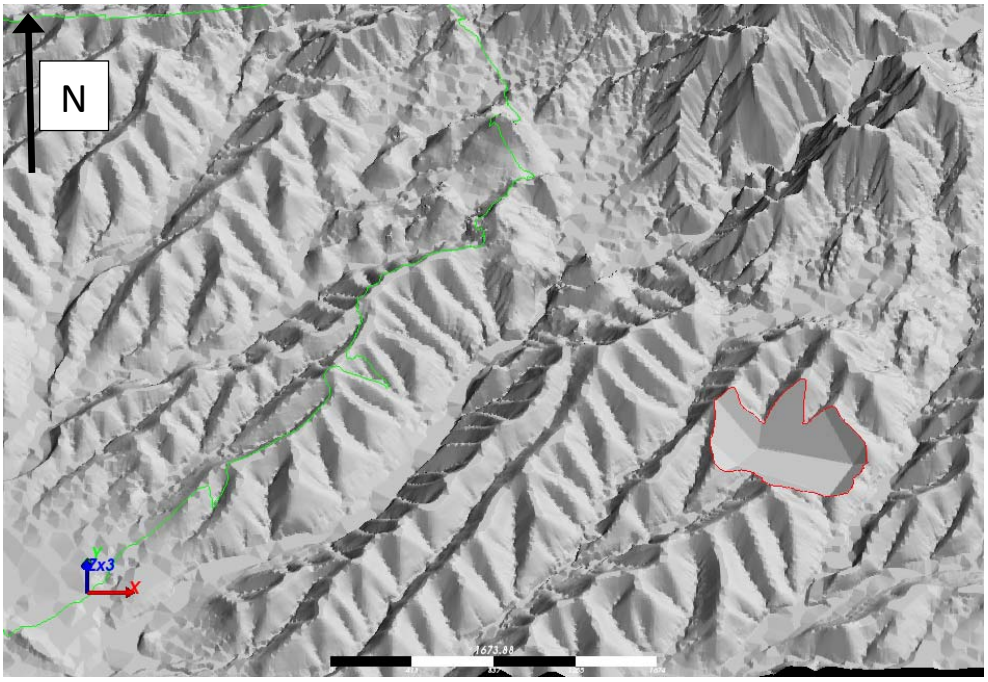


Figure 6 **B4 Gila Conglomerate Borrow Excavation – Happy Camp Option 2**

Note: 3x Vertical Exaggeration

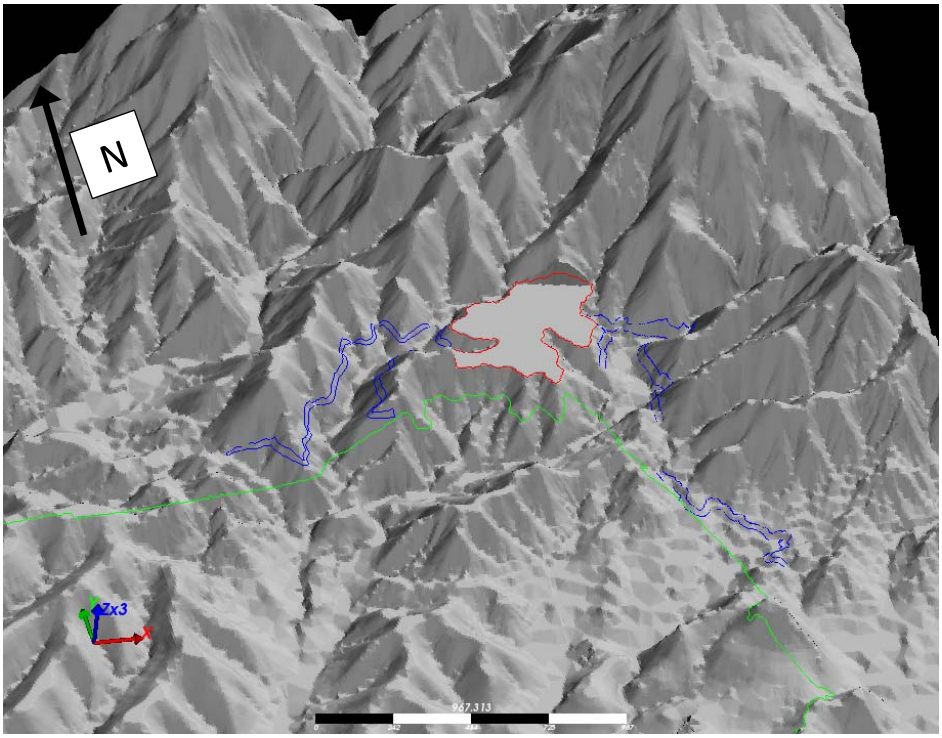


Figure 7 **B5 Pinal Schist Borrow Excavation – North Option**

Note: 3x Vertical Exaggeration

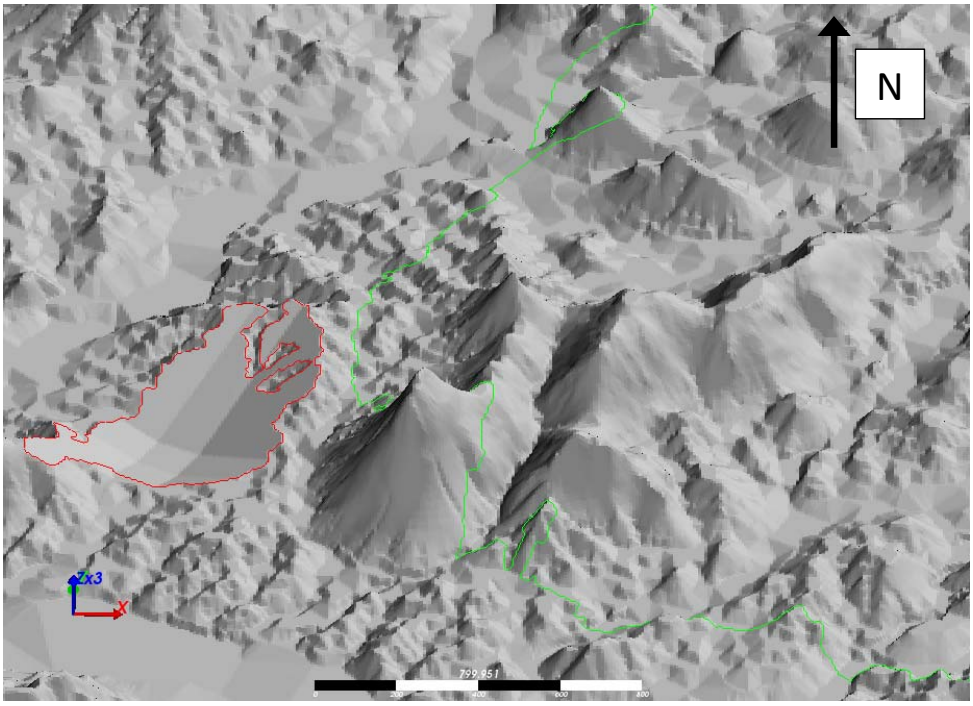


Figure 8 **B6 Pinal Schist Borrow Excavation – South Option**

Note: 3 x Vertical Exaggeration

APPENDIX XIV

Bill of Quantities

Appendix XIV
Bill of Quantities

XIV-1 GENERAL

This appendix presents two bills of quantities (BOQ) for the Near West Tailings Storage Facility (TSF): one for the North Dam base case design and the other for the North Dam alternative design.

The North Dam base case BOQ is based on the design illustrated in Figure 5.10; the North Dam alternative BOQ is based on the North Dam illustrated in Figure 5.11.

XIV-2 SCOPE SUMMARY

The BOQ provides an annual breakdown of quantities for the pre-production, operation and closure phases.

The facilities included in the BOQ are as follows:

- Scavenger starter dams and deposition berms;
- Cleaner starter dam;
- Internal cleaner deposition access berms;
- Upstream diversion channels;
- Seepage collection dams;
- Embankment underdrains;
- Embankment raises;
- North Dams;
- Closure diversion channels; and
- Closure covers for the impoundment.

The BOQ includes the following items:

<u>Earth Works</u>

1. Capital and Operations phases:
    - clearing, grubbing and foundation preparation for all facilities;
    - construction of starter dams, seepage collection dams, North Dams, and tailings deposition berms;
    - construction of diversion channels, spillways, and underdrains; and

- compaction of fill on embankment slope.

2. Closure phase
   - construction of impoundment closure covers; and
   - construction of closure diversion channels.

This BOQ does not include the following:

- processing plants, or other mining facilities;
- tailing deposition and placement;
- geotechnical and environmental instrumentation and monitoring; and
- tailings transport and water reclaim pumps and pipelines (found in Appendix XII).

XIV-3 RESULTS

The capital, operations and closure material quantities for the North Dam base case and the North Dam alternative BOQ are presented in Table 1 and Table 2, respectively.

Compared to the alternative design, the North Dam base case design requires:

- less general fill as most of the embankment is constructed of scavenger tailings;
- less grout curtain, core trench excavation, asphalt core and core filter;
- additional drain rock and filter material for the scavenger embankment underdrains and local blanket drains; and
- additional upstream embankment raise fill, toe armouring and closure slope re-vegetation.

Table 1 Near West TSF Bill of Quantities
Base Case North Dam Design

Item		Units	Description	Figure Reference	Pre-Production (End of year)			Operation (End of Year)															
					-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Scavenger Starter Dams	Clear and Grub	acre	-	4.1, 4.3, 4.6, 5.1 - 5.3, 5.11	-	-	28	17	2.9	4.9	2.9	1.5	1.3	1.2	5.3	3.9	65	4.3	23	4.1	5.1	-	6.2	-	1.1
	Foundation Preparation	acre	-		-	-	28	17	2.9	4.9	2.9	1.5	1.3	1.2	5.3	3.9	65	4.3	23	4.1	5.1	-	6.2	-	1.1
	General Fill	yd^3	for starter dams - 12" max. particle size, max. 15% fines		-	-	1,281,871	335,275	-	-	-	-	-	-	-	-	1,676,872	-	710,947	-	-	-	-	-	-
	General Fill	yd^3	for deposition berms - 12" max. particle size, max. 15% fines		-	-	-	87,190	70,310	112,393	121,187	50,298	89,015	68,557	193,310	84,765	229,539	74,995	94,971	72,464	89,296	-	109,272	-	20,093
	Construction Length	ft	spillway construction (not designed)	n/a	-	-	2,165	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleaner Starter Dam	Clear and Grub	acre	-	4.1, 4.3	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-		-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	12" max. particle size, max. 15% fines		-	-	2,161,307	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction Length	ft	spillway construction (not designed)	n/a	-	-	1,362	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upstream Diversion Channels	Clear and Grub	acre	-	7.1 - 7.3	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-		682,750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seepage Collection Dams	Clear and Grub	acre	-	5.8 - 5.9	-	14	-	-	-	-	-	-	-	-	-	-	22	-	3.5	-	-	-	-	-	-
	Foundation Preparation	acre	-		-	14	-	-	-	-	-	-	-	-	-	-	22	-	3.5	-	-	-	-	-	-
	Grout Curtain	ft	3 rows x 16.4 ft spacing x 82 ft deep		-	57,087	-	-	-	-	-	-	-	-	-	-	60,089	-	11,073	-	-	-	-	-	-
	Excavation	yd^3	for core trench to bedrock		-	36,413	-	-	-	-	-	-	-	-	-	-	38,328	-	7,063	-	-	-	-	-	-
	Asphalt Core	yd^3	asphalt concrete		-	12,741	-	-	-	-	-	-	-	-	-	-	15,841	-	1,428	-	-	-	-	-	-
	Core Filter	yd^3	2.5" minus gravel		-	33,975	-	-	-	-	-	-	-	-	-	-	42,247	-	3,807	-	-	-	-	-	-
	General Fill	yd^3	12" maximum particle size		-	321,396	-	-	-	-	-	-	-	-	-	-	683,880	-	84,296	-	-	-	-	-	-
	Riprap	yd^3	D_{50} = 8", thickness = 16"		-	7,972	-	-	-	-	-	-	-	-	-	-	12,637	-	2,017	-	-	-	-	-	-
	Excavation	yd^3	for spillway		-	8,707	-	-	-	-	-	-	-	-	-	-	11,042	-	2,225	-	-	-	-	-	-
Embankment Underdrains	Drain Rock	yd^3	for underdrains; high capacity screened crushed rock (1" to 4")	5.7, 5.11	-	-	311,313	-	-	-	-	-	-	-	-	-	447,559	-	-	-	-	-	-	-	-
	Filter	yd^3	for underdrains; 3/4" minus sand and gravel with D_{15} between 0.2 mm to 0.6 mm and a maximum fines content of 5%		-	-	253,468	-	-	-	-	-	-	-	-	-	361,620	-	-	-	-	-	-	-	-
	Drain Rock	yd^3	for local blanket drain; high capacity screened crushed rock (1" to 4")		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Filter	yd^3	for local blanket drain; 3/4" minus sand and gravel with D_{15} between 0.2 mm and 0.6 mm and a maximum fines content of 5%		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embankment Raises	Compacted Zone	yd^3	60 ft wide zone on slope	5.1-5.3, 9.1	-	-	-	424,881	151,211	255,840	490,697	601,807	854,430	913,547	946,741	1,058,198	705,402	2,361,640	764,127	913,062	1,144,295	742,179	742,179	651,562	918,704
	Riprap	yd^3	for embankment slope; D_{50} = 4", thickness = 8"		-	-	-	19,651	6,902	10,274	21,694	17,264	31,583	35,575	33,117	34,541	27,235	139,339	45,847	58,176	61,447	80,902	-	37,424	51,533
	Riprap	yd^3	for toe armouring; D_{50} = 8", thickness = 16"		-	-	-	23,010	22,808	11,064	16,010	3,175	4,117	5,529	8,338	6,455	7,715	-	10,977	10,977	10,977	10,977	10,977	12,512	12,512
Cleaner Tailings Deposition Access Berms	General Fill	yd^3	-	4.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
North Dams	Clear and Grub	acre	-	4.7 - 4.12, 5.10, 5.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grout Curtain	yd^3	3 rows x 16.4 ft spacing x 82 ft deep		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	for core trench to bedrock		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Asphalt Core	yd^3	asphalt concrete		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Core Filter	yd^3	2.5" minus gravel		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	12" max. particle size, max. 15% fines		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Riprap	yd^3	D_{50} = 8", thickness = 16"		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closure of Embankment Slope	Riprap	yd^3	for closure diversion channels along dam slope; D_{50} = 8", thickness = 16"	5.11, 10.1 - 10.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	for closure diversion channel, in natural ground		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	Seeding and revegetation (for embankment slope)		-	-	-	-	22	9	12	27	31	45	48	50	56	44	10	40	51	56	78	-	34
Closure of Tailings Beaches	Uncompacted Fill	yd^3	30" uncompacted fill (for cleaner area store and release cover), 6" max. particle size	10.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Compacted General Fill	yd^3	12" compacted fill (for cleaner area store and release cover), 6" max. particle size		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Armouring	yd^3	6" sand and gravel (for entire beach)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	Seeding and revegetation (for entire beach)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1 Near West TSF Bill of Quantities
Base Case North Dam Design

Item		Units	Operation (End of Year)																							
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Scavenger Starter Dams	Clear and Grub	acre	2.4	2.4	-	25	-	7.3	-	18	-	-	4.7	1.8	-	-	15	-	-	2	8	-	-	-	2	-	-
	Foundation Preparation	acre	2.4	2.4	-	25	-	7.3	-	18	-	-	4.7	1.8	-	-	2.0	-	-	2	8	-	-	-	2	-	-
	General Fill	yd^3	-	-	-	-	-	255,521	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	42,035	42,117	-	449,755	-	-	-	320,790	-	-	83,635	31,556	188,816	-	35,311	-	-	30,638	146,776	-	-	-	26,768	-	-
	Construction Length	ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleaner Starter Dam	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction Length	ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upstream Diversion Channels	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seepage Collection Dams	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grout Curtain	ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Asphalt Core	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Core Filter	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Riprap	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embankment Underdrains	Drain Rock	yd^3	86,325	-	-	22,018	-	-	-	22,018	-	-	-	-	13,595	-	-	-	-	-	-	-	-	-	-	-	-
	Filter	yd^3	65,921	-	-	22,018	-	-	-	22,018	-	-	-	-	13,595	-	-	-	-	-	-	-	-	-	-	-	-
	Drain Rock	yd^3	-	23,602	-	38,226	-	-	-	38,226	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Filter	yd^3	-	24,651	-	39,925	-	-	-	39,925	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embankment Raises	Compacted Zone	yd^3	743,522	825,908	772,741	386,371	386,371	867,625	433,813	867,625	721,584	721,584	892,630	797,758	749,731	776,805	148,320	284,631	1,426,977	576,909	576,909	288,798	288,798	288,798	288,798	72,765	109,147
	Riprap	yd^3	27,402	61,476	42,590	22,191	22,788	42,868	22,330	57,704	40,219	42,838	51,445	43,049	42,146	43,824	8,474	15,972	80,940	32,700	32,748	15,721	15,301	16,154	18,278	3,987	6,108
	Riprap	yd^3	12,512	12,512	10,300	5,150	5,150	4,609	2,304	4,609	7,495	7,495	8,492	7,116	7,356	8,904	2,142	931	4,877	2,306	2,306	499	499	499	499	251	376
Cleaner Tailings Deposition Access Berms	General Fill	yd^3	-	-	-	-	-	-	-	-	59,211	75,864	64,547	81,247	84,567	81,742	9,770	105,418	89,652	59,894	45,933	46,121	30,732	13,694	-	-	15,342
North Dams	Clear and Grub	acre	-	0.4	-	0.9	1.3	0.8	1.2	1.5	3.1	0.9	0.9	0.5	1.2	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-	0.4	-	0.9	1.3	0.8	1.2	1.5	3.1	0.9	0.9	0.5	1.2	-	-	-	-	-	-	-	-	-	-	-	-
	Grout Curtain	yd^3	-	1,530	-	73	109	73	109	1,525	3,432	1,144	1,144	741	2,509	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	2,857	-	135	203	135	203	2,848	6,407	2,136	2,136	1,383	4,684	-	-	-	-	-	-	-	-	-	-	-	-
	Asphalt Core	yd^3	-	306	-	160	257	178	284	684	3,083	1,199	1,371	988	2,478	-	-	-	-	-	-	-	-	-	-	-	-
	Core Filter	yd^3	-	816	-	427	685	476	757	1,823	8,221	3,198	3,655	2,635	6,607	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	-	4,018	-	13,094	27,333	23,350	42,717	78,036	244,797	87,772	83,769	52,073	101,221	-	-	-	-	-	-	-	-	-	-	-	-
	Riprap	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	8,948	-	-	-	-	-	-	-	-	-	-	-	-
Closure of Embankment Slope	Riprap	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	48	39	78	39	-	117	-	-	-	119	-	-	121	-	-	-	122	-	-	60	-	-	-	-	-
Closure of Tailings Beaches	Uncompacted Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Compacted General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Armouring	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1 Near West TSF Bill of Quantities
Base Case North Dam Design

Item		Units			Closure (End of Year)					Post-Closure (End of Year)	Total Start-up	Total Operating	Total Closure
			44	45	Year 46	Year 47	Year 48	Year 49	Year 50	Year 50+			
Scavenger Starter Dams	Clear and Grub	acre	2	-	-	-	-	-	-	-	28	240	-
	Foundation Preparation	acre	2	-	-	-	-	-	-	-	28	227	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	1,281,871	2,978,616	-
	General Fill	yd^3	29,099	-	-	-	-	-	-	-	-	2,994,951	-
	Construction Length	ft	-	-	-	-	-	-	-	-	2,165	-	-
Cleaner Starter Dam	Clear and Grub	acre	-	-	-	-	-	-	-	-	26	-	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	26	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	2,161,307	-	-
	Construction Length	ft	-	-	-	-	-	-	-	-	1,362	-	-
Upstream Diversion Channels	Clear and Grub	acre	-	-	-	-	-	-	-	-	22	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	682,750	-	-
Seepage Collection Dams	Clear and Grub	acre	-	-	-	-	-	-	-	-	14	26	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	14	26	-
	Grout Curtain	ft	-	-	-	-	-	-	-	-	57,087	71,161	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	36,413	45,391	-
	Asphalt Core	yd^3	-	-	-	-	-	-	-	-	12,741	17,269	-
	Core Filter	yd^3	-	-	-	-	-	-	-	-	33,975	46,054	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	321,396	768,176	-
	Riprap	yd^3	-	-	-	-	-	-	-	-	7,972	14,654	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	8,707	13,267	-
Embankment Underdrains	Drain Rock	yd^3	-	-	-	-	-	-	-	-	311,313	591,515	-
	Filter	yd^3	-	-	-	-	-	-	-	-	253,468	485,172	-
	Drain Rock	yd^3	-	-	-	-	-	-	-	-	-	100,054	-
	Filter	yd^3	-	-	-	-	-	-	-	-	-	104,501	-
Embankment Raises	Compacted Zone	yd^3	181,912	-	-	-	-	-	-	-	-	29,117,326	-
	Riprap	yd^3	10,520	-	-	-	-	-	-	-	-	1,532,277	-
	Riprap	yd^3	627	-	-	-	-	-	-	-	-	307,939	-
Cleaner Tailings Deposition Access Berms	General Fill	yd^3	-	-	-	-	-	-	-	-	-	863,734	-
North Dams	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	13	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	-	13	-
	Grout Curtain	yd^3	-	-	-	-	-	-	-	-	-	12,389	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	23,125	-
	Asphalt Core	yd^3	-	-	-	-	-	-	-	-	-	10,988	-
	Core Filter	yd^3	-	-	-	-	-	-	-	-	-	29,300	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	758,178	-
	Riprap	yd^3	-	-	-	-	-	-	-	-	-	8,948	-
Closure of Embankment Slope	Riprap	yd^3	-	-	78,514	-	-	-	-	-	-	-	78,514
	Excavation	yd^3	-	-	30,190	-	-	-	-	-	-	-	30,190
	Re-vegetation	acre	-	-	-	-	-	-	-	-	-	1,355	-
Closure of Tailings Beaches	Uncompacted Fill	yd^3	-	-	1,393,532	1,393,532	1,393,532	-	-	-	-	-	4,180,595
	Compacted General Fill	yd^3	-	-	597,228	597,228	597,228	-	-	-	-	-	1,791,683
	Armouring	yd^3	-	-	587,722	587,722	587,722	-	-	-	-	-	1,763,166
	Re-vegetation	acre	-	-	740	740	740	-	-	-	-	-	2,221

Table 2 Near West TSF Bill of Quantities
Alternative North Dam Design

Item		Units	Description	Figure Reference	Pre-Production (End of year)			Operation (End of Year)															
					-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Scavenger Starter Dams	Clear and Grub	acre	-	4.1, 4.3, 4.6, 5.1 - 5.3, 5.11	-	-	28	18	4.0	6.4	6.9	2.9	5.0	3.9	11.0	4.8	66	4.3	23	4.1	5.1	-	6.2	-	1.1
	Foundation Preparation	acre	-		-	-	28	18	4.0	6.4	6.9	2.9	5.0	3.9	11.0	4.8	66	4.3	23	4.1	5.1	-	6.2	-	1.1
	General Fill	yd^3	for starter dams - 12" max. particle size, max. 15% fines		-	-	1,281,871	335,275	-	-	-	-	-	-	-	-	1,676,872	-	710,947	-	-	-	-	-	-
	General Fill	yd^3	for deposition berms - 12" max. particle size, max. 15% fines		-	-	-	87,190	70,310	112,393	121,187	50,298	89,015	68,557	193,310	84,765	229,539	74,995	94,971	72,464	89,296	-	109,272	-	20,093
	Construction Length	ft	spillway construction (not designed)	n/a	-	-	2,165	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleaner Starter Dam	Clear and Grub	acre	-	4.1, 4.3	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-		-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	12" max. particle size, max. 15% fines		-	-	2,161,307	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction Length	ft	spillway construction (not designed)	n/a	-	-	1,362	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upstream Diversion Channels	Clear and Grub	acre	-	7.1 - 7.3	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-		682,750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seepage Collection Dams	Clear and Grub	acre	-	5.8 - 5.9	-	14	-	-	-	-	-	-	-	-	-	-	22	-	3.5	-	-	-	-	-	-
	Foundation Preparation	acre	-		-	14	-	-	-	-	-	-	-	-	-	-	22	-	3.5	-	-	-	-	-	-
	Grout Curtain	ft	3 rows x 16.4 ft spacing x 82 ft deep		-	57,087	-	-	-	-	-	-	-	-	-	-	60,089	-	11,073	-	-	-	-	-	-
	Excavation	yd^3	for core trench to bedrock		-	36,413	-	-	-	-	-	-	-	-	-	-	38,328	-	7,063	-	-	-	-	-	-
	Asphalt Core	yd^3	asphalt concrete		-	12,741	-	-	-	-	-	-	-	-	-	-	15,841	-	1,428	-	-	-	-	-	-
	Core Filter	yd^3	2.5" minus gravel		-	33,975	-	-	-	-	-	-	-	-	-	-	42,247	-	3,807	-	-	-	-	-	-
	General Fill	yd^3	12" maximum particle size		-	321,396	-	-	-	-	-	-	-	-	-	-	683,880	-	84,296	-	-	-	-	-	-
	Riprap	yd^3	D_{50} = 8", thickness = 16"		-	7,972	-	-	-	-	-	-	-	-	-	-	12,637	-	2,017	-	-	-	-	-	-
	Excavation	yd^3	for spillway		-	8,707	-	-	-	-	-	-	-	-	-	-	11,042	-	2,225	-	-	-	-	-	-
Embankment Underdrains	Drain Rock	yd^3	for underdrains; high capacity screened crushed rock (1" to 4")	5.7, 5.11	-	-	311,313	-	-	-	-	-	-	-	-	-	447,559	-	-	-	-	-	-	-	-
	Filter	yd^3	for underdrains; 3/4" minus sand and gravel with D_{15} between 0.2 mm to 0.6 mm and a maximum fines content of 5%		-	-	253,468	-	-	-	-	-	-	-	-	-	361,620	-	-	-	-	-	-	-	-
	Drain Rock	yd^3	for local blanket drain; high capacity screened crushed rock (1" to 4")		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Filter	yd^3	for local blanket drain; 3/4" minus sand and gravel with D_{15} between 0.2 mm and 0.6 mm and a maximum fines content of 5%		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embankment Raises	Compacted Zone	yd^3	60 ft wide zone on slope	5.1-5.3, 9.1	-	-	-	424,881	151,211	255,840	490,697	601,807	854,430	913,547	946,741	1,058,198	705,402	2,361,640	764,127	913,062	1,144,295	742,179	742,179	651,562	918,704
	Riprap	yd^3	for embankment slope; D_{50} = 4", thickness = 8"		-	-	-	19,651	6,902	10,274	21,694	17,264	31,583	35,575	33,117	34,541	27,235	139,339	45,847	58,176	61,447	80,902	-	37,424	51,533
	Riprap	yd^3	for toe armouring; D_{50} = 8", thickness = 16"		-	-	-	23,085	22,883	11,100	16,063	3,186	4,130	5,547	8,365	6,476	7,741	-	11,013	11,013	11,013	11,013	11,013	12,553	12,553
Cleaner Tailings Deposition Access Berms	General Fill	yd^3	-	4.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
North Dams	Clear and Grub	acre	-	4.7 - 4.12, 5.10, 5.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	5
	Foundation Preparation	acre	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	5
	Grout Curtain	yd^3	3 rows x 16.4 ft spacing x 82 ft deep		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,962	981	2,943
	Excavation	yd^3	for core trench to bedrock		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,662	1,831	5,493
	Asphalt Core	yd^3	asphalt concrete		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	196	147	883
	Core Filter	yd^3	2.5" minus gravel		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	523	392	2,354
	General Fill	yd^3	12" max. particle size, max. 15% fines		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39,632	22,980	93,068
	Riprap	yd^3	D_{50} = 8", thickness = 16"		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closure of Embankment Slope	Riprap	yd^3	for closure diversion channels along dam slope; D_{50} = 8", thickness = 16"	5.11, 10.1 - 10.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	for closure diversion channel, in natural ground		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	Seeding and revegetation (for embankment slope)		-	-	-	-	22	9	12	27	31	45	48	50	56	44	10	40	51	56	78	-	34
Closure of Tailings Beaches	Uncompacted Fill	yd^3	30" uncompacted fill (for cleaner area store and release cover), 6" max. particle size	10.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Compacted General Fill	yd^3	12" compacted fill (for cleaner area store and release cover), 6" max. particle size		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Armouring	yd^3	6" sand and gravel (for entire beach)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	Seeding and revegetation (for entire beach)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2 Near West TSF Bill of Quantities
Alternative North Dam Design

Item		Units	Operation (End of Year)																							
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Scavenger Starter Dams	Clear and Grub	acre	2.4	2.4	-	25	-	-	-	18	-	-	4.7	-	-	-	4	-	-	2	-	-	-	-	-	-	-
	Foundation Preparation	acre	2.4	2.4	-	25	-	-	-	18	-	-	4.7	-	-	-	0.6	-	-	2	-	-	-	-	-	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	42,035	42,117	-	449,755	-	-	-	320,790	-	-	83,635	-	-	-	10,013	-	-	30,638	-	-	-	-	-	-	-
	Construction Length	ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleaner Starter Dam	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Construction Length	ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upstream Diversion Channels	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seepage Collection Dams	Clear and Grub	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grout Curtain	ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Asphalt Core	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Core Filter	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Riprap	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embankment Underdrains	Drain Rock	yd^3	-	-	-	22,018	-	-	-	22,018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Filter	yd^3	-	-	-	22,018	-	-	-	22,018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Drain Rock	yd^3	-	-	-	38,226	-	-	-	38,226	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Filter	yd^3	-	-	-	39,925	-	-	-	39,925	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embankment Raises	Compacted Zone	yd^3	743,522	825,908	772,741	386,371	386,371	867,625	433,813	867,625	455,986	455,986	683,979	683,979	697,545	697,545	124,507	233,584	1,167,920	467,168	462,598	231,299	230,528	230,528	230,528	50,993	76,489
	Riprap	yd^3	27,402	61,476	43,785	21,892	21,892	49,161	24,580	49,161	25,837	25,837	38,755	38,755	39,524	39,524	7,055	13,235	66,176	26,470	26,212	13,106	13,062	13,062	13,062	2,889	4,334
	Riprap	yd^3	12,553	12,553	3,938	1,969	1,969	8,117	8,117	8,117	2,971	2,971	4,457	4,457	917	917	164	580	2,902	1,161	439	220	220	220	220	44	66
Cleaner Tailings Deposition Access Berms	General Fill	yd^3	-	-	-	-	-	-	-	-	59,211	75,864	64,547	81,247	84,567	81,742	9,770	105,418	89,652	59,894	45,933	46,121	30,732	13,694	-	-	15,342
North Dams	Clear and Grub	acre	7	-	8.9	7.1	8.4	8.0	8.1	13.4	6.1	6.4	4.5	5.9	5.0	5	1	5	5	4	4	2	2	2	2	2	2
	Foundation Preparation	acre	7	-	8.9	7.1	8.4	8.0	8.1	13.4	6.1	6.4	4.5	5.9	5.0	5	1	5	5	4	4	2	2	2	2	2	2
	Grout Curtain	yd^3	2,943	2,943	4,520	1,601	3,274	2,925	2,552	3,270	2,305	2,305	1,536	1,503	1,503	1,503	201	1,503	504	336	336	168	168	126	126	126	126
	Excavation	yd^3	5,493	5,493	8,438	2,988	6,112	5,460	4,764	6,103	4,302	4,302	2,868	2,805	2,805	2,805	376	2,805	940	627	627	313	313	234	234	234	234
	Asphalt Core	yd^3	1,766	-	2,708	2,468	2,769	3,614	4,858	9,804	4,833	5,179	3,606	5,634	5,860	6,085	845	6,536	6,612	4,441	4,475	2,246	2,254	2,261	2,267	2,273	2,279
	Core Filter	yd^3	4,709	-	7,222	6,582	7,384	9,637	12,956	26,143	12,888	13,809	9,616	15,025	15,626	16,227	2,253	17,430	17,631	11,844	11,933	5,989	6,011	6,028	6,045	6,062	6,078
	General Fill	yd^3	215,391	-	271,757	367,715	422,381	553,676	759,941	1,574,095	764,277	790,997	534,042	824,083	843,031	847,933	113,903	857,857	859,944	572,360	572,528	286,430	286,540	286,651	286,761	286,872	286,982
	Riprap	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closure of Embankment Slope	Riprap	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	48	39	78	39	-	117	-	-	-	119	-	-	121	-	-	-	122	-	-	60	-	-	-	-	-
Closure of Tailings Beaches	Uncompacted Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Compacted General Fill	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Armouring	yd^3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Re-vegetation	acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2 Near West TSF Bill of Quantities
Alternative North Dam Design

Item		Units			Closure (End of Year)					Post-Closure (End of Year)	Total Start-up	Total Operating	Total Closure
			44	45	Year 46	Year 47	Year 48	Year 49	Year 50	Year 50+			
Scavenger Starter Dams	Clear and Grub	acre	-	-	-	-	-	-	-	-	28	232	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	28	228	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	1,281,871	2,723,094	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	-	2,546,638	-
	Construction Length	ft	-	-	-	-	-	-	-	-	2,165	-	-
Cleaner Starter Dam	Clear and Grub	acre	-	-	-	-	-	-	-	-	26	-	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	26	-	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	2,161,307	-	-
	Construction Length	ft	-	-	-	-	-	-	-	-	1,362	-	-
Upstream Diversion Channels	Clear and Grub	acre	-	-	-	-	-	-	-	-	22	-	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	682,750	-	-
Seepage Collection Dams	Clear and Grub	acre	-	-	-	-	-	-	-	-	14	26	-
	Foundation Preparation	acre	-	-	-	-	-	-	-	-	14	26	-
	Grout Curtain	ft	-	-	-	-	-	-	-	-	57,087	71,161	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	36,413	45,391	-
	Asphalt Core	yd^3	-	-	-	-	-	-	-	-	12,741	17,269	-
	Core Filter	yd^3	-	-	-	-	-	-	-	-	33,975	46,054	-
	General Fill	yd^3	-	-	-	-	-	-	-	-	321,396	768,176	-
	Riprap	yd^3	-	-	-	-	-	-	-	-	7,972	14,654	-
	Excavation	yd^3	-	-	-	-	-	-	-	-	8,707	13,267	-
Embankment Underdrains	Drain Rock	yd^3	-	-	-	-	-	-	-	-	311,313	491,595	-
	Filter	yd^3	-	-	-	-	-	-	-	-	253,468	405,656	-
	Drain Rock	yd^3	-	-	-	-	-	-	-	-	-	76,452	-
	Filter	yd^3	-	-	-	-	-	-	-	-	-	79,850	-
Embankment Raises	Compacted Zone	yd^3	100,141	-	-	-	-	-	-	-	-	27,205,776	-
	Riprap	yd^3	5,674	-	-	-	-	-	-	-	-	1,424,421	-
	Riprap	yd^3	110	-	-	-	-	-	-	-	-	269,112	-
Cleaner Tailings Deposition Access Berms	General Fill	yd^3	-	-	-	-	-	-	-	-	-	863,734	-
North Dams	Clear and Grub	acre	2	-	-	-	-	-	-	-	-	134	-
	Foundation Preparation	acre	2	-	-	-	-	-	-	-	-	134	-
	Grout Curtain	yd^3	126	-	-	-	-	-	-	-	-	44,411	-
	Excavation	yd^3	234	-	-	-	-	-	-	-	-	82,901	-
	Asphalt Core	yd^3	2,286	-	-	-	-	-	-	-	-	99,185	-
	Core Filter	yd^3	6,095	-	-	-	-	-	-	-	-	264,493	-
	General Fill	yd^3	287,092	-	-	-	-	-	-	-	-	13,908,918	-
	Riprap	yd^3	-	-	37,802	37,802	37,802	-	-	-	-	-	113,405
Closure of Embankment Slope	Riprap	yd^3	-	-	78,514	-	-	-	-	-	-	-	78,514
	Excavation	yd^3	-	-	30,190	-	-	-	-	-	-	-	30,190
	Re-vegetation	acre	-	-	-	-	-	-	-	-	-	1,355	-
Closure of Tailings Beaches	Uncompacted Fill	yd^3	-	-	1,393,532	1,393,532	1,393,532	-	-	-	-	-	4,180,595
	Compacted General Fill	yd^3	-	-	597,228	597,228	597,228	-	-	-	-	-	1,791,683
	Armouring	yd^3	-	-	587,722	587,722	587,722	-	-	-	-	-	1,763,166
	Re-vegetation	acre	-	-	740	740	740	-	-	-	-	-	2,221

APPENDIX XV

Closure Design

MEMORANDUM

TO: File **DATE:** September 5, 2014

FROM: Michelle Liew **FILE NO:** M09441A14.730

SUBJECT: Appendix XV - Closure Design

1 INTRODUCTION

This memorandum presents the closure cover design, closure water management plan and closure water balance for the Tailings Storage Facility (TSF) at the Near West site.

2 CLOSURE COVER DESIGN

The preliminary closure cover design alternatives for the Near West TSF are:

- Cleaner tailings with a "store-and-release" evaporative cover; and
- Scavenger tailings with a simple erosion cover.

For the cleaner tailings analysis, the store-and-release cover consists of the following materials:

- 0 m – 0.15 m *(0 ft -0.49 ft)* Erosion Resistant Material
- 0.15 m – 0.85 m *(0.49 ft – 2.79 ft)* Uncompacted Select Fill; and
- 0.85 m – 1.15 m *(2.79 ft – 3.77 ft)* Compacted Select Fill

For the scavenger tailings analysis, only the erosion resistant material was assumed.

Closure cover riprap for the 5H:1V TSF embankment slope was sized based on empirical stability equations for riprap on steep channel gradients (Smith & Kells 1995). This methodology is for idealized conditions. Additional riprap may be required in engineered channels along the embankment slope. This will be evaluated in future design stages. The equations are a function of peak flow and embankment slope. The 1000-year 5-minute precipitation depth (27 mm *(1.06 inches)*) was selected as the design storm, and the rational method with a runoff coefficient of 1.0 was used to calculate peak flow.

The closure cover riprap for the embankment slope was calculated to have a median stone size of D_{50} = 100 mm *(3.94 inches)* and a layer thickness of 200 mm *(7.87 inches)*.

Riprap armoring at the TSF embankment toe will be maintained through closure to continue to act as seepage and runoff collection ditches. This armoring has a median stone size of D_{50} = 200 mm *(7.87 inches)* and a riprap layer thickness of 400 mm *(15.75 inches)*.

Analyses were done to assess the cover design for the Near West TSF. Climate data from regional stations were used in the analyses; the climate data will be reviewed in upcoming design stages.

The VADOSE/W computer model distributed by GEO-SLOPE International Ltd (Geo-slope) was used for the analyses. VADOSE/W is a two dimensional finite element model that couples heat and mass transfer, and vapour flow in the soil with real climate data for prediction of ground surface moisture flux.

2.1 Model Set-Up

The two cases analyzed are presented in the one dimensional soil columns shown in Figure 2.1 and Figure 2.2.

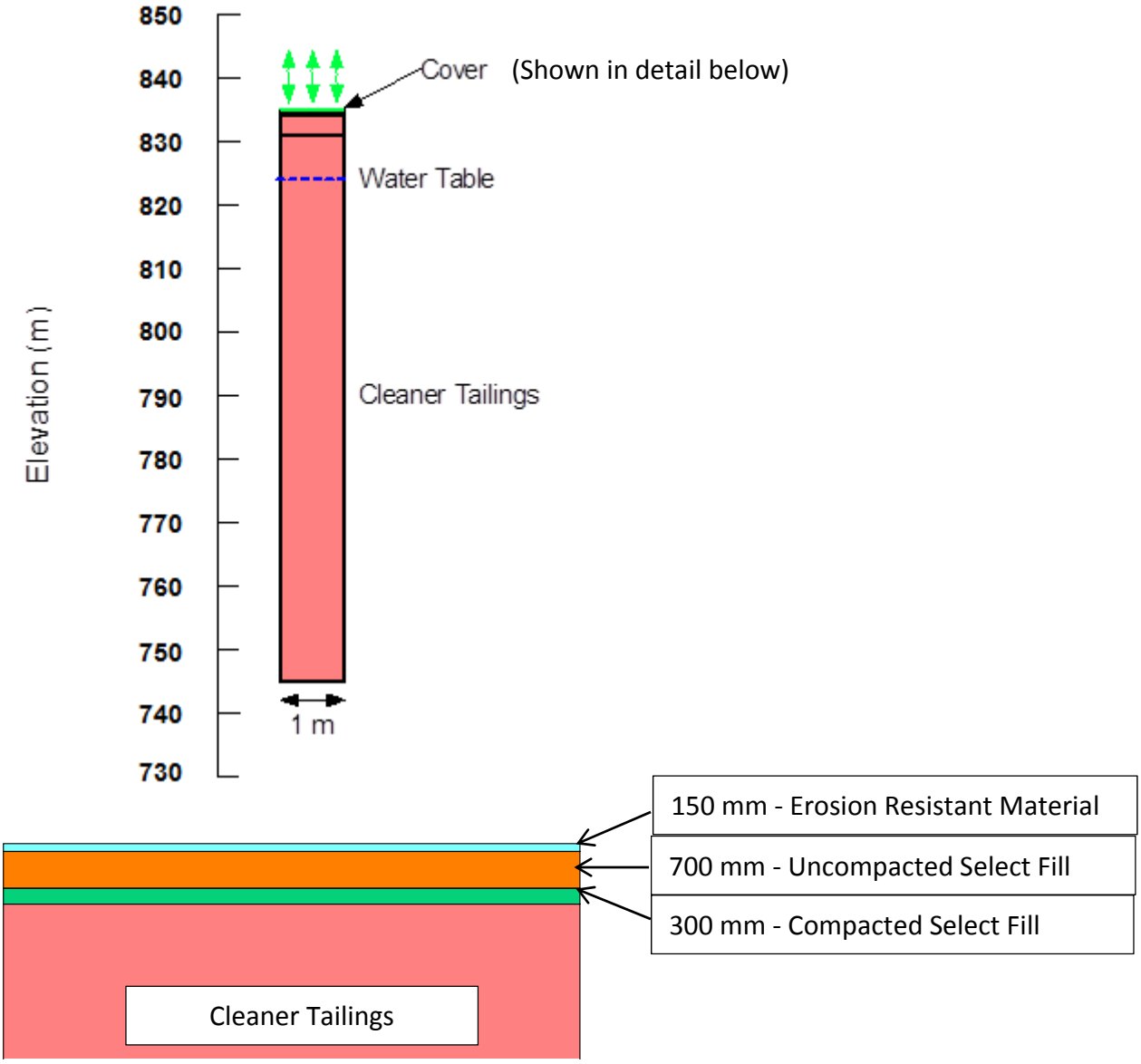


Figure 2.1 Cleaner Tailings One Dimensional Model (top) and Cover Detail (bottom)

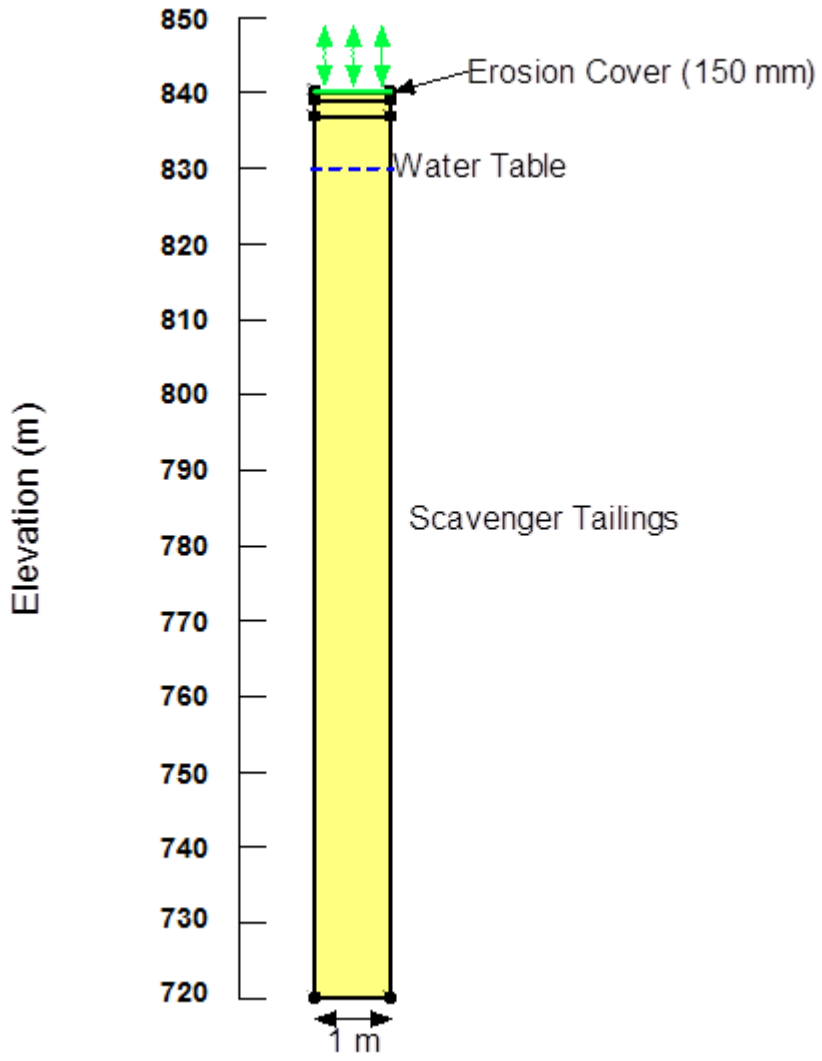


Figure 2.2 Scavenger Tailings One Dimensional Model

2.2 Modeling Methodology

2.2.1 Modeling Approach

Two years of daily precipitation, relative humidity, temperature and wind speed data were used to calculate water flux into and out of the tailings. Since the cover materials chosen are not susceptible to desiccation and cracking, no extreme dry year simulation was modelled. The years used are 2006 and 2008 (discussed in Section2.2.6) from a combined dataset from nearby climate stations. Both years have less than the average annual precipitation at the Near West site but are labelled as "average year" and "wet year" based on the average annual precipitation at the climate stations.

2.2.2 Modeling Assumptions

The assumptions listed in Table 2.1 were used for modeling at this preliminary design stage. Calculation details within the model code itself are not explained in this document, but are listed in "Vadose Zone Modeling with VADOSE/W 2007 an Engineering Methodology" (GEO-SLOPE International 2010).

Table 2.1 Parameter Assumptions

Model Parameter	Assumption
Hydraulic functions (hydraulic conductivity and volumetric water content)	Hydraulic functions estimated from laboratory tests, particle size distributions, literature values or a combination of these methods
Thermal functions (thermal conductivity and volumetric specific heat)	Functions included in Vadose for typical materials ("silt" and "sand) were for materials in the model with similar gradation
Daily climate data	An average year was chosen to give typical results, and a wet year was chosen to give higher-bound infiltration rates for an evaporative cover
Vegetation	No vegetation in the model; conservative assumption
Height of initial water table	10 m *(32.8 ft)* below tailings surface
Initial ground temperature	15 °C
Excess precipitation	Excess precipitation ponds on surface without runoff; conservative assumption

2.2.3 Material Properties

Material properties used in the analysis are provided in Table 2.2, and are described in detail in Attachment I.

Table 2.2 Material Properties

Material	Hydraulic Functions		Thermal Functions	
	Vertical Hydraulic Conductivity at Saturation (m/s) *(ft/s)*	Volumetric Water Content at Saturation (m^3/m^3) *(ft^3/ft^3)*	Thermal Conductivity Dry/Saturated (kJ/day/m/°C) *(BTU/hr/ft/°F)*	Volumetric Specific Heat Dry/Saturated (kJ/m^3) *($BTU(IT)/ft^3$)*
Erosion Resistant Material (Rock Fill)	$1x10^{-4}$ *($3.28x10^{-4}$)*	0.25	98 – 190 *(0.66 – 12.7)*	1320 – 2580 *(35.43 – 69.25)*
Scavenger Tailings	$5x10^{-8}$ *($16.40x10^{-8}$)*	0.36	50 – 97 *(0.33 – 0.65)*	1260 – 2850 *(33.82 – 76.49)*
Cleaner Tailings	$5x10^{-9}$ *$16.40x10^{-9}$)*	0.46	50 – 97 *(0.33 – 0.65)*	1260 – 2850 *(33.82 – 76.49)*
Uncompacted Select Fill	$1x10^{-6}$ *($3.28x10^{-6}$)*	0.41	50 – 97 *(0.33 – 0.65)*	1260 – 2850 *(33.82 – 76.49)*
Compacted Select Fill	$1x10^{-7}$ *($3.28x10^{-7}$)*	0.39	50 – 97 *(0.33 – 0.65)*	1260 – 2850 *(33.82 – 76.49)*

The hydraulic conductivity of the scavenger and cleaner tailings was obtained from laboratory testing results and literature. Hydraulic conductivities for erosion resistant material, and uncompacted and compacted select fill were estimated from test work completed by KCB for other projects.

The full thermal material model was used in the analysis. Representative thermal conductivity and volumetric heat capacity functions were adopted for silt and sand soil types (see Attachment I for functions).

2.2.4 Initial Conditions

The initial water table elevation in the tailings was assumed to be 10 m *(32.8 ft)* below the surface of the tailings beach. These conditions are expected to be representative at closure where some drain-down of the saturated tailings has occurred.

In all analyses, the initial ground temperature is assumed to be 15°C *(59°F)*.

2.2.5 Boundary Conditions

The boundary conditions are applied to the top and bottom of the one dimensional soil column. It is assumed in the model that the sides are no-flow boundaries. The climate conditions are applied to the top of the tailings column in all scenarios.

The base of the tailings column is set as a free flow boundary where water can enter and exit the model. This was achieved by setting a constant head boundary at the base of the model, as given in Table 2.3.

Table 2.3 Head Boundary Conditions

VADOSE/W Analysis	Constant Head Boundary (masl)
Scavenger Tailings	825 (initial water table) *(2,706 fasl)*
Cleaner Tailings	830 (initial water table) *(2,722 fasl)*

2.2.6 Climate Data

A complete climate data set in VADOSE/W includes daily precipitation, maximum and minimum temperature, maximum and minimum relative humidity, and average wind speed. The analysis was completed using two sets of climate data from:

1. Whitlow Ranch Dam
2. Magma FRS

Climate data was obtained from the Whitlow Ranch Dam weather station in Arizona which is part of the Flood Control District of Maricopa County. The climate data provided from this station ranges from January 1, 2001 to December 30, 2012. Data for maximum and minimum relative humidity and average wind speed was not available from the Whitlow Ranch Dam station. This data was obtained from the Magma FRS weather station, also a part of the Flood District of Maricopa County. The climate data for the Magma FRS station is from January 1, 1996 to December 30, 2012. Precipitation data from Whitlow Ranch Dam and Magma FRS are shown on an annual basis in Figure 2.3.

Two years were used in the analyses, shown in Figure 2.3. The full climate datasets are given in Attachment II.

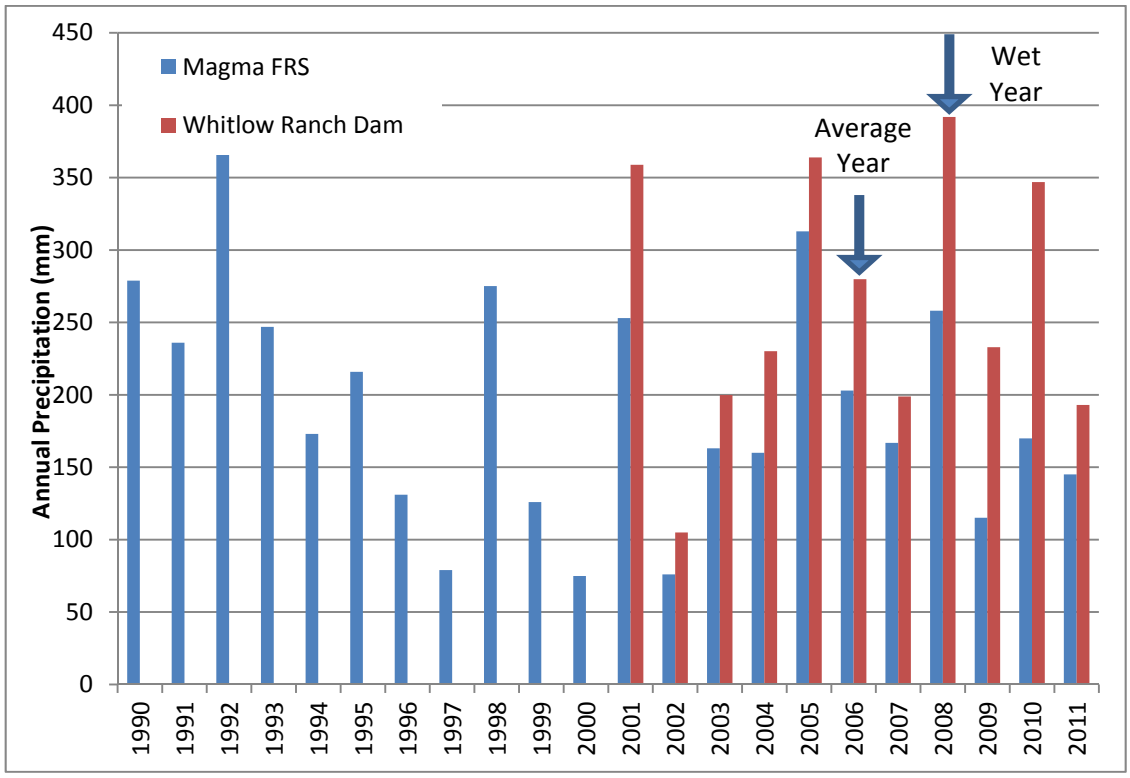


Figure 2.3 Annual Precipitation Data

2.2.7 Evaporation

The "actual" evaporation rate from a soil surface is dependent on the degree of saturation of the soil and is therefore less than or equal to the "potential" evaporation rate that would occur from a saturated soil or free water surface. Actual evaporation is calculated by VADOSE/W using the Penman-Wilson formulation which accounts for net radiation, wind speed, and the relative humidity of both the air and soil surface while calculating the evaporation from the unsaturated soil surface.

2.3 Results

Results are provided in Table 2.4 for average and wet years. The results show that the store-and-release cover is effectively limiting percolation to less than 1% into the cleaner tailings column. Field data from similar cover types in semi-arid or arid regions suggest small percolation rates of less than 1% through evaporative covers are possible (Albright, 2003).

For the simple erosion cover on the scavenger tailings, percolation at 1 m *(3.28 ft)* depth in the tailings column ranges from 2% to 7% of the total precipitation.

Table 2.4 Evaporative Cover Results

Climate Year	Analysis	Liquid Flux† (%)	# Days of Percolation
Average Year (2006)	Scavenger Tailings	2	8
	Cleaner Tailings	0	0
Wet Year (2008)	Scavenger Tailings	7	43
	Cleaner Tailings	0	5

† - Flux was measured below the cover for the cleaner tailings case and 1 m *(3.28 ft)* below the tailings surface for the scavenger tailings case. Flux is shown as a percentage of annual precipitation.

Percolation into tailings for a one year period is shown in Figure 2.4 and Figure 2.5. Negative fluxes represent downwards flow (percolation) into the tailings whereas positive flux indicates upwards flow. Figures showing infiltration, actual evaporation and precipitation at surface and degree of saturation with depth are included in Attachment III.

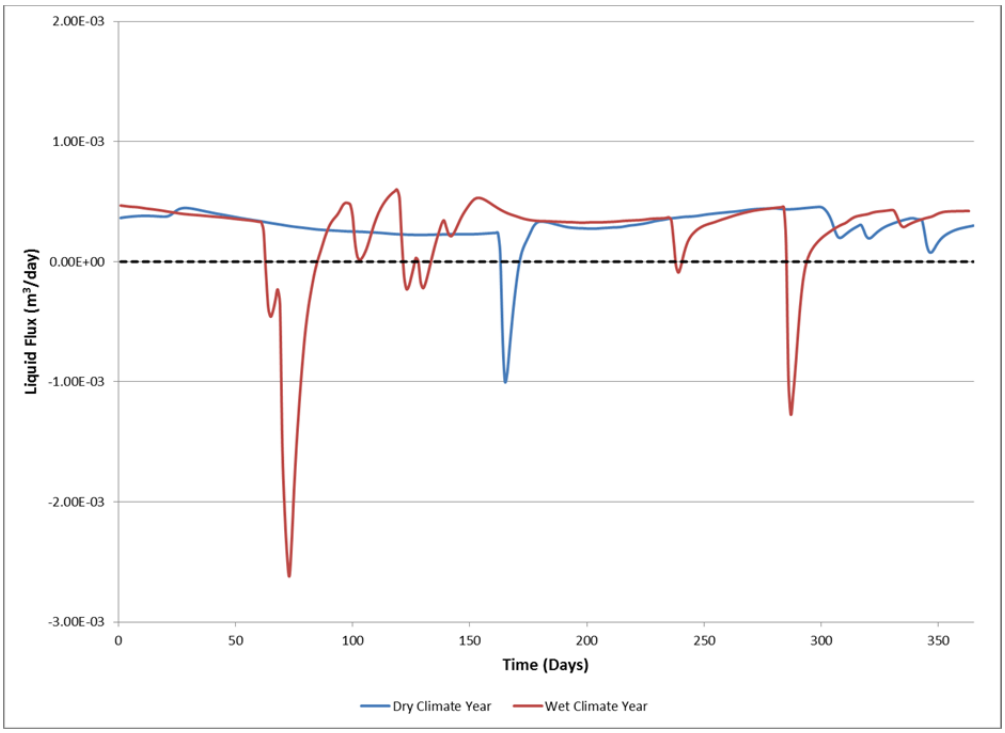


Figure 2.4 Liquid Flux into Scavenger Tailings @ 1 m *(3.28 ft)* Depth

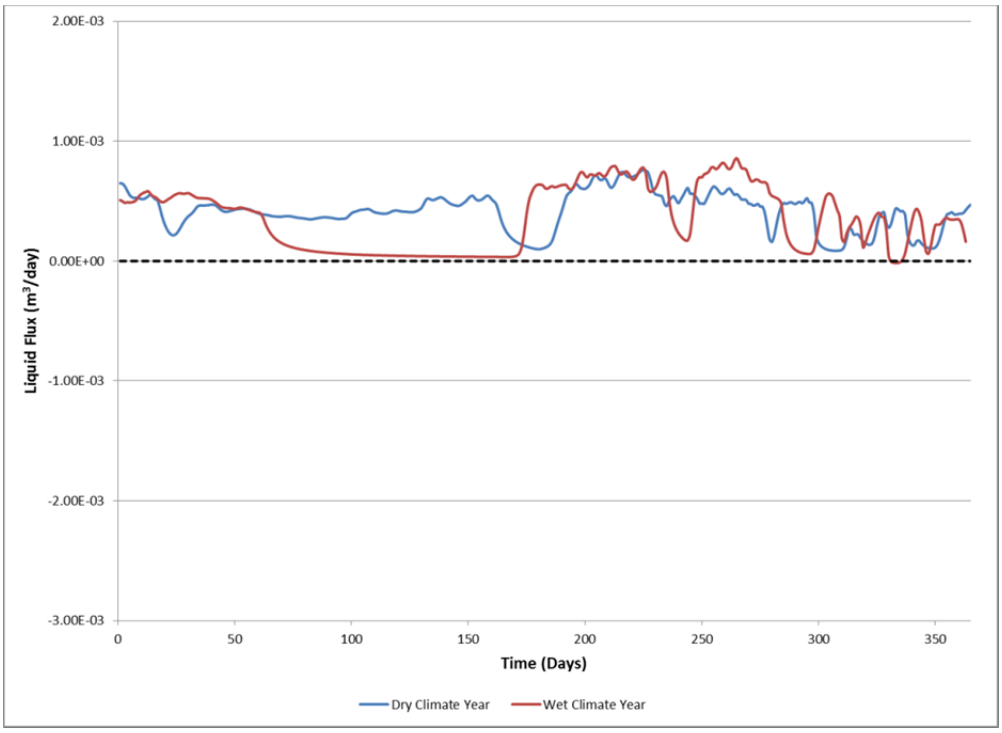


Figure 2.5 Liquid Flux into Cleaner Tailings below Cover @ 1 m *(3.28 ft)* Depth

2.4 Conclusions

Preliminary analyses indicate that a "store-and-release" cover could limit percolation into the cleaner tailings to less than 1% of annual precipitation. For the scavenger tailings, where the "store-and-release" cover was not assumed in the model, percolation would be in the range of 2% to 7% of precipitation.

Further refinements and optimizations of the effects of cover material thickness on percolation rates should be modeled taking into account additional climate data and additional information on leaf area index and geochemical, geotechnical and hydrological properties of tailings and Gila Conglomerate.

3 CLOSURE WATER MANAGEMENT PLAN

The initial closure water management plan consists of the following, however it is recognized that it will likely change and be refined through NEPA:

- maintaining the upstream diversion channels and the north dams;
- constructing additional diversion channels on the tailings embankment slopes and natural ground to divert embankment surface runoff around seepage collection dams (SCDs); and
- maintaining the SCDs for seepage storage, and actively managing the pond water for as long as required until the pond areas can passively manage the pond with evaporation.

Additional diversion channels will be constructed upstream of the SCDs to divert non-contact runoff around the ponds. The closure diversion channels will be constructed as a bench on the lower slopes of the tailings embankment and excavated into natural ground. A typical diversion channel was designed based on SCD S4. Figure 10.1 in the main report shows the closure diversion channel layouts for all SCDs.

The design criteria for the closure diversion channels are as follows:

- 1000-yr 24-hr peak flow (the 1000-yr 24-hr precipitation depth is 165 mm *(6.50 inches)*);
- 0.6 m *(1.97 ft)* freeboard;
- Manning's n of 0.035; and
- CN = 85.

For the S4 closure diversion channel, two typical channel sections were evaluated: a channel section with a 1% slope along the tailings embankment slope, and a channel section with a 10% slope excavated in bedrock. The calculated design flow and channel sizing are summarized in Table 3.1. Cross-sections for the typical channels on the embankment slope and in bedrock can be found in Figure 10.2 in the main report.

Table 3.1 Typical Closure Diversion

Typical Section	Design Flow (m^3/s) *(ft^3/s)*	Side Slope H:1V	Base Width (m) *(ft)*	Channel Slope (%)	Flow Velocity (m/s) *(ft/s)*	Flow Depth (m) *(ft)*	Flow Depth + Freeboard (m) *(ft)*	Riprap D_{50} (min) (mm) *(inches)*
1% section	24 *(848)*	2.5	2 *(6. 6)*	1%	2.6 *(8.5)*	1.6 *(5.2)*	2.2 *(7.2)*	180 *(7.1)*
10% section	24 *(848)*	1.0	2 *(6.6)*	10%	6.9 *(22.6)*	1.1 *(3.6)*	1.7 *(5.6)*	N/A[1]

Note:
1. Assumed to be excavated in bedrock, therefore no riprap is necessary.

REFERENCES

Western Regional Climate Center (WRCC). 2013. "Climate Summaries." Accessed April 16, 2013. http://www.wrcc.dri.edu/summary/Climsmaz.html

Smith C.D. and Kells J.A. (Smith & Kells). 1995. Stability of riprap channel linings on steep gradients. Proceedings, CSCE Annual Conference. Ottawa. 317-326.

Attachments:

Attachment I – Closure Cover Modeling Material Properties
Attachment II – Closure Cover Modeling Climate Datasets
Attachment III – Closure Cover Modeling Results

ATTACHMENT I

Closure Cover Modeling Material Properties

Volumetric Water Content Functions

The volumetric water content (VWC) functions for the scavenger and cleaner tailings were estimated using the saturated water content, grain size curves (D_{10} and D_{60}) and the liquid limits. The saturated water content is equivalent to the porosity of the tailings; this was calculated from the void ratios obtained in Tailings Consolidation Analyses.

Tailings properties used to generate the VWC curves are summarized in Table I-1.

Table I-1 Tailings Properties

Tailings Type	Saturated VWC (m^3/m^3) *(ft^3/ft^3)*	D_{10} (mm)*(inches)*	D_{60} (mm)*(inches)*	LL (%)
Cleaner	0.46 *(0.46)*	0.0002 *($7.9e^{-6}$)*	0.024 *($9.4e^{-4}$)*	18.4
Scavenger	0.36 *(0.46)*	0.0021 *($8.3e^{-5}$)*	0.098 *($3.9e^{-3}$)*	19.9

VWC functions for the uncompacted and compacted select fills were estimated for typical soils.

Volumetric water content and hydraulic conductivity functions are shown on Figure I-1 to Figure I-10.

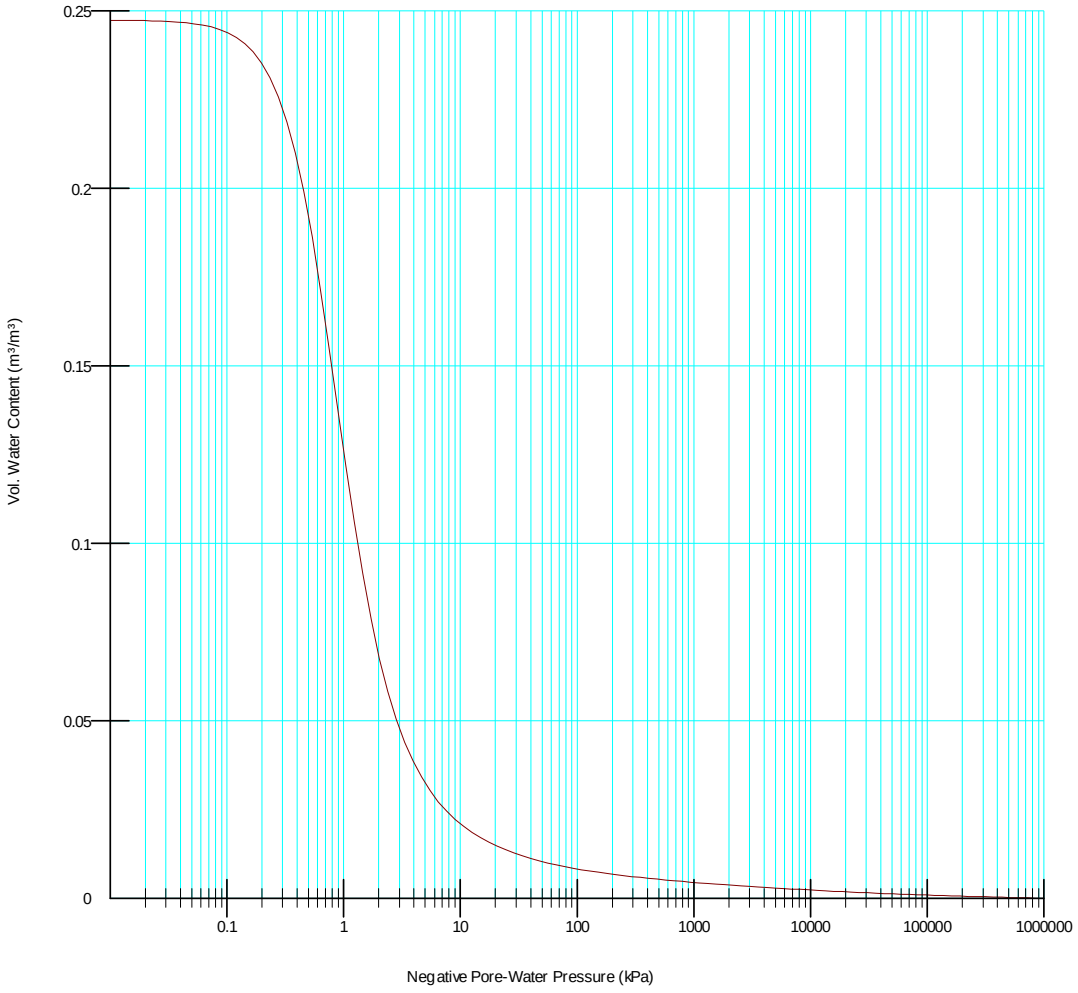


Figure I-1 Erosion Resistant Material Volumetric Water Content Function

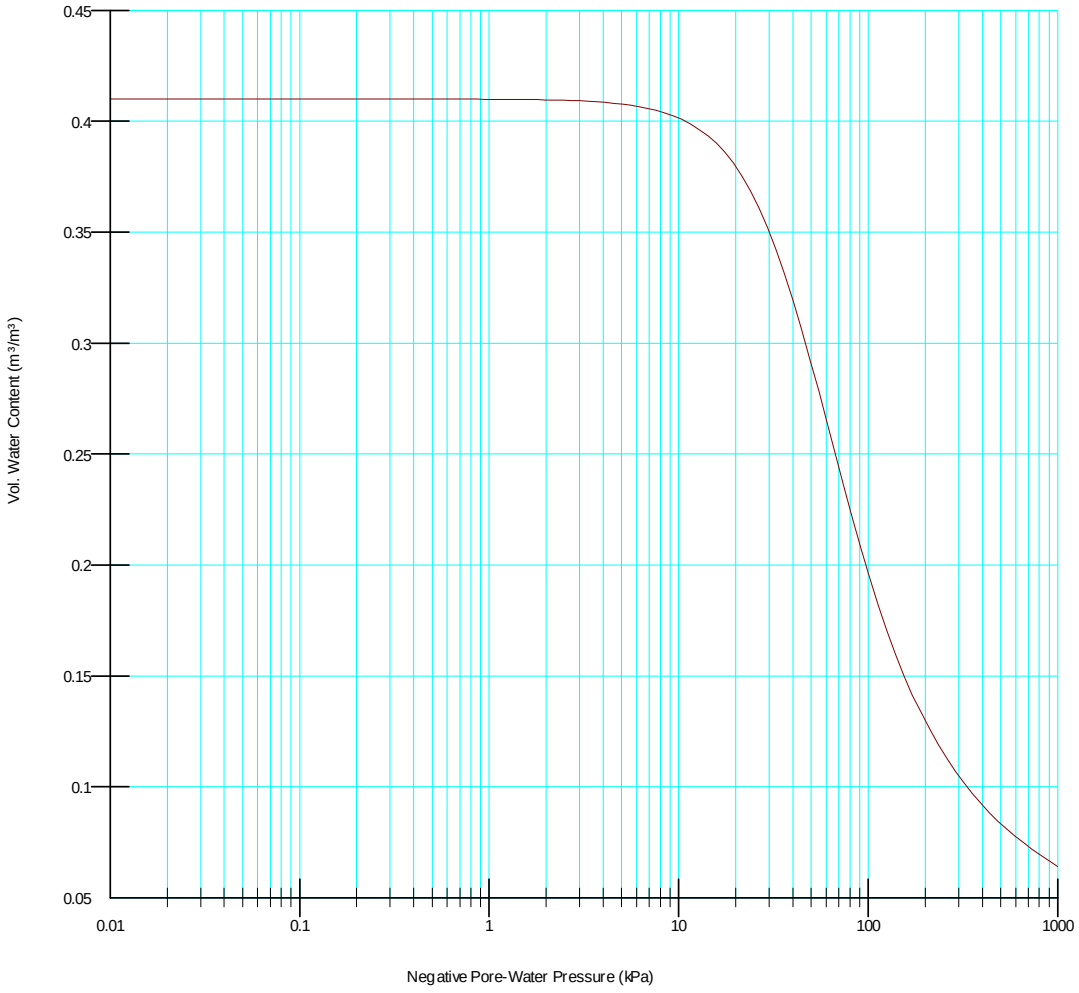


Figure I-2 Uncompacted Select Fill Volumetric Water Content Function

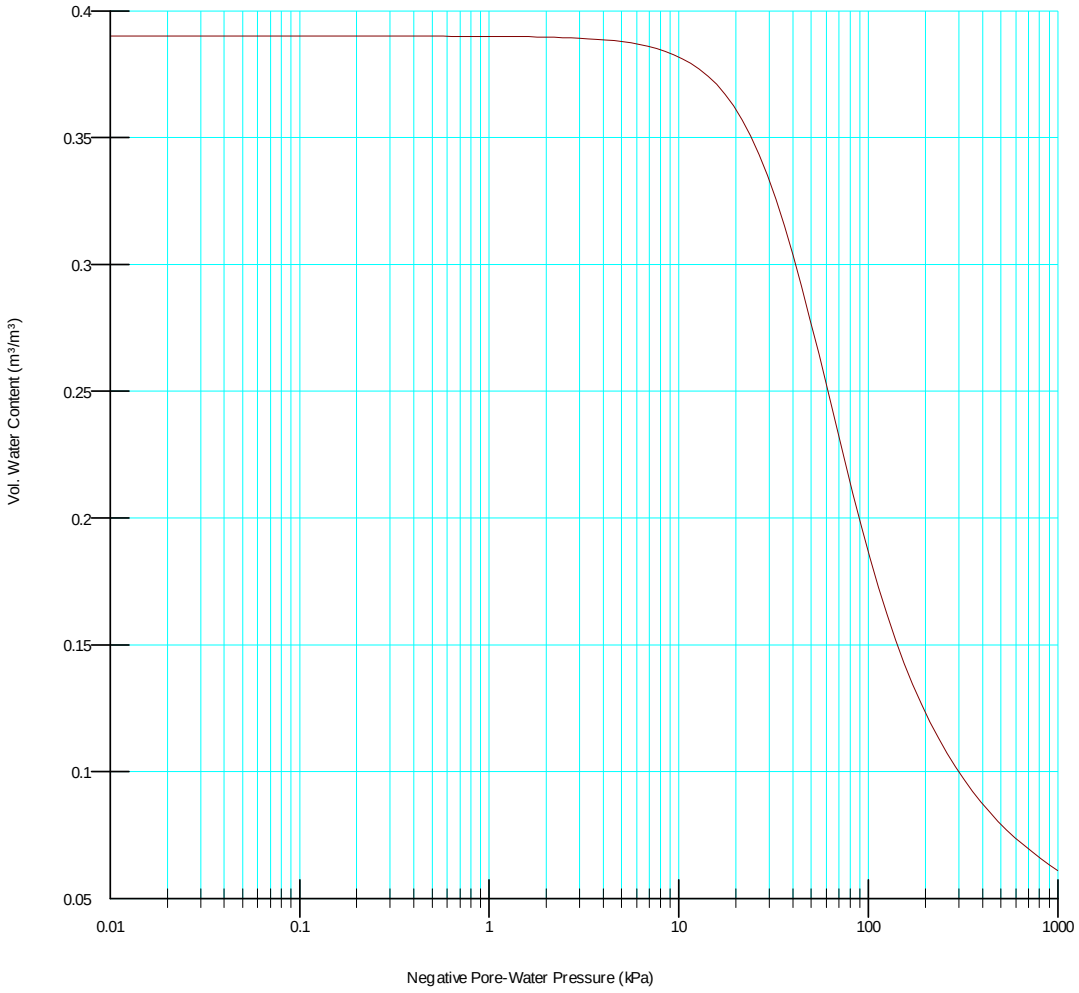


Figure I-3 Compacted Select Fill Volumetric Water Content Function

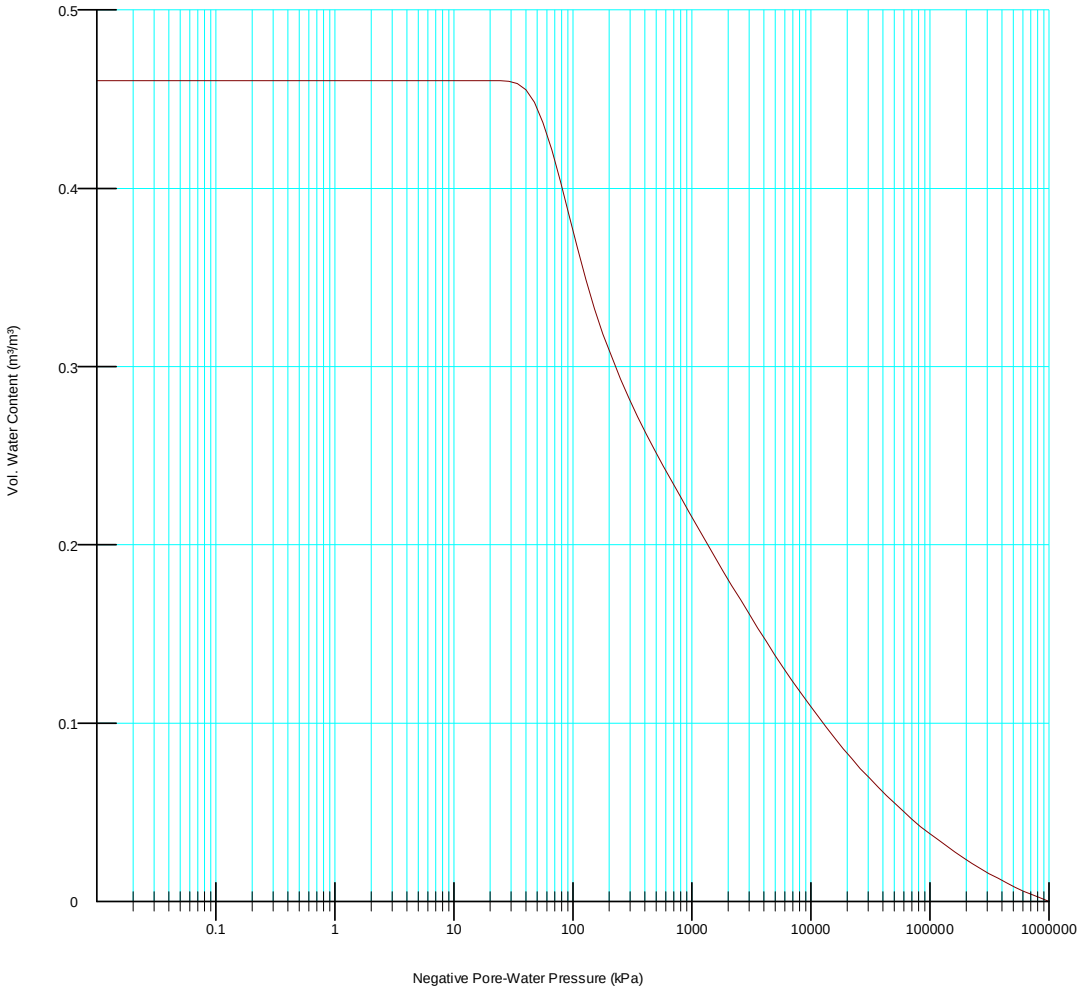


Figure I-4 Cleaner Tailings Volumetric Water Content Function

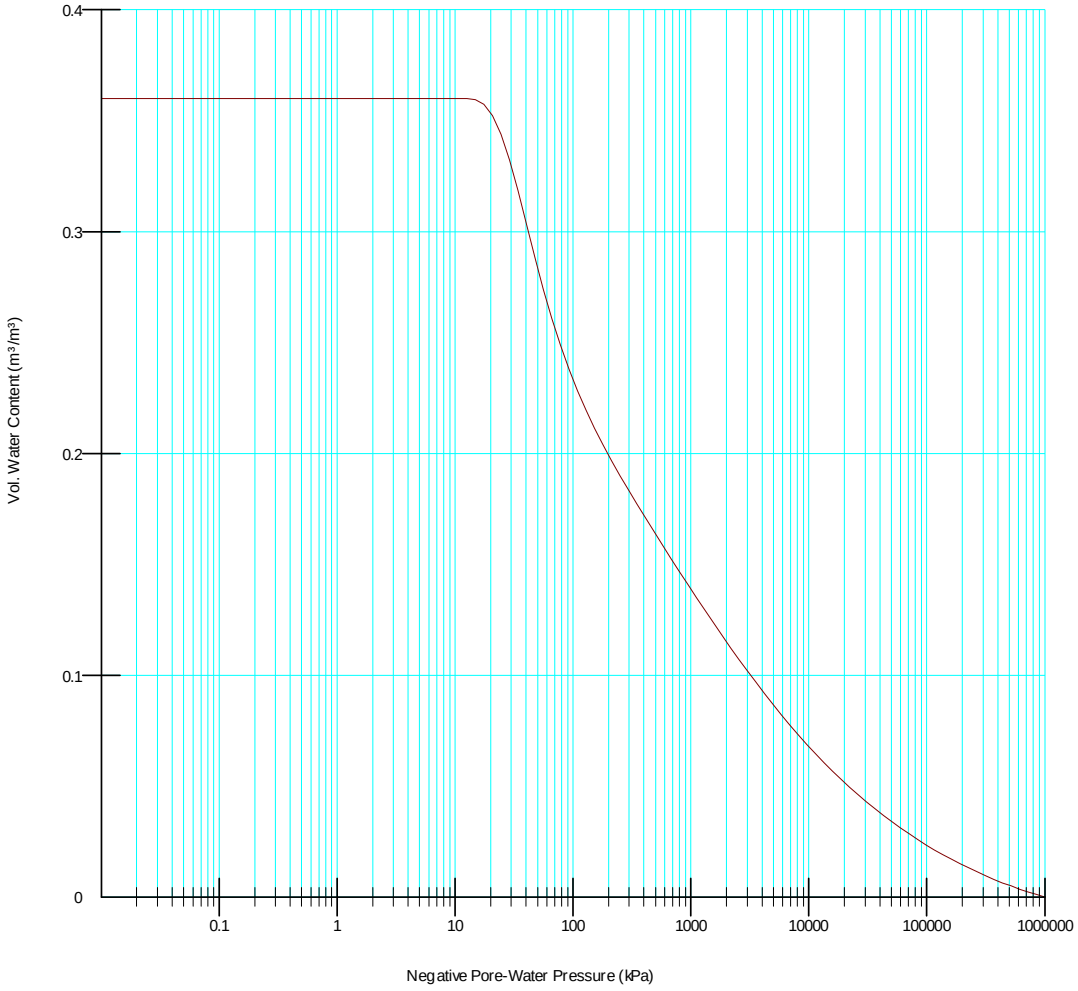


Figure I-5 Scavenger Tailings Volumetric Water Content Function

Hydraulic Conductivity Functions

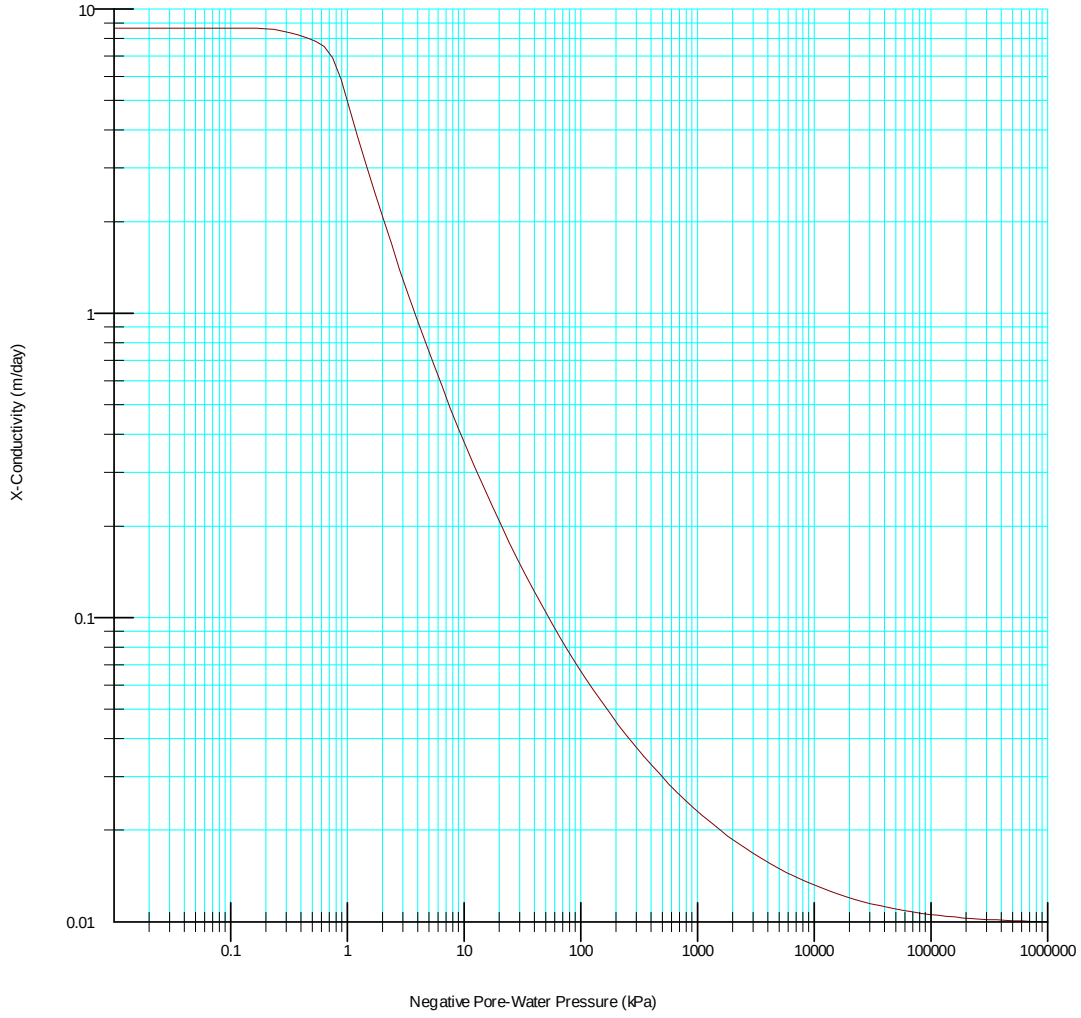


Figure I-6 Erosion Resistant Material Hydraulic Conductivity Function

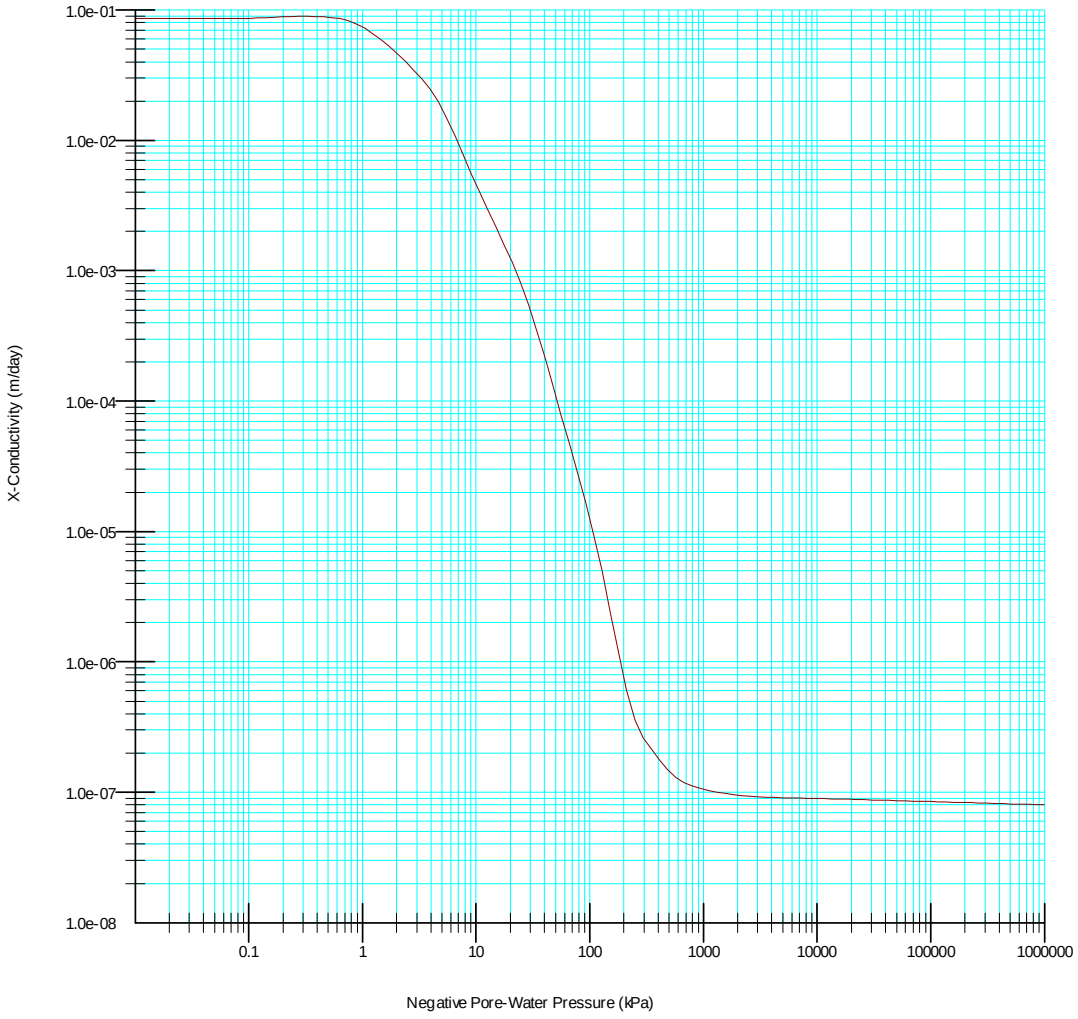


Figure I-7 Uncompacted Select Fill Hydraulic Conductivity Function

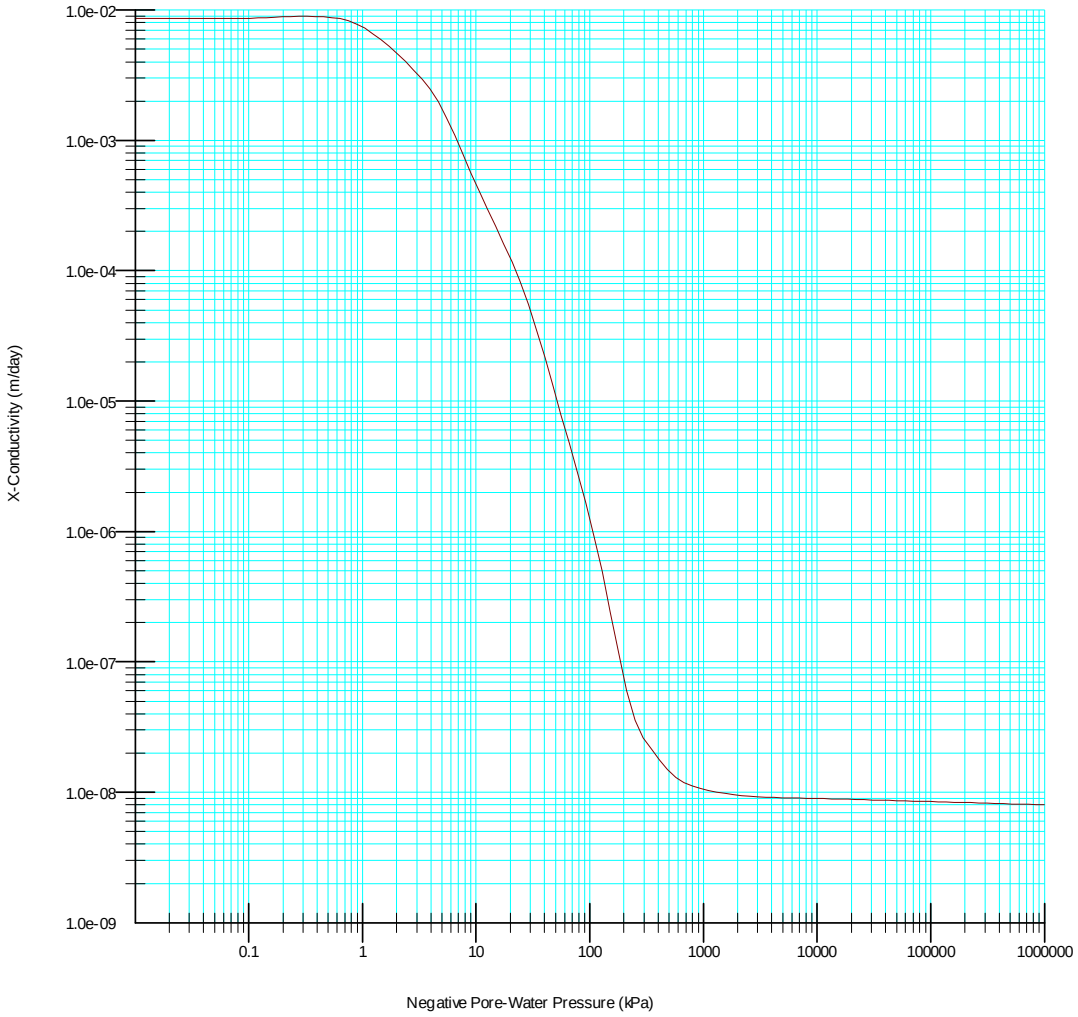


Figure I-8 Compacted Select Fill Hydraulic Conductivity Function

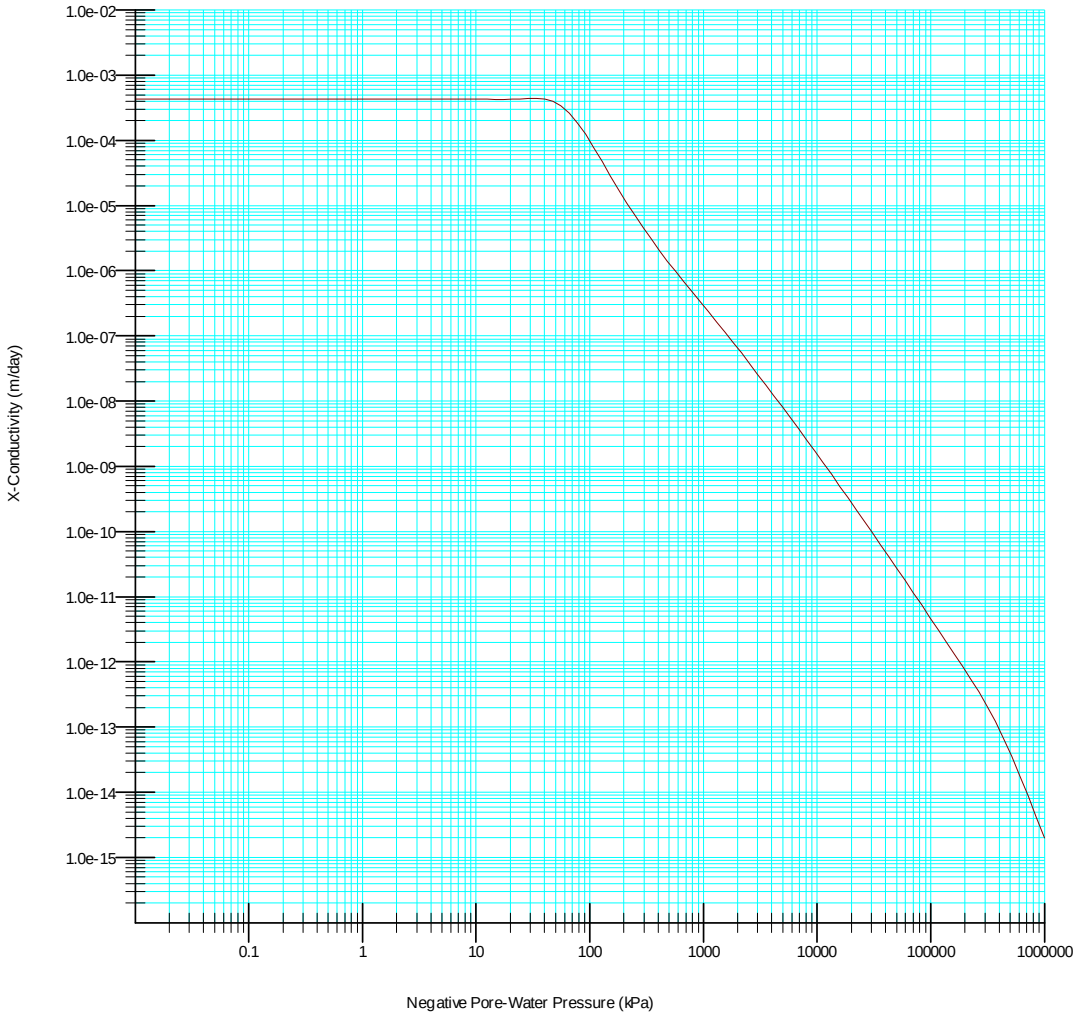


Figure I-9 Cleaner Tailings Hydraulic Conductivity Function

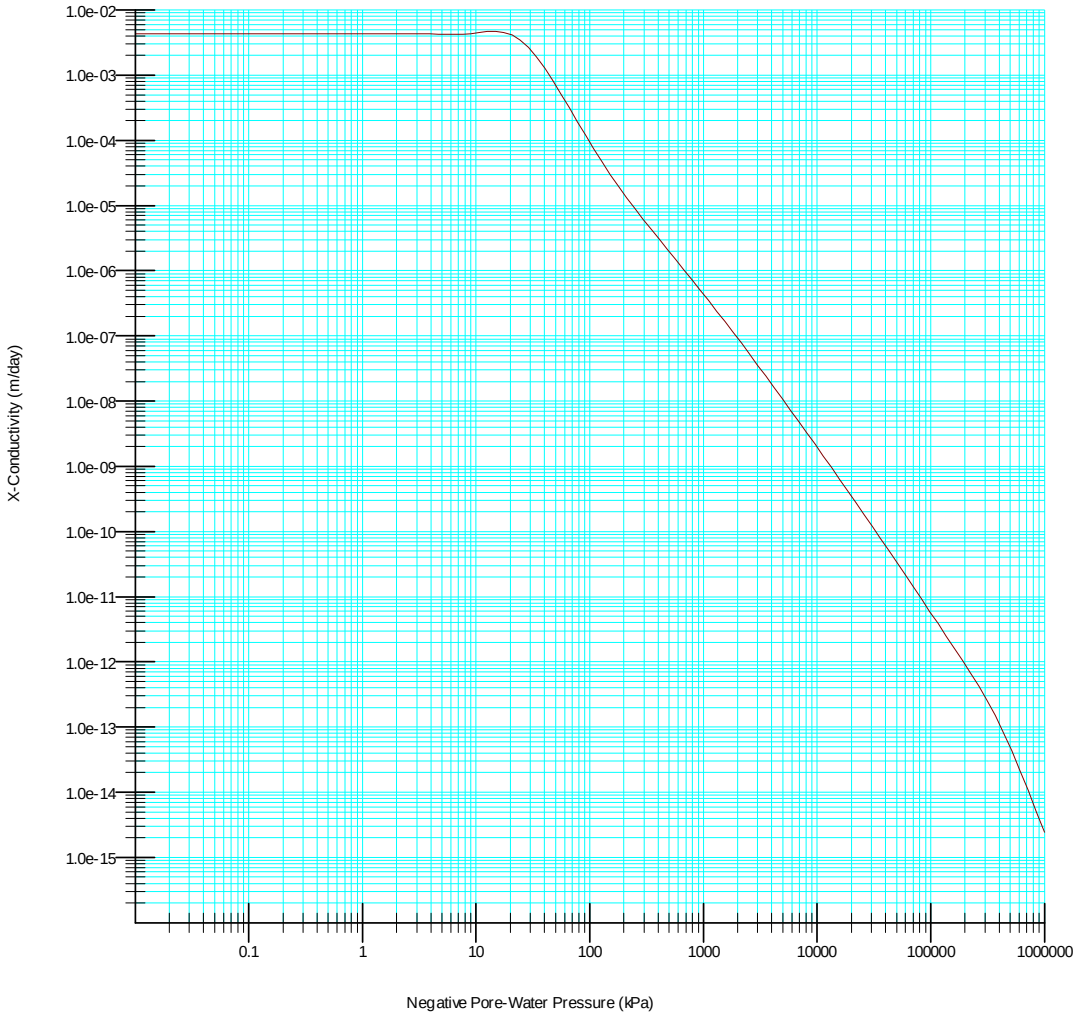


Figure I-10 Scavenger Tailings Hydraulic Conductivity Function

Specific Heat & Thermal Conductivity Functions

The thermal functions were estimated using the "silt" or "sand" functions provided in Vadose. The table below specifies the thermal conductivity function applied to each material in the analysis. Figure I-11 to Figure I-14 present the assumed functions.

Soil Type	Thermal Conductivity Dry/Saturated (kJ/days/m/°C) *(BTU/hr/ft/°F)*	Volumetric Specific Heat Dry/Saturated (kJ/m^3) *(BTU/ft^3)*	Function
Uncompacted Select Fill	50-97 *(0.33-0.65)*	1260-2850 *(33.82-76.49)*	Silt
Compacted Select Fill	50-97 *(0.33-0.65)*	1260-2850 *(33.82-76.49)*	Silt
Erosion Resistant Layer	98-190 *(0.66-12.7)*	1320-2580 *(35.43-69.25)*	Sand
Scavenger Tailings	50-97 *(0.33-0.65)*	1260-2850 *(33.82-76.49)*	Silt
Cleaner Tailings	50-97 *(0.33-0.65)*	1260-2850 *(33.82-76.49)*	Silt

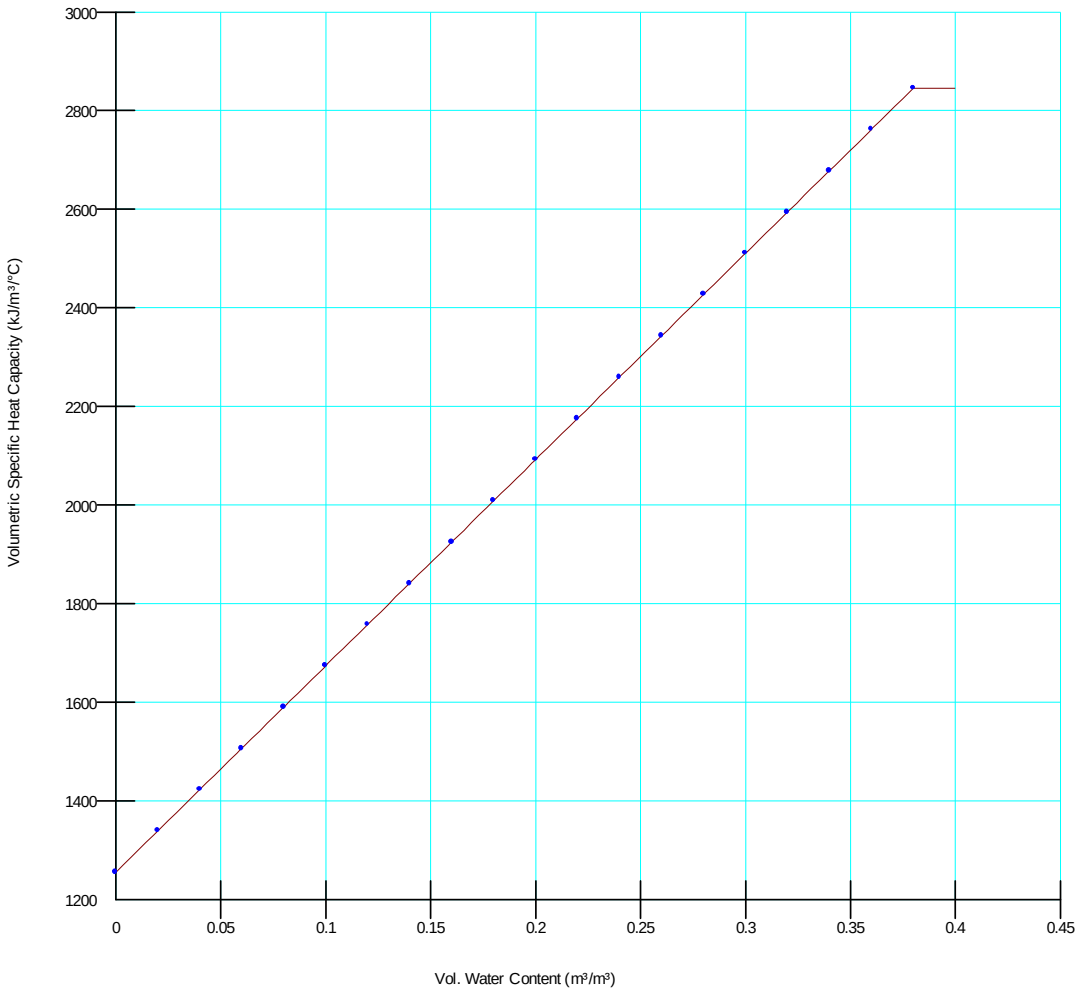


Figure I-11 Specific Heat Function – "Silt"

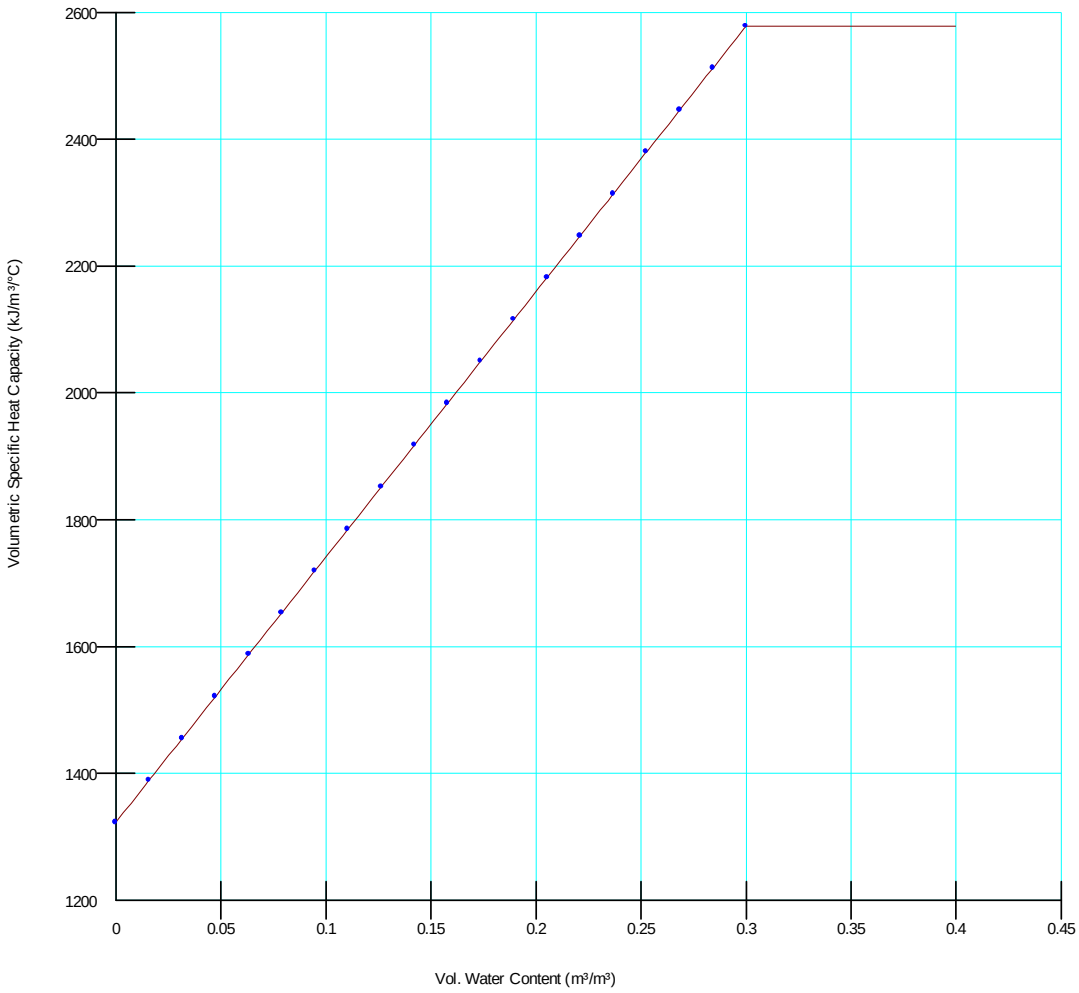


Figure I-12 Specific Heat Function – "Sand"

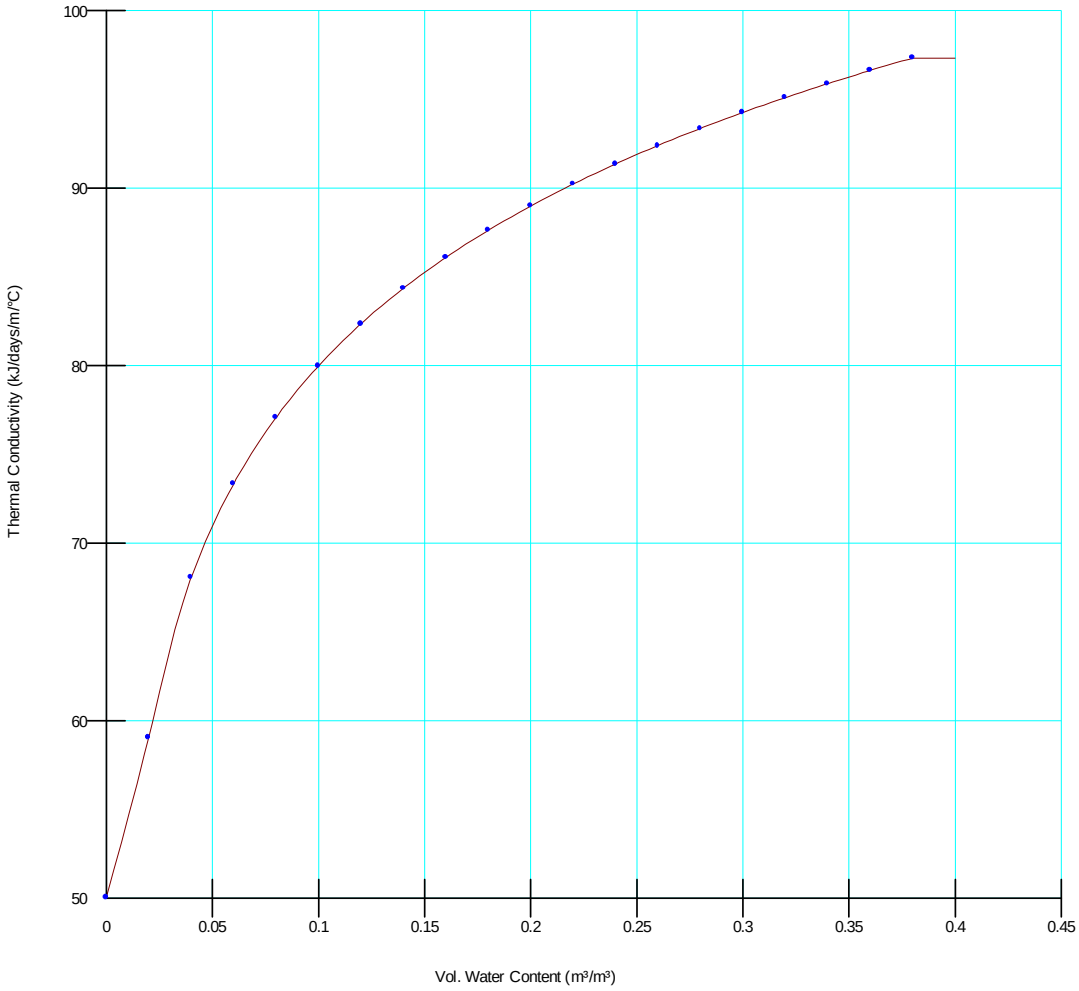


Figure I-13 Thermal Conductivity Function – "Silt"

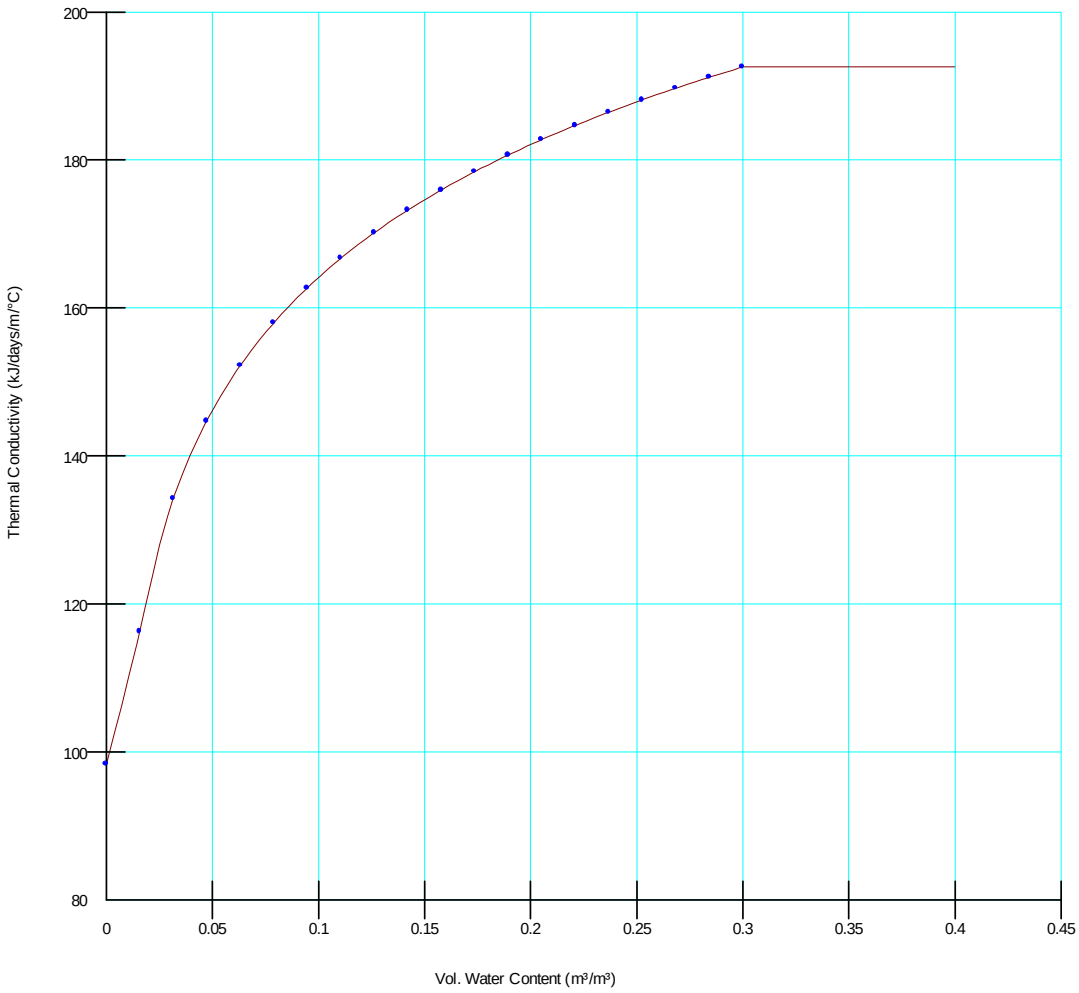


Figure I-14 Thermal Conductivity Function – "Sand"

ATTACHMENT II

Closure Cover Modeling Climate Datasets

AVERAGE YEAR (Water Year 2006)

Precipitation Data from Whitlow Station

Humidity, Wind Speed and Temperature from Magma Station

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
10/1/2005	1	38	19	34	9	2.5	0	12	18
10/2/2005	2	37	22	46	14	2.0	0	12	18
10/3/2005	3	37	23	84	21	4.0	0	12	18
10/4/2005	4	35	22	84	32	2.9	0	12	18
10/5/2005	5	36	21	59	27	2.2	0	12	18
10/6/2005	6	38	18	55	21	3.7	0	12	18
10/7/2005	7	38	24	45	13	5.4	0	12	18
10/8/2005	8	35	24	43	15	6.0	0	12	18
10/9/2005	9	28	17	61	15	3.8	0	12	18
10/10/2005	10	28	13	52	14	1.7	0	12	18
10/11/2005	11	30	13	36	10	1.8	0	12	18
10/12/2005	12	31	12	35	10	0.8	0	12	18
10/13/2005	13	35	13	30	9	3.8	0	12	18
10/14/2005	14	32	20	48	21	5.5	0	12	18
10/15/2005	15	31	19	53	20	4.4	0	12	18
10/16/2005	16	30	22	34	14	4.4	0	12	18
10/17/2005	17	33	18	98	20	5.4	4	12	18
10/18/2005	18	26	13	100	50	6.0	10	12	18
10/19/2005	19	23	10	100	34	1.5	0	12	18
10/20/2005	20	28	11	94	29	2.3	0	12	18
10/21/2005	21	32	14	82	19	2.4	0	12	18
10/22/2005	22	32	13	75	21	1.2	0	12	18
10/23/2005	23	28	13	67	29	2.1	0	12	18
10/24/2005	24	32	13	40	21	4.4	0	12	18
10/25/2005	25	31	18	59	21	5.2	0	12	18
10/26/2005	26	29	14	73	30	0.6	0	12	18
10/27/2005	27	29	13	73	23	2.6	0	12	18
10/28/2005	28	29	16	58	26	2.6	0	12	18
10/29/2005	29	29	13	69	27	1.7	0	12	18
10/30/2005	30	28	14	64	30	1.9	0	12	18
10/31/2005	31	31	12	63	11	2.7	0	12	18
11/1/2005	32	33	13	32	10	3.8	0	12	18
11/2/2005	33	33	18	25	10	3.9	0	12	18
11/3/2005	34	29	14	52	20	2.2	0	12	18
11/4/2005	35	29	11	58	21	1.6	0	12	18
11/5/2005	36	28	9	61	18	1.0	0	12	18
11/6/2005	37	31	9	50	16	2.8	0	12	18
11/7/2005	38	31	14	38	16	3.0	0	12	18
11/8/2005	39	34	17	34	11	2.5	0	12	18
11/9/2005	40	32	17	44	21	2.0	0	12	18
11/10/2005	41	28	12	62	23	1.2	0	12	18
11/11/2005	42	24	12	88	37	2.9	0	12	18
11/12/2005	43	23	9	73	37	1.3	0	12	18
11/13/2005	44	27	7	80	26	3.3	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
11/14/2005	45	27	11	60	23	1.4	0	12	18
11/15/2005	46	26	10	56	10	4.4	0	12	18
11/16/2005	47	27	11	30	14	4.2	0	12	18
11/17/2005	48	26	12	35	18	1.7	0	12	18
11/18/2005	49	27	14	23	12	4.5	0	12	18
11/19/2005	50	26	7	35	14	1.5	0	12	18
11/20/2005	51	26	13	34	15	4.8	0	12	18
11/21/2005	52	29	9	41	11	2.2	0	12	18
11/22/2005	53	28	8	33	13	3.2	0	12	18
11/23/2005	54	24	9	36	16	0.9	0	12	18
11/24/2005	55	26	10	41	15	1.0	0	12	18
11/25/2005	56	26	11	48	22	1.2	0	12	18
11/26/2005	57	23	12	55	26	2.8	0	12	18
11/27/2005	58	13	2	40	17	4.9	0	12	18
11/28/2005	59	14	-2	34	9	0.8	0	12	18
11/29/2005	60	19	1	22	9	0.3	0	12	18
11/30/2005	61	21	3	42	11	0.2	0	12	18
12/1/2005	62	24	4	60	23	0.7	0	12	18
12/2/2005	63	23	8	48	20	1.6	0	12	18
12/3/2005	64	22	9	53	30	2.2	0	12	18
12/4/2005	65	18	4	60	15	1.9	0	12	18
12/5/2005	66	18	1	29	10	1.6	0	12	18
12/6/2005	67	17	-1	26	11	0.2	0	12	18
12/7/2005	68	18	-1	29	12	0.4	0	12	18
12/8/2005	69	19	2	30	10	3.1	0	12	18
12/9/2005	70	23	7	31	11	1.4	0	12	18
12/10/2005	71	22	3	29	12	0.5	0	12	18
12/11/2005	72	22	6	32	15	0.4	0	12	18
12/12/2005	73	19	8	91	16	1.2	0	12	18
12/13/2005	74	19	6	100	27	1.1	0	12	18
12/14/2005	75	19	2	80	22	0.7	0	12	18
12/15/2005	76	17	4	46	15	2.4	0	12	18
12/16/2005	77	18	1	36	14	0.5	0	12	18
12/17/2005	78	18	1	43	18	1.6	0	12	18
12/18/2005	79	19	3	52	24	1.6	0	12	18
12/19/2005	80	19	3	55	25	1.7	0	12	18
12/20/2005	81	22	3	61	25	1.4	0	12	18
12/21/2005	82	27	7	55	15	2.7	0	12	18
12/22/2005	83	27	7	44	14	1.7	0	12	18
12/23/2005	84	24	8	47	19	1.3	0	12	18
12/24/2005	85	26	8	48	18	0.9	0	12	18
12/25/2005	86	26	6	42	14	1.1	0	12	18
12/26/2005	87	26	8	48	18	1.7	0	12	18
12/27/2005	88	22	7	70	32	1.0	0	12	18
12/28/2005	89	23	6	72	26	0.4	0	12	18
12/29/2005	90	21	8	56	24	1.6	0	12	18
12/30/2005	91	21	3	67	24	3.4	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
12/31/2005	92	20	6	59	27	2.5	0	12	18
1/1/2006	93	22	7	55	33	0.2	0	12	18
1/2/2006	94	27	12	39	19	3.9	0	12	18
1/3/2006	95	22	7	77	23	1.3	0	12	18
1/4/2006	96	19	2	77	30	0.4	0	12	18
1/5/2006	97	27	15	24	9	3.0	0	12	18
1/6/2006	98	27	11	23	10	5.3	0	12	18
1/7/2006	99	27	12	27	10	3.8	0	12	18
1/8/2006	100	23	5	37	15	1.4	0	12	18
1/9/2006	101	22	4	39	8	3.3	0	12	18
1/10/2006	102	25	5	22	8	3.6	0	12	18
1/11/2006	103	24	3	23	11	1.9	0	12	18
1/12/2006	104	21	4	25	12	0.9	0	12	18
1/13/2006	105	27	3	33	11	3.0	0	12	18
1/14/2006	106	24	12	27	13	3.8	0	12	18
1/15/2006	107	17	8	52	24	3.4	0	12	18
1/16/2006	108	14	1	70	26	2.3	0	12	18
1/17/2006	109	17	-2	50	12	1.7	0	12	18
1/18/2006	110	19	2	33	10	2.0	0	12	18
1/19/2006	111	16	5	50	16	4.6	0	12	18
1/20/2006	112	17	0	61	18	2.2	0	12	18
1/21/2006	113	19	-2	41	14	2.0	0	12	18
1/22/2006	114	20	0	34	15	1.8	0	12	18
1/23/2006	115	23	0	40	14	4.7	0	12	18
1/24/2006	116	24	13	30	13	7.2	0	12	18
1/25/2006	117	20	6	35	13	5.1	0	12	18
1/26/2006	118	20	2	56	21	0.5	0	12	18
1/27/2006	119	18	2	54	19	3.4	0	12	18
1/28/2006	120	19	2	65	20	1.8	0	12	18
1/29/2006	121	20	5	47	20	1.5	0	12	18
1/30/2006	122	23	2	57	19	2.6	0	12	18
1/31/2006	123	21	8	47	25	3.4	0	12	18
2/1/2006	124	22	7	58	21	3.1	0	12	18
2/2/2006	125	23	6	55	20	2.3	0	12	18
2/3/2006	126	24	7	50	22	1.4	0	12	18
2/4/2006	127	27	7	52	12	2.9	0	12	18
2/5/2006	128	23	8	33	17	1.4	0	12	18
2/6/2006	129	24	8	30	6	4.9	0	12	18
2/7/2006	130	26	9	14	4	4.6	0	12	18
2/8/2006	131	29	9	13	4	3.7	0	12	18
2/9/2006	132	23	13	68	7	4.0	0	12	18
2/10/2006	133	24	7	82	22	1.8	0	12	18
2/11/2006	134	24	6	53	6	4.6	0	12	18
2/12/2006	135	24	8	16	7	3.5	0	12	18
2/13/2006	136	26	9	16	8	1.1	0	12	18
2/14/2006	137	27	9	17	9	3.5	0	12	18
2/15/2006	138	25	9	48	11	6.9	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
2/16/2006	139	21	8	68	19	1.7	0	12	18
2/17/2006	140	19	10	50	22	1.7	0	12	18
2/18/2006	141	19	4	43	22	2.8	0	12	18
2/19/2006	142	19	3	59	25	0.8	0	12	18
2/20/2006	143	18	2	59	22	0.9	0	12	18
2/21/2006	144	19	3	56	21	2.8	0	12	18
2/22/2006	145	19	2	50	16	2.1	0	12	18
2/23/2006	146	24	3	37	13	1.3	0	12	18
2/24/2006	147	24	3	35	16	1.5	0	12	18
2/25/2006	148	26	7	33	13	2.3	0	12	18
2/26/2006	149	29	9	24	7	5.4	0	12	18
2/27/2006	150	27	8	23	9	1.8	0	12	18
2/28/2006	151	28	14	45	11	2.7	0	12	18
3/1/2006	152	23	13	66	46	2.2	0	12	18
3/2/2006	153	26	9	88	20	2.2	0	12	18
3/3/2006	154	26	9	41	12	3.5	0	12	18
3/4/2006	155	23	8	33	15	1.2	0	12	18
3/5/2006	156	27	7	30	9	1.3	0	12	18
3/6/2006	157	25	10	22	9	2.5	0	12	18
3/7/2006	158	24	11	57	16	3.2	0	12	18
3/8/2006	159	18	8	63	30	4.3	0	12	18
3/9/2006	160	19	7	53	20	3.0	0	12	18
3/10/2006	161	17	9	96	27	6.0	0	12	18
3/11/2006	162	10	4	100	71	4.2	40	12	18
3/12/2006	163	14	3	100	32	4.0	9	12	18
3/13/2006	164	17	2	95	23	1.9	0	12	18
3/14/2006	165	26	3	91	15	2.7	0	12	18
3/15/2006	166	23	9	91	25	1.9	0	12	18
3/16/2006	167	23	7	87	28	1.9	0	12	18
3/17/2006	168	26	11	69	18	3.2	0	12	18
3/18/2006	169	18	11	59	36	3.8	0	12	18
3/19/2006	170	14	6	100	49	3.5	3	12	18
3/20/2006	171	8	7	98	84	3.0	1	12	18
3/21/2006	172	19	9	100	36	4.9	2	12	18
3/22/2006	173	14	4	100	25	0.8	0	12	18
3/23/2006	174	21	2	70	6	3.7	0	12	18
3/24/2006	175	22	10	33	6	4.9	0	12	18
3/25/2006	176	23	6	49	5	3.4	0	12	18
3/26/2006	177	22	7	36	10	1.3	0	12	18
3/27/2006	178	20	12	50	20	3.0	0	12	18
3/28/2006	179	19	12	56	25	4.9	0	12	18
3/29/2006	180	18	8	86	22	6.9	4	12	18
3/30/2006	181	16	7	83	30	0.9	1	12	18
3/31/2006	182	19	7	66	22	2.9	0	12	18
4/1/2006	183	18	7	64	24	2.8	0	12	18
4/2/2006	184	21	3	64	12	1.1	0	12	18
4/3/2006	185	23	8	48	12	1.8	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
4/4/2006	186	22	12	48	16	4.4	0	12	18
4/5/2006	187	18	7	63	20	5.7	0	12	18
4/6/2006	188	14	1	60	21	1.6	0	12	18
4/7/2006	189	20	2	57	11	1.1	0	12	18
4/8/2006	190	24	6	39	6	1.4	0	12	18
4/9/2006	191	25	6	33	6	1.9	0	12	18
4/10/2006	192	21	9	39	14	2.0	0	12	18
4/11/2006	193	21	6	53	13	1.4	0	12	18
4/12/2006	194	27	8	35	5	3.3	0	12	18
4/13/2006	195	28	7	29	4	2.2	0	12	18
4/14/2006	196	26	12	42	10	7.9	0	12	18
4/15/2006	197	19	7	63	21	1.7	0	12	18
4/16/2006	198	23	6	57	12	2.1	0	12	18
4/17/2006	199	23	7	42	14	3.2	0	12	18
4/18/2006	200	22	6	32	9	1.0	0	12	18
4/19/2006	201	24	6	31	7	2.4	0	12	18
4/20/2006	202	29	7	25	5	1.3	0	12	18
4/21/2006	203	32	11	44	2	2.7	0	12	18
4/22/2006	204	31	13	29	3	5.4	0	12	18
4/23/2006	205	24	11	36	10	4.4	0	12	18
4/24/2006	206	24	7	48	11	1.5	0	12	18
4/25/2006	207	29	9	33	6	2.2	0	12	18
4/26/2006	208	31	11	509	2	3.6	0	12	18
4/27/2006	209	22	10	52	15	4.9	0	12	18
4/28/2006	210	21	7	62	28	2.3	0	12	18
4/29/2006	211	28	12	53	12	1.6	0	12	18
4/30/2006	212	33	13	39	11	1.8	0	12	18
5/1/2006	213	34	17	28	5	1.9	0	12	18
5/2/2006	214	34	17	21	4	2.4	0	12	18
5/3/2006	215	33	18	21	3	3.5	0	12	18
5/4/2006	216	31	13	23	5	4.4	0	12	18
5/5/2006	217	27	13	24	9	3.9	0	12	18
5/6/2006	218	30	15	32	10	1.7	0	12	18
5/7/2006	219	31	16	29	9	2.0	0	12	18
5/8/2006	220	32	17	27	7	2.0	0	12	18
5/9/2006	221	33	14	27	8	2.2	0	12	18
5/10/2006	222	34	17	25	7	1.5	0	12	18
5/11/2006	223	36	17	23	4	2.0	0	12	18
5/12/2006	224	37	18	22	4	1.8	0	12	18
5/13/2006	225	36	18	18	4	2.2	0	12	18
5/14/2006	226	37	19	20	4	1.8	0	12	18
5/15/2006	227	37	19	16	5	4.1	0	12	18
5/16/2006	228	37	23	36	10	6.3	0	12	18
5/17/2006	229	36	21	46	8	5.3	0	12	18
5/18/2006	230	37	21	31	7	1.6	0	12	18
5/19/2006	231	37	21	22	6	2.6	0	12	18
5/20/2006	232	38	19	28	5	2.0	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
5/21/2006	233	38	21	18	4	4.9	0	12	18
5/22/2006	234	29	18	38	9	9.1	0	12	18
5/23/2006	235	31	13	44	8	2.6	0	12	18
5/24/2006	236	37	17	25	5	1.4	0	12	18
5/25/2006	237	37	21	18	4	2.4	0	12	18
5/26/2006	238	36	20	18	2	5.0	0	12	18
5/27/2006	239	33	17	30	5	7.2	0	12	18
5/28/2006	240	29	16	46	7	3.6	0	12	18
5/29/2006	241	32	12	17	4	2.2	0	12	18
5/30/2006	242	33	14	13	2	1.7	0	12	18
5/31/2006	243	37	16	12	2	1.1	0	12	18
6/1/2006	244	40	18	13	1	2.2	0	12	18
6/2/2006	245	41	26	18	4	5.3	0	12	18
6/3/2006	246	41	22	34	5	2.3	0	12	18
6/4/2006	247	40	25	17	6	3.4	0	12	18
6/5/2006	248	38	26	26	8	3.4	0	12	18
6/6/2006	249	37	24	36	12	5.6	0	12	18
6/7/2006	250	38	26	51	9	3.8	0	12	18
6/8/2006	251	38	24	53	11	4.0	0	12	18
6/9/2006	252	38	22	25	4	4.0	0	12	18
6/10/2006	253	38	19	17	3	2.8	0	12	18
6/11/2006	254	38	20	15	0	3.2	0	12	18
6/12/2006	255	38	21	9	0	3.8	0	12	18
6/13/2006	256	41	21	16	4	1.8	0	12	18
6/14/2006	257	38	24	18	3	3.2	0	12	18
6/15/2006	258	37	21	20	4	5.3	0	12	18
6/16/2006	259	36	21	22	5	2.7	0	12	18
6/17/2006	260	38	22	17	4	2.1	0	12	18
6/18/2006	261	40	22	16	4	1.3	0	12	18
6/19/2006	262	42	24	23	4	2.0	0	12	18
6/20/2006	263	39	25	20	7	2.1	0	12	18
6/21/2006	264	39	24	25	9	2.6	0	12	18
6/22/2006	265	39	25	32	5	2.9	0	12	18
6/23/2006	266	39	26	29	9	3.0	0	12	18
6/24/2006	267	38	28	25	9	5.4	0	12	18
6/25/2006	268	42	27	40	7	6.2	0	12	18
6/26/2006	269	40	23	49	9	4.8	0	12	18
6/27/2006	270	38	26	44	14	5.2	0	12	18
6/28/2006	271	38	24	54	13	3.2	0	12	18
6/29/2006	272	39	26	46	15	4.9	0	12	18
6/30/2006	273	39	27	45	13	3.2	0	12	18
7/1/2006	274	41	27	45	12	3.7	0	12	18
7/2/2006	275	38	28	44	20	3.5	0	12	18
7/3/2006	276	39	27	41	16	3.2	0	12	18
7/4/2006	277	37	23	73	21	4.3	3	12	18
7/5/2006	278	31	21	91	42	5.2	13	12	18
7/6/2006	279	37	24	81	21	4.3	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
7/7/2006	280	36	23	79	25	5.2	0	12	18
7/8/2006	281	38	23	70	18	2.8	0	12	18
7/9/2006	282	40	25	54	11	2.2	0	12	18
7/10/2006	283	39	27	34	12	4.0	0	12	18
7/11/2006	284	41	26	41	8	1.6	0	12	18
7/12/2006	285	42	27	36	13	3.2	0	12	18
7/13/2006	286	43	31	40	12	4.0	0	12	18
7/14/2006	287	44	31	38	12	3.3	0	12	18
7/15/2006	288	44	31	43	9	5.1	0	12	18
7/16/2006	289	42	27	58	13	4.5	0	12	18
7/17/2006	290	40	27	63	20	2.2	0	12	18
7/18/2006	291	43	30	45	8	5.5	0	12	18
7/19/2006	292	43	31	33	11	4.3	0	12	18
7/20/2006	293	42	33	33	14	3.8	0	12	18
7/21/2006	294	46	29	35	8	5.2	0	12	18
7/22/2006	295	45	33	23	7	4.9	0	12	18
7/23/2006	296	43	32	36	9	4.3	1	12	18
7/24/2006	297	44	29	43	11	2.3	0	12	18
7/25/2006	298	41	24	89	18	5.4	23	12	18
7/26/2006	299	36	24	89	33	3.2	2	12	18
7/27/2006	300	32	23	97	48	3.9	14	12	18
7/28/2006	301	34	24	88	41	3.6	1	12	18
7/29/2006	302	35	25	84	38	4.3	17	12	18
7/30/2006	303	33	23	95	45	3.0	6	12	18
7/31/2006	304	35	24	85	35	3.8	10	12	18
8/1/2006	305	36	24	87	27	2.6	2	12	18
8/2/2006	306	37	27	63	25	1.3	0	12	18
8/3/2006	307	37	26	69	27	5.8	0	12	18
8/4/2006	308	36	26	74	30	1.5	1	12	18
8/5/2006	309	37	24	68	16	2.0	0	12	18
8/6/2006	310	39	24	52	14	2.4	0	12	18
8/7/2006	311	39	29	46	21	4.2	0	12	18
8/8/2006	312	41	31	50	22	3.8	0	12	18
8/9/2006	313	39	26	73	22	2.9	12	12	18
8/10/2006	314	40	28	66	25	3.4	0	12	18
8/11/2006	315	37	26	68	28	3.9	0	12	18
8/12/2006	316	36	23	93	26	4.0	30	12	18
8/13/2006	317	38	28	65	25	4.6	0	12	18
8/14/2006	318	38	23	89	25	4.9	7	12	18
8/15/2006	319	34	24	89	30	2.2	0	12	18
8/16/2006	320	35	28	60	26	3.6	0	12	18
8/17/2006	321	38	27	60	15	2.7	0	12	18
8/18/2006	322	39	27	49	13	3.1	0	12	18
8/19/2006	323	41	27	38	11	3.8	0	12	18
8/20/2006	324	41	30	39	16	5.5	0	12	18
8/21/2006	325	42	26	72	16	5.2	0	12	18
8/22/2006	326	36	27	70	30	4.2	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start (hr)	End (hr)
8/23/2006	327	38	26	68	24	2.2	0	12	18
8/24/2006	328	32	22	93	40	3.1	5	12	18
8/25/2006	329	37	24	82	33	2.7	0	12	18
8/26/2006	330	38	26	63	21	3.2	0	12	18
8/27/2006	331	38	25	59	9	2.0	0	12	18
8/28/2006	332	41	22	48	7	2.2	0	12	18
8/29/2006	333	39	26	42	17	3.2	0	12	18
8/30/2006	334	38	27	52	23	2.7	0	12	18
8/31/2006	335	38	26	57	21	2.4	0	12	18
9/1/2006	336	40	27	48	16	2.3	0	12	18
9/2/2006	337	38	22	95	21	5.1	17	12	18
9/3/2006	338	34	22	94	33	5.0	5	12	18
9/4/2006	339	34	24	71	32	3.7	0	12	18
9/5/2006	340	35	27	63	34	4.3	0	12	18
9/6/2006	341	36	24	71	28	3.0	0	12	18
9/7/2006	342	29	19	95	45	3.7	34	12	18
9/8/2006	343	33	19	96	38	3.5	0	12	18
9/9/2006	344	32	22	87	43	3.2	3	12	18
9/10/2006	345	34	21	92	21	0.5	0	12	18
9/11/2006	346	37	21	76	18	2.5	0	12	18
9/12/2006	347	34	23	64	22	6.3	0	12	18
9/13/2006	348	34	23	60	27	4.0	0	12	18
9/14/2006	349	35	24	63	19	5.0	0	12	18
9/15/2006	350	33	21	48	15	5.0	0	12	18
9/16/2006	351	32	19	51	23	1.3	0	12	18
9/17/2006	352	32	19	64	13	1.7	0	12	18
9/18/2006	353	33	17	56	8	1.5	0	12	18
9/19/2006	354	35	17	51	12	3.4	0	12	18
9/20/2006	355	33	21	63	20	5.0	0	12	18
9/21/2006	356	31	15	55	5	2.5	0	12	18
9/22/2006	357	32	18	57	20	5.0	0	12	18
9/23/2006	358	31	18	53	19	2.0	0	12	18
9/24/2006	359	35	22	36	13	2.5	0	12	18
9/25/2006	360	37	24	37	14	4.3	0	12	18
9/26/2006	361	38	23	44	13	3.8	0	12	18
9/27/2006	362	36	23	44	12	1.3	0	12	18
9/28/2006	363	38	21	31	5	1.9	0	12	18
9/29/2006	364	37	19	32	5	2.1	0	12	18
9/30/2006	365	38	17	26	4	2.8	0	12	18

WET YEAR (Water Year 2008)

Precipitation Data from Whitlow Station

Humidity, Wind Speed and Temperature from Magma Station

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
10/1/2007	1	32	25	57	34	3.9	0	12	18
10/2/2007	2	34	24	83	34	2.4	0	12	18
10/3/2007	3	36	22	68	28	0.7	0	12	18
10/4/2007	4	35	24	53	28	4.1	0	12	18
10/5/2007	5	33	21	52	13	6.4	0	12	18
10/6/2007	6	24	13	44	12	2.1	0	12	18
10/7/2007	7	27	10	27	9	3.1	0	12	18
10/8/2007	8	36	11	32	8	4.2	0	12	18
10/9/2007	9	36	18	28	13	2.2	0	12	18
10/10/2007	10	34	18	32	10	1.2	0	12	18
10/11/2007	11	34	16	27	11	1.9	0	12	18
10/12/2007	12	34	17	27	5	3.5	0	12	18
10/13/2007	13	26	14	42	23	2.3	0	12	18
10/14/2007	14	28	13	47	21	1.3	0	12	18
10/15/2007	15	31	13	45	14	1.7	0	12	18
10/16/2007	16	29	16	36	19	5.0	0	12	18
10/17/2007	17	27	14	57	21	3.5	0	12	18
10/18/2007	18	27	12	57	20	2.4	0	12	18
10/19/2007	19	33	13	49	12	2.7	0	12	18
10/20/2007	20	34	15	41	10	2.1	0	12	18
10/21/2007	21	27	14	40	5	5.0	0	12	18
10/22/2007	22	26	13	18	7	4.9	0	12	18
10/23/2007	23	31	14	17	6	3.8	0	12	18
10/24/2007	24	34	22	18	9	5.4	0	12	18
10/25/2007	25	34	19	21	7	3.6	0	12	18
10/26/2007	26	34	18	21	9	2.1	0	12	18
10/27/2007	27	33	17	25	10	2.3	0	12	18
10/28/2007	28	36	17	25	8	4.5	0	12	18
10/29/2007	29	34	23	21	6	4.9	0	12	18
10/30/2007	30	32	18	27	10	3.6	0	12	18
10/31/2007	31	29	13	39	14	0.4	0	12	18
11/1/2007	32	30	12	38	12	1.4	0	12	18
11/2/2007	33	29	12	36	11	0.9	0	12	18
11/3/2007	34	32	11	32	10	1.7	0	12	18
11/4/2007	35	34	17	30	9	3.5	0	12	18
11/5/2007	36	33	16	32	11	2.3	0	12	18
11/6/2007	37	34	16	28	9	3.9	0	12	18
11/7/2007	38	34	19	33	11	4.5	0	12	18
11/8/2007	39	32	18	35	13	1.5	0	12	18
11/9/2007	40	29	16	36	18	2.0	0	12	18
11/10/2007	41	28	12	47	20	0.6	0	12	18
11/11/2007	42	26	13	50	30	1.5	0	12	18
11/12/2007	43	26	11	57	25	1.6	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
11/13/2007	44	30	12	49	21	0.7	0	12	18
11/14/2007	45	29	11	52	18	1.6	0	12	18
11/15/2007	46	26	14	39	14	4.8	0	12	18
11/16/2007	47	27	16	38	14	3.6	0	12	18
11/17/2007	48	27	13	43	20	2.1	0	12	18
11/18/2007	49	29	12	46	19	0.3	0	12	18
11/19/2007	50	32	11	38	9	1.3	0	12	18
11/20/2007	51	30	15	30	11	2.9	0	12	18
11/21/2007	52	27	13	34	17	2.2	0	12	18
11/22/2007	53	26	13	46	21	1.6	0	12	18
11/23/2007	54	20	8	56	10	1.5	0	12	18
11/24/2007	55	21	6	38	13	4.8	0	12	18
11/25/2007	56	19	9	48	17	4.2	0	12	18
11/26/2007	57	20	7	34	16	1.4	0	12	18
11/27/2007	58	23	6	43	14	4.0	0	12	18
11/28/2007	59	24	9	44	16	1.1	0	12	18
11/29/2007	60	22	14	75	23	3.7	0	12	18
11/30/2007	61	21	16	100	68	3.0	34.036	12	18
12/1/2007	62	19	11	100	53	9.0	5.08	12	18
12/2/2007	63	18	7	96	37	1.8	0	12	18
12/3/2007	64	22	5	96	28	1.8	0	12	18
12/4/2007	65	23	9	79	26	1.4	0	12	18
12/5/2007	66	23	8	90	30	1.5	0	12	18
12/6/2007	67	24	11	74	27	0.8	0	12	18
12/7/2007	68	22	14	100	46	8.5	20.828	12	18
12/8/2007	69	14	9	100	61	4.4	21.082	12	18
12/9/2007	70	16	8	100	54	2.5	0	12	18
12/10/2007	71	13	8	100	75	3.4	9.906	12	18
12/11/2007	72	12	7	100	74	2.5	5.08	12	18
12/12/2007	73	14	3	100	57	1.3	0	12	18
12/13/2007	74	18	3	100	36	3.1	0	12	18
12/14/2007	75	13	4	100	48	2.2	0	12	18
12/15/2007	76	15	1	100	18	1.7	0	12	18
12/16/2007	77	18	3	57	14	2.3	0	12	18
12/17/2007	78	19	4	70	14	3.1	0	12	18
12/18/2007	79	21	4	77	16	2.7	0	12	18
12/19/2007	80	17	5	75	30	1.0	0	12	18
12/20/2007	81	19	3	84	27	2.5	0	12	18
12/21/2007	82	14	3	76	29	4.4	0	12	18
12/22/2007	83	13	-1	75	20	2.6	0	12	18
12/23/2007	84	15	-1	72	21	1.2	0	12	18
12/24/2007	85	19	2	78	20	2.2	0	12	18
12/25/2007	86	14	3	76	11	5.6	0	12	18
12/26/2007	87	14	-1	59	13	2.5	0	12	18
12/27/2007	88	11	0	61	21	3.4	0	12	18
12/28/2007	89	12	-1	56	18	0.6	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
12/29/2007	90	13	0	57	13	0.5	0	12	18
12/30/2007	91	16	0	71	24	0.7	0	12	18
12/31/2007	92	17	0	82	14	3.1	0	12	18
1/1/2008	93	21	9	16	8	5.6	0	12	18
1/2/2008	94	19	13	18	11	6.8	0	12	18
1/3/2008	95	22	13	57	13	4.5	0	12	18
1/4/2008	96	23	11	71	29	3.0	0	12	18
1/5/2008	97	21	13	100	27	3.5	0	12	18
1/6/2008	98	16	12	100	61	3.3	11.938	12	18
1/7/2008	99	14	9	100	80	6.1	13.97	12	18
1/8/2008	100	17	6	100	46	1.5	0	12	18
1/9/2008	101	17	6	100	55	0.7	0	12	18
1/10/2008	102	17	4	100	50	0.0	0	12	18
1/11/2008	103	18	4	100	40	0.2	0	12	18
1/12/2008	104	19	4	100	29	1.3	0	12	18
1/13/2008	105	18	5	85	22	3.5	0	12	18
1/14/2008	106	19	10	40	14	4.9	0	12	18
1/15/2008	107	18	6	67	19	2.5	0	12	18
1/16/2008	108	17	3	74	15	3.6	0	12	18
1/17/2008	109	14	3	48	12	4.5	0	12	18
1/18/2008	110	14	-1	72	13	1.8	0	12	18
1/19/2008	111	19	1	57	10	2.4	0	12	18
1/20/2008	112	19	3	48	10	4.9	0	12	18
1/21/2008	113	18	4	61	21	1.8	0	12	18
1/22/2008	114	18	5	64	22	1.7	0	12	18
1/23/2008	115	18	2	77	22	2.7	0	12	18
1/24/2008	116	16	9	82	43	1.5	0	12	18
1/25/2008	117	19	7	97	28	2.0	0	12	18
1/26/2008	118	22	4	80	24	3.0	0	12	18
1/27/2008	119	16	13	100	41	3.9	35.052	12	18
1/28/2008	120	17	10	100	48	6.1	4.064	12	18
1/29/2008	121	16	5	100	25	2.5	1.016	12	18
1/30/2008	122	13	4	99	40	4.8	0	12	18
1/31/2008	123	14	2	70	15	2.3	0	12	18
2/1/2008	124	17	2	84	21	1.6	0	12	18
2/2/2008	125	19	2	91	27	0.5	0	12	18
2/3/2008	126	17	6	76	42	5.6	0	12	18
2/4/2008	127	14	3	100	53	7.3	16.002	12	18
2/5/2008	128	12	1	100	45	1.7	0	12	18
2/6/2008	129	14	1	100	34	2.1	0	12	18
2/7/2008	130	16	3	96	34	1.4	0	12	18
2/8/2008	131	19	3	100	37	1.5	0	12	18
2/9/2008	132	23	4	100	29	1.6	0	12	18
2/10/2008	133	23	8	82	29	1.3	0	12	18
2/11/2008	134	23	9	81	28	1.0	0	12	18
2/12/2008	135	23	7	89	22	1.4	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
2/13/2008	136	22	7	82	26	4.0	0	12	18
2/14/2008	137	18	11	65	32	3.2	0	12	18
2/15/2008	138	11	7	100	65	2.9	12.954	12	18
2/16/2008	139	13	6	100	62	2.2	1.016	12	18
2/17/2008	140	18	4	100	41	0.5	0	12	18
2/18/2008	141	21	4	100	31	1.3	0	12	18
2/19/2008	142	22	8	95	30	1.6	0	12	18
2/20/2008	143	21	9	80	30	2.7	0	12	18
2/21/2008	144	17	6	100	38	3.3	0	12	18
2/22/2008	145	17	8	100	35	3.3	1.016	12	18
2/23/2008	146	19	8	95	34	0.9	0	12	18
2/24/2008	147	23	8	78	26	3.5	0	12	18
2/25/2008	148	21	8	87	38	0.9	0	12	18
2/26/2008	149	26	7	95	12	3.0	0	12	18
2/27/2008	150	27	10	54	11	3.7	0	12	18
2/28/2008	151	27	10	66	14	2.2	0	12	18
2/29/2008	152	28	8	70	17	0.8	0	12	18
3/1/2008	153	26	11	70	21	2.5	0	12	18
3/2/2008	154	21	9	59	11	4.4	0	12	18
3/3/2008	155	19	5	57	12	3.1	0	12	18
3/4/2008	156	21	3	65	12	2.8	0	12	18
3/5/2008	157	21	4	65	13	2.8	0	12	18
3/6/2008	158	18	3	46	11	3.1	0	12	18
3/7/2008	159	22	3	49	11	1.7	0	12	18
3/8/2008	160	21	5	55	11	2.2	0	12	18
3/9/2008	161	24	7	49	17	2.5	0	12	18
3/10/2008	162	27	6	63	10	2.2	0	12	18
3/11/2008	163	27	8	56	14	2.2	0	12	18
3/12/2008	164	27	9	57	14	2.2	0	12	18
3/13/2008	165	28	11	46	12	1.8	0	12	18
3/14/2008	166	27	11	39	7	4.9	0	12	18
3/15/2008	167	23	7	47	9	1.7	0	12	18
3/16/2008	168	14	7	74	29	4.1	0	12	18
3/17/2008	169	16	7	76	29	2.6	0	12	18
3/18/2008	170	22	3	76	16	2.1	0	12	18
3/19/2008	171	27	6	57	9	2.3	0	12	18
3/20/2008	172	28	8	43	8	1.8	0	12	18
3/21/2008	173	29	11	38	7	1.4	0	12	18
3/22/2008	174	28	8	43	8	2.4	0	12	18
3/23/2008	175	29	16	29	6	3.7	0	12	18
3/24/2008	176	31	16	33	10	3.8	0	12	18
3/25/2008	177	31	10	48	8	1.4	0	12	18
3/26/2008	178	30	12	31	7	2.3	0	12	18
3/27/2008	179	29	12	32	11	2.1	0	12	18
3/28/2008	180	30	14	36	10	2.6	0	12	18
3/29/2008	181	29	13	37	10	3.4	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
3/30/2008	182	27	13	42	18	5.2	0	12	18
3/31/2008	183	25	8	47	12	1.4	0	12	18
4/1/2008	184	28	7	45	9	2.3	0	12	18
4/2/2008	185	29	12	35	9	3.2	0	12	18
4/3/2008	186	25	10	40	16	3.1	0	12	18
4/4/2008	187	27	12	48	8	1.8	0	12	18
4/5/2008	188	28	11	31	9	3.7	0	12	18
4/6/2008	189	29	13	30	10	2.6	0	12	18
4/7/2008	190	27	13	29	12	2.6	0	12	18
4/8/2008	191	29	13	36	7	3.4	0	12	18
4/9/2008	192	21	13	42	19	4.1	0	12	18
4/10/2008	193	23	10	51	9	3.6	0	12	18
4/11/2008	194	26	7	31	9	2.2	0	12	18
4/12/2008	195	30	18	13	5	3.1	0	12	18
4/13/2008	196	34	16	16	4	4.5	0	12	18
4/14/2008	197	36	21	13	3	4.4	0	12	18
4/15/2008	198	33	17	14	4	4.0	0	12	18
4/16/2008	199	27	13	23	7	5.3	0	12	18
4/17/2008	200	23	8	26	8	3.6	0	12	18
4/18/2008	201	32	7	29	3	3.0	0	12	18
4/19/2008	202	31	12	26	5	3.2	0	12	18
4/20/2008	203	28	12	28	7	3.7	0	12	18
4/21/2008	204	29	10	36	5	1.5	0	12	18
4/22/2008	205	31	9	21	4	2.5	0	12	18
4/23/2008	206	31	13	27	8	3.7	0	12	18
4/24/2008	207	29	13	34	9	3.4	0	12	18
4/25/2008	208	30	12	30	5	2.7	0	12	18
4/26/2008	209	33	12	18	5	2.6	0	12	18
4/27/2008	210	33	21	7	2	5.0	0	12	18
4/28/2008	211	34	21	11	4	4.5	0	12	18
4/29/2008	212	37	16	15	4	3.0	0	12	18
4/30/2008	213	33	17	21	6	5.7	0	12	18
5/1/2008	214	27	14	33	9	3.7	0	12	18
5/2/2008	215	27	10	18	5	2.2	0	12	18
5/3/2008	216	32	12	17	5	2.6	0	12	18
5/4/2008	217	33	13	25	5	3.4	0	12	18
5/5/2008	218	33	16	30	8	4.2	0	12	18
5/6/2008	219	28	15	41	13	4.9	0	12	18
5/7/2008	220	31	14	54	14	1.8	0	12	18
5/8/2008	221	33	15	39	9	1.8	0	12	18
5/9/2008	222	34	18	19	2	5.0	0	12	18
5/10/2008	223	34	14	18	6	1.4	0	12	18
5/11/2008	224	36	17	19	4	3.1	0	12	18
5/12/2008	225	33	17	21	6	4.5	0	12	18
5/13/2008	226	24	14	57	22	4.1	2.032	12	18
5/14/2008	227	28	10	70	20	1.3	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
5/15/2008	228	32	16	42	12	4.6	0	12	18
5/16/2008	229	33	18	46	14	5.2	0	12	18
5/17/2008	230	36	21	38	12	2.6	0	12	18
5/18/2008	231	39	22	27	6	2.9	0	12	18
5/19/2008	232	40	23	17	8	2.6	0	12	18
5/20/2008	233	41	23	22	8	3.3	0	12	18
5/21/2008	234	33	22	36	9	7.5	0	12	18
5/22/2008	235	23	10	100	36	6.9	32.004	12	18
5/23/2008	236	19	11	100	39	4.5	8.89	12	18
5/24/2008	237	22	14	89	46	2.9	0	12	18
5/25/2008	238	27	12	100	26	2.7	0	12	18
5/26/2008	239	27	14	62	20	2.1	0	12	18
5/27/2008	240	32	14	70	12	2.6	0	12	18
5/28/2008	241	32	16	55	10	2.1	0	12	18
5/29/2008	242	34	16	43	9	2.2	0	12	18
5/30/2008	243	34	17	39	4	1.6	0	12	18
5/31/2008	244	37	19	23	4	1.5	0	12	18
6/1/2008	245	38	18	27	6	2.0	0	12	18
6/2/2008	246	37	21	25	7	4.1	0	12	18
6/3/2008	247	37	19	28	5	2.4	0	12	18
6/4/2008	248	36	19	30	5	7.1	0	12	18
6/5/2008	249	31	19	46	11	3.5	0	12	18
6/6/2008	250	36	18	25	6	2.2	0	12	18
6/7/2008	251	38	19	27	9	3.9	0	12	18
6/8/2008	252	37	20	35	11	1.9	0	12	18
6/9/2008	253	39	21	30	6	1.1	0	12	18
6/10/2008	254	41	22	25	6	2.9	0	12	18
6/11/2008	255	37	23	24	8	3.9	0	12	18
6/12/2008	256	37	21	29	7	1.8	0	12	18
6/13/2008	257	39	20	20	5	1.8	0	12	18
6/14/2008	258	41	21	24	5	2.0	0	12	18
6/15/2008	259	43	26	18	7	2.3	0	12	18
6/16/2008	260	42	26	27	11	3.2	0	12	18
6/17/2008	261	43	26	29	9	3.3	0	12	18
6/18/2008	262	42	26	30	4	4.7	0	12	18
6/19/2008	263	43	24	12	3	2.4	0	12	18
6/20/2008	264	44	24	12	3	1.9	0	12	18
6/21/2008	265	44	26	21	4	4.3	0	12	18
6/22/2008	266	43	30	25	9	5.0	0	12	18
6/23/2008	267	42	28	20	8	2.9	0	12	18
6/24/2008	268	43	26	18	7	2.5	0	12	18
6/25/2008	269	41	26	37	11	4.9	0	12	18
6/26/2008	270	40	26	45	18	5.1	0	12	18
6/27/2008	271	41	25	46	14	3.3	0	12	18
6/28/2008	272	41	27	32	9	3.5	0	12	18
6/29/2008	273	42	28	27	10	4.2	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
6/30/2008	274	42	31	29	14	4.0	0	12	18
7/1/2008	275	43	31	28	12	4.5	0	12	18
7/2/2008	276	42	28	39	13	2.8	0	12	18
7/3/2008	277	42	31	41	11	3.4	0	12	18
7/4/2008	278	40	27	46	22	3.0	1.016	12	18
7/5/2008	279	38	28	51	23	3.4	0	12	18
7/6/2008	280	41	28	48	20	4.6	0	12	18
7/7/2008	281	39	25	70	21	4.5	0	12	18
7/8/2008	282	41	29	48	18	6.0	0	12	18
7/9/2008	283	38	27	56	25	5.0	0	12	18
7/10/2008	284	36	23	100	31	5.0	65.024	12	18
7/11/2008	285	33	22	100	45	3.7	8.89	12	18
7/12/2008	286	36	24	100	34	4.6	0	12	18
7/13/2008	287	34	26	91	38	3.0	6.096	12	18
7/14/2008	288	35	26	100	41	3.4	0	12	18
7/15/2008	289	38	26	84	25	2.2	0	12	18
7/17/2008	290	41	28	60	17	1.3	0	12	18
7/18/2008	291	41	28	57	18	2.6	0	12	18
7/19/2008	292	38	25	84	29	5.3	0	12	18
7/20/2008	293	36	24	99	32	4.0	0	12	18
7/21/2008	294	39	27	70	29	2.3	0	12	18
7/22/2008	295	41	29	60	23	3.8	0	12	18
7/23/2008	296	40	29	55	18	3.9	0	12	18
7/24/2008	297	42	29	64	18	2.7	0	12	18
7/25/2008	298	40	26	68	25	3.7	0	12	18
7/26/2008	299	39	27	68	30	2.8	0	12	18
7/27/2008	300	38	28	52	22	2.8	0	12	18
7/28/2008	301	39	26	52	15	2.2	0	12	18
7/29/2008	302	40	23	39	11	1.7	0	12	18
7/30/2008	303	41	24	42	12	2.6	0	12	18
7/31/2008	304	42	26	37	11	3.7	0	12	18
8/1/2008	305	44	31	32	11	3.5	0	12	18
8/2/2008	306	41	30	43	17	3.2	0	12	18
8/3/2008	307	38	28	61	25	4.6	0	12	18
8/4/2008	308	37	27	68	29	2.8	0	12	18
8/5/2008	309	40	25	82	21	5.4	10.922	12	18
8/6/2008	310	41	24	90	19	2.6	0	12	18
8/7/2008	311	42	26	81	20	4.2	0	12	18
8/8/2008	312	36	24	82	30	3.2	0	12	18
8/9/2008	313	37	27	61	27	4.1	0	12	18
8/10/2008	314	38	27	62	25	3.2	0	12	18
8/11/2008	315	39	27	57	17	2.6	0	12	18
8/12/2008	316	39	27	46	17	2.5	0	12	18
8/13/2008	317	39	29	54	26	5.1	0	12	18
8/14/2008	318	37	23	100	27	3.9	7.112	12	18
8/15/2008	319	38	27	66	30	3.2	0	12	18

		Temperature (°C)		Relative Humidity (%)		Wind Speed	Precipitation	Precipitation Period	
Date	Day #	Max	Min	Max	Min	(m/s)	(mm)	Start	End (hr)
8/16/2008	320	38	25	70	25	5.6	0	12	18
8/17/2008	321	37	24	67	29	3.9	0	12	18
8/18/2008	322	38	26	57	25	2.5	0	12	18
8/19/2008	323	39	26	61	19	1.9	0	12	18
8/20/2008	324	39	26	45	16	2.2	0	12	18
8/21/2008	325	41	26	43	14	2.0	0	12	18
8/22/2008	326	39	26	45	18	1.5	0	12	18
8/23/2008	327	39	26	46	18	5.2	0	12	18
8/24/2008	328	42	28	55	13	4.2	0	12	18
8/25/2008	329	37	23	100	29	4.6	14.986	12	18
8/26/2008	330	33	23	100	41	2.7	12.954	12	18
8/27/2008	331	34	22	100	41	3.2	4.064	12	18
8/28/2008	332	37	23	100	38	2.6	6.858	12	18
8/29/2008	333	38	23	100	24	3.3	0	12	18
8/30/2008	334	37	22	83	31	5.8	0	12	18
8/31/2008	335	33	22	100	41	4.3	1.016	12	18
9/1/2008	336	35	23	82	36	1.6	0	12	18
9/2/2008	337	38	23	84	20	2.3	0	12	18
9/3/2008	338	38	27	48	20	3.2	0	12	18
9/4/2008	339	39	26	56	12	2.7	0	12	18
9/5/2008	340	40	22	48	9	2.2	0	12	18
9/6/2008	341	41	22	46	8	2.0	0	12	18
9/7/2008	342	40	25	34	11	3.4	0	12	18
9/8/2008	343	38	27	41	17	4.5	0	12	18
9/9/2008	344	37	24	48	18	2.5	3.048	12	18
9/10/2008	345	37	23	79	26	3.1	9.144	12	18
9/11/2008	346	34	20	93	28	4.9	1.016	12	18
9/12/2008	347	33	20	77	25	3.3	0	12	18
9/13/2008	348	34	21	60	14	2.7	0	12	18
9/14/2008	349	39	21	45	9	2.0	0	12	18
9/15/2008	350	36	26	38	17	5.7	0	12	18
9/16/2008	351	34	25	52	20	6.3	0	12	18
9/17/2008	352	36	22	63	19	2.5	0	12	18
9/18/2008	353	37	22	46	15	2.3	0	12	18
9/19/2008	354	38	21	45	15	2.2	0	12	18
9/20/2008	355	38	24	41	17	2.2	0	12	18
9/21/2008	356	37	24	49	16	3.2	0	12	18
9/22/2008	357	37	23	41	15	2.3	0	12	18
9/23/2008	358	37	23	43	15	2.3	0	12	18
9/24/2008	359	39	23	37	11	4.0	0	12	18
9/25/2008	360	38	26	33	10	5.0	0	12	18
9/26/2008	361	37	26	49	20	4.1	0	12	18
9/27/2008	362	38	24	50	15	3.3	3.81	12	18
9/28/2008	363	37	22	42	9	4.5	0	12	18
9/29/2008	364	37	24	24	9	5.9	0	12	18
9/30/2008	365	37	28	23	13	5.3	0	12	18

ATTACHMENT III

Closure Cover Modeling Results

CLEANER TAILINGS

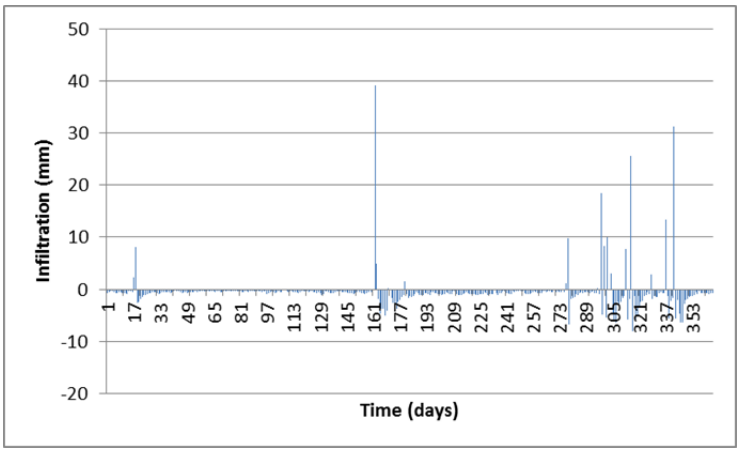


Figure II-1 Infiltration from Average Climate Year (negative infiltration indicates upwards movement of water)

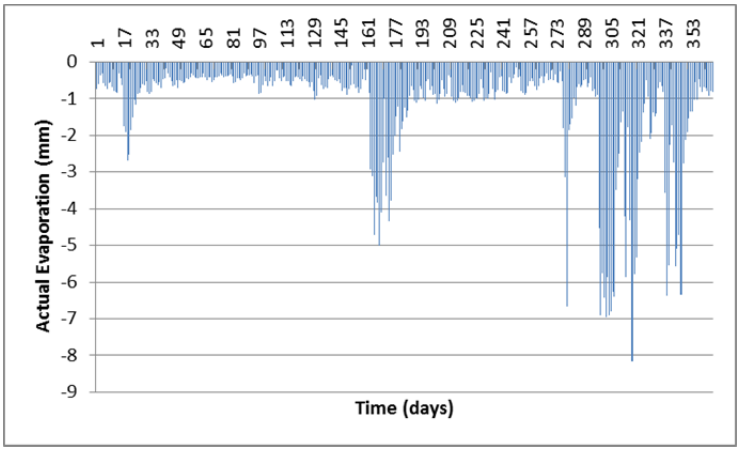


Figure II-2 Actual Evaporation from Average Climate Year

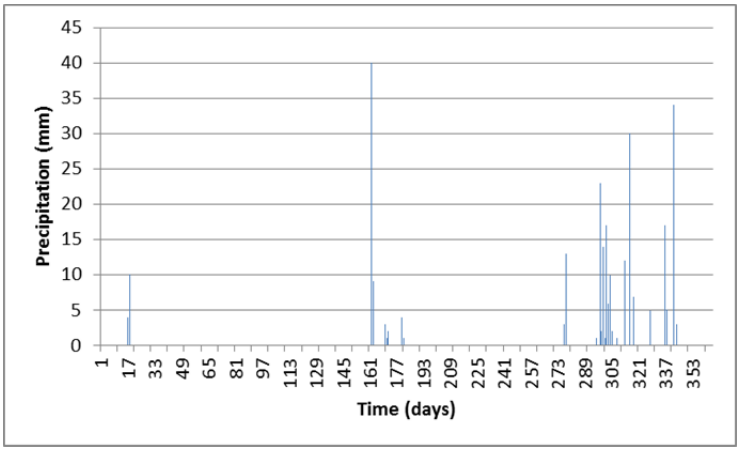


Figure II-3 Precipitation from Average Climate Year

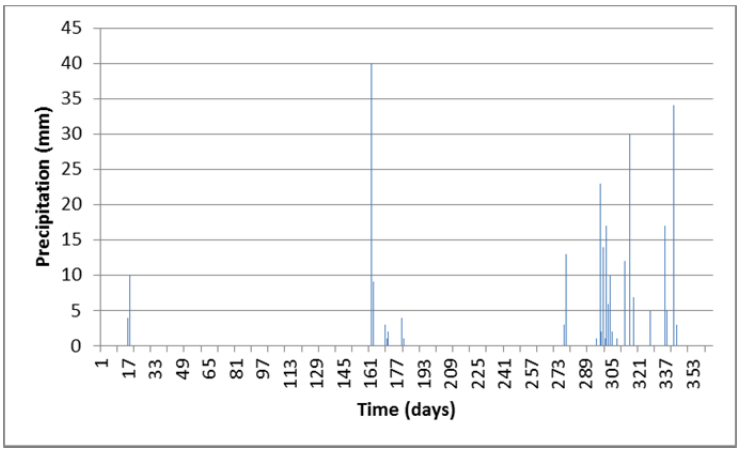


Figure II-4 Infiltration from Wet Climate Year

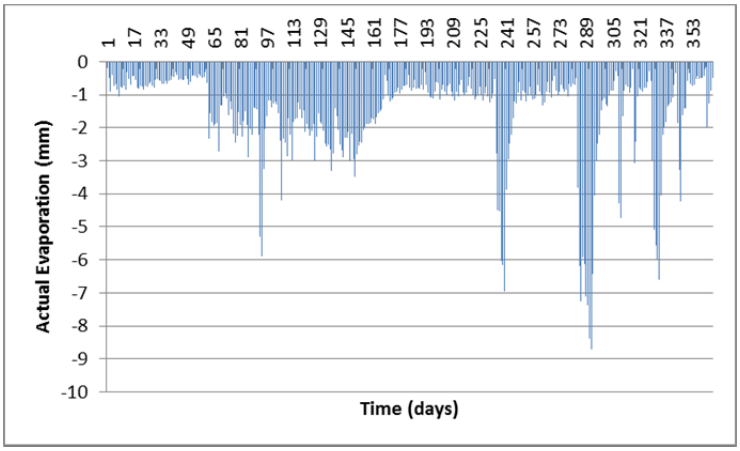


Figure II-5 Actual Evaporation from Wet Climate Year

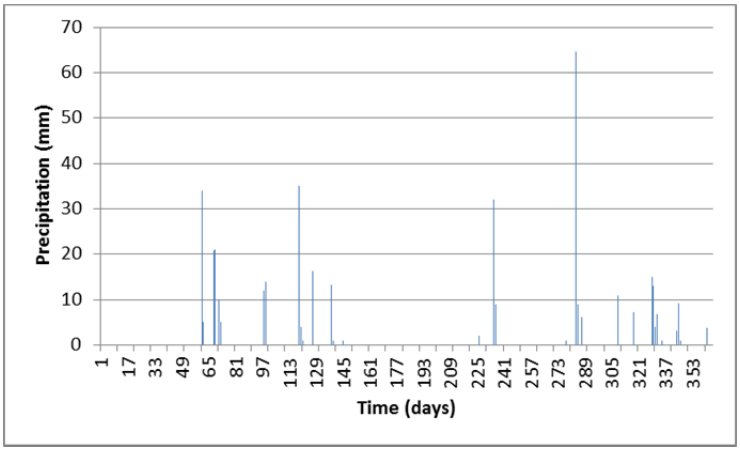


Figure II-6 Precipitation from Wet Climate Year

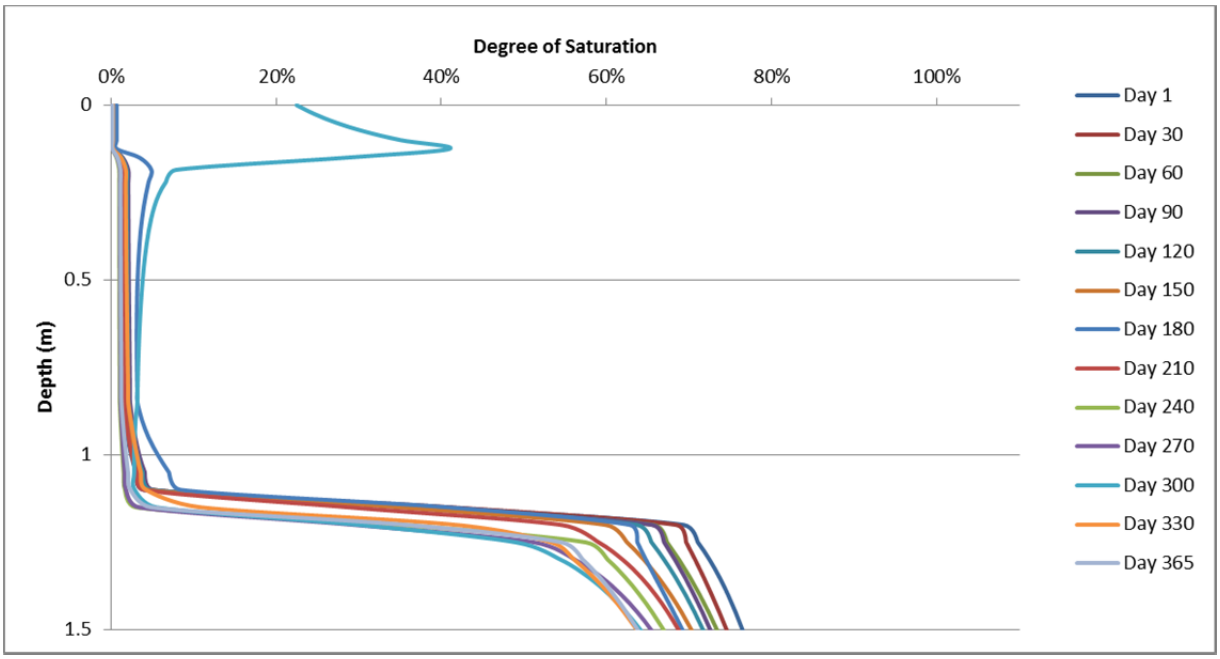


Figure II-7 Degree of Saturation to 35 m Depth – Average Climate Year

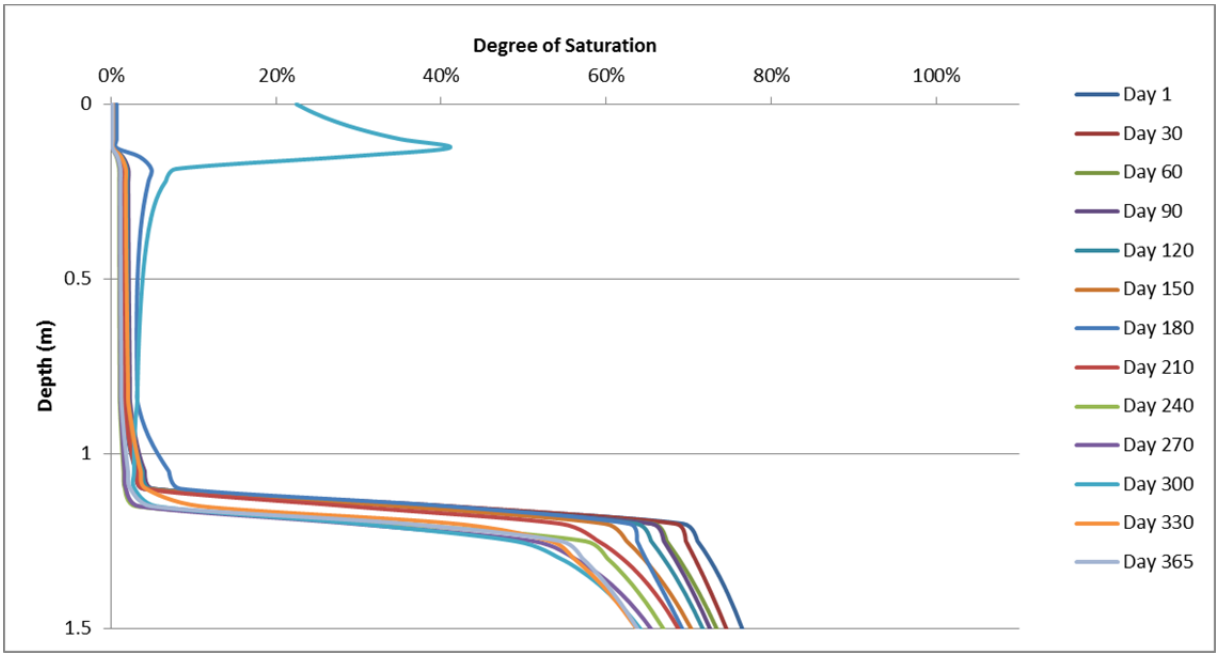


Figure II-8 Degree of Saturation to 1.5 m Depth – Average Climate Year

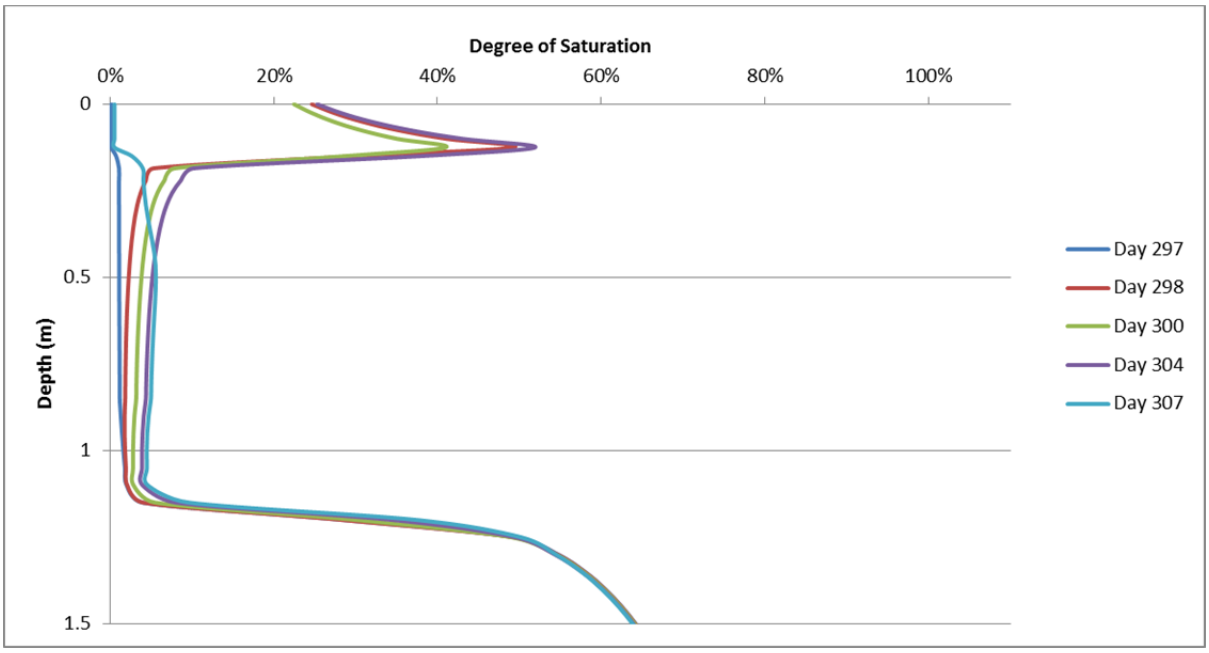


Figure II-9 Degree of Saturation around Precipitation Event – Average Climate Year

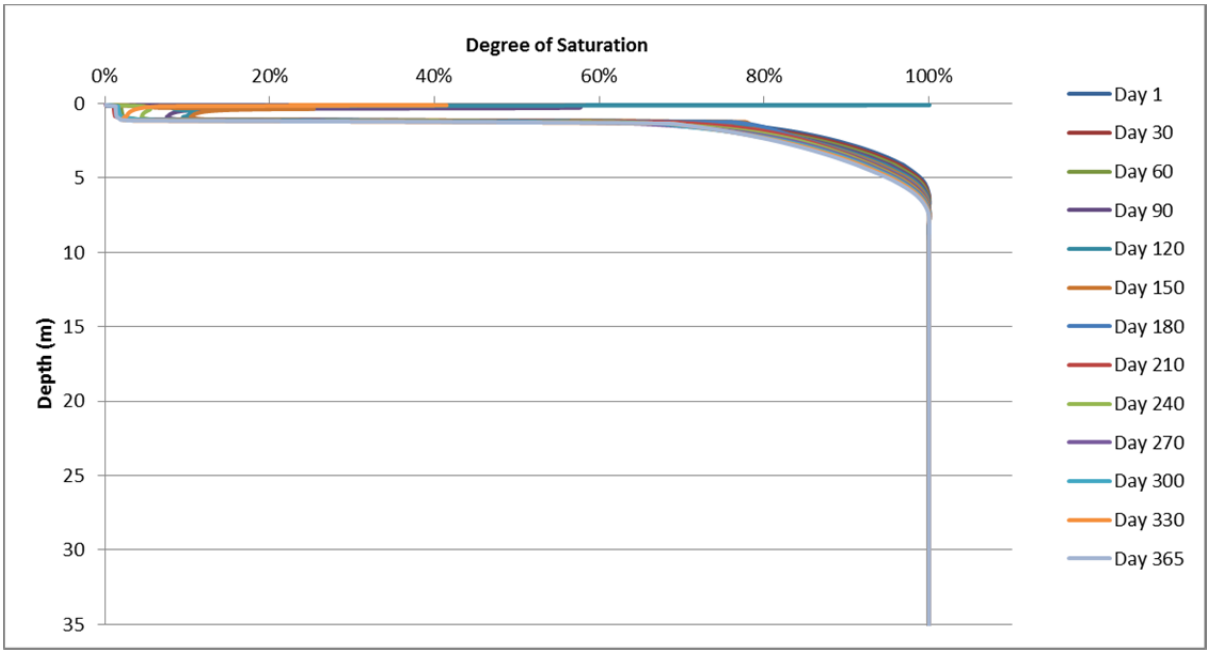


Figure II-10 Degree of Saturation at 35 m Depth – Wet Climate Year

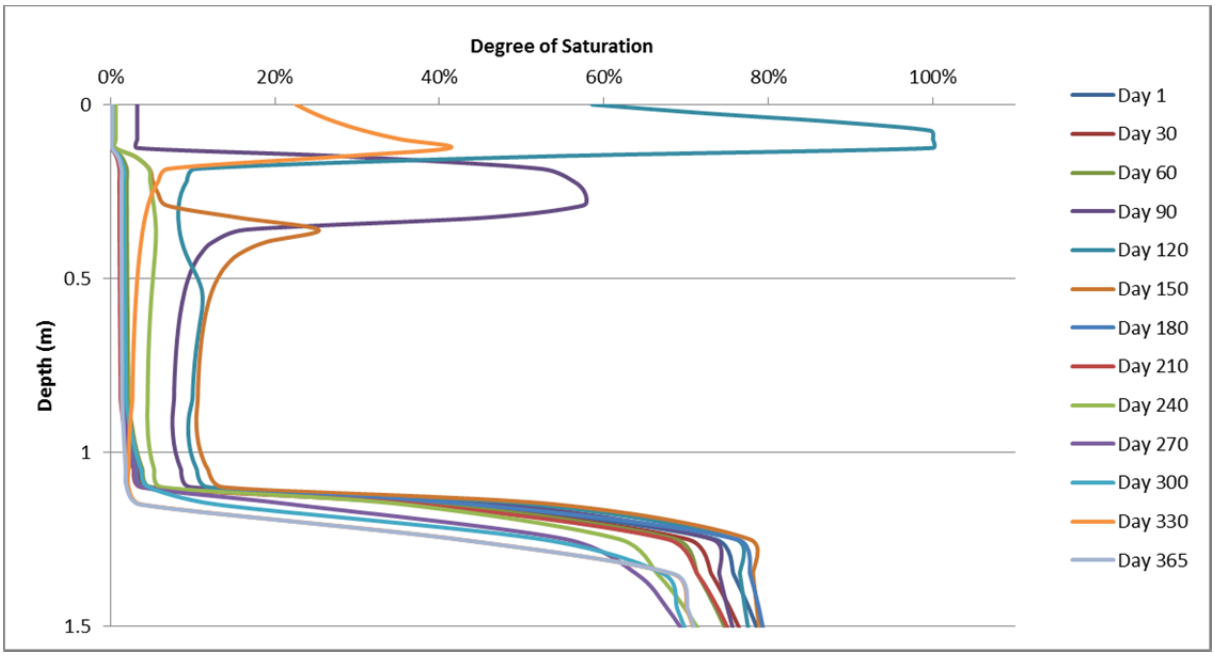


Figure II-11 Degree of Saturation at 35 m Depth – Wet Climate Year

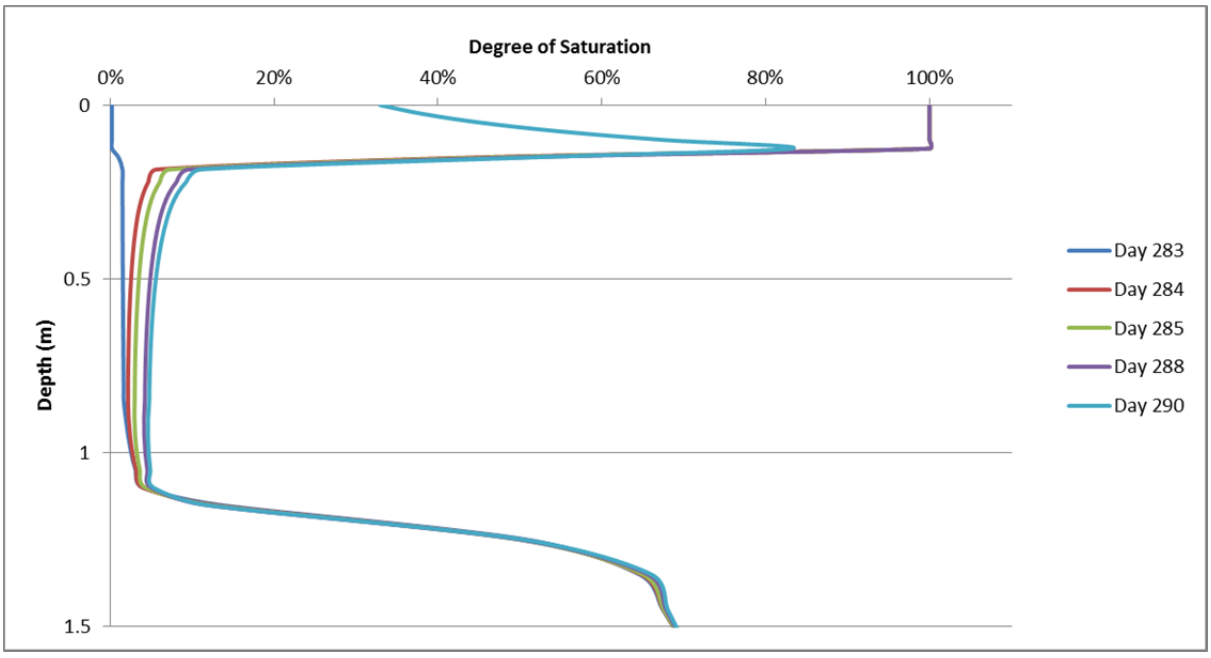


Figure II-12 Degree of Saturation around Precipitation Event – Wet Climate Year

SCAVENEGER TAILINGS

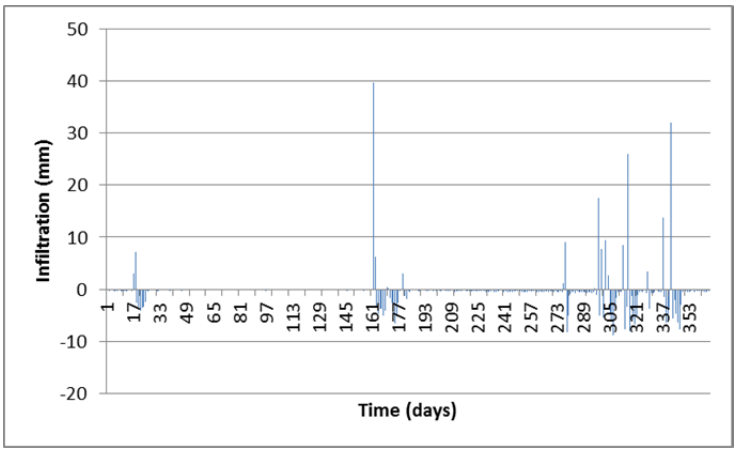


Figure II-13 Infiltration from Average Climate Year

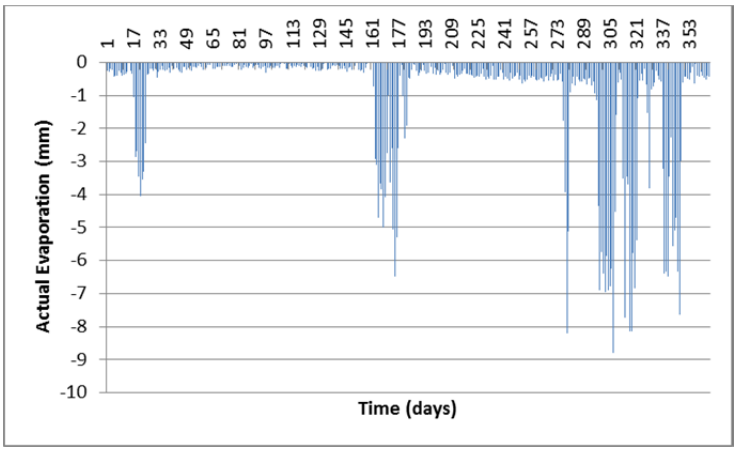


Figure II-14 Actual Evaporation from Average Climate Year

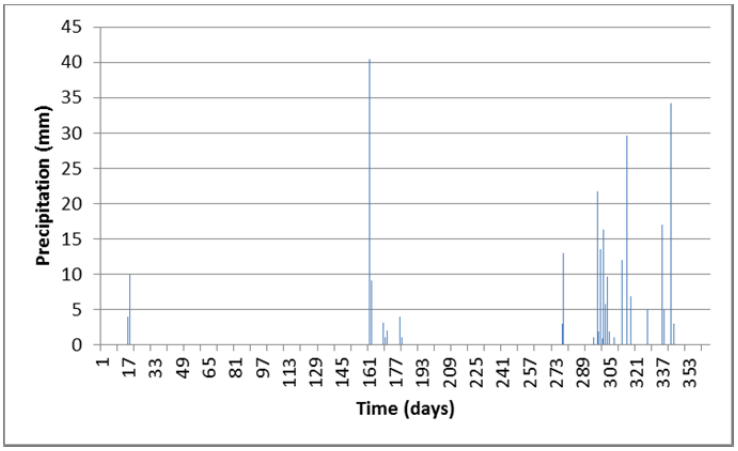


Figure II-15 Precipitation from Average Climate Year

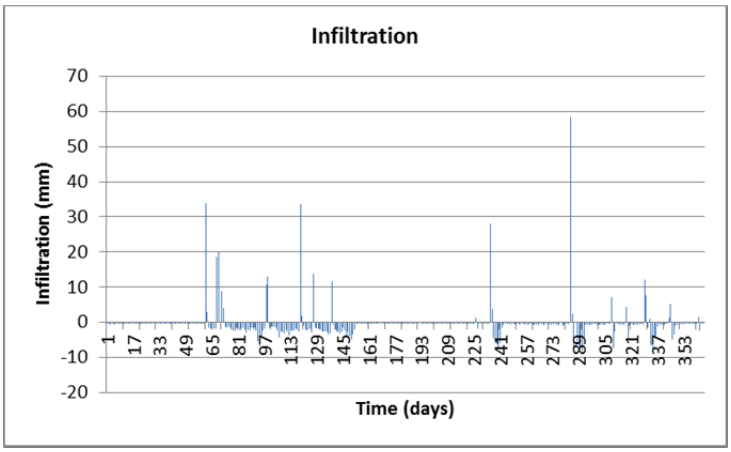


Figure II-16 Infiltration from Wet Climate Year

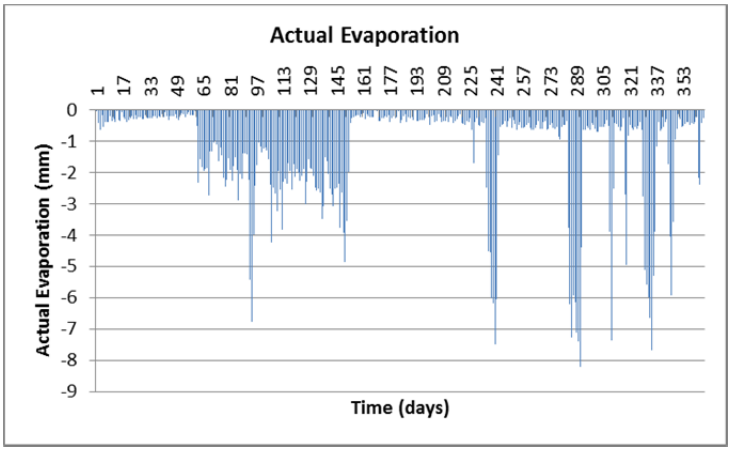


Figure II-17 Actual Evaporation from Wet Climate Year

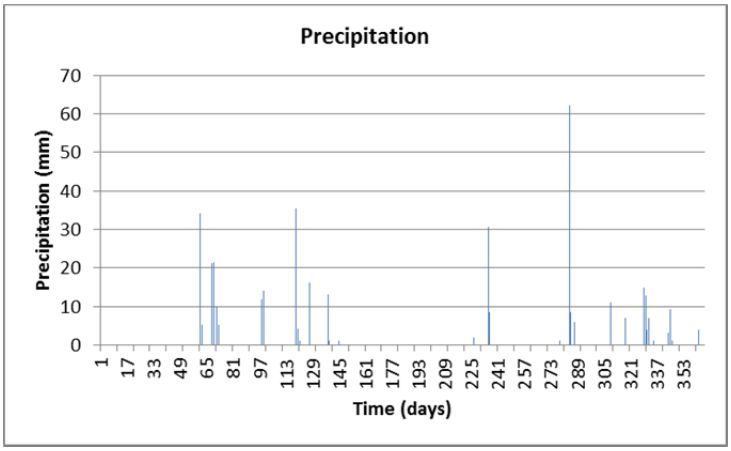


Figure II-18 Precipitation from Wet Climate Year

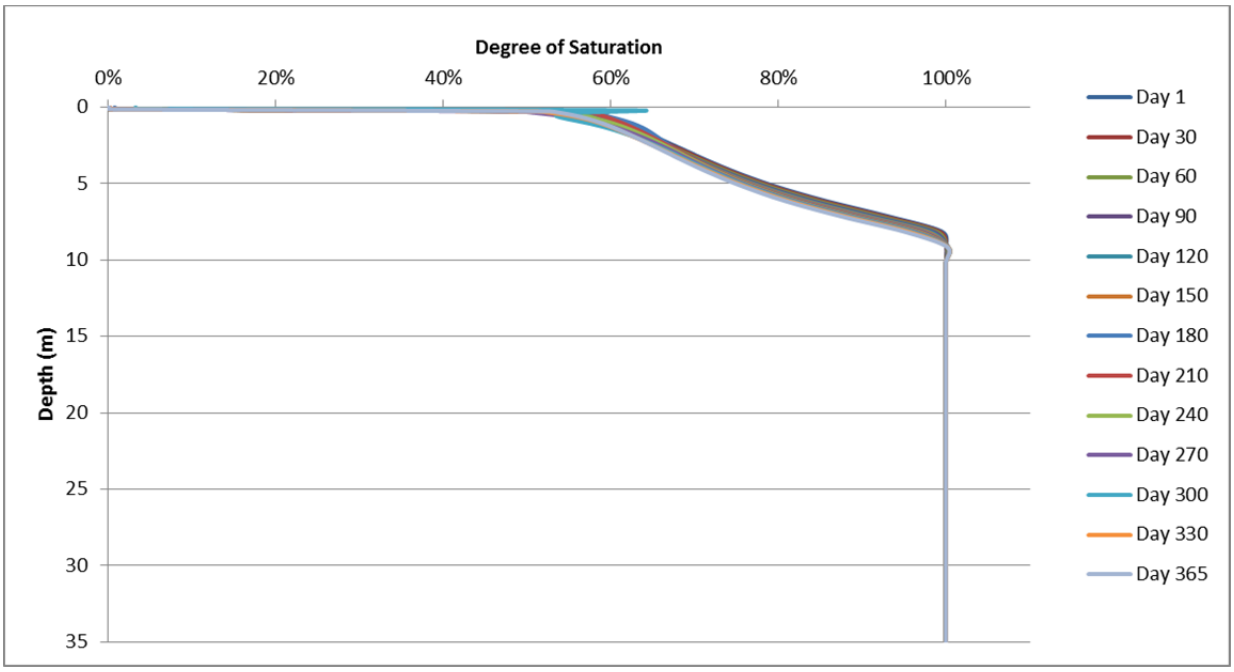


Figure II-19 Degree of Saturation to 35 m Depth – Average Climate Year

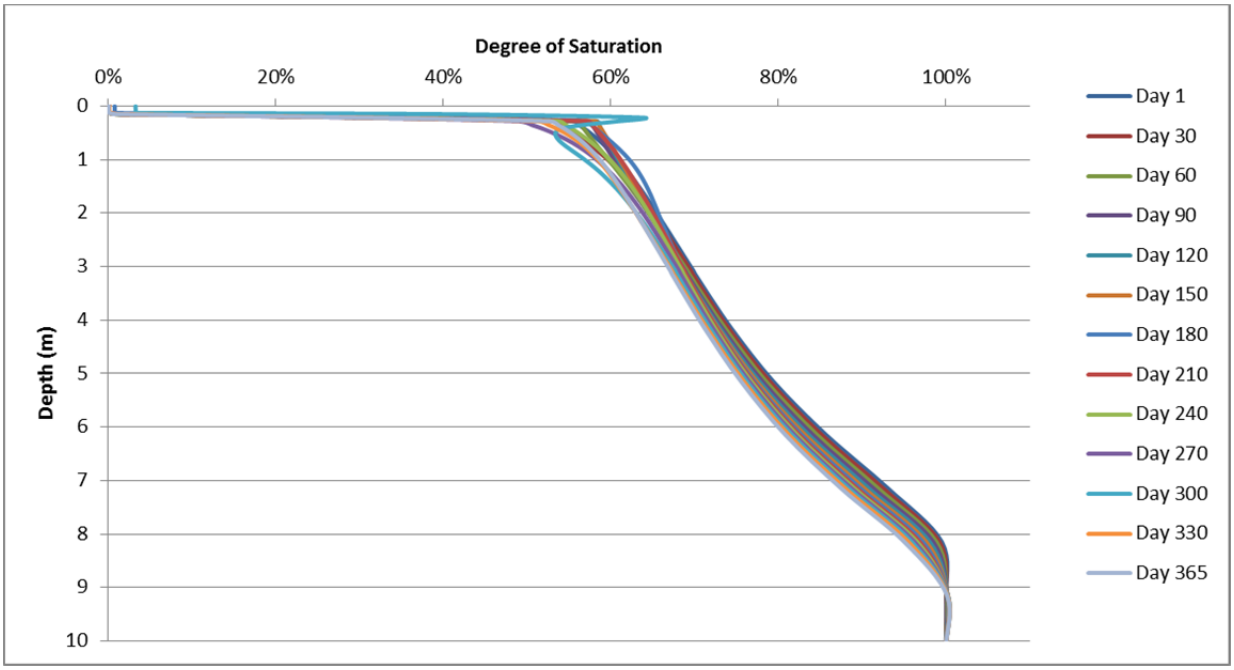


Figure II-20 Degree of Saturation to 10 m Depth – Average Climate Year

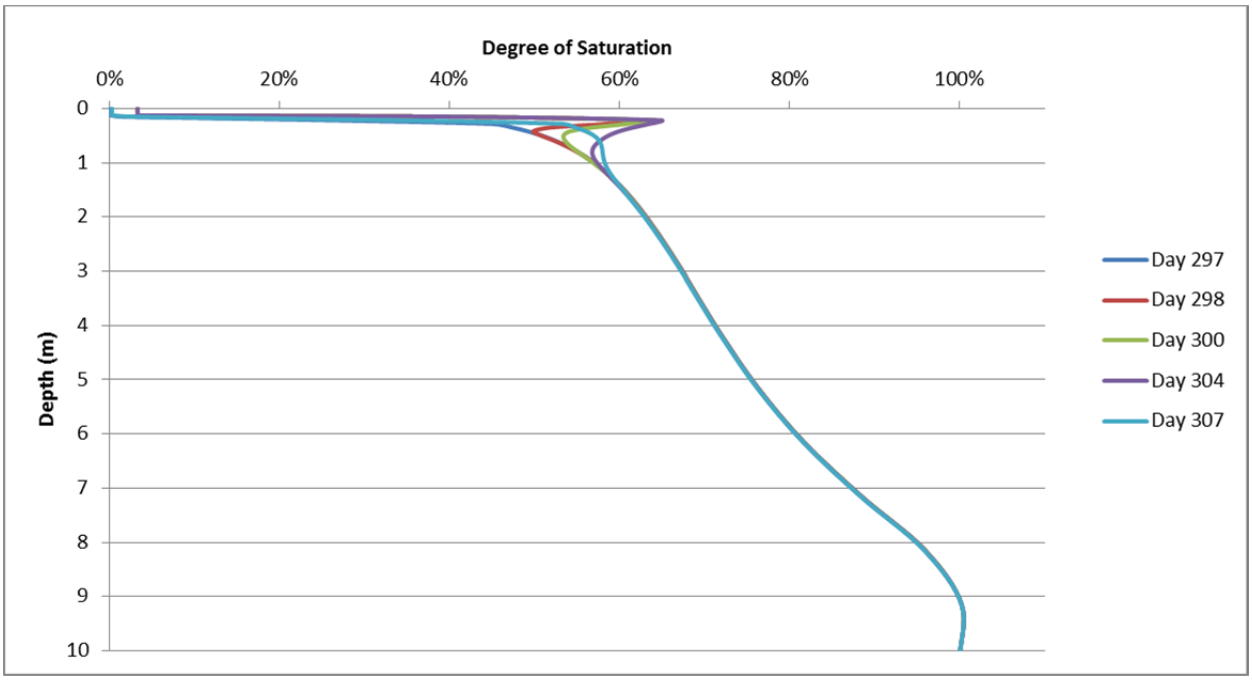


Figure II-21 Degree of Saturation around Precipitation Event – Average Climate Year

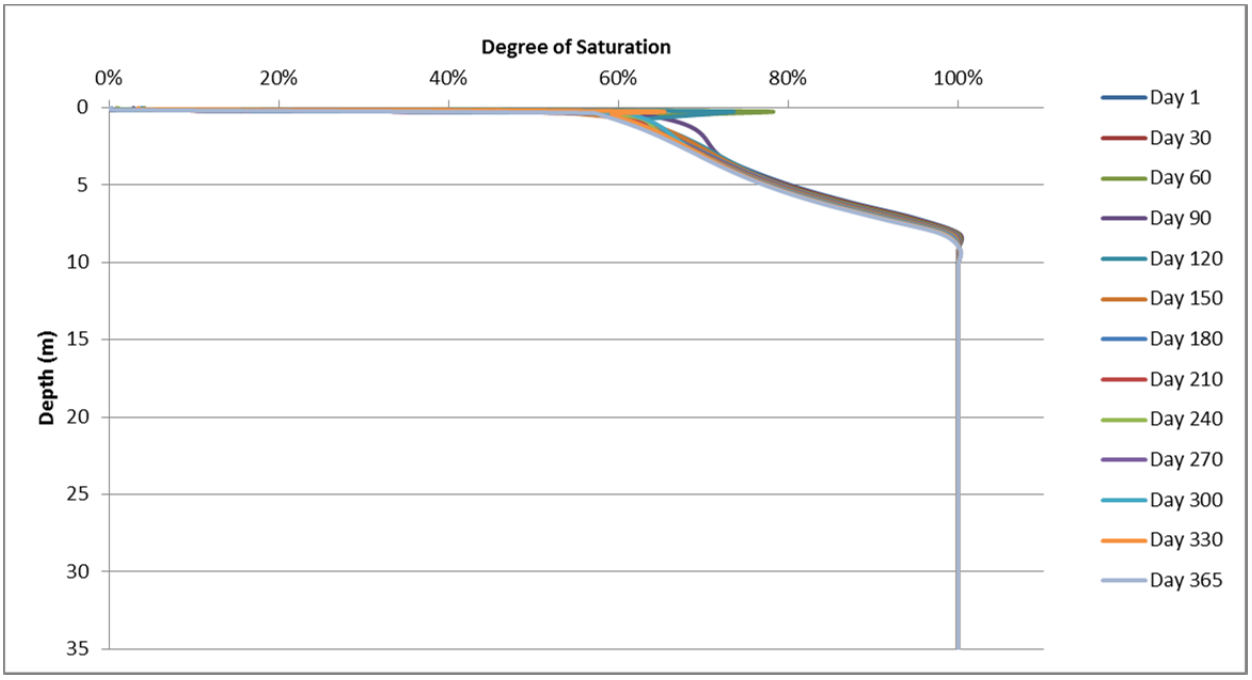


Figure II-22 Degree of Saturation at 35 m Depth – Wet Climate Year

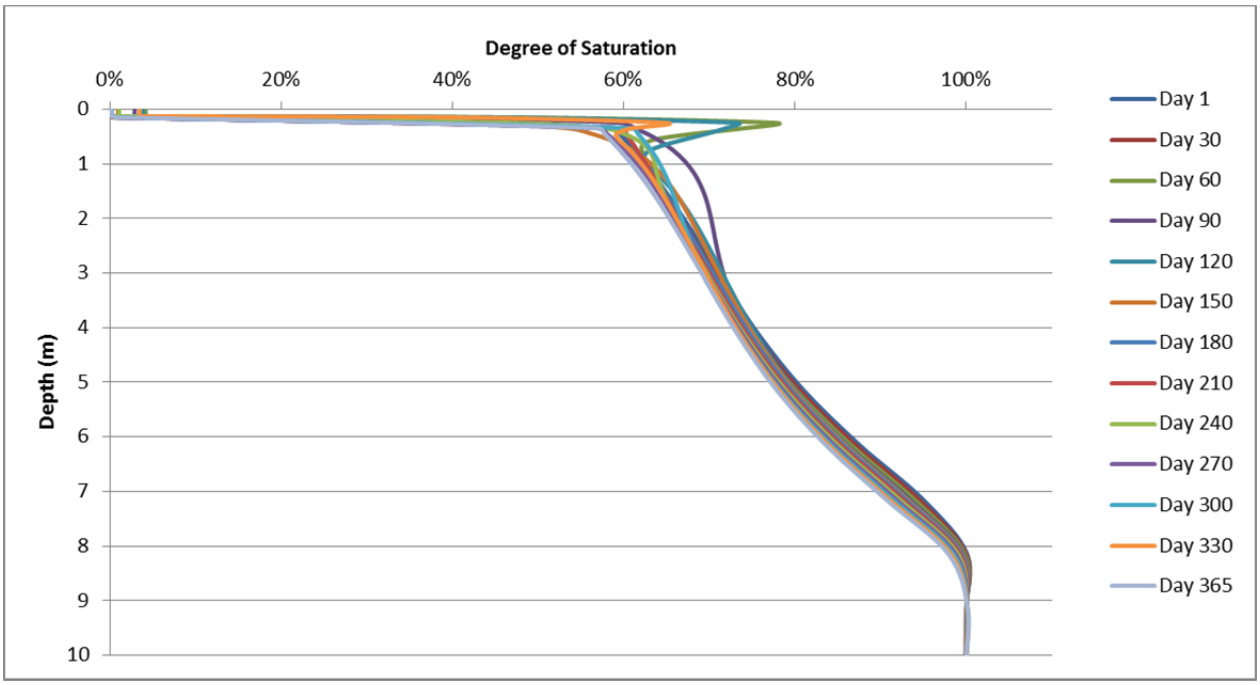


Figure II-23 Degree of Saturation to 10 m Depth – Wet Climate Year

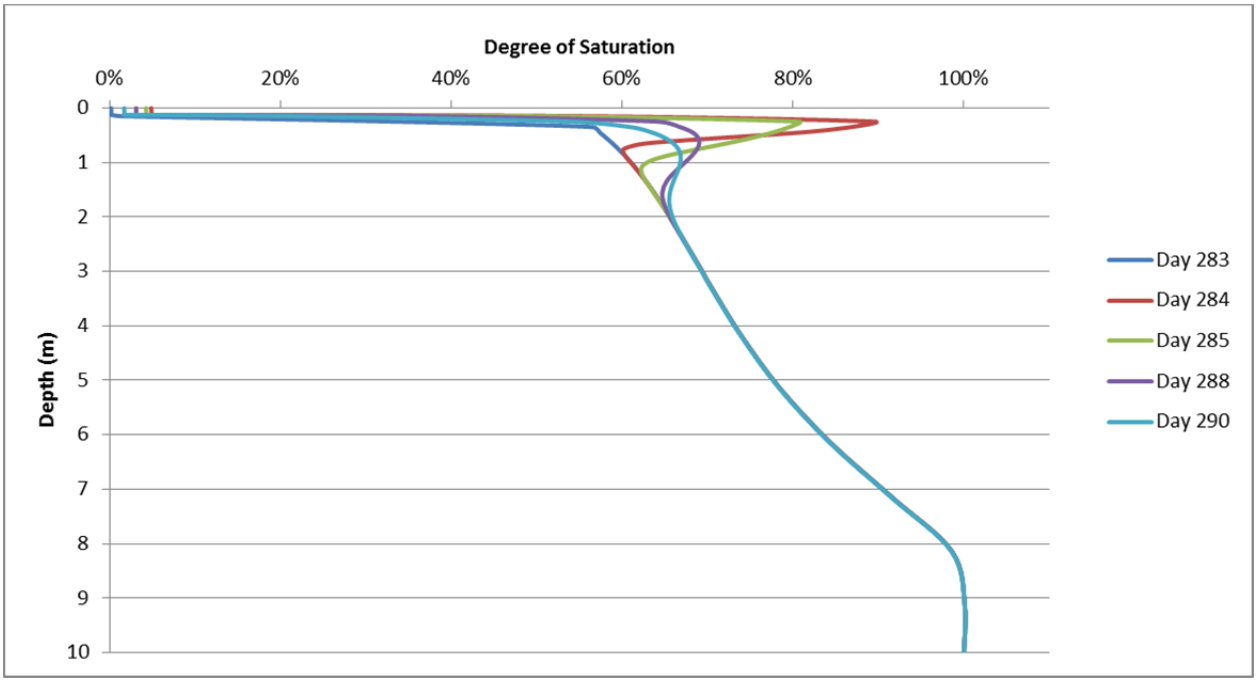


Figure II-24 Degree of Saturation around Precipitation Event – Wet Climate Year