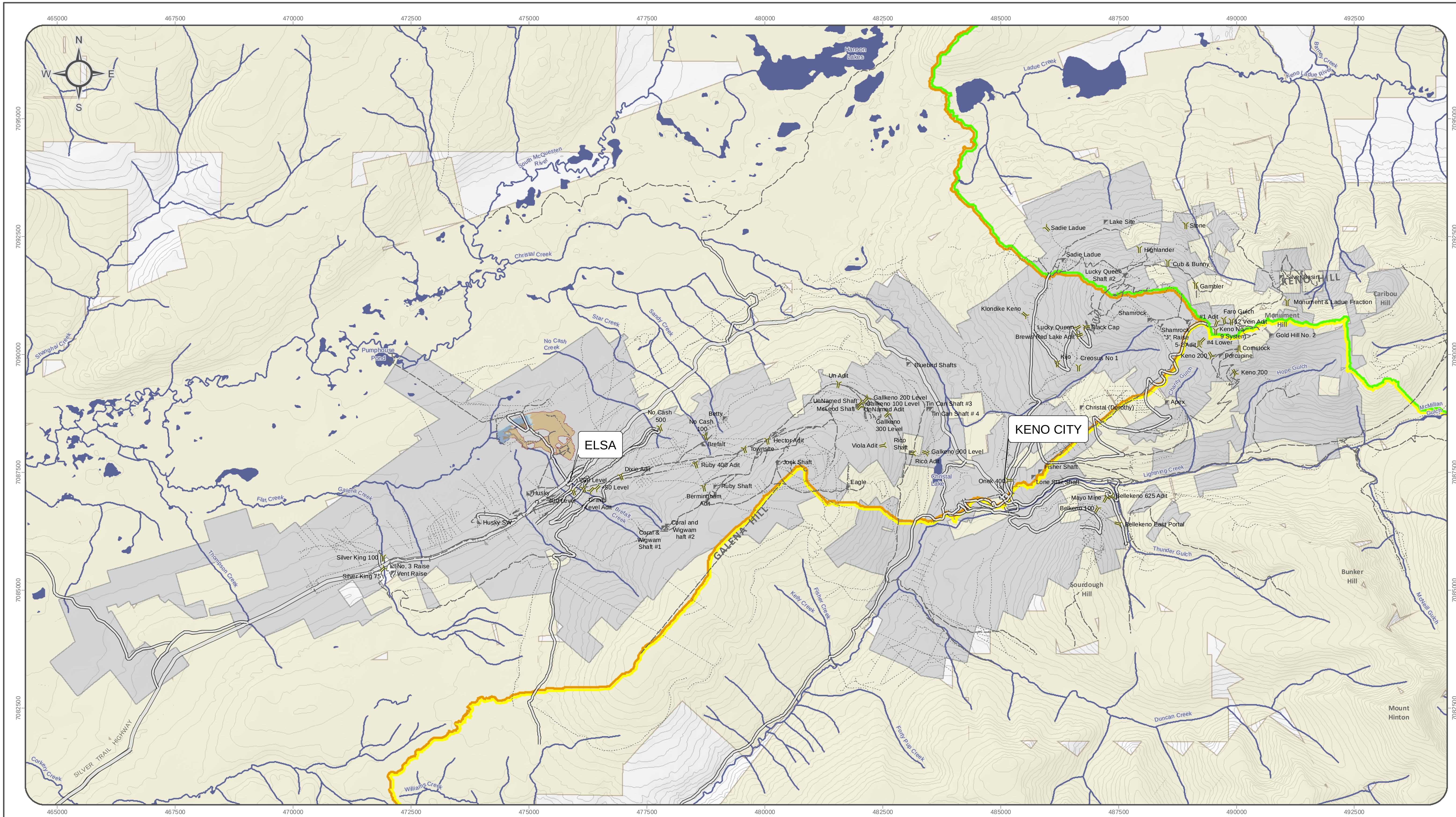
EXISTING STATE OF MINE RECLAMATION PLANNING TECHNICAL STUDIES – KENO HILL, YUKON

TECHNICAL FACT SUMMARY SHEETS

As part of the reclamation and closure of the Keno Hills Silver District (for location see Figure 1), a comprehensive closure plan for the existing state of the mine (ESM Reclamation Plan) will be developed and undergo environmental assessment and licensing processes. In order to support the selection of reclamation options for sites, and allow for environmental assessment and water, significant technical backup and studies are required to support the assumptions and strategies developed for the ultimate reclamation and closure option selected.

This compilation provides a brief summary of the main points of highlighted technical studies completed to-date and serves to inform interested parties and the public at large of the main technical points that will assist in selecting appropriate closure options and eventually, final options for the ESM Reclamation Plan.



Canvec compiled by Natural Resources Canada at a scale of 1:10,000 - 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced underlicense from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved. Watersheds derived from Canvec data using ESRI Spatial Analyst and National Hydrology Network.

Quartz claim boundaires and ownership are current as of Mar 26th 2012. Data obtained from Yukon Mining Recorder. Data source: http://geomaticsyukon.ca.

Datum: NAD 83; Map Projection: UTM Zone 8N

1:75,000 (when printed on 11 x17 inch paper)

Kilometers
0 0.5 1 2 3 4 5

Adit
Shaft
Contours (100 ft)
Watercourse

Waterbody
Valley Tailings Ponds
Valley Tailings
Other Quartz Claims
ERDC Owned Quartz Clains

Catchments
Keno Ladue River
Mayo River
South McQuesten River

ERDC
ACCESS

ELSA RECLAMATION AND DEVELOPMENT COMPANY

CLOSURE OPTIONS REPORT

FIGURE 1
PROPERTY OVERVIEW

FEBRUARY 2013

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UNITED KENO HILL MINE

TECHNICAL FACT SUMMARY SHEETS

CONTENTS

UNITED KENO HILL MINE

TECHNICAL FACT SUMMARY SHEETS

LIST OF FIGURES

WATER QUALITY AND RECEIVING ENVIRONMENT CONDITIONS STUDIES

Objectives have been identified by ERDC and INAC in coordination with FNNND and GY that will drive the closure planning process. Among these are a number of objectives for the preservation or remediation of the water quality standard in the South McQuesten River and its tributaries. Water degradation as a result of historical mining and the ongoing impacts produced by historical mine workings have led to significant attention being paid to this area of closure.

This section details studies that have been completed with respect to water quality and conditions in the receiving environment at the Keno Hill Property and the aquatic environment.

1. WATER QUALITY DATA REVIEW

Date:

July 2008 – present

Performed By:

ACG/Minnow Environmental

Objective:

Comprehensively review the water quality database and add any additional information from others; and using this as source data,

Maintain the site-wide database and loading balance

Facts/Description of Study:

- Past sampling programs at Keno Hill have provided a depth of information sufficient for assessing water quality impacts and trends
- The Keno Hill water quality database was updated to include all available known water quality results, and all historic stations were renamed under a common set of KV numbers. A table of concordance exists for all stations
- Water quality data was vetted to ensure the inclusion of only the most reliable, trustworthy results for future analysis, including mass balance updating. This was based on data filters applied by Minnow Environmental
- The database was migrated to a newer, more efficient system for streamlined data input/output
- The database continues to be updated on a regular basis, as new results are obtained
- The data contained in the current, vetted database is the source for inputs to the site-wide loading balance

Information Gaps:

Flow and groundwater monitoring data, although not presently a part of the dataset, is a necessary addition to supplement the overall site loading balance inputs

Results/Conclusions:

- The current Keno Hill Mines water quality database is now an excellent data repository containing reliable data back to 1994 and will serve to provide good input data for models in the future.

Deliverables:

Water Quality Assessment Report for United Keno Hill Mines (Minnow 2008)

2. Hydrological Update and Assessment

Date:

2007

Performed By:

Clearwater Consultants

Objective:

To refine the understanding of the UKHM hydrology that was originally developed in 1996 and to provide guidance on developing hydrological inputs to the site-wide water balance.

Facts/Description of Study:

- The following three steps were outlined to achieve the aforementioned objective:

    a. Process historical records of water level, direct discharge measurements and survey data collected at the mine's three streamflow gauging stations (KV-7, KV-9 and KV-41)

    b. Use streamflow records developed in (step a) to assess accuracy of flow-estimation techniques documented in the 1996 climate and hydrology study; and,

    c. Outline a proposed method for estimating flows around the Keno Hill property based on the original hydrology study and the streamflow records for the three mine site gauging stations

- Processing of the gauging station data (Step a) was used to produce a mean annual runoff (MAR) for each of the sites which could in turn be used to validate the method developed in the 1996 Hydrological Study (step b)
- The 1996 Hydrology Study developed an empirical relationship between MAR and catchment mean elevation

Information Gaps:

2006 freshet data for Station KV-9 could not be located by the time the memorandum from CCL was issued. The mean annual runoff for KV-9 was thus estimated through a correlation analysis with regional Water Survey of Canada stations.

Water level data collected at mine adits was not processed as the data appears to be of dubious quality

Results/Conclusions:

- It was found that the streamflow data collected at the three gauging stations offers an excellent basis for validating the adopted relationship between MAR and catchment median elevation; moreover,
- The hydrological inputs for the new water balance could be estimated using the original techniques presented in the 1996 Hydrology Study; however,

- The availability of the streamflow record at KV-7, KV-9 and KV-41 may offer a more accurate method of assessing chemical loads
- The most complete and accurate data available are for Water Years 2005 and 2006 (i.e. the period from October 1, 2004 to September 31, 2006) and should be used for the next set of water and load balances
- The conditions on the McQuesten River would be expected to best represent seasonal flow conditions at Christal Cr, while those on the North Klondike River provide a reasonable estimation of the seasonal flow distribution for Lightning Cr.

3. SURFACE WATER HYDROLOGY REPORT

Date:

March 2013

Performed By:

Interralogic

Introduction:

Field investigations were performed in 2011 in order to review the surface water hydrology and hydraulic structure conditions of the Keno Hill Silver District. Three field sessions occurred in the months of May, August, and September of 2011. These field investigations were performed during varying seasons to allow an examination of the conditions and functionality of existing facilities during both the spring freshet and dryer summer months.

Objective:

A high level evaluation of basin peak flows, culvert capacities, and diversion channel design specifically for Alternative 2B of the Closure Options Report was undertaken using the Design Criteria. The objective of this analysis was to understand existing hydrologic and hydraulic conditions near respective facilities and provide suggested design modifications where necessary to minimize erosion and reduce contact of storm waters with historic mine materials such as the Valley Tailings Facility, the hillside tailings along the Porcupine Creek corridor below the town of Elsa, and the Flat Creek watershed below.

Facts/Description of Study:

All existing watersheds within the area including vegetative cover and drainage routes were mapped to obtain an understanding of site conditions and respective responses during potential runoff conditions. In 2010, Interralogic provided a Design Criteria that included design storms for evaluating site conditions under closure scenarios. This Design Criteria storm event of the 200-year, 24-hour plus freshet was used in modeling watershed responses to the areas near or adjacent to existing facilities.

Results/Conclusions:

- Several areas were identified that would require modification to meet the Design Criteria and evaluation objective.
- Recommendations have been made including culvert size modifications and reducing the upgradient watershed area of Porcupine Creek and Flat Creek by constructing additional diversions on the hillside above the Town of Elsa.
- The recommended modifications achieve the requirements of the Design Criteria, providing a complete and comprehensive hydrologic system of controls to minimize erosion and direct flows away from facilities to the greatest extent possible.

Deliverables:

Final Report: 2013 Keno Surface Water Hydrology Report (Interralogic 2013)

4. SITE WIDE WATER BALANCE/MASS LOADING BALANCE UPDATE

Date:

2009

Performed By:

ACG

Objective:

To update the site wide loading and water balance based on new information including the update water quality database and the UKHM Hydrological Update and Assessment.

Facts/Description of Study:

- In 1996, as part of the Site Characterization, a mass balance for the site was constructed based on sub-watershed catchment basins. The water balance, which forms the basis for calculating site loading, was developed based on regional hydrological and weather data
- In 2007, Clearwater Consultants Ltd. confirmed the hydrological input parameters that were used to determine the water balance
- Hydrological and water balance data serve as a frame for loading model development. The network of water quality monitoring stations contribute necessary contaminant node inputs
- Together, hydrological data and contaminant information are used to calculate loads at critical points along watershed pathways and at outlet points for each of the three site watersheds (Christal, Flat, and Lightning Creeks)
- In 2008, the contaminant loads were updated to reflect more recent conditions. Data from 2006 – 2008 was used to determine year by year loads from adit discharges and in receiving waters
- Adit discharges have similarly been updated with more recent flow volumes exiting from the adits

Information Gaps:

Clearwater Consultants have recommended that the hydrology for the model be updated based on flow data gathered at the site, coupled with regional hydrology data where appropriate.

Because the model is based on observed loads at output nodes, it is difficult to predict what those loads would look like under different loading scenarios without making assumptions about the site attenuation capacity. The attenuating properties of the site will be under investigation in summer 2009 so that more concrete statements can be made about contaminant dissipation.

Results/Conclusions:

- o The highest loads originate from the Galkeno 300 and Onek adits. Galkeno represents the highest treated load (on the order of 40kg Zn/year after treatment), while Onek produces the highest untreated load (at between 575 – 975kg Zn/year). Both discharges report to ground

- The mass balance model has served to produce an estimation of the degree of attenuation at the site. When loading is at its highest (i.e. in years where there is little or no treatment at any of the adits) the attenuation capacity has been shown to be roughly 90% of the load entering the watersheds

Deliverables:

An excel spreadsheet has been developed and refined which accepts inputs from a master water quality database and calculated loads at eleven basin output points, including Lightning Creek, Christal Creek immediately before discharge to the South McQuesten, and the final discharge point on the South McQuesten River for all site drainage. Mass Loading Model 2008 Update report by ACG in 2009.

5. MASS LOAD MODELS

Date:

October 2011 – November 2013

Performed By:

Interralogic

Introduction:

Flat, Christal and Lighting Creek watersheds contain sites impacted by legacy mining activities. These sites have the potential to contribute metal loads to Flat Creek and Christal Creeks, tributaries to the South McQuesten River and to Lightning Creek which drains into the Mayo and Stewart Rivers; all rivers ultimately drain into the Yukon River. Reclamation alternatives to reduce metal loads to Flat, Crystal and Lightning Creeks are being investigated as part of the closure studies for the Keno Hill Silver District. To aid in the evaluation of reclamation alternatives, three separate simulation models of metal loads have been developed for Flat, Christal and Lightning Creeks.

Objective:

The mass load models were developed to aid in the evaluation of reclamation alternatives to reduce metal loads in all three tributaries as part of the closure studies for the Keno Hill Silver District.

Facts/Description of Study:

Constituents incorporated into the models are cadmium, zinc, sulfate, arsenic, copper, nickel, lead, selenium and silver. Nitrate was included in the Flat Creek model only. The primary focus of the investigation centers on load contributions from zinc, and cadmium as they have been identified as the contaminants of concern. The model was developed in the GoldSim simulation framework (www.goldsim.com).

The simulation settings for the simulation model run from January 1, 2008 to end of January 2041 for a total of 32 years. The simulation period was calibrated to periods between 2008 through July 2013 using available data. Future simulations were run in two phases: phase 1 as the baseline condition in which no new reclamation options were considered for mitigating loads to the creeks. The second phase incorporates the potential effects of different reclamation options for decreasing metal loads relative to the baseline condition. Each reclamation option has an independent start date that can be configured via the user interface. Simulations of potential reductions in metal loads are present for a range of reclamation options and the results for each case are presented in the document.

The structure of the GoldSim simulation model was designed to estimate chemical loads and is most suited to evaluating reclamation options in terms of changes in chemical loads for the contaminants of concern (zinc and cadmium). However, the models were updated to estimate other metal concentrations (Cd, Zn, As) in Christal, Lightning and Flat Creeks from the model resulting from the various reclamation alternatives for us as an aid in the evaluation of reclamation options. Model calculations do not take into account potential variability in hydrogeochemical, biological, and physical processes that can affect concentrations in natural stream systems particularly over short time frames such as seasons. The concentrations produced by the model should be understood to be indicative of approximate ranges expected to occur over yearly to longer time-scales rather than precise predictions of day-to-day concentrations.

Model-derived estimates of mean, median, and maximum concentrations for zinc, cadmium, arsenic, lead and silver for the year 2025 for the various reclamation options was chosen because it reflects a period when the effects of the reclamation options are expected to be fully implemented and reach steady state conditions. The concentrations should be considered as estimates that provide a relative measure of the potential concentrations and ranges potentially achievable for the simulated reductions in chemical loads.

Results/Conclusions:

The revised mass load model reports for Christal, Lightning and Flat Creeks provide simulations of potential reductions in metal loads for a range of reclamation options and the results for each case are presented in the documents for arsenic, cadmium, lead silver and zinc. The user friendly interface (GoldSim Player) for the mass load models allows users to model different scenarios in the Closure options and to see the results for various combinations of the options not presented in the report plus expanded parameters including: copper, nickel, selenium, sulfate, ammonia and nitrate (available upon request).

Deliverables:

Draft Report: Mass Load Model for Flat Creek: Description and Results (Interralogic 2013)

Draft Report: Mass Load Model for Christal Creek: Description and Results (Interralogic 2013)

Draft Report: Mass Load Model for Lightning Creek: Description and Results (Interralogic 2013)

6. Surface Water Quality Assessment for United Keno Hill Mine Complex

Date:

2007

Performed By:

Minnow Environmental

Objective:

To identify parameters and locations of concern within the downstream waters relative to established guidelines and background. This data, together with toxicity data and receiving watershed use objectives will be combined to develop an approach for considering the development of a Site Specific Water Quality Objectives (SSWQO) or water quality goals for various parameters and locations.

Facts/Description of Study:

- The following steps were outlined to achieve the aforementioned objective:
    a. The data were screened to identify where data should be removed from analysis due to errors.
    b. Background concentration for each parameter were established based on the upper limit of background data distribution for the combined data from KV-1 and KV-37
    c. Background concentrations which exceed the Canadian Water Quality Guidelines (CWQG) were identified
    d. Locations that exceed background and/or CWQG at measurable and sustainable frequencies were identified
    e. Parameters and locations where concentrations are highest were identified
    f. An assessment of trends over time was conducted to anticipate if concentrations are increasing or decreasing relative to CWQG and/or background
    g. Modifying factors and toxicity literature were considered to assess the opportunity for SSWQO development following the guidelines

Results/Conclusions:

- Background concentrations of several parameters exceed the CWQG, suggesting that concentrations of these parameters are naturally elevated. Contaminants of concern were identified as **total Zn** and **Cd**, while potential contaminants of concern were identified as: **total Al, As, Cr, Mn, Nitrite, P, Se, and Ag**
- Many stations were found to have concentrations for numerous parameters that exceeded CWQG in more than 10% of samples

- Significantly fewer stations were found to have concentrations for numerous parameters that exceeded CWQG in more than 50% of samples. The stations that exhibited this were concentrated at Christal Creek, No Cash Creek, and the upper portion of Lightning Creek and Flat Creek watersheds.
- Only a few locations exhibited parameters with median values 5X or more the CWQG; however, it was not uncommon for parameter maximum values to exceed 5X the CWQG
- The key locations of concern are KV-39, KV-29, KV-21 and KV-47
- While background concentrations are elevated for some parameters, even these high background values are exceeded in some cases (notably at Christal Creek, No Cash Creek, and the upper portion of Lightning Creek and Flat Creek watersheds); thus, a two-tiered approach to SSWQO is suggested which could permit higher concentrations in some near-field areas and higher protection in downstream areas

7. BENTHIC INVERTEBRATE MONITORING PROGRAMS

Date:

Summer 2007 – March 2008

Performed By:

Laberge Environmental Services

Objective:

To determine the population size and diversity of benthic invertebrate communities within the Keno Hill watersheds, and explain these variables through metal concentration levels.

Facts/Description of Study:

- Water quality, stream sediment and substrate samples for benthic invertebrate sampling were collected for laboratory analysis
- Stream sediment samples were collected from areas of deposition along stream banks
- Substrate samples for benthic invertebrate sampling were collected from riffle areas at each sample location

Information Gaps:

Historical benthic and sediment data was recently acquired and will be incorporated into future assessment of Keno Hill benthic data, including a report on Environmental Conditions at the property.

Results/Conclusions:

- CCME guidelines were exceeded for Cd and Zn in waters of all drainages, including the background drainage
- Concentrations of As, Cd, Pb and Zn were high in stream sediments at most sites, including at the background site, KV-1
- Highest sediment metals concentrations were documented at KV-9, Flat Creek
- Over time, metal concentrations have been greater in the sediments at Flat and Christal Creeks than the South McQuesten and Lightning drainages
- Benthic invertebrate populations were robust and healthy in the South McQuesten river and Lightning Creek drainages; good representation of chemically-sensitive insects indicates a healthy aquatic environment
- KV-6, Christal Creek at Keno Highway, was the least diverse of the site studied
- Populations at the other two sites on Christal Creek and KV-9 at Flat Creek, were depressed
- High concentrations of metals at Flat and Christal Creeks appear to be negatively impacting benthos community health

8. Fisheries Assessment and Update

Date:

September 17 – 19, 2008

Performed By:

ACG

Introduction:

Fish living in polluted waters tend to accumulate heavy metals in their tissues. These metals can accumulate in significant quantities without causing mortality in species. The KHSD is an environment where high levels of metals have been observed in the aquatic environment (see previous Water Quality and Receiving Environment Conditions studies), and where fish that are used for human consumption exist. As a result, understanding the level of metals that are present in fish species in waters of the KHSD is necessary from a closure perspective.

This study investigates fish and fish habitat at a total of seven sites on Christal Lake, Christal Creek, Lightning Creek and Flat Creek. Results of fish tissue analysis were compared to the results of previous studies, and barriers to fish movement were investigated.

Objective:

To investigate fish and fish habitat in several aquatic environments in the KHSD to determine levels of metals uptake in fish, and the potential risk to humans by consumption of these fish, and to identify any barriers to fish movement in streams and assess the feasibility of their removal.

Facts/Description of Study:

Fish Tissue Analysis:

- Sites were fished using Gee's minnow traps and electrofishing where conditions allowed.
- Species at each site were identified and enumerated, and fork length measured before release.
- Water quality parameters temperature, conductivity, pH and dissolved oxygen were collected at each site

Habitat Barrier Investigation:

- The fisheries investigations carried out in 1995 and 2006 were reviewed as they identified former bridge crossings that posed barriers to fish movement in Christal Creek.
- The locations of the barriers was revisited, and re-evaluated for their potential to present partial or complete obstruction to upstream fish movement.
- Considerations were given to the need for and method of removal of these barriers.

<u>Results/Conclusions:</u>

Fish Tissue Analysis:

- Lightning Creek yielded slimy sculpin and arctic grayling, Flat Creek yielded northern pike, Christal Creek yielded slimy sculpin, and no fish were retrieved from Christal Creek.
- Variation from 2006 analysis:
    - Christal Lake (slimy sculpin): values within range of variation for Christal Lake, with the exception of manganese, which had decreased by roughly half
    - Lightning Creek (slimy sculpin): values within range of variation for Lightning Creek, with the exception of nickel, which had increased by an order of magnitude
    - Lightning Creek (arctic grayling): values within range of variation for Lightning Creek, with the exception of nickel, which had a value of 0.93 in 2008 vs. non-detect in 2006
    - Flat Creek (slimy sculpin vs. arctic grayling): most values were within the reasonable range of variation compared with other values in Flat Creek, with the following exceptions: 2008 values for arsenic, lead and manganese were notably low compared with previous evaluations.
- Grayling have been singled out as the primary fish-based source of heavy metals consumption by humans in this geographic area. Based on the results of chemical analysis, the metals levels found in Lightning Creek grayling tissue were well below acceptable human consumption levels. The only exception to this is that the level of arsenic in grayling tissue was found to exceed the threshold for consumption by toddlers.

Habitat Barrier Investigation:

- Three of four barriers identified in 1995 and 2006 were still in place in 2008
- The barrier were confirmed as an impediment to fish movement
- It was recommended that the barriers be removed according to best practices and in adherence with regulations. Recommendations are made in the report to achieve this.

<u>Deliverables:</u>

Final Report: Fisheries Assessment Project

9. AQUATIC RESOURCE ASSESSMENT FOR UNITED KENO HILL MINES

Date:

April 2008 – March 2009

Performed By:

Minnow Environmental

Objective:

To provide an integrated assessment of the available biotic (fish and benthic invertebrate community) and abiotic (water and sediment) data such that current conditions within the headwaters tributaries down gradient of the mine and further downstream in the South McQuesten River are characterized.

This report, along with the Water Quality Assessment Report for United Keno Hill Mines will serve as key supporting documents for other ERDC initiatives, such as preparation of the Closure Plan, determination of water quality goals and objectives, and the development of a long-term monitoring program

Facts/Description of Study:

- The following steps were outlined to achieve the aforementioned objectives:

  a. The watershed characteristics for each watershed were assessed and an overview of mine influences and habitat characteristics were determined

  b. The water quality assessment for UKHM was considered in view of the aquatic characteristics of the site

  c. Current and historical sediment quality at the Keno Hill mine was evaluated

  d. Benthic invertebrate community health was evaluated

  e. Current and historical fisheries data including community composition, fish condition and metal concentrations in tissues was considered and evaluated

  f. Data was integrated to provide an exhaustive assessment of the current aquatic conditions at Keno Hill

Results/Conclusions:

- Analysis of water quality identified cadmium and zinc as key contaminants of concern in waters downstream of the Keno Hill property. Concentrations of these substances are at levels that are potentially toxic to aquatic biota in portions of the tributaries receiving mine drainage (particularly Christal Creek). However, contaminant levels in the South McQuesten River are currently below levels of concern

- Sediment guidelines are based on concentrations measured in whole sediment samples (not just the fine fraction), so potential risks to benthic biota cannot be ascertained from the available sediment data

- Benthic invertebrate communities in lower Christal and Flat Creeks were characterized by relatively low abundance and number of taxa compared to reference and other, mine exposed areas. Correlation analysis suggested that reduced number of taxa may be related to elevated water concentrations of mine-related variables such as major ions (e.g., sulphate, hardness, conductivity), cadmium, and zinc

- The presence of both adult and juvenile Arctic grayling in most watercourses indicates availability of suitable spawning and rearing habitats. Portions of Christal Creek showed limited fish diversity and densities, particularly at KV-7 where no fish were found in 2006. No large and consistent patterns were evident in mine-exposed areas that would suggest that conditions had either improved or degraded over time

- Whole body analysis of slimy sculpin showed levels of arsenic in excess of reference sediment concentrations and wildlife consumption benchmarks at most areas downstream of UKHM, particularly in Christal and Flat Creeks. Metal concentrations in Arctic grayling muscle were less than human or wildlife consumption benchmarks in almost all samples from all areas. No consistent increases or decreases were evident over time based on comparison of data from 2006 to data from 1994-95

- Modifications and guidance for developing a long-term monitoring program for Keno Hill were recommended based on the findings of the water quality and aquatic resources assessment, in particular ensuring that monitoring programs retrieve all necessary data and that redundancies are eliminated.

Technical Study:

10. Approach for Developing Water Quality Goals for United Keno Hill Mines

Date:

2011

Performed By:

Minnow Environmental

Introduction:

Minnow Environmental was retained by ERDC to provide an assessment of water quality and biological characteristics at the Keno Hill Mines Property. Extending from those assessments, Minnow was requested to assist in developing a framework for determining water quality goals for each watershed affected by the Keno Hill Mines. Based on that framework, Minnow has also included a discussion which proposes achievable goals for the Keno Hill Mines receiving environment.

Objective:

To develop an approach to assessing water quality downstream of Keno Hill Mines that will serve to protect resident biota and prevent further degradation of water quality within the immediate receiving environment and allow for no further degradation in the South McQuesten Rive relative to upstream conditions.

Facts/Description of Study:

- Aqueous cadmium and zinc concentrations were assessed for routine monitoring stations in Christal Creek, Flat Creek and the South McQuesten River both upstream and downstream of Keno Hill Mines relative to Canadian Water Quality Guidelines (CWQG)
- For stations where trends were observed over time, slopes were plotted and statistically compared using analysis of covariance
- Toxicity information was gathered from Environment Canada and scientific literature for cadmium and zinc
- Because of the significant impact of hardness levels on toxicity, reported effects concentrations for cadmium and zinc were converted based on common water hardness (a hardness of 100mg/L was used as an appropriate, conservative value for Keno Hill)
- The lowest toxic effect concentration corresponding to an exposure hardness of 100mg/L was identified for each study and species where possible, and other measures were used to derive a toxic effect concentration when hardness data was not available
- Recent water concentrations of cadmium and zinc measured at key locations downstream of Keno Hill were compared to toxic threshold concentrations reported in the literature for different aquatic species (at a water hardness of 100mg/L).

- Water quality in each of the watersheds was evaluated relative to toxicity data and an approach to developing appropriate water quality goals was derived.

<u>Results/Conclusions:</u>

South McQuesten River

- o In mid-2007 it was noted that concentrations of various metals including cadmium and zinc had increased upstream in the South McQuesten River at KV-1. Over the same period, concentrations of cadmium and zinc were found to be increasing at the same rate downstream at KV-4 and KV-5 as upstream at KV-1.
- o The conclusion is that a source upstream of KV-1 was responsible for the increase in water concentrations at KV-1 and that Keno Hill Mines are not causing a measurable increase in concentrations downstream of the mines at KV-4 and KV-5
- o Because the concentrations continue to increase, and it is not known whether or for how long this will continue, it is not possible to establish a single numerical value that represents the upper limit of upstream background conditions.
- o Rather than a single numerical value, it is proposed that water quality objectives in the South McQuesten downstream of Keno Hill Mines be linked to upstream concentrations and allow for no further degradation of water quality. Minnow makes detailed recommendations as to the analysis and statistical methods to be carried out to achieve this in their report.

Lightning Creek

- o Concentrations of metals in Lightning Creek have generally been below CWQG, and as such the existing or proposed CWQG should be adequate as water quality goals for this watershed

Flat and Christal Creeks

- o Historical concentrations of cadmium and zinc have been elevated well above (10x or more) CWQG.
- o It is not realistic to propose CWQG as goals for these watersheds as the number of sources and uncertainty of future loads from surface contamination are great.
- o Thus, the approach taken for Flat and Christal Creeks must be a species-specific approach based on toxicity levels.
- o The toxicity data for species in Flat and Christal Creeks show that if cadmium and zinc concentrations remain stable or decline over time, biological impacts will be minimal and existing biological communities will be protected.
- o The report goes on to describe specific measures to be carried out in order to assess whether or not the diversity and abundance of resident biota are being protected.

Deliverables:

Approach to Developing Water Quality Goals for United Keno Hill Mines (Minnow 2012)

11. LONG-TERM AQUATIC MONITORING PROGRAM FOR UNTIED KENO HILL MINES

Date:

2010-2011

Performed By:

Minnow Environmental

Introduction:

ERDC has requested that Minnow Environmental Inc. assist in identifying the requirements of a comprehensive, site-wide Long-Term Aquatic Monitoring Program (LTAMP). Such a program will need to support the environmental assessment, closure planning, and regulatory processes in the short-term and provide adequate information to evaluate environmental conditions relative to closure initiatives and redevelopment/operations in the long-term.

Objective:

To develop a Long Term Monitoring Program for Keno Hill Mines

Facts/Description of Study:

Approach for Monitoring Water Quality

- The current known conditions for water quality indicate that cadmium and zinc are contaminants of concern, and there are a number of other potential substances that cannot be ruled out as possible contaminants of concern due to limitation of the data set, which should be addressed in an LTAMP.
- Factors that need to be considered and incorporated into the LTAMP study design include: planned remediation measures, the scope of future mining, placer mining activities and adequate characterization of reference areas (which does not currently exist at the Keno Hill Mines Property).
- Minnow proposes a framework for water quality monitoring in a number of areas including the location of sites, parameters for analysis, total vs. filtered metals, flow, method and frequency of collection, data analysis and the incorporation of these items into a future water licence for closure.
- Given the framework defined by Minnow for comprehensive monitoring of water quality, they propose a starting point for the LTAMP, which would evolve over time as data are collected. The LTAMP begins with the collection of a significantly greater amount of data over the course of two to three years in the receiving environment to quantitatively determine the minimum number of data points that will need to be collected in the future to fully characterize the impact of the mines and the closure plan.

Approach for Monitoring Sediments

- Metal analyses over the past 20 years have shown that arsenic, cadmium, lead, manganese and zinc occur at levels well above Canadian Sediment Quality Guidelines (CSQG) in the fine fraction of sediments. Bulk analysis in 2009 showed that the levels of arsenic, cadmium, lead and zinc are elevated in bulk samples, as well as in fines.

- As with water quality monitoring, consideration must be given to a number of factors that influence contamination levels in sediments, including: locations where deposition may occur most rapidly and the amount of particulate metal in the water. In the case of Keno Hill Mines, it can be noted that these two factors converge to produce an environment where benthic communities are most likely exposed to mine-related substances via water pathways rather than sediment pathways

- Similar to the LTAMP associated with water quality, Minnow presents a framework and establishes parameters for determining the most appropriate locations, analyses and collection methods for sediment monitoring. Minnow proposes a sediment monitoring program for the LTAMP based on these parameters, and incorporates monitoring for reference areas (which do not exist in the current monitoring program).

Approach to Monitoring Benthic Invertebrate Communities

- Benthic communities within Christal Creek and Flat Creek have shown impairment through reduced abundances and number of taxa relative to the other watercourses sampled in the area. The benthic communities within the South McQuesten River and Lightning Creek had higher numbers of taxa and abundance suggesting limited impairment at these locations. This corresponds to the observation that water quality is significantly lower in the areas of Flat and Christal Creeks than the South McQuesten River and Lightning Creek.

- Minnow expounds the merits of benthic monitoring as a way of assessing the potential effects of the chemical condition of water and sediment on the health of aquatic systems.

- A report is underway for completion in 2010 which aims to determine the most effective study design and sampling method for benthic community monitoring within the context of the LTAMP.

Approach to Monitoring Fish Communities

- Fish community composition and relative species abundances should be tracked at key near-field locations near the UKHM over time (Christal Creek, Flat Creek, and South McQuesten River) and compared to the communities at reference areas possessing similar habitat characteristics. Methods will be similar to those used in previous surveys and slimy sculpin populations should be assessed.

Data Quality Objectives and Quality Control

- Minnow details a standard approach to developing data quality objectives and implementing quality control as a component of the LTAMP as a way of qualitatively defining sensitivity, precision, accuracy, comparability, compatibility, representativeness and completeness of the dataset.

Reporting

- Reporting is suggested as a method of review to regularly assess and report the condition of water quality, sediment quality, benthic community health and fish community health. Two types of reports are detailed: Annual Water Quality Reports and Comprehensive Aquatic Ecosystem Study Reports.

Results/Conclusions:

The LTAMP will integrate biological and chemical information for a weight-of-evidence approach, including the following components:

- Water Chemistry and Hydrology (flow): Water quality monitoring is important as water is the main vector for off-site transport of contaminants and can be monitored frequently to serve as an early warning indicator of changing conditions
- Sediment Chemistry: The receiving environment downstream of UKHM is generally erosional and deposits of fine sediments are typically sparse and patchy. Therefore, exposure to sediments by biota is likely quite limited
- Benthic Invertebrate Community Monitoring: Benthic invertebrates are good, community-level integrators of localized conditions over time, they are important components of aquatic food webs and there are standardized methods for their collection and evaluation
- Fish Community and Population Assessment: Fish tend to occupy the upper trophic levels of aquatic ecosystems and are often their most visible and valued components. Both population and community-level assessment can be used as indicators of longer-term exposure conditions (e.g., over years)

The LTAMP will incorporate a standard quality control program and be subject to regular reporting for purposes of review.

Deliverables:

Interim Long-Term Aquatic Monitoring Program for Untied Keno Hill Mines (Minnow 2011)

12. Contaminants of Concern for the UKHM Long-term Monitoring Program

Date:

2013

Performed By:

Minnow Environmental

Objective:

To develop a final list of COC's for the UKHM area that could be used in the assessment and monitoring of closure conditions.

Facts/Description of Study:

In order to identify the COCs, the following steps were undertaken:

- Established an upper limit of background (95th percentile) for each analyte.
- Compared the upper limit of background to the Canadian Water Quality Guidelines (CWQG; CCME, 2007 plus updates) to identify naturally elevated substances.
- Compared the concentrations of each analyte at each mine-exposed station to background and CWQG and flagged those that exceeded these benchmarks.
- Analytes that exceeded background but not CWQG were plotted over time (2005 to 2012) together with analytes with maximum concentrations above guidelines to determine if the concentrations of these analytes are increasing over time and as such represent potential future COCs.
- Total and filtered concentrations for analytes which exceeded CWQG were plotted to determine if both fractions exceeded the guideline.
- Analytes were considered for inclusion as COCs if the median concentration was higher than background and CWQG or if the maximum concentration was two times the CWQG for both total and dissolved measures.
- Analytes for which no guideline exists were considered for inclusion as COC's if the median concentration was ten times background.

Information Gaps:

Recommendations provided in the Long-Term Aquatic Monitoring Program for UKHM report that allowed for deficiencies in the water quality data base included and were added to the monitoring program:

- monitoring frequencies were increased to monthly,
- additional reference areas were added to the program,
- the list of substances to be analyzed was increased to include those for which limited or no information was available
- method detection limits were established at levels less than relevant guidelines, and
- several laboratory measures were included to aid in the interpretation of the water quality data (hardness, dissolved organic carbon (DOC), total suspended solids (TSS)).

Results/Conclusions:

Based on the assessment of analytes:

- Station KV-60 should not be used as a reference station.
- Cadmium and zinc should remain COCs for the LTAMP and no additional COCs are warranted.
- The LTAMP should include monitoring of the following analytes; hardness, alkalinity, specific conductance, pH, DOC, TSS, aluminum, ammonia, arsenic, cadmium, calcium, copper, cobalt, cyanide, chromium, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, silicon, sodium, strontium, sulphate, silver, uranium and Based on the assessment above, the following recommendations are provided:
- Station KV-60 should not be used as a reference station.
- Cadmium and zinc should remain COCs for the LTAMP and no additional COCs are warranted.
- The LTAMP should include monitoring of the following analytes; hardness, alkalinity, specific conductance, pH, DOC, TSS, aluminum, ammonia, arsenic, cadmium, calcium, copper, cobalt, cyanide, chromium, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, silicon, sodium, strontium, sulphate, silver, uranium and zinc. These represent mine related analytes but only cadmium and zinc are currently observed at levels which could be harmful to aquatic life.
- Given the fluctuations in the concentrations of total metals, dissolved metals should be analyzed as well.
- The assessment provided herein is based on existing monitoring data. It is possible that in the future, additional COC could be identified if new sources were to connect to the downstream receiving environments. The adaptive management plan for the district should be structured to allow for identification of new COC's in the future in response to changes in source areas.

Deliverables:

Memo: Evaluation of Contaminants of Concern for the United Keno Hill Mines Long Term Monitoring Program (Minnow 2013)

GROUNDWATER STUDIES

13. Existing Hydrogeological Investigations

Date:

2008-2012

Performed By:

ACG

Introduction:

There have been several groundwater investigations conducted in the Keno District for the Keno City area, Keno City and Bellekeno Mill Area, and the Valley Tailings area.

Objective:

- Interralogic (March 2012) was commissioned to investigate the Keno City area groundwater to determine where flow from Onek adit, which was known to infiltrate into the subsurface, may have contaminated groundwater.
- As part of the permitting process for the Bellekeno Mine, a limited groundwater investigation was undertaken in the area around the (at that time) proposed District Mill.
- SRK (2008) performed an analysis of groundwater impacts and flow patterns around the Valley Tailings Facility.

Facts/Description of Study:

Keno City (Interralogic)

- Study focused on 5 private well, 5 monitoring wells, 1 Onek well, and 2 surface water locations.

Bellekeno Mill area (SRK)

- 3 monitoring wells were installed and monitored for this investigation in addition to 1 Keno City well. The study also evaluated Lightening Creek.

Valley Tailings (SRK)

- 12 monitoring wells (6 upstream/downstream crests of Dams 1, 2 and 3 and 6 within tailings deposit). Surface water was not included in this study.

Results/Conclusions:

Keno City

- Direction of groundwater flow, groundwater and surface water interaction, and the impact of Onek 400 on the Keno City water supply was determined from this investigation.

Bellekeno Mill area

- Risk to Keno City groundwater is considered negligible based on groundwater flow being away from Keno City.

Valley Tailings

- A low hydraulic gradient exists in the groundwater under the Valley Tailings and peat is present across the area and is considered to be a geochemical filter to impede metal migration.

<u>Deliverables:</u>

Memo: Summary of Existing Hydrogeological Information in the Keno District 2013 Site Investigation (ACG 2013)

14. GROUNDWATER MONITORING PLAN SUMMARY

Date:

2013

Performed By:

ACG

Introduction:

This current groundwater monitoring program has been initiated within the Keno District to begin to fulfill clauses 38-41 of the Yukon Water Board, Water Use Licence: QZ12-057. Groundwater monitoring wells have been installed at 11 specified sites across the district.

Objective:

- Determine potential impacts of those sites under care and maintenance which currently have treatment, or where elevated levels of contaminants of potential concern have been found to exist;
- Estimate, to a high degree of certainty, the hydraulic conductivity of all potentially impacted aquifers;
- Determine the groundwater flow direction;
- Determine vertical and horizontal hydraulic gradients, and
- Determine the potential flux of contaminants in groundwater in all receptors
- Use the site wide hydrogeological information to help understand groundwater migration patterns or evaluate potential groundwater impacts in the broad areas that had not been studied before between the Valley Tailings and the Keno City.

Facts/Description of Study:

The following sites were investigated by installing and monitoring wells:

- Silver King
- Husky and Husky Southwest
- Ruby 400 Adit
- Bermingham
- Galkeno 300 and 900
- Keno 700
- Sadie Ladue (two wells)
- Silver Trail Highway near Elsa and Husky mines near Flat Creek
- Onek in the receiving environment area near Christal Lake

The field program consisted of the following tasks:

- Borehole drilling and monitoring well installation
- Monitoring well development
- Groundwater sampling
- Insitu hydraulic conductivity testing to provide a measurement of hydraulic conductivity, which is a parameter that is necessary to understand the potential for groundwater migration

Results/Conclusions:

These groundwater monitoring results have provided preliminary indications of groundwater impacts in the district. Future study will provide a better understanding of groundwater to surface water interactions and the potential for loading to the surface water that is near these mines, and the extent of groundwater plumes that may exist near these mines.

MINE POOL STUDIES

15. HECTOR-CALUMET MINE POOL INVESTIGATION

Date:

May November 2011

Performed By:

ACG/Interralogic

Introduction:

High costs and operation difficulties of treating discharge from the Galkeno 300 adit during the cold-weather period could be significantly reduced if adit water could be stored in existing mine workings over the winter and treatment resume during the warm-weather months. The following study, mine pool pump testing and dye tracer testing was initiated to determine that a hydraulic connection exists between the Galkeno 300 adit and the flooded Hector-Calumet Mine workings (mine pool).

Objective:

To determine if a hydraulic connection exists between the Galkeno 300 adit and the flooded Hector Calumet mine pool by pumping the mine pool and running a dye trace test.

Facts/Description of Study:

Dye Tracer Testing:

The purpose of the dye tracer test was to investigate:

- Hydraulic connections between the Hector and Calumet open pits and the underlying flooded workings; and a possible hydraulic connection between the mine pool and the Galkeno 300 flowing adit.

The test was generally performed by dosing the pit snow pack with fluorescent dyes and monitoring for dye concentrations in the Galkeno 300, Galkeno 900, and No Cash 400 adits. Also monitored was a spring on the southeast side on Galena Hill.

Testing for Hydraulic Conductivity:

A hydrologic test hole, drilled from the east side of Galena Hill, successfully intersected a mine opening at the bottom of the Hector-Calumet underground mine. Drilling was difficult and the initial hole was abandoned due to drilling deviating from the target and a second hole was drilled with the air RC method. The 334 m vertical boring is currently a 5.25-inch open hole penetrating hard quartzite. The test hole was completed late in the field season and cold weather precluded additional 2011 field work.

Results/Conclusions:

- o After two months of monitoring, there were no detections of dye at any of the sampling stations, so the time duration between placement and retrieval of the charcoal packets was increased to 2 to 4 weeks depending on location; and

- o At the end of 2011, there were no detections of dye at any of the monitoring sites.
- o To date, the dye test has not confirmed a hydraulic connection between the Hector- Calumet open pits and the Galkeno 300 adit or spring discharge on the side of Galena Hill.
- o The dye test is on-going and monitoring will be continued into 2012. It is recommended that the carbon samplers be retrieved once per month through the end of 2012 field season.

Recommended activities for 2012 include (1) using the test hole to obtain additional water samples of the mine pool water, (2) performing a pumping test to further evaluate the connection between the mine pool and Galkeno 300, and (3) possibly injecting a dye tracer into the mine pool.

<u>Deliverables:</u>

Memo: 2011 Work Activities Related to the Hector-Calumet Mine Pool (Interralogic 2012)

ADIT WATER QUALITY STUDIES

16. ADIT DISCHARGE SURVEY

Date:

Summer 2007

Performed By:

ACG

Objective:

To reaffirm the understanding of adit flow paths and down gradient water quality.

Facts/Description of Study:

- The following survey components were outlined to achieve the aforementioned objective:

    a. Determine the discharge path from adit to a surface water source if possible;

    b. GPS the discharge path;

    c. Establish sample locations;

    d. Obtain water samples at locations along the path;

    e. Collect in-situ water quality;

    f. Receive lab results of water's analysis;

    g. Collect a photo library; and

    h. Report on the results of the survey.

- The adits included in the study were: Silver King 100, Husky South West, Bermingham, Ruby, No Cash 500, Galkeno 300, Galkeno 900, Keno 700, Onek, and Sadie Ladue (**Error! Reference source not found.**)

- Results were compared with CCME Fresh Water Aquatic Life Guidelines and Effluent Standards as Part E of the Water Use Licence (QZ06-074)

Results/Conclusions:

- o The survey was able to successfully identify and confirm the receiving waters drainage for the adit network
- o Site locations for AMP monitoring were successfully identified
- o Hydraulic catchment areas for the mass loading model were verified

17. ONEK AND NO CASH PATHWAY INVESTIGATION

Date:

2007

Performed By:

ACG

Introduction:

Based on measured loads of zinc and other contaminants from the No Cash 500 and Onek adits, considerably higher metals loads are expected down gradient in both Christal and Flat Creek than are observed. Modelling loading contamination with the Mass Loading Model developed for the site has shown a net negative balance of contaminants along the downstream path from these two adits.

Objective:

This study aims to identify the mode of contaminant reduction in the No Cash 500 and Onek drainages, and to account for the negative variance in estimated versus actual contaminant load in Christal Creek and Flat Creek, thereby confirming that geochemical attenuation and reduction are occurring.

Facts/Description of Study:

The following steps were carried out to achieve the study objective:

A review of the mass balance for the Christal Creek and Flat Creek areas was undertaken to establish the magnitude of load reduction within the watersheds

An investigation of the location of No Cash and Onek adit flow paths was carried out to delineate contaminant pathways

At Onek and No Cash adits, test pits were hand dug to groundwater, and manually-driven piezometers were installed within shallow groundwater. The pits and piezometers were sampled for zinc, other metals (including cadmium, iron, manganese, silicon) and for major ions of interest. Ions of interest particularly included sulfate and bicarbonate

At No Cash, sulfide precipitates or sulfide odors were observed which indicated an ion transfer process is occurring, which suggests attenuation mechanisms. The iron and manganese precipitates (ferricrete) below No Cash adit were several feet thick.

A chemical analysis of the results was carried out to establish the likely mechanisms responsible for load reduction. The two principle mechanisms investigated were dilution from groundwater sources and attenuation.

Results/Conclusions:

Field observations and laboratory analyses indicated to the study team that at both No Cash 500 and Onek, naturally occurring organic materials are breaking down under anaerobic sulphate-reducing conditions, precipitating zinc as a sulphide mineral from concentrations as high as 90 PPM at Onek and under steep hydraulic gradients such as exist at No Cash 500, and in both cases result in groundwater and surface water seepage high in bicarbonate concentrations and substantially devoid of zinc loading.

<u>Deliverables:</u>

Final Report: Contaminant Loading and Transport Pathways Investigation – Onek and No Cash 500

18. Bioreactor Pilot Test

Date:

April 2010-2012

Performed By:

Alexco Resource US Corp.

Introduction:

The Galkeno 900 Adit discharges high metals content water continuously at steady rate of 3-4l/s. The adit discharges from the side of Galena Hill within a distance of 1km of Christal Lake. There is limited room for natural attenuation or wetlands treatment of adit discharge prior to surface water contact in Christal Lake and Christal Creek. Consequently, this location will likely require some active water treatment and management, and this consideration led to the determination that a pilot test bioreactor would be located at the Galkeno 900 site.

Objective:

The objective of this study is to demonstrate the viability of sulphate reduction technology for the removal of metals, especially zinc and other metals that react with aqueous sulphide. The goal is ultimately to promote bioreactor cell treatment as a viable long-term treatment alternative for mines in the district with suitable water characteristics as well as the Galkeno 900 adit

Facts/Description of Study:

The bioreactor solid phase substrate is comprised of coarse rock collected from a nearby placer mining operation. Baffles have been constructed within the cell to direct flow in a sinuous manner through the bioreactor. The first few months of operation involved a growth phase for naturally-occurring sulphate-reducing bacteria (SRB) to colonize the surface of the gravels, in time forming a microbial coating. An organic growth substrate comprised of dissolved organic carbon forms (sugars, alcohols, complex carbohydrates and proteins from milk) is used to promote this colonization. The organic substrate supports microbial growth until sulfate reduction is the predominant microbial activity in the reactor, and then to support microbial sulfate reduction, which is a microbial reaction that transfers electrons from organic carbon, causing sulfate to be reduced to sulfide. Sulfide reacts with many dissolved metals, forming highly insoluble precipitates, which are filtered by the gravels within the cell. The reactor also has the potential for other reactions to occur as a result of alkalinity being formed from the oxidation of organic carbon, and it is common to observe carbonate mineral formation within the reactor

Results/Conclusions:

The minimum goal of 0.5 mg/L zinc was consistently achieved with one exception, during the period of the pump failure. Other metals were also consistently improved with the exception of a short period when reduction onset occurred when some metals were released with the reductive dissolution of iron and manganese.

Hydraulic residence times associated with the 0.5l/s flow rate (9 to 21 days hydraulic residence time) were sufficient to consistently achieve treatment goals. Hydraulic residence times associated with the 1.0l/s flow rate (4.5 to 10.5 days hydraulic residence time) may have been sufficient to achieve treatment goals, with the pump failure being the source of uncertainty in this assessment.

When continuous flow was maintained to the bioreactor at acceptable flow rates, effective treatment was maintained. At higher flow rates the transformation of metals from their dissolved forms to an insoluble form was accomplished, but the filtration efficiency of the coarse rock in the bioreactor did not filter the insoluble precipitates effectively. Full scale application of the sulphate reduction bioreactor technology appears feasible if slight design modifications are made to ensure gravity flow from the adit, avoidance of siphoning due to freezing, and improved sizing of the bioreactor media.

Deliverables:

Final Report: Galkeno 900 Sulphate-Reducing Bioreactor 2008-2011 Operations Final Report (AEG 2012)

19. NATURAL ATTENUATION SUMMARY

Date:

2009 - 2012

Performed By:

Interralogic, INC.

Introduction:

The Natural Attenuation Project is a multi-disciplinary, multi-year scientific study that has been developed and implemented to support the Elsa Reclamation and Development Company (ERDC) closure obligations at the Keno Hill Silver District (KHSD) near Elsa, Yukon Territory.

Objective:

The purpose of the Natural Attenuation Project is to evaluate the technical suitability of a managed natural attenuation approach as a closure option, or as part of a closure option, for the No Cash Creek mines, Husky SW, Sadie Ladue, and Silver King adit discharges.

Facts/Description of Study:

The natural attenuation evaluation was conducted through the following iterative/phased approach:

- Evaluation of available historical water quality data for the target sites.
- Development and execution of initial phase of field and laboratory activities.
- Interpretation of data and presentation of results and conclusions to team members.
- Incorporation of team input to develop the next season's field and laboratory activities.
- Report development to inform the closure options process.

The technical goal was to understand:

- the nature of the natural attenuation mechanisms,
- its seasonality,
- if there were any environmental constraints or limitations,
- the sustainability of the processes; and
- its reliability as part of a potential closure option for the target areas.

Results/Conclusions:

Husky SW

Natural attenuation appears to be a viable closure option for the Husky SW system:

- The Husky SW source term is fairly consistent over the period of record.
- Zinc mass loading is significantly (over two orders of magnitude) lower than that observed at the No Cash 500 adit discharge.
- Natural attenuation of zinc and other metals has been shown to be effectively removing these constituents from the flow path.
- Biogeochemical conditions at Husky SW are very similar to those at NCC, which have resulted in attenuation mechanisms which are likely occurring at this location.

- The cascading reach and a terminal pond area are not present at this location resulting in less aeration of the discharge, and a receiving environment (Flat Creek) that can be monitored.

Sadie Ladue

Baseline study and technical evaluations indicate the following conclusions:

- Natural attenuation of zinc and other metals may be occurring along the Sadie Ladue drainage, the un-named lake and further downgradient; however, results of attenuation are currently being masked by sources related to dispersed tailings and inflows of potentially impacted water from tributaries.
- Complexities related to on- and off-claim issues, as well as the significant amount of dispersed tailings along the creek and in the un-named lake, make it unlikely that this area would be a good candidate for natural attenuation at this time.
- Hydrologic conditions are well suited to natural attenuation with the multiple cascading reaches present along the creek.
- Biogeochemical conditions are uncertain with respect to natural attenuation due to the relatively low manganese in adit discharge compared to those on Galena Hill.

Silver King

Natural attenuation appears to be a viable closure option for the Silver King/Galena Creek system. Baseline study and technical evaluations indicate the following conclusions:

- The Silver King 100 source term is fairly consistent over the period of record.
- Zinc mass loading is significantly (about 1 order of magnitude) lower than that observed at the No Cash 500 adit discharge.
- Biogeochemical conditions at Silver King are very similar to those at Husky SW and NCC, which have resulted in attenuation mechanisms that would also work at this location.
- The cascading reach and a terminal pond area are not present at this location resulting in less aeration of the discharge, and a receiving environment (Flat Creek) that can be monitored.
- Detailed design, informed by additional site-specific evaluation, would be conducted to address the site-specific conditions.

No Cash Creek

Natural attenuation appears to be a viable closure option for the NCC system. Baseline study and technical evaluations indicate the following conclusions:

- The NCC zinc source term is fairly consistent with gradually decreasing metals concentrations typical of the evolution of historical mine workings which have flooded.
- Natural attenuation of zinc and other metals of concern has been shown to be consistently effective over the complete history (approximately 30 years) of observations along NCC.
- Biogeochemical mechanisms of attenuation are well characterized and understood; zinc attenuation relies predominantly on aeration and co-precipitation with manganese and these mechanisms are reliable and sustainable. Additional, "polishing" reactions occur in the bog related to sulfate reduction and metal-sulfide precipitation.

- The transformation of metals into a stable sediment apparently results in low risk to the receiving environment including water, plants, animals, and humans. This will be verified by appropriate ongoing monitoring.
- Reclamation of existing sources such as dispersed tailings, waste rock and adits, combined with engineered enhancements will provide additional reduction in mass loading and improved system performance.
- Monitoring and adaptive management will provide flexibility to address potential changes in the natural or man-made components of the natural attenuation system.

Deliverables:

Draft: Natural Attenuation Evaluation United Keno Hill Mines Elsa, YT (Interratlogic 2012)

VALLEY TAILINGS STUDIES

The Valley Tailings Area (VTA) has long been a significant source of contamination to the receiving environment of the Flat Creek drainage.

20. VALLEY TAILINGS GEOTECHNICAL CLOSURE STUDY

Date:

October 2007

Performed By:

SRK Consulting

Introduction:

The summary outlines the section of the geotechnical closure studies conducted by SRK that pertains to the Valley Tailings Area.

Objective:

To develop an understanding of the foundation conditions under VTF Dams #1, #2 and #3 for use in determining the long-term dam stability. Monitor physical hydrogeology, geochemistry and temperature at a number of common locations along the dams.

To develop an understanding of the current conditions at selected waste rock piles so that closure measures can be developed on a pile-by-pile basis. Assess the geotechnical suitability and realistic reclamation outcomes for the re-sloped footprint of select piles.

Facts/Description of Study:

- A field study was conducted at the VTA to help assess the first objective:

  a. Six boreholes were drilled at the crests of Dams #1, #2 and #3 to log soil stratigraphy, depth to bedrock, geotechnical conditions and permafrost extent and monitor groundwater flow and thermal regime

  b. Boreholes were drilled within the tailings impoundments behind Dams #1 and #3 to determine the extent of tailings, overburden, permafrost, bedrock depth and lithology, to collect soils for soils characterization, and to monitor water levels and groundwater chemistry

  c. Other boreholes were completed to monitor water chemistry and levels, background characteristics, and groundwater down gradient of the VTF

- Additional information on dam performance was gathered from the following information repositories:

  a. 2007 seismic hazard calculation

  b. 2007 VTA dam classification

  c. Review of historical records

  d. 1996 flood frequency analysis

e. Review of the stability analysis completed by EBA in 1982

- Waste rock sites were inspected and assessed via the following:

  a. A review of the historical stability of the waste rock piles

  b. Water management considerations, including assessment of running surface waters that could pose a risk of future undercutting and instability

  c. An assessment of the state of deterioration of wooden support structures

  d. Resloping considerations

<u>Information Gaps:</u>

A desktop study to evaluate the stability of selected crown pillars was to be conducted based on a review of operational records of the shallow stopes at the major mines. However, the records consist of a digital library of tens of thousands of unsorted data files which through considerable effort was not able to produce more information on crown pillar stability.

<u>Results/Conclusions:</u>

Valley Tailings Foundation Conditions

- The VTF dams are currently under static loading conditions, but it is unclear whether their respective safety factors meet appropriate values for closure

- The parameters used in the stability analysis completed for static loading conditions in 1982 are believed to be reasonable and can be used in future analysis to assess their current and post-closure stability

- These same parameters, coupled with the recent seismic hazard information, can be used for pseudo-static analyses to evaluate the stability of the dams under seismic loading assuming that the foundation layers will not liquefy

- At some point prior to final closure design, the assumption that the foundation stratum immediately below the peat at each of the permanently installed dams will not liquefy in response to the design earthquake should be checked with a geotechnical drilling program that will obtain suitable relative density data using Standard Percussion Tests or other suitable methods

Waste Rock Pile Closure Options

- A decision matrix has been developed for Keno Hill waste rock piles to provide a framework for stakeholders to assess the requirements for closure (**Error! Reference source not found.**)

- Waste rock closure options are currently in the process of being established; for most waste rock dumps this will mean resloping either with or without vegetative cover

- Also included in the example decision matrix are a number of considerations for implementation of a closure measure for a given waste rock pile. For example, one closure option might be to reslope the waste rock. A consideration in this case might be the additional land that would be covered during the resloping exercise. Stakeholders may wish to consider weighing the benefits of resloping against covering the additional footprint area with waste rock

21. Valley Tailings Groundwater Sampling Program

Date:

Summer 2006

Performed By:

ACG

Objective:

To intersect and sample groundwater flowing through the Valley Tailings

Facts/Description of Study:

- Two piezometers were placed upstream and two downstream of the observed linear vegetation feature west of Valley Tailings Pond #1
- Potential Sampling locations were surveyed by walking the entire length of the vegetation feature. Low-lying areas and indications of water neat the surface were surveyed.
- Potential install locations were selected by driving a piezometer to test for the presence of water.
- Where water was found, it was tested to determine whether it was flowing or stagnant. If found to be flowing, a piezometer was installed

Results/Conclusions:

- Groundwater samples are successfully retrieved from the installed piezometers and are stored in a groundwater quality database. These data contribute to the understanding of groundwater chemistry influenced by the valley tailings area.

22. Valley Tailings Groundwater Mass Loading and Contaminant Mass Balance Report

Performed By:

Alexco Resource Corp.

Objective:

To provide baseline conditions about the quantity, source and transport of contaminants within the Valley Tailings Area drainage prior to the implementation of closure measures, with special emphasis on the impact of groundwater contamination.

Facts/Description of the Study:

- The report derives water and mass balances for nodes within and around the tailings via an estimation of contamination and flow
- The study involved two phases; first, a field program was carried out to collect groundwater samples from the Valley Tailings area using drive-point piezometers. Second, the surface water quality database for the site was investigated together with the flow regime of the Valley Tailings Area
- During the first phase, drive-point piezometers were installed in the Valley Tailings and nearby areas and water samples collected for contaminant analysis. Tubing was installed to allow future access to the wells and a cap placed atop to prevent contamination
- In the second phase, the water quality database was examined together with estimated flow to derive an estimate of contaminant load produced by surface water travelling through the Valley Tailings Area and Flat Creek watershed.
- The second phase was also used to determine an estimate of the groundwater and contamination flux from the Valley Tailings into the Flat Creek watershed based on observed chemical loads in the area.
- Data from these two phases were analyzed in context with each other to determine the magnitude of potential loading from groundwater contamination in and around the Valley Tailings Area.

Results/Conclusions:

Outcomes of this study are:

- Waters passing through the Flat and Porcupine Creek basins accumulate significant loadings of dissolved salts, dissolved zinc, and other soluble contaminants
- Sulphate, arsenic and zinc are all mobile in the saturated tailings and transmit between the tailings interface beneath and down gradient from the Valley Tailings.
- Significant flows of water transmit at the interface between the tailings and the surface of the original terrain.

- Thus, it can be concluded that the Valley Tailings are a source of contaminant loading to the South McQuesten River Valley.
- There is a new understanding that groundwater seepage from the tailings represent a significant load, which is potentially far greater than the surface loading posed by decant discharges.

A number of recommendations were made following the results of this study. Because of the potential for zones of high variability around and beneath the tailings, it was suggested that a systematic study be carried out along given transects to better understand the spatial distribution of organic levels, metals/sulphate contamination and groundwater flow velocities. This would provide a baseline for measuring the effectiveness of various cover systems, and may help determine how closure strategies could be used to enhance natural processes to reduce groundwater loading.

Deliverables:

Final Report: Valley Tailings Groundwater Mass Loading and Contaminant Mass Balance Report.

23. Assessment of Groundwater Regime at the Valley Tailings Facility

Date:

Summer 2007 – February 2008

Performed By:

SRK Consulting

Objective:

To develop an understanding of the physical hydrogeology of the Valley Tailings Facility to enable an estimation of groundwater flux through the facility to be derived. This flux will be used to estimate current contaminant loadings from the VTA into the receiving environment.

Facts/Description of Study:

- To achieve the above objectives, the following broad measures were taken:

  a. Review all available data

  b. Conduct a geotechnical percussion drilling program to provide information on the unconsolidated materials at the site

  c. Develop a conceptual hydrogeological model for the site

  d. Calculate groundwater flux

- Available data reviewed for the study included previous reports, memos and drill logs, grain size analysis data from boreholes, aerial photography and EBA reports

- Results of the drill program and conceptual model were used to estimate the hydraulic characteristics of the unconsolidated materials beneath the tailings and the dams

Information Gaps:

Percussion drilling creates a grain size bias towards coarse soil fractions as a result of fines being flushed with water or circulating air. This can impact on the interpretation of grain size analysis results which are used to estimate hydraulic conductivity. Thus, hydraulic conductivity was derived using low estimations of grain size.

Results/Conclusions:

- A net flux of $18m^3$/day was estimated to leave the VTF via groundwater flow beneath Dam 3

- The flux was estimated using data not collected under ideal conditions. Because the flux is sensitive to changes in hydraulic conductivity, further information should be gathered to increase the hydrogeological understanding, including:

  a. Refinement of the site water balance to allow better estimates of the seepage loss from the Porcupine Diversion

b. Slug testing in the existing well to attempt to derive a better estimate of hydraulic conductivity in the overburden beneath the VTF

- There is little evidence to support the idea that Zn is being carried into deep seated water beneath the tailings (see 2007/08 Geochemical Studies: Tailings Geochemical Assessment)

24. Tailings Geochemical Assessment

Date:

Summer 2007 – February 2009

Performed By:

SRK

Objective:

To better understand in-situ tailings weathering conditions at the Valley Tailings Facility (VTF).

Facts/Description of Study:

- To support the evaluation of closure options, a work plan was developed to answer the following questions:
  - What is the current metal loading from the VTF?
  - What is the widespread potential for order-of-magnitude increases in metal loading rates due to widespread and significant decreases in tailings pH?
- To tackle the questions listed above, test pits were excavated in May 2007, from which tailings horizons were logged and water chemistry was obtained. Water chemistry in the pits was considered an approximation of tailings pore water chemistry immediately adjacent.
- Shallow drive points were installed to measure water quality in July and August of 2007
- Paired sets of test wells were installed in October 2007. Samples continue to be collected and tested for water quality.

Results/Conclusions:

- Current contaminant loading exiting the VTF occurs through both surface water and groundwater pathways. These pathways report to the west of Dam #3 and to the Porcupine Diversion
- Portions of Porcupine Creek, Brefault Creek, and the Porcupine Diversion traverse exposed tailings, and contribute most of the chemical load to the Porcupine Diversion and Flat Creek

  Current Contaminant Loading

  - The average contained zinc mass of 21kg/m2 is in the range of attenuation capacity of 2 to 3 metres of peat by sorption processes alone (this is equal to the amount of peat observed in borehole profiles)
  - Complete leaching of all contained zinc from the tailings is highly unlikely, in part due to the fact that much of the tailings is saturated and thus not available for oxidation

- There appears to be sufficient capacity within the underlying peat to attenuate all the zinc contained within the tailings (should it be released) by sorption alone. It is however, unlikely, that 100% of the zinc will be leached out of all the tailings

Potential for Increased Metal Loading due to Acid Generation

- The implications of the mineralogical findings for future contaminant loadings from the VTF as a whole are that widespread, highly acidic (pH<4) conditions are not expected to develop, and no significant remobilization of sorbed zinc is anticipated
- Current contaminant loadings can be considered to provide a good indication of the magnitude of future loadings

25. VALLEY TAILINGS FACILITY GEOCHEMICAL SUMMARY

Date:

2012

Performed By:

Interralogic

Objective:

To describe the geochemical characteristics of tailings, soil, and groundwater encountered during the geotechnical drilling operation at the Valley Tailings Pond conducted in May 2011.

Facts/Description of Study:

- Soil and groundwater samples were collected during geotechnical drilling operations on the existing Valley Tailing ponds in May 2011.
- Drilling was conducted in all three tailings ponds to establish thickness of the tailings and soil characteristics. Concurrent with the geotechnical program, soil samples were collected for analysis by acid-base accounting (ABA) analysis and trace metal concentration (ICP/MS).
- Groundwater grab samples were collected from three of the borings and metals analysis was conducted on the samples.

Results/Conclusions:

- Tailings samples had circumneutral pH, low TOC and elevated concentrations of total sulphur. Typically zinc, lead and manganese concentrations were elevated and often approaching or exceeding detection limits (>10,000 ppm or 1 Wt%). Cadmium concentrations were elevated but typically an order of magnitude or two lower than the other metals.
- Generally, the concentration of metals decreased sharply at the contact with the peat layers that were rich in TOC. This is likely due to the accumulation of metal at this interface where metals are dissolved in the tailings and migrate downward with infiltrating water (precipitation and/or melt water). When the metals-rich water encounters the peat, sorption onto carbon and/or reductive precipitation of metal sulphides occur.
- The sharp decrease with metal concentration is accompanied by a decrease in pH (between 4.8 and 6.2) and total sulphur, and an increase in TOC (corresponding to the peat material). Where till is observed, TOC decreases and pH rises to more neutral values. All of the borehole profiles exhibited similar behavior as described above.
- Total metals concentrations were elevated; however, dissolved metals were fairly low except for manganese which was high in all piezometers.
- Despite the effects of potential mixing of tailings pore water with the underlying groundwater, dissolved concentrations of zinc and other metals are quite low. Because groundwater pH values are neutral and metals are low relative to soil values it is speculated that higher metals in soil represent precipitated solids that are not currently mobile.

26. VALLEY TAILINGS REPROCESSING ASSESSMENT

Date:

June 2009

Performed By:

Elsa Reclamation Development Company

Introduction:

Between 1920 and 1989, approximately 4.6 million tons of tailings were deposited in the Elsa Tailings Facility in the upper Flat Creek valley, encompassing an area of roughly 130ha. Under final closure of the tailings, consolidation and movement are likely to be carried out to some degree. As such, investigating a reprocessing scenario associated with final closure is logical and prudent in that it offers the potential to offset closure costs and create a reduced footprint for final covering.

Objective:

To offer a scoping level assessment of the potential economics of reprocessing silver from the Elsa Valley Tailings using conventional techniques.

Facts/Description of Study:

- Previous assessments were studied in detail to extract historical information about the original placement of the tailings and their estimated volume and grade. This information was used for comparison to the recent work that has been carried out at the Valley Tailings with respect to the economic potential of the tailings.

- As a part of the Valley Tailings Closure Study (see following study), 19 test pits were excavated throughout the Valley Tailings in 2007 to collect geochemical information.

- The results of investigating historical work were compared with and combined with the results of the recent work done by SRK in 2007 and equivocated to produce a reasonable assessment of the economics of reprocessing the Valley Tailings.

Results/Conclusions:

- Results of the recent work carried out in 2007 confirm the findings of previous studies.

- Reprocessing the Valley Tailings is an economically feasible option.

- There is a significant quantity of silver in the tailings, with the addition of an appreciable amount of manganese and gold.

27. Valley Tailings Closure Options

Date:

June 2009

Performed By:

SRK Consulting

Introduction:

Elsa Reclamation and Development Company Ltd. (ERDC) is in the process of preparing a closure plan for the various components of the former United Keno Hill Mine (UKHM) property in the Yukon. In 2007/08 SRK reviewed the geochemical stability, local hydrogeological and geotechnical conditions of the Valley Tailings Facility (VTF) as part of the closure studies (SRK 2008a, 2008b, 2009a). The results of these investigations showed the main issues that require consideration in selection of a closure option for the VTF are:

- Prevention of wind dispersion of tailings and erosion of tailings by surface runoff; and
- Management of surface water through and/or around the VTF

Objective:

The objective of this study is to conduct and use a closure options analysis to support the selection of the preferred closure option for the VTF

Facts/Description of Study:

The following areas were investigated here through previous studies to determine closure options that would be best suited to the VTF:

- The quantities and volumes were estimated used for costing of closure options were estimated based on the results of prior field investigations by Alexco, BGC, and SRK.
- The results from the SRK's previous field investigations were combined with Alexco's Soils Characterization and Drilling Report to develop a computer generated model in GEMS© that was used to estimate the volume of cover material within the Potential Borrow Area.
- Addition of lime during tailings relocation is an appropriate way to minimize short term metal release from existing pore water and stored salts. Testing was conducted to develop site specific lime demands for the VTF tailings as a part of the 2008 VTF site investigation.

Results/Conclusions:

Two broad options that meet the requirements for closure of the VTF have been identified. The first option (Option 1) consists of leaving the tailings in place and constructing a soil cover over the tailings. There are two variants, to Option 1 that define how surface water in and around the VTF will be managed. The second option (Option 2) consists of relocating the older thin tailings located behind Dams #2 and #3 as well as along the south east quadrant of the VTF to behind Dam #1.

Option 1A: Cover in Place

Option 1B: Cover in Place with Spillway

Option 2: Partial Relocation

Deliverables:

Final Report: 2009 Valley Tailings Facility Closure Options

OTHER TAILINGS STUDIES

28. MACKENO AND WERNECKE TAILINGS ASSESSMENT

Date:

Sept 30 – Oct 1, 2008

Performed By:

ACG

Objective

To conduct an investigation at both tailings sites to characterize the tailings in terms of geochemical and physical stability, and potential effect to the environment and to identify and develop remedial and closure options.

Facts/Description of Study:

- Three main tasks were carried out in order to complete this study:
  - Historic data review
  - Site inspection
  - Closure option development
- The data review covered the Keno Valley/Dublin Gulch Environmental Baseline Assessment and Baseline Environmental Report United Keno Hill Mines Property
- The site inspection involved the excavation of test pits at both Wernecke and Mackeno. The sites of these pits were sampled and tests run for ICP metals, Acid Base Accounting (ABA), metal leaching and fire assay.
- Physiographic parameters were investigated and recorded at each site including, stratigraphy, groundwater and field screening pH
- Tailings volumes were assessed for closure option development based on estimated spatial extent and thickness of tailings

Results/Conclusions:

Site Inspection

- Volume estimates: Mackeno: 4,689m^3 with additional tailings to the north of the main deposit; Wernecke: 1,159m^3 with additional tailings downslope and at the unnamed lake.
- ICP metals showed exceedences in Contaminated Sites Regulations in all test pits at both Wernecke and Mackeno, indicating that the impact of the tailings to the receiving environment and aquatic

life may be considerable. The work Minnow is conducting with respect to the LTAMP will recognize the effects from the Mackeno Tailings for the Christal Creek drainage.

- At the Wernecke site, ABA results showed that there is potential for acid-generation in the tailings, and more work is required to better understand acid-generation at this site, particularly because the tailings exist over a larger geographic extent (the tailings have migrated downslope and all the way to an unnamed lake). The Mackeno tailings have real acid generation potential and may be causing detrimental effects to the receiving environment as a result of acid generation.
- Stream sediment quality in Christal Creek at KV-6 (only 150m downstream of the Mackeno Tailings) is degraded, which can almost certainly be attributed to the impact of the Mackeno Tailings upstream of this site.
- Water quality at Christal Creek at KV-6 shows the highest levels of dissolved metals in the creek, also likely attributable to the impact of the Mackeno Tailings

Closure Options

- It would be economically feasible to reprocess the tailings at Wernecke and Mackeno, but only in conjunction with reprocessing of the Elsa Tailings. This will be considered as part of a potential "relocation" scenario for these tailings facilities if the tailings at Elsa are reprocessed.
- Relocation: Tailings would be excavated, placed in haul trucks and taken to the Valley Tailings Area at Elsa. The excavations would be filled with inert soil, resloped and revegetated.
- Stabilization and Cover: Stabilize the tailings areas to prevent erosion, and cover to prevent infiltration of runoff.

<u>Deliverables:</u>

Final Report: Mackeno and Wernecke Tailings Assessment

29. DISPERSED TAILINGS

Date:

2012

Performed By:

Interralogic

Introduction:

Three areas in the Keno Hill Silver District contain mine tailings material that has been reworked and distributed downstream of the original deposit area; the dispersed tailings in Flat Creek downstream of the Valley Tailings Facility, those downstream of the Mackeno tailings in Christal Creek, and those downstream of the Wernecke tailings in the Sadie Ladue Creek on Keno Hill. This report describes results of area surveys of the Flat Creek and Wernecke dispersed tailings, including analytical results. The Mackeno tailings survey was snowed out due to late season scheduling so the proposed detailed field survey of Christal Creek was not completed.

Objective:

- To characterize the distribution, stability, and leaching potential of tailings that have been dispersed in the surface water drainages downstream of the primary tailings deposits; and
- To develop conceptual closure options in case it is determined that mitigation of the dispersed tailings is necessary.

Facts/Description of Study:

Flat Creek

The dispersed tailings program in Flat Creek included:

- assess the location and stability of tailings that may have been deposited in the Flat Creek floodplain downstream of Dam #2;
- evaluate the potential effects of dispersed tailings on the water quality in Flat Creek; and
- delineate zones of tailings impacted areas for reclamation

An additional activity included improving the estimation of volumes and geochemistry of tailings deposited directly below Dam #3. The program consisted primarily of three main field tasks that were executed as part of the VTF field program in 2010-2011. These tasks included:

- Flat Creek synoptic water quality sampling;
- Field survey of dispersed tailings in the lower Flat Creek drainage; and
- Borehole logging and sample collection directly downstream of Dam #3

A total of 21 sites were surveyed in the Flat Creek flood plain where the presence of tailings was observed. Field indications of the presence of dispersed tailings include raised ground with little to no vegetation and metalliferrous, gray to tan, possibly iron streaked, very well graded silt or fine sand.

Water chemistry in the Flat Creek was evaluated within the framework of both shallow groundwater and surface water due to the potential of rapid exchange between these two components. Two general mechanisms are suggested that affect trends in concentrations of zinc in Flat Creek downstream of Dam #3:

- Inflow of groundwater or surface water causing either a pure dilution or, in the case of increasing concentration, addition of dissolved metals mass.
- Chemical equilibria in Flat Creek that may cause either precipitation of metals bearing minerals (natural attenuation) or weathering of additional sources of zinc including dispersed tailings

Wernecke

Three traverses perpendicular to the main drainage were planned and conducted along the drainage path at roughly equally spaced intervals. The first of these fell within the UKHM claim boundary, the other two were on non-UKHM claim land.

Investigation of the extent and depth of the tailings in all areas of the drainage were done by visual observation and manual shovel. No borings were conducted. Tailings samples were not collected from deposits on the UKHM claims.

Observations were carried out to the UKHM claim boundary, where a natural break in slope occurs and the drainage broadens to a maximum width of about 200 m. The Sadie Ladue 600 level adit and immediate drainage area was also observed; the slope west of the road between the Sadie Ladue 600 and the Wernecke camp is covered with a significant, singular deposit of tailings material of unknown depth. The tails are reported to have been deposited directly on the slope or allowed to overflow from the impoundment structure.

Results/Conclusions:

Flat Creek

Tailings were historically eroded and redistributed to a great extent in the Flat Creek floodplain. Laboratory analysis confirms the presence of tailings at DVT-17 which is located more than 3 km downstream from Dam #3. Visual field identification suggests large areas of dispersed tailings as far as 4.5 km downstream from Dam #3. The presence of a thin layer of dispersed tailings at location DTB-10, elevated approximately 50 cm above the lower floodplain, further suggests the wide distribution of dispersed tailings in the Flat Creek floodplain during high-flow events.

Wernecke

The Sadie Ladue drainage and Wernecke tailings site is more complex from a closure standpoint than others in the District, arising from its location, crossing over both UKHM and privately-held claims. The majority of the tailings from the Wernecke mill have settled at the bottom of the drainage in the unnamed lake.

The tailings dispersion has occurred along the full length of the Sadie Ladue drainage, with large deposits noted immediately below the impoundment and at the base of the drainage where the shallow slope brings low erosional energy and an increase in sediment deposition. The dispersed tailings occur with decreasing depth and extent in steeper areas with higher erosional energy. The total volume of tailings is not known, nor could it be estimated, due to the highly variable extent of deposition and natural vegetative cover.

Deliverables:

Dispersed Tailings and Drainage Studies United Keno Hill Mines, Yukon (Interralogic 2012)

30. Wernecke Off-Claim Tailings Assessment

Date:

September – November, 2013

Performed By:

ACG/Interralogic

Objective:

Identify the presence of dispersed tailings along Sadie Ladue Creek, in Wernecke Lake, Ladue Creek between Wernecke and Gambler Lakes, and in Gambler Lake.

Facts/Description of Study:

A series of transects were sampled over the lower portion of Sadie Ladue Creek, and across Wernecke Lake from the tailings delta to the opposite shore. Water samples and flow measurements were collected in Sadie Ladue and Ladue Creeks, Gambler Gulch and in Wernecke and Gambler Lakes. Bathymetric measurements were made in Wernecke Lake, and a staff gauge was also installed.

The soil samples were evaluated for metals and total organic carbon, with a selected set also sampled for leachability and acid base accounting. Water samples were analyzed for dissolved and total metals and carbon, as well as general solute chemistry. The data were evaluated to characterize the distribution, and to determine the physical and geochemical stability of dispersed tailings beyond the UKHM claim boundary and to develop conceptual closure options.

Results/Conclusions:

The following summarizes the findings of the various investigation tasks:

- Tailings were identified within seven tailings pods delineated along the Sadie Ladue drainage, within the active stream channel of Sadie Ladue creek, and within the tailings delta and sediments of Wernecke Lake;
- Early pioneering plant species are colonizing outward from the edge of undisturbed areas into the tailings delta at Wernecke Lake and tailings pods within the Sadie Ladue creek stream channel and confined flood plain;
- ICP trace metals results for tailings sampling showed that for all of the elements for which CCME Sediment Quality Guidelines for the protection of freshwater aquatic life exist (As, Cd, Cu, Pb, Hg, Zn), at least 72% of samples exceeded the guideline;
- COPC metals were elevated within the Ladue Creek stream channel (and tailings pods) and in the tailings delta where tailings were known and expected.
- COPC metal concentrations within tailings sediments throughout Wernecke Lake were generally similar to samples collected in tailings delta and pods within Sadie Ladue Creek;

- Despite the presence of elevated levels of zinc and cadmium in Wernecke Lake, zinc and cadmium attenuation and/or dilution appears to occur from the Sadie Ladue adit to the outlet of Gambler Lake;

- The total estimated volume of tailings determined from this investigation ranges from 191,880 to 217,935 m3 with an average of 204,908 m3. Including the upslope tailings impoundment the total estimated volume of tailings would be 206,078 m3 on average; and

Considerations for closure include:

- Tailings pods and the tailings delta in Wernecke Lake have partially revegetated naturally and stabilized over the last 80 years.

- The small pods of tailings down near Wernecke Lake are sufficiently small as to have only limited impact to water quality and likely would require limited reclamation that could be accomplished with small or portable equipment, whereas the upper pods (6 and 7) may require a more aggressive reclamation effort with access for larger trucks/equipment; and

- A key consideration of reclaiming the tailings pods and delta will be the trade-off between financial and environmental cost of additional disturbance of ground (i.e., from road construction, borrow pits, and new facilities) and the short and long-term benefit of various aggressiveness levels of reclamation.

<u>Information Gaps:</u>

Further investigation that could provide additional needed context to closure options for the Wernecke dispersed tailings include:

- Observations of seasonal fluctuations of Wernecke Lake to determine the importance of Sadie Ladue creek to lake level; Winter lake ice measurements on Wernecke Lake to determine is the lake freezes to the bottom in winter;

- Summer fish surveys in the Ladue drainage to determine if the watershed provides critical habitat to any fish species;

- Collections of seeds of pioneer species present on the tailings delta;

- Higher resolution surveying of the tailings materials to get a better estimate of volumes of tailings pods and the delta;

- Sampling of the Wernecke Lake bottom material to determine the thickness and extent of burial of tailings in the lake bottom sediments; and

- Additional flow measurements at the entrance to Wernecke Lake and along Ladue Creek and Gambler Gulch.

<u>Deliverables</u>

Final Report: Wernecke Dispersed Tailings [Off Claim] (ACG 2013)

WASTE ROCK STUDIES

31. WASTE ROCK GEOTECHNICAL CLOSURE STUDY

Date:

October 2007

Performed By:

SRK Consulting

Introduction:

The summary outlines the section of the geotechnical closure studies conducted by SRK that pertains to the waste rock dumps at the property.

Objective:

To develop an understanding of the foundation conditions under VTF Dams #1, #2 and #3 for use in determining the long-term dam stability. Monitor physical hydrogeology, geochemistry and temperature at a number of common locations along the dams.

To develop an understanding of the current conditions at selected waste rock piles so that closure measures can be developed on a pile-by-pile basis. Assess the geotechnical suitability and realistic reclamation outcomes for the re-sloped footprint of select piles.

Facts/Description of Study:

- A field study was conducted at the VTA to help assess the first objective:

    a. Six boreholes were drilled at the crests of Dams #1, #2 and #3 to log soil stratigraphy, depth to bedrock, geotechnical conditions and permafrost extent and monitor groundwater flow and thermal regime

    b. Boreholes were drilled within the tailings impoundments behind Dams #1 and #3 to determine the extent of tailings, overburden, permafrost, bedrock depth and lithology, to collect soils for soils characterization, and to monitor water levels and groundwater chemistry

    c. Other boreholes were completed to monitor water chemistry and levels, background characteristics, and groundwater down gradient of the VTF

- Additional information on dam performance was gathered from the following information repositories:

    a. 2007 seismic hazard calculation

    b. 2007 VTA dam classification

    c. Review of historical records

    d. 1996 flood frequency analysis

   e. Review of the stability analysis completed by EBA in 1982

- Waste rock sites were inspected and assessed via the following:

   a. A review of the historical stability of the waste rock piles

   b. Water management considerations, including assessment of running surface waters that could pose a risk of future undercutting and instability

   c. An assessment of the state of deterioration of wooden support structures

   d. Resloping considerations

Information Gaps:

A desktop study to evaluate the stability of selected crown pillars was to be conducted based on a review of operational records of the shallow stopes at the major mines. However, the records consist of a digital library of tens of thousands of unsorted data files which through considerable effort was not able to produce more information on crown pillar stability.

Results/Conclusions:

Valley Tailings Foundation Conditions

- The VTF dams are currently under static loading conditions, but it is unclear whether their respective safety factors meet appropriate values for closure
- The parameters used in the stability analysis completed for static loading conditions in 1982 are believed to be reasonable and can be used in future analysis to assess their current and post-closure stability
- These same parameters, coupled with the recent seismic hazard information, can be used for pseudo-static analyses to evaluate the stability of the dams under seismic loading assuming that the foundation layers will not liquefy
- At some point prior to final closure design, the assumption that the foundation stratum immediately below the peat at each of the permanently installed dams will not liquefy in response to the design earthquake should be checked with a geotechnical drilling program that will obtain suitable relative density data using Standard Percussion Tests or other suitable methods

Waste Rock Pile Closure Options

- A decision matrix has been developed for Keno Hill waste rock piles to provide a framework for stakeholders to assess the requirements for closure
- Waste rock closure options are currently in the process of being established; for most waste rock dumps this will mean resloping either with or without vegetative cover
- Also included in the example decision matrix are a number of considerations for implementation of a closure measure for a given waste rock pile. For example, one closure option might be to

reslope the waste rock. A consideration in this case might be the additional land that would be covered during the resloping exercise. Stakeholders may wish to consider weighing the benefits of resloping against covering the additional footprint area with waste rock

32. WASTE ROCK GEOCHEMICAL ASSESSMENT

Date:

October 2007 – February 2009

Performed By:

ERDC/SRK

Objective:

To characterize and assess long term geochemical stability of various waste rock piles.

Facts/Description of Study:

- Samples were collected as part of the baseline environmental assessment conducted in 1996; however, the samples were not analyzed at that time due to financial difficulties. The samples were revisited in 2007 and those deemed intact and uncompromised were sent to the lab for analytical testing
- To identify and site considerations that required consideration for each dump, a matrix was developed that consisted of the categorized dumps (by size), a suite of closure considerations, and various candidate closure options
- Acid Base Accounting (ABA) testing (total sulphur, sulphate sulphur, by both NaCL and NaCO3 leach, inorganic carbon, and Sobek NP) and elemental analysis (four acid digestion with ICP-AES finish) were carried out on the samples
- A toe seep survey was carried out

Results from the extraction tests were used to develop reasonable worst-case estimates of current chemical loading from individual waste rock piles. Worst-case loading estimates were then compared to known load sources to evaluate whether loading from waste rock piles is likely to be significant at district scale

Results/Conclusions:

- o All leach extraction tests demonstrated that the various dumps contained a store of soluble oxidation products. Any dump disturbance (e.g. for resloping or relocation purposes) will lead to a short-term increase in loading from the disturbed material. Column test results from 1996 showed and initial zinc release exceeding steady-state release by 14 to 300 times – these results provide an indication of the increases in short term loads that might be expected immediately following disturbance of waste rock
- o Results from the shake flask extraction work indicated that the largest waste rock load is likely to be generated by the Hector Adit dump. Scoping calculations carried out to provide an indication of porewater chemistry indicated that zinc concentrations could be on the order of a few hundred mg/L. For comparison, the porewater zinc concentrations suggested by the scoping calculations are of the same magnitude as concentrations observed in the Galkeno 300 adit discharge.

- The Hector Adit dump is several kilometers from the nearest downgradient receiving water (as is the case for most other dumps in the district). Based on the modest chemical loadings from the waste rock dumps relative to other sources in the district, and based on the length and attenuating nature of the downgradient flowpath to the receiving environment, it is unlikely that contaminants from the waste rock dumps pose a significant risk to water quality in the receiving streams that are the focus of reclamation across the former UKHM site.

33. ALTRUA WASTE ROCK GEOCHEMICAL ANALYSIS

Date:

January 2008

Performed By:

Altrua Environmental Consulting

Introduction:

Review static test data of 1996 Keno Hill site-wide waste rock characterization sampling that were analyzed in 2006 for standard ICP multi-elements, acid base accounting, and leachate extraction.

Objective:

Objective is to identify any geochemical parameters that are controlling or are strongly correlated with generation of net acidity and/or Zn or Pb leaching. This purpose of this review is to provide a tool to assist in prediction of ARD/ML in any future development in the Keno Hill area, and to provide a basis for field classification of potentially reactive material during excavation.

Facts/Description of Study:

This review consisted of four phases:

- Conduct general review of data and generate of statistical summaries;
- Identify reactive samples in dataset;
- Analyze data for trends and database criteria that appear to control or correlate strongly with
- Sample reactivity, and that can be used to isolate reactive samples; and
- Check of criteria against the database to determine over or under-filtering

Results/Conclusions:

- In the 47-sample leachate extraction database examined, net acidic samples are defined as those yielding a leachate pH ≤5.5. Metal leaching samples are defined as those with Zn loading ≥10 mg/kg, and/or Pb loading ≥3 mg/kg. Any sample meeting at least one of these three conditions is defined as “reactive”.
- As observed in section 7 of the 1996 Characterization Study, it is important to note that most samples were taken from adit dump waste rock pile samples, and thus tend to be comprised of material in close proximity to mineralization. Samples from open pit waste piles, comprised of a greater amount of rock further from the vein systems, are less sulphidic and show less evidence of acidity and metal solubilization.
- Of the 47 samples, 17 (36%) meet one or more of the “reactive” criteria, with 6 of the 17 being net acidic, 13 zinc-leaching, and 8 lead-leaching. The quartzite units sampled showed the highest proportion of reactive samples (46%), followed by mixed quartzite and schist (40%), and vein

(25%). Pit wall samples appear to store less soluble products, (none of the pit wall samples were reactive), likely a function of the more exposed environment relative to a waste rock dump with limited infiltration and transport of solutes.

- An average of 40% of sulphur is in the soluble form of sulphate, as indicated by an average SO4: Total S ratio of 0.4 for the 47 samples. Other elements with elevated soluble fraction are Ca, Co, Cd, Mn, and Zn (averaging 11%, 11%, 9%, 6% and 5% respectively).

- Various geochemical parameters were evaluated to identify a simple filter to best isolate the reactive samples from the non-reactive samples, using information normally available in an exploration database (eg. lithology, ICP analyses, simple field tests). While priority was given to ensuring complete isolation of the net acidic samples, it was considered that minor under-filtering of metalleaching would not be detrimental to overall drainage quality of a waste rock storage area. After several trials, the following filter criteria were identified to discriminate reactive samples in the 47- sample database:

  1. S_{via} ICP ≥ 0.25% and Ca ≤ 0.51%; or
  2. Pb ≥ 5000ppm; or
  3. Zn ≥ 5000ppm.

- When these criteria are applied to the 47-sample database, 16 of the 17 reactive samples are isolated, along with 4 non-reactive samples. 100% of the net acidic samples, 92% of the zinc-leaching samples, and 100% of the lead-leaching samples are isolated. On the other hand, 13% of the samples isolated using these criteria were actually non-reactive in the leachate extraction test, indicating that some potential ‘dilution’ by non- ARD/ML waste rock is possible if using this filter for waste rock classification.

- Similar results are obtained when substituting a Fizz Rating of <3 in place of ICP Calcium ≤ 0.51% – the reactive samples are filtered identically, however ‘dilution’ by non-reactive samples increases to 20%. Nonetheless, these results indicate Fizz Rating to be a potential screening parameter, which is of interest as a field screening tool for segregating rock during active mining.

UNDERGROUND MINE AND ADIT STUDIES

34. Adit Closure Studies

Date:

Summer 2007

Performed By:

SRK Consulting

Objective:

Build on existing risk rankings for adits and move towards a specific closure measure for each adit, in consideration of the broad range of adit conditions that exists at the site.

Facts/Description of Study:

- Each of the 70 adits at Keno Hill will require a site-specific closure measure
- Restricting public access is a requirement for all adits. Certain adits will require long-term drainage control with restricted public access, yet allow operational access. Other adits are fully collapsed and require no additional work.
- For adits which produce water, water control issues must be addressed. Where water is acceptable for direct discharge, the closure measure must allow free drainage while preventing public access. Where water requires treatment, an additional consideration of how to collect and treat the water is necessary.
- Adit closure designs fall into four categories: plugs, seals, barriers and natural collapses
- Adit plugs fill a portion of the mine shaft and are designed as permanent structures. They can be used where preventing access, controlling adit discharge, or minimizing brow collapse is necessary.
- Adit seals are any closure measure where the sole purpose is to prevent access. If rehabilitation of the adit is required later, costs can become expensive. They are not intended to control drainage, but allow free drainage.
- Adit barriers are a closure method which prevents inadvertent access by the public (such as grates or gates). They are not intended to control drainage, but allow free drainage.
- Natural collapses are where sufficient adit collapse has already produced a situation where little safety risk remains. These can be grouped into 'do nothing' closures, and 'do nothing now and inspect later' closures.

Information Gaps:

Once adit closure measures have been considered and selected, further modifications will need to be made on a site-by-site basis for the design to be implemented under different conditions.

Water treatment sites are in the process of being assessed to determine water management closure options, at which point an appropriate closure option will be selected.

Results/Conclusions:

- SRK has developed an adit closure matrix for the 70 adits at Keno Hill. Closure requirements for each adit in this study are outlined in this matrix, presented in **Error! Reference source not found.**, alongside the recommended closure option for that site.

35. MINE HYDROGEOLOGICAL MODEL

Date:

2007

Performed By:

ERDC

Objective:

To prepare a hydrogeological model for the mine site in an effort to better understand the potential future changes in mine water discharge points, quantities and quality, such as occurred at the Galkeno 300 adit in 1997. It will aim to understand the interconnectedness of the mine workings including underground workings, veins, faults, surface topography and likely flow pathways.

To prepare a geometric model of the mine workings to cover areas of environmental interest.

Facts/Description of Study:

- Models of the Silver King, Husky, Galkeno and Bellekeno mine workings with partial surfaces were produced.
- The 3-dimensional surfaces of the models were created using the 2-metre digital elevation model generated from aerial photography flown in 2006.
- These models are initial and intended for demonstrative purposes only.
- Updating of the models is ongoing. Engineering plans and sections are being digitized along with survey data to increase the accuracy of the models.

Results/Conclusions:

- Although the models are preliminary in nature, they are illustrative in terms of the relationship between various underground mine components.

REVEGETATION AND TERRESTRIAL STUDIES

36. Terrestrial Effects Assessment (Phases I, II and III)

Date:

September 2007 – March 2008

Performed By:

EDI Environmental Dynamics Inc.

Objective:

To determine if aerial dispersion of metals has occurred and, if so, determine the extent of such dispersion into the natural terrestrial ecosystem surrounding the Valley Tailings Facilities.

Facts/Description of Study:

- The study focused on lichen as they receive most of their nutrients from air and rainfall, and thus are excellent indicators of airborne contamination
- Samples were collected along 8 transects radiating outwards in cardinal directions from the centre of the Valley Tailings. Plots were established along the transects for sampling at increasing distances from the first plot
- Results were analyzed to determine if metals levels were elevated compared to Yukon background data and to control site data, and if so, the magnitude and spatial extent of the contamination
- Analysis also included a review of the comparability of the two lichen species collected

Results/Conclusions:

- There is indication of contamination of metals (As, Cd, Ag, Zn) immediately around the eastern ‘dry’ portion of the tailings facility, although to limited spatial extent, especially when compared to other Yukon sites
- The Valley Tailings may have the potential to continue to contribute metals to the surrounding terrestrial environment. To assess if this is the case, deployment of moss bags is recommended
- There may be a need to assess other components of the terrestrial ecosystem in the future

37. VALLEY TAILINGS REVEGETATION ASSESSMENT

Date:

August 2007 – January 2008

Performed By:

S.P. Withers

Objective:

To facilitate future revegetation efforts at the Valley Tailings Area of the former Keno Hill mine site

Facts\Description of Study:

- Archived reports on earlier tailings revegetation trials were reviewed
- An inventory of the state of natural revegetation occurring on the mill tailings was carried out and the vegetation types were delineated on a current aerial photograph

Results/Conclusions:

- Some notable conclusions were reached during revegetation tests carried out between 1976 and 1984

  a. The principal contributor to the inhibition of long-term plant growth on much of the tailings is the impenetrable surface that occurs when salts, primarily zinc sulphate, migrate upward through the tailings slimes

  b. The slightly acidic nature of the tailings (pH 6 – 7) produces a top layer of soil with pH between 6.7 – 6.8, which is near enough to neutral to not significantly impede plant growth

  c. Phytotoxic concentrations of Cd, Pb, Zn, Cu and Mn are found in the rooting zones of most soils on the unvegetated portion of the tailings impoundment; the high levels of extractable ions appear to be a significant impediment to the establishment of vegetation on these areas

  d. Plant development on the metalliferous tailings is restricted by very low levels of macronutrients (nitrogen, phosphorous and potassium) and high concentrations of phytotoxic metals; as such, repetitive application of nitrogen fertilizers and phosphorous is required for plant growth

- The vegetation types observed in the valley tailings during the 2007 assessment are primarily locally occurring indigenous species that have naturally colonized the tailings. Their type and extent is illustrated in **Error! Reference source not found.**

- There are large sections of barren ground in the tailings area; to resume efforts to vegetate these areas, the following are recommended:

  a. Soil samples were collected from nine test pits on the valley tailings impoundment in 2007, and in order to help characterize the current state of the impounded tailings, should be analyzed for texture, total metals, extractable ions, organic content, available nutrients, cation exchange capacity, carbon-nitrogen ratio and pH

b. A field survey of the unvegetated area of the tailings should include a series of transects with in-situ measurements of soil pH and moisture content and an examination of soil permeability

c. Experimentation with soil caps should be conducted

38. REVEGETATION TRIALS – GALENA HILL WASTE ROCK DUMPS

Date:

July 2007 – January 2008

Performed By:

S.P. Withers

Objective:

To establish effective measures for revegetating the discontinued waste rock dumps in the Elsa area

Facts/Description of Study:

- Three revegetation test sites were established on Galena Hill including two waste rock dumps and one control site
- The sites' physical characteristics were assessed prior to the test plots
- The sites were recontoured and seed and fertilizer were added

Results/Conclusions:

- The level of available nitrogen and potassium was low at the waste rock dump sites
- Available phosphorous was moderate at the Simes dump and low at the Hector dump
- A visual examination of the test plots should take place in mid-summer 2008, including an assessment of soil erosion
- Soil and vegetation samples should be taken from the test plots and analyzed for metal concentrations; soil should be texture classified and analyzed for available nutrients, pH, cation exchange capacity, carbon-nitrogen ratio and the percent of organic matter
- More fertilizer should be added in the fall 2008

39. Soil and Vegetation Metals Baseline Study

Date:

2011-present

Performed By:

ACG

Objective:

Implementation of a soil and vegetation sampling program to monitor health and function of local ecosystems and identify areas requiring phytoremediation efforts.

Facts\Description of Study:

- Review 2007 to 2010 data form several sources and integrate information, including 2011 field data, into a workable data base
- Select appropriate plant species that uptake metals and could be key vectors for metals to transfer to higher trophic levels
- Locate undisturbed sites that could be used as control sites
- Develop sampling system for Keno city to understand degree and dispersal patterns of COPCs within and around village; data will feed into HHRA report for Keno by SENES

Information Gaps:

- Expanded vegetation and soil sampling into areas not previously sampled

Results/Conclusions:

- Sampling locations included point sources, tailings impoundments and contaminated areas around and below mine WRSAs and Keno City
- Point sources contributed to down slope sites through water transport; higher levels of Zn and Cd concentrations occurred at or below stream confluences
- Tailings areas had very high levels of COPCs
- WRSA vegetation regeneration was limited, likely due to elevated and phytotoxic Zn concentrations
- Plant tissue concentrations of Cd and Zn appeared to be elevated in areas downslope from soil containing high concentrations of metals
- Study is currently in its third and final year

40. DISTURBED SITES SOILS METAL STUDY

Date:

2012-present

Performed By:

ACG

Objective:

- To characterize soil metal contents within the footprint of Keno City and Elsa, the results of which will lead to the determination of appropriate closure approaches for impacted areas.

Facts/Description of Study:

Disturbed and unvegetated sampling sites were selected in the field, by placing a numbered 100 meter square grid over an aerial map of the Elsa townsite and adjacent areas, which measured 2100m longitudinally and 1500 m latitudinally. Generally, due to the regular refusal at shallow depths of approximately 30 cm caused by gravel layers, hard ground, excessive sloughing or frozen ground, sample collection was restricted to within the upper 30 centimeters.

Site Assessment Criteria

The 2012/2013 DAWE identified that ERDC's proposed soil standards for remediation efforts were to be based on the YCSR Schedule 1 Generic Numerical Soil Industrial Standards. This standard does not contain criteria for all of the metals (elements) identified in the analytical results. Therefore, additional guidelines were selected. Where Schedule 1 Generic Numerical Soil Industrial Standards do not exist, the Schedule 2 Matrix Numerical Soil Standards for Commercial Lands (CL) guidelines were used. Standards in Schedule 2 are listed under site-specific factors ranging from environmental protection (EP) to human health protection (HH). In most cases, for this study, the guidelines for human health protection were used as they are consistent with the Human Health Risk Assessment carried out in Keno City by Senes Consulting in 2012. However, for the cases of copper and zinc, YSCR Schedule 2 environmental protection guidelines (CL) were used as a reference for comparison to the human health protection (HH) guidelines. The guidelines for human health are much higher than their corresponding environmental protection guidelines: (50,000 (HH) to 250 (EP) mg/kg and 30,000 (HH) to 150 (EP) mg/kg for copper and zinc, respectively).

Results/Conclusions:

A total of 37 samples (including 4 blind duplicates) were taken and analyzed in a laboratory to provide a basis from which to focus the 2013/2014 field program efforts on. Based on the laboratory analysis results from this coarse scale sampling event, a refined sampling event will be conducted and reported on in 2013/2014. The objective for all of these sampling events is to determination the appropriate closure recommendations for the sampled sites which are to be included as part of the final closure plan.

A better understanding of areas of high metals contamination will enable ERDC to develop a cost effective metals remediation and mitigation plan and support of the Closure Plan.

METEOROLOGICAL STUDIES

41. Meteorological Station Planning and Installation

Date:

Spring 2007 - present

Performed By:

ACG

Objective:

To install an automated meteorological station (measuring temperature, precipitation, solar radiation, wind speed and direction) and accompanying data logger on Galena Hill and tie station with existing YG snow course

Facts\Description of Study:

- ERDC purchased and installed an Onset HOBO Datalogging Weather Station on Galena Hill above the Hector Adit
- The station is equipped with the following sensors:
    a. Air temperature
    b. Relative humidity
    c. Barometric pressure
    d. Rainfall
    e. Wind speed and direction
    f. Solar radiation and,
    g. Soil temperature
- Sensors relay 15-minute average values to the logger, which records and stores readings every 15 minutes continuously
- Data is downloaded from the station monthly and is integrated into the Site Environmental Database for closure planning purposes

Results/Conclusions:

- Data is being collected on an ongoing basis for future assessment

42. METEOROLOGICAL DATA SUMMARY

Date:

2007-2013

Performed By:

ACG

Introduction:

This memo describes the meteorological data collected since 2007 at the Calumet weather station, since 2011 at the District Mill meteorological station, and since 2012 at the Valley Tailings meteorological station.

Objective:

The data collected is used to determine monthly averages for the following parameters:

- temperature
- relative humidity
- barometric pressure
- rainfall
- wind speed
- wind direction
- solar radiation (Calumet only)
- soil temperature (Calumet only
- soil water content (Valley Tailings only)

Facts/Description of Study:

Data from each of the three weather stations was recorded in various intervals by dataloggers. This data was used compile monthly averages for the parameters listed above. Snow surveys were also conducted at 10 monitoring stations in order to adequately represent the varying snow conditions and to determine the snow water equivalent (SWE).

Results/Conclusions:

Calumet Weather Station

- Monthly averages were calculated from 15-minute values recorded by the data logger.
- The station was down between April 15 and June 3, 2013.
- The wind sensor experienced occasional icing during the winter months and extended periods of zero wind speed were invalidated.
- No total precipitation gauge or snowfall conversion adaptor is installed at this time, therefore only rainfall was measured.

District Mill Meteorological Station

- Monthly averages were calculated from hourly values recorded by the data logger.

- Relative humidity readings were found to be invalid from time of commissioning until May 7, 2012, at which time the problem was corrected by sending a revised program to the datalogger.
- The wind sensor experienced occasional icing during the winter months and extended periods of zero wind speed were invalidated.
- No total precipitation gauge or snowfall conversion adaptor was installed in 2011 or 2012, therefore only rainfall was measured. A snowfall converter was installed on October 15, 2013 and will record total precipitation going forward.
- Valley Tailings Meteorological Station
- The tipping bucket can only record rainfall (not total precipitation), so little or no data can be collected during the winter months.
- The wind sensor experienced frequent icing during the winter months and extended periods of zero wind speed in combination with wind gusts of less than 1 m/s were invalidated. Similarly, extended periods with identical wind directions were also invalidated.

The logging interval was changed to 15 minutes on May 16, 2013, as this interval is sufficient for the purposes of this

SITE REMEDIATION

43. PHYSICAL HAZARDS REDUCTION PROGRAM

Date:

September 2005 – Present

Performed By:

Access Consulting Group

Introduction:

As a result of 75 years of mining in the Keno Hill District, the Keno Hill Property contains numerous health and safety hazards. Many of the hazardous sites are accessible to the public, and in some cases local literature even encourages tourists to visit these sites. As a result there is a high risk of human exposure to health and safety hazards such as open shafts and stopes, unstable pit walls, and open or partially accessible adits and buildings.

Since 2006, ERDC has been systematically working to remove these hazards in order to reduce the risk to public health and safety. Through a combination of review of documentation and local knowledge of the Property and consultation with stakeholders including INAC, GY Department of Heritage and the First Nation of Nä Cho N'yak Dun (FNNND), ERDC has been responsibly eliminating these hazards to protect the public.

The Physical Hazard Reduction Program is ongoing.

Objective:

To identify, rank and mitigate the risks associated with each site observed and documented as hazardous.

Facts/Description of Study:

- The first overall step in eliminating property hazards occurred in 2005-06, when SRK was contracted by ERDC to document baseline conditions and identify high risk sites to be remediated.
- Documented physical hazard information on the Keno Hill Property was reviewed to determine which sites required attention. The body of information included: PWGSC Environmental Baseline Assessment, the SRK Preliminary Baseline Assessment Report, the 2006 ERDC Physical Hazards Report and discussions with site caretakers and historic operators possessing historical knowledge of site operations.
- A register of physical hazards was developed and hazards were ranked according to their severity. This register is updated on an annual basis as sites are remediated.
- Work was begun in 2007 on sites which required the most immediate attention.
- Every season since 2007, additional hazards at Keno Hill have been reduced or mitigated through the Hazards reduction program. To date remediated sites and items include:
    - ✓ Coral and Wigwam

- ✓ Dixie
- ✓ Bermingham Adit and Ruby Shaft House
- ✓ No Cash 100 Adit and Brefalt Shaft House
- ✓ Hector-Calumet Pit
- ✓ Onek, Lonestar and Fisher Shaft
- ✓ Black Cap, Shepard and Lucky Queen Adits
- ✓ Lucky Queen Shaft House
- ✓ Lakeview Head Frame
- ✓ Highlander Adit
- ✓ Keno Mine Area on Keno Hill
- ✓ Keno No. 9 System
- ✓ Townsite Adit
- ✓ Sadie Ladue
- ✓ Wernecke Shaft
- ✓ Wire Hazards
- ✓ Keno 700 Area

- Prepare a final project report.

Results/Conclusions:

- o Risk registry; ongoing demolition program

Deliverables:

Risk Register and annual summary reports including details on demolishment of several buildings in Elsa as part of 2011 program.

44. HYDROCARBON CONTAMINATION

Date:

June 2008 – March 2009

Performed By:

ACG

Introduction:

From the result of 75 years of mining activity in the Keno Hill Silver District, the property contains a large volume of hydrocarbon impacted soil. Since 2000, several studies and investigations have identified potential locations that may contain hydrocarbon impacted soils in the district. These sites were identified from past practices, Underground Storage Tanks (USTs), and above ground storage tank locations, fuel and containment spills.

These potential locations that had been identified in the district containing hydrocarbon impacted soils had not been thoroughly investigated, sampled or delineated.

Objective:

The objective of the Hydrocarbon Contamination assessment was to conduct a thorough investigation of the potential hydrocarbon impacted sites that have been identified in the district. The investigation was to include detailed soil sampling to confirm the presence or absence of hydrocarbon impacts, characterize the contaminants of concern (if any) and delineate the areas impacted with hydrocarbons. The assessment also was to estimate the total volume of hydrocarbon impacted soils in the region as well as identify areas for a potential land treatment facility (LTF) in the district.

Facts/Description of Study:

In August and September/October 2008, ACG conducted hydrocarbon and LTF field assessments throughout the Keno Hill Silver District. The assessments consisted of a visual inspection and soil sampling program (which included test pitting) of all the potential hydrocarbon impacted areas identified in the previous reports as well as all any new disturbed areas that were safely accessible.

Soils were logged and field-screened for potential contamination. Based on field observations and VOC screening results, twenty three (23) soil samples were submitted for laboratory hydrocarbon analyses and eleven (11) samples were submitted for metal analyses.

Test pits were excavated to 3 m in eight potential LTF locations during the field program as part of the LTF site selection process.

Results/Conclusions:

All the objectives and assessment tasks outlined in the assessment were completed. Previous data was reviewed, complied and verified. A hydrocarbon field program was conducted and soil samples were submitted to an approved laboratory for characterization and confirmation analysis. Detailed results are presented in the Access Consulting Group March 2009 report entitled "*Elsa Reclamation and Development*

Company Keno Hill Mine Site Investigation and Improvements, Special Projects Hydrocarbon Contamination".

The volume of impacted soil in the Keno Hill Silver District is estimated to be 6,950 m^3. This includes several areas with special waste impact (30,000 ppm or higher).

Eight potential LTF locations were assessed and identified during the LTF field inspection. Five of the eight LTF locations are optimal due to the proximity of the majority of contamination within the district, including: the old Elsa school yard, the framing/carpentry yard, near bunkhouse 1 and near fuel storage areas 3 and 4 (also located within Elsa). The construction and operation of an LTF will follow guidelines as well as regulations, limitations, permits and specific considerations as prescribed by the Yukon Government (YG).

Deliverables:

A final report detailing the results of the hydrocarbon investigation was completed in March 2009 by Access Consulting Group entitled "*Elsa Reclamation and Development Company Keno Hill Mine Site Investigation and Improvements, Special Projects Hydrocarbon Contamination"*. The report characterizes the impacted areas, presents the analytical results in tables, identifies the areas investigated on figures, estimates the volume of impacted soil at each location as well as within the district and identifies potential LTF locations for future hydrocarbon remediation.

45. HAZARDOUS WASTE

Date:

June 2008 – March 2009

Performed By:

Access Consulting Group

Introduction:

Hazardous wastes include a broad range of materials such as manufacturing residues (e.g. waste acids, contaminated sludges and complex chemicals), waste pesticides, PCBs in transformer and lamp ballasts, asbestos, motor oil, and other hydrocarbon products. As part of the implementation of the closure planning at the Keno Hill property, various buildings require demolition (mill, storage areas, residences, assay lab, bunk houses). Hazardous wastes need to be identified and documented and require special handling in order to reduce adverse effects to water quality and human health from the hazardous wastes generated from the project remediation.

Objective:

The objective of the Hazardous Waste assessment was to characterize and quantify the volume of waste as well as to develop closure alternatives and recommendations for managing hazardous materials. PCB transformers, waste oil, batteries, unknown liquids and materials, lead paint siding and asbestos siding are common wastes found in the district that could be encountered during the demolition of physical hazards.

Facts\Description of Study:

Access Consulting Group conducted the hazardous waste assessment on two separate occasions. The first assessment was conducted during August 25th to August 28th, 2008. The second assessment was conducted on January 30th to February 4th 2009.

Buildings were entered and inspected for hazardous waste including any asbestos material, lead paint, chemicals, used oil, PCB ballasts, batteries, etc. Various ballasts from florescent lighting representative of each building were removed and compared to a capacitor/lamp ballast/transformer identification chart to determine if PCBs could be present.

Swabs for metal analysis were collected from dust buildup inside the buildings and paint chips were collected from sections of the buildings to confirm the presence or absence of lead paint.

Thirty-five (35) samples were submitted to a certified laboratory. Based on field observations, the following analyses were conducted:

- Twenty seven (27) samples were analyzed for asbestos types and concentrations.
- Three (3) paint samples from the fire assay office, No. 1 bunkhouse and Keno 700 bunkhouse were analyzed for lead concentrations and two of the three samples were analyzed further for lead TCLP leachate concentrations.

- The three (3) swab samples from the boiler plant, crusher and generator building within Elsa were analyzed for Total Metals using strong acid digestion.

In June 2010 Access Consulting Group submitted a Yukon Environmental and Socio-economic Assessment proposal for the demolition of 17 buildings in the village of Elsa as well as the secondary buildings at Husky and Husky SW. The decision document issued by INAC in September 2010 requested additional paint samples be collected from the buildings and tested for leachable lead and polychlorinated biphenyls (PCBs).

- Two (2) additional samples were analyzed for asbestos types and concentrations.
- Fifteen (15) paint samples were analyzed for lead and lead TCLP leachate concentrations.
- Seven (7) exterior paint samples were also analyzed for PCB concentrations.

Results/Conclusions:

All the objectives and tasks outlined in the work plan were assessed and completed. Hazardous waste including batteries, partially full drums with unknown material, asbestos, PCB lamp ballasts, lead paint and containers with unknown chemicals were identified in buildings throughout the district.

August 2008 and January/February 2009 sample results:

- Metals: Antimony, arsenic, cadmium, chromium, copper, lead, silver and zinc concentrations in all three swab samples exceeded applicable CSR standards. Molybdenum concentrations from the boiler plant sample and selenium concentrations from the mill/crusher building sample also exceeded the CSR levels.
- Lead Paint: two of the three paint samples submitted for lead analysis exceeded CSR criteria. Two samples were submitted for TCLP lead leachate and did not exceed applicable criteria.
- Asbestos: Chrysotile or Amosite asbestos fiber concentrations were identified in nineteen (19) of the twenty seven (27) samples submitted for analysis.

September 2010 sample results:

- All leachable lead and PCB concentrations in the paint samples were either below the reportable detection limit or did not exceed the applicable criteria.
- One asbestos sample collected from an overhead utilidor contained Amosite asbestos.

A WCB approved site specific demolition plan was developed outlining worker safety and the handling of hazardous materials. The plan focuses on the protection of workers, the public and the environment as well as outlines the best management practices to handle hazardous waste. Applicable permits have been obtained that identify the appropriate handling, storage and disposal of hazardous wastes.

Deliverables

A final report detailing the results of the hazardous waste investigation as well as a hazardous waste inventory was completed in March 2009 by Access Consulting Group. The report was entitled "*Elsa Reclamation and Development Company Keno Hill Mine Site Investigation and Improvements, Special Projects Hazardous Waste Assessment*".

46. Landfill Requirements

Date:

May 2008 – March 2009

Performed By:

Access Consulting Group

Introduction:

There are a number of old buildings, structures and related construction materials that are located throughout the Keno Hill Mine property that will require disposal. The property buildings and structures were inspected and waste types, volumes and non-hazardous materials were documented and reported for the Keno Hill Mine property. Wastes were divided into either *hazardous waste* or *landfill waste.* The mitigation work is different for each waste category; therefore, there were two work plans for dealing with each type of waste generated. This work plan assessed potential non-hazardous waste landfill sites and determines estimates of the types and volumes of waste to be expected during demolition.

The historic landfill on the Keno Hill Mine property near the town of Elsa was deemed "*out of commission*" and required assessment for closure options.

Objective:

The objective of this assessment was to develop estimated quantities of materials including volumes and types necessary to be land filled or handled as non hazardous or hazardous wastes during decommissioning. The identification of a suitable location for a closure landfill was also required. In addition, the old historic landfill (which is no longer in use) required assessment to determine the presence or absence of contaminants and to develop closure approaches.

Facts/Description of Study:

In August, September/October 2008 and January/February 2009, ACG conducted landfill field assessments throughout the Keno Hill Silver District. The field program consisted of a building inventory and waste volume estimation, new landfill locations assessment and an assessment of the historic Elsa dump site.

The Yukon Environment Act Solid Waste Regulations was followed with particular attention to Schedule 1 Operating Standards for Dumps. To determine the volume of waste to be buried in Elsa as well as throughout the Keno Hill Silver District, a building inventory was completed along with determining the length and width of each building to calculate the square meter of buildings. The square meters were then multiplied by 1.5, which is a bulking factor used by demolition companies to determine the volume of rubble and waste that requires disposal.

Test pits were excavated during the field program as part of the landfill site selection process. Five test pits were also excavated at the base of the Historic Elsa Dump to identify any potential leachate and/or soil contamination along the toe of the dump.

Results/Conclusions:

All the objectives and tasks outlined in the landfill work plan were assessed and completed. In conjunction with the hazardous waste assessment a building inventory and waste volume was estimated, potential landfill locations were selected and the historic Elsa dump site was assessed.

It was estimated that 43,985 m^3 of building waste is required to be buried throughout the district, including Elsa. The estimated volume of building waste to be buried within Elsa was 28,244 m^3. Hazardous waste was assessed under a separate investigation.

Potential locations based on the concentrations of the buildings requiring demolition/disposal include but not limited to: near the old Elsa school yard, near the current houses, near the bunkhouses and on the flat terraces (essentially cut/fill areas). It was estimated that 3 landfills are required in the village of Elsa and one at Keno 700.

All hydrocarbon concentrations did not exceed CSR standards from the historic Elsa dump. All samples from the toe of the dump exceeded CSR standards for arsenic, but were below the background soil concentrations. Cadmium concentrations from one at 3 m slightly exceeded the CSR criteria. The Historic Elsa dump will be decommissioned as per the YG Environment Act Regulations including *Schedule 1 Operating Standards for Dumps, Closure and Abandonment.*

Deliverables:

A final report detailing the results of the landfill investigation was completed in March 2009 by Access Consulting Group entitled "*Elsa Reclamation and Development Company Keno Hill Mine Site Investigation and Improvements, Special Projects Landfill Requirements*".

REGULATORY AND CONSULTATION

47. CLOSURE PLAN ENVIRONMENTAL ASSESSMENT

Date:

Ongoing

Performed By:

ACG

Introduction:

The Environmental Conditions Report provides a description of the regional setting for the Keno Hill Silver District with respect to the physical, biological and human environments. The descriptions provided in the report are not intended to be interpreted as baseline environmental conditions prior to the start of mining in the area a century ago. The collection of data to describe baseline environmental conditions was not a consideration during early mining development, and as such no baseline data was documented. Over the course of time the local ecosystem has changed, and in some areas adjusted or even adapted to reflect mining activities in the area. The report provides detail on the site-specific conditions in the region, and can be considered an expansion of the description of the regional environmental setting previously documented in the 1996 *Site Characterization Report* (Access Mining Consultants Ltd, 1996). It is based on environmental conditions at the time of writing.

Objective:

To provide a description of the regional setting for the Keno Hill Silver District with respect to the physical, biological and human environments prior to mine closure.

Facts/Description of Study:

This report details the major physiological aspects of the Keno Hill Mining Region, including:

- Climate (precipitation and evaporation)
- Terrestrial Resources (geology, quaternary geomorphology, physiography and soils)
- Surface Water (water quality of catchments, treatment sites and adit discharges)
- Hydrology
- Groundwater
- Aquatic Resources (fisheries, stream sediments, benthic invertebrates)
- Wildlife
- Vegetation (metals levels, revegetation trials)
- Heritage Resources

- Land Use Considerations
- Socio-Economic Conditions
- Consultation

Deliverables:

Final Report: Environmental Conditions Report Version No. 2 (April 2010)

48. ANNUAL GEOTECHNICAL ASSESSMENT

Date:

Ongoing on an annual basis

Performed By:

EBA

Objective:

The objective of the annual geotechnical investigation is to assess tailings facility dams and related structures and settling pond facilities at adit treatment sites for geotechnical, physical stability and report the findings. The facilities are routinely inspected on an annual basis by EBA Engineering Consultants Ltd.

Facts/Description of Study:

The following tasks are carried out each year as a part of the geotechnical inspections:

- Review annual inspection with EBA, YG Water Resources and INAC to identify remediate works or actions as necessary
- Review recent geotechnical inspection reports, primarily EBA report summarizing geotechnical inspections and conditions relating to Valley Tailings Area (VTA) dams and associated facilities;
- Discuss previous year's recommendations with YG Water Resources; and
- Undertake physical site inspection of VTA and associated facilities during open weather season and document inspection results.
- Review recent geotechnical inspection reports, primarily EBA report summarizing geotechnical inspections and conditions relating to water treatment settling ponds (Silver King, Galkeno 900, Galkeno 300, Sime sludge pit, Bellekeno 625);
- Discuss previous year's recommendations with YG Water Resources; and
- Undertake physical site inspection of water treatment settling ponds and associated facilities during open weather season and document inspection results.
- Compile information on the state of geotechnical structures and prepare recommendations for maintenance work to be carried out.

Results/Conclusions:

Results of the annual geotechnical assessment vary from year to year depending on the previous years' upgrades and site conditions. The results are documented each year in a report issued by EBA.

Deliverables:

Final Report: Inspection of Tailings Facility, Water Treatment Ponds and Porcupine Diversion Ditch, United Keno Hill Mines Property, Elsa, YT

49. WATER TREATMENT CAPITAL IMPROVEMENTS

Date:

November 2007 - Present

Performed By:

ERDC

Introduction:

ERDC is responsible for care and maintenance of the historic environmental conditions and liabilities within the Keno Hill Silver District, including the year-round operation of four water treatment facilities and one seasonal treatment site. Care and maintenance activities are carried out according to the terms and conditions of Water Licence QZ06-074 issued to ERDC in November 2007. There are also contractual obligations for care and maintenance within the Subsidiary Agreement between Canada and ERDC.

Objective:

Capital improvements to the treatment sites are a means of reducing overall risk and liability, both for Canada and ERDC, associated with these treatment sites.

The objectives of this water treatment capital improvements work plan include:

- Modify existing treatment facilities to consistently meet water license discharge standards;
- Reduce risk and liability for both INAC and ERDC through upgrading treatment sites for effective and consistent operation and addressing employee health and safety hazards;
- Provide operating efficiency and effectiveness that provides cost sharing reductions for both INAC and ERDC.

Facts/Description of Study:

The following tasks will be carried out during the 2010 – 2011 year to ensure continued successful operation of the existing water treatment facilities:

- Task 1 Installation of guardrails around treatment ponds at treatment facilities
- Task 2 Upgrades to the Galkeno 300 Treatment System
- Task 3 Galkeno 300 Adit Repair
- Task 4 Prepare As-Built Drawings

Capital Improvements carried out in previous years include:

- Upgrades to the Galkeno 300 Treatment Facility, including installation of a new clarifier
- Installation of a retention berm at the Sime Pit to add additional capacity
- Construction of a new pond and liner at Silver King 100 Treatment Facility

- Installation of new piping at Galkeno 300, including a pipeline to connect the sludge pond with the Sime Pit for streamlined de-sludging

Deliverables:

Activities are documented in the QZ12-057 Annual Report and will continue to be reported in renewed Water Use Licence Q12-057.

50. ONGOING CARE AND MAINTENANCE

Date:

November 2007 - Present

Performed By:

ERDC

Introduction:

On June 1, 2006, ERDC became responsible for day to day care and maintenance at the Keno Hill District through a Care and Maintenance Contract between ERDC and Yukon Government (YG). The Contract has been subsequently transferred to and managed by Indian and Northern Affairs Canada (INAC).

On November 14, 2007 ERDC was issued Water Licence QZ06-074 (WL) and gained title and ownership to the Keno Hill district. Reporting and performance obligations defined during the contract period changed due to new conditions and requirements contained in the WL. The WL and its supporting documentation describe the Care and Maintenance activities that required at the site.

Objective:

The objective of care and maintenance activities at the Keno Hill District is to minimize and/or prevent further environmental degradation caused by effluents released from various old mine areas, and to ensure the safety and security of all sites in the Keno Hill District to protect both humans and wildlife.

Description of Activities:

Care and Maintenance includes earthworks to enhance or maintain stability of mine structures, physical upgrades to the treatment facilities, replacement and repair of various site items, physical inspections to ensure safety, and any activity the aim of which is to protect the environment and provide safety and security. Water management activities are conducted in accordance with the Adaptive Management Plan (AMP), which provides measures for monitoring, reviewing, and assessing the effects if any, old mine workings are having on the environment. The focus of the AMP, and associated water management activities, is to ensure that negative trends in water quality are assessed quickly, and mitigative response be implemented immediately thereafter. If during regular sampling events it is determined that discharge from the District is out-of-compliance with licence conditions, then specific actions are taken to mitigate any out-of-compliance issues, with a primary focus on ensuring the safety of the environment.

Prevention of environmental degradation at Keno Hill is accomplished largely by the daily operation of lime-addition water treatment systems existing at Galkeno 900, Galkeno 300, Silver King 100, and Bellekeno 625 adits. The Valley Tailings Facility is also treated on an as-required basis during spring and early summer. Performance monitoring (i.e. water quality testing) is undertaken by ERDC, using on-site laboratory facilities for daily and weekly water quality analysis. Monitoring of surface and groundwater sites as well as physical conditions is completed as per WL monitoring schedules.

Deliverables:

Annual Reports as per Water Licence QZ12-057.

51. Human Health and Ecological Risk Assessments

Date:

2011-2012

Performed By:

SENES/ACG

Objectives:

A Human Health and Ecological Risk Assessment (HHERA) for exposure to Constituents of Potential Concern (COPC) at the United Keno Hill Mines, Yukon, was carried out in 2011 (SENES 2011) to support the "Reclamation Plan for the Existing State of the Mine" being developed by ERDC. New data have been collected since this time and this document updates the risk assessment using the new data. The HHERA considered humans camping on the site. A separate Human Health Risk Assessment (HHRA) has been carried out for Keno City residents (SENES 2012).

Facts/Description of Study:

The risk assessment was undertaken for the purpose of determining whether COPC concentrations in various media (soil, sediment, surface water, vegetation, fish) may have an adverse effect on humans or animals that either use, or may potentially use the site or the environment. The assessment included the following, consistent with those provided by regulatory agencies such as Health Canada and the CCME:

- problem formulation and receptor characterization;
- exposure assessment;
- hazard assessment; and
- risk characterization.

A screening process was carried out to develop a list of COPC at the United Keno Hill Mines for a detailed evaluation. Antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, uranium, vanadium zinc and zirconium were selected as COPC. The assessment was based on reasonable maximum likely exposures to these COPC.

Results/Conclusions:

The results of the assessment indicated that there are unlikely to be any adverse effects on people camping or living year round in the area. In addition, the assessment demonstrated that consumption of moose organs can potentially lead to unacceptable exposures and therefore consumption of moose kidneys and livers should only occur on an occasional basis (i.e., one time per month), which is not unexpected given that cadmium is known to accumulate in organ meat. It should be noted that there is a Health Advisory issued by Health and Social Services of the Government of Yukon with respect to organ meat consumption from Yukon wildlife in order to reduce exposure to cadmium.

Deliverables:

Updated Human Health and Ecological Risk Assessment for the United Keno Hill Mines (SENES 2012)

Human Health Risk Assessment for Residents of Keno City, Yukon (SENES 2012)

OTHER STUDIES

52. BORROW STUDY

Date:

September 16 & 17 2012

Performed By:

ACG/ERDC

Introduction:

The test pitting investigation was completed between September 16th and 17th, 2012 and focused on two previously identified potential sources of till - the area to the north of the Valley Tailings and an areas to the SSE of the 3 km3 marker on the G300 Access Road– also referred to as Hector-Calumet Road

Objective:

2012 Keno Hill supplementary borrow test pitting investigation was initiated for the purpose of identifying potential sources of cover material for use in closure design.

Facts/Description of Study:

The test pitting was completed using a CAT 325 track mounted excavator. Test pits were generally excavated to the full reach of the excavator (about 4.5 m) or until digging became too difficult due to either hard permafrost or encountering frost shattered bedrock. Test pits were logged and photographed and representative samples were collected for subsequent laboratory analysis. All test pits were backfilled upon completion.

Results/Conclusions:

The 2012 borrow investigation confirmed the presence of a large quantity of potential cover material. Additional test pitting and/or drilling will be required to verify the full volume of fill available. Any plans to exploit borrow from these areas will need to recognize both the existence of oversized cobble/boulders and the presence of frozen soils. Sorted cobbles and boulders may be suitable for incorporation as erosion protection and rip-rap.

Deliverables:

Draft Memo: 2012 Supplementary Borrow Search for Potential Revegetated Cover Materials – North Valley Tailings and Galena Hill (ACG 2013)

53. PIT STABILITY STUDY

Date:

November 2012

Performed By:

EBA Engineering

Introduction:

The pits are located at the Keno Hill and Galena Hill regions within the Keno Silver District (KHSD) in the Yukon Territory. The purpose of the berms is for both safety and/or water diversion purposes. For safety, the berms are required to minimize the potential risk to the public through inadvertent access to the steep walled and deep abandoned open pits.

Objective:

The objective to identify whether the pit walls of the abandoned open pits are stable or not to allow for the design and construction of berms around their perimeter.

Facts/Description of Study:

Review of background reports: EBA reviewed the following two reports; (i) Alexco Environmental Group report entitled, "Keno Hill Silver District Draft Closure Option Reports," dated May 11, 2011, and (ii) SRK report entitled, "Baseline Environmental Report, United Keno Hill Mines Property," dated April 2007.

Inspection of abandoned open pits: Inspection of the slopes was carried out from August 20 to 23, 2012. The assessment was made by visual means behind the crest of the pits. Direct access to the floor of the pit was limited to where field conditions allowed for safe access. The main task conducted at each pit consisted of traversing the perimeter of the pit to observe the presence of tension cracks around the pit edges, observing the rock mass geotechnical conditions of the pit walls, observing the rock structure and its potential influence of wall stability (e.g. the presence and orientation of major pervasive geological planes of weakness in the rock forming the pit walls), and observing surface water.

Engineering Analysis and Evaluation: The information obtained during the field assessment was analyzed and evaluated in order to establish the location of the berms beyond the potential area of ground that can be disturbed by the failure of the open pit walls over the long-term.

Results/Conclusions:

Conclusions are listed in a table format within the assessment. Additional recommendations are listed below:

- It is recommended that where possible the material used to construct the berm consists of unweathered rock fill. If only weathered rock fill is available, the least weathered or hardest material should be used, and the berm may need to be supplemented with appropriate surface stabilization.
- Clearly stating the risk to public safety and prohibiting public access, should be erected at appropriate locations around the berms. Signs should be high enough so they are not covered by snow.
- All entrances to the pits should be blocked.

Deliverables:

Keno Hill Abandoned Open Pits – Geotechnical Assessments for Design and Construction of Berms Around Pits Report (EBA 2012)

54. Aerial Photography and Orthophoto Development

Date:

2006

Performed By:

Aero Geometrics Ltd.

Objective

To create new colour airphotos of the UKHM properties and prepare orthorectified images for closure planning and baseline environmental assessment purposes

Facts/Description of Study:

- Fly new 1:10 000 colour aerial photographs of the UKHM district
- Produce orthophotos from aerial stereopairs

Results/Conclusions:

- o Site wide orthophotos were produced at 1: 10 000 scale. These form the base for site mapping of baseline environmental data.

ERDC

December 8th, 2009

Attention: Keno Hill Existing State of Mine Closure Risk Assessment Group

Memorandum: Keno Hill Closure Planning Risk Assessment

This memo outlines the results of the 2009 Keno Hill Closure Planning Risk Assessment. It has led to the selection of preferred closure options for further consultation. The preferred options will be used to shape the final closure plan for the Keno Hill District.

The risk assessment process was completed for eight (8) major sites at Keno Hill, and covered all closure components presently existing at the site including waste rock storage areas, pits, adits and their associated water management and the valley tailings area.

The risk assessment was recorded in a standard risk matrix which logged both the probability and severity of a potential risk, and in turn identified the resulting risk rating. These risks and their ratings are provided alongside this memo in a second file for your review as necessary. For completeness, mine site components that were not expressly addressed, but were peripherally discussed in the risk assessment have been added.

Risk identification and rating was based on the premise that each scenario was an unmitigated measure for closure. In the future, mitigative measures for each closure scenario will be identified and a residual risk assessment performed, leading to selection of a preferred closure option for each mine site component at each mine site.

Mine site areas and mine site closure components (namely, infrastructure) that were not addressed in the initial risk assessment will be addressed in a future assessment carried out by a smaller working group. Moreover, mitigation for each risk will be considered, and a residual risk assessment conducted at that time. During that process, a preferred option will be selected for each site. We will be in contact to determine who the attendees should be, and when the assessment will be carried out. We expect to schedule this assessment in late June/early July 2009.

KENO HILL EXISTING STATE OF MINE CLOSURE OPTIONS RISK ASSESSMENT

SUMMARY AND RESULTS

DECEMBER 2009

Closure Option Risk Assessment Process

A Description of the Process Leading to the Risk Results Herein

1. An area of the site is introduced and a closure option is described.

2. For each component of the option, the group is asked to identify scenarios or conditions leading to risks. Each scenario or condition is followed through to a consequence shown on the Consequence Severity matrix. For example, if a "dam failure" scenario is suggested, the group is asked to work though the subsequent chain of events, such as "tailings release leading to severe long-term contamination."

3. The group then agrees where the consequence lies on the C-S scale. In the above example, it would likely be a "Major" or "Critical" consequence in the "Environmental" category.

4. The group then assesses likelihood. It is important to understand that the likelihood in question is that of the final consequence. Again using the above example, the likelihood of a dam failure is one quantity, but the quantity we need is the likelihood of a dam failure leading to tailings release leading to a "Major" environmental consequence.

5. Other consequences of the given risk scenario or condition are then examined in the same manner. The above example would certainly also have "Consequence Costs." It would also have "Legal" and "Community/Media/Reputation" consequences.

6. The next risk scenario or condition for that option is examined in the same manner.

7. Repeat for next closure option and continue until all options are addressed.

8. Once all options are assessed, the group returns to very high risks where mitigation measures are available, and discusses the mitigation measure and its costs. This will invariably lower the risk rating, and that new risk rating is applied to the scenario.

Example Risk Matrix Results Table

Component & Option Description					
	Consequence Severity				
Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

Groupings for summary presentation of risk results

1 Risks associated with **WRSA** closure options
Risk of waste rock contamination
Risks associated with physical stability
Aesthetics

2 Risks associated with **adit closure** options
Risk of adit failure/collapse

3 Risks specific to each alternative, including cost risks
Risks of engineering and system design failures
Risks of non-catastrophic maintenance failure
Risks that biological treatment or in-mine treatment systems do not perform adequately
Risks of structural failure of diversions, pipelines, slopes, etc.
Risks of implementation costs being higher than estimated
Risks of operating, maintenance and repair costs being higher than estimated
Quality assurance/quality control risks

WRSA Closure Options Risks

WRSA Closure Option - Do Nothing

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely	2E	1E, 3R			
Possible					
Unlikely					
Very Unlikely					

Physical Stability Risks

1E	WRSA Leave as is: Failure of the waste rock dump or load out, leading to blockage of creek and washout or
2E	WRSA Leave as is: Failure of the waste rock dump or load out, leading contamination of the stream.

Community Concerns

3R	WRSA Leave as is: Results in disagreement with public or community groups about whether it is aesthetically

WRSA Closure Option - Reslope 2.5:1 & Revegetate

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely					
Possible		1E, 2E, 3E	4R		
Unlikely					
Very Unlikely					

Risks of waste rock contamination

1E	Resloping WRSA will cause short-term, one-time only increases in load over steady state conditions. Impacts on water quality
2E	Resloping WRSA will cause short-term, one-time only increases in load over steady state conditions. Impacts produces contaminated dust
3E	Resloping WRSA will cause short-term, one-time only increases in load over steady state conditions. Impacts on natural footprint
4R	The physical look of the waste rock piles reflects the heritage and mining past of the region and is preferable to some inhabitants of the area. Inhabitants may oppose altering the physical character of the WRSA, leading to public concern and unrest

Open Pit Closure Options Risks

Pit Closure Option - Berm and Sign

Likelihood	Consequence Severity				
	Very Low	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain					
Likely					
Possible			**1H**		
Unlikely					
Very Unlikely					

1H Access to the pits is not effectively prohibited, leading to inadvertant access and injury.

Adit Closure Options Risks

Adit Closure Options - Adit Bulkhead, Plug, or Rock Pile

Likelihood	Consequence Severity				
	Very Low	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain					
Likely			**2E**		
Possible		**1C**			
Unlikely					
Very Unlikely					

Risk of adit failure

1C Collapse of the adit/workings leads to an inability to manage the water discharging from it, obscuring or hindering the performance of the plug

Risk of plug/engineering failure

2E Catastrophic failure via strength loss and plug fails, leading to a significant flux of water into the receiving environment

Galkeno 900 Adit Water Treatment Options Risks

Galkeno 900 Option 1 - Ex-situ Bioreactor with Lime Treatment Contingency

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			4R		
Possible			3E		
Unlikely			6H	5H, 7H	
Very Unlikely			1E, 2E	8H	

	Risks of bioreactor system failure/design flaws
1E	Wholescale failure of bioreactor treatment facility at a slow rate, leading to release of contaminants into the environment.
	Risks of the natural environment
2E	Increase in the levels of zinc from the linked workings of Hector-Calumet, leading to exposure of the receiving environment to additional contaminants.
3E	Uncontrolled seepage from the seeps in the hillside leading to contamination of the hillside, and ultimately the receiving environment.
4R	Uncontrolled seepage from the seeps in the hillside enter the Christal Creek receiving environment, leading to negative public perceptions about the quality of water in the Christal Creek watershed, and ultimately, the South
	External health and safety risks of reagents/chemicals
5H	Release of H_2S from the bioreactor with human exposure leading to serious illness or a fatality.
6H	Line leak (as a result of vandalism) leading to expulsion of methanol/ethanol to environment and exposure causing blindness/bodily harm/toxicity effects.
7H	Inability to deliver ethanol/methanol safely to treatment facility at GK900 (once a day frequency), leading to a fatal accident.
8H	Inability to deliver ethanol/methanol safely to treatment facility at GK900 (once a year frequency), leading to a fatal accident.

Galkeno 900 Option 2 - Upgrade Current Treatment System

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			2R		
Possible			1E, 3C		
Unlikely				4H	
Very Unlikely				5H	

Risks of the natural environment

1E	Uncontrolled seepage from the seeps in the hillside leading to contamination of the hillside, and ultimately the receiving environment.
2R	Uncontrolled seepage from the seeps in the hillside enter the Christal Creek receiving environment, leading to negative public conceptions about the quality of water in the Christal Creek watershed, and ultimately, the South
3C	Significant deterioration in water quality leading to need for capital inprovements for a new treatment system.

External health and safety risks of reagents/chemicals

4H	Human health and safety risk associated with the ability to deliver lime safely on rough roads (once a day frequency)
5H	Human health and safety risk associated with the ability to deliver lime safely on rough roads (once a year frequency)

Galkeno 900 Option 3 - Batch In-Mine Pool Bioreactor Treatment

	Consequence Severity				
Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			5R		
Possible			4E		
Unlikely				6H	
Very Unlikely	1E			2H, 3H, 7H	

	Risks of bioreactor system failure/design flaws
1E	Wholescale failure of bioreactor in-mine pool treatment at a slow rate, leading to release of contaminants into the environment.
	Risks of the natural environment
4E	Uncontrolled seepage from the seeps in the hillside leading to contamination of the hillside, and ultimately the receiving environment.
5R	Uncontrolled seepage from the seeps in the hillside enter the Christal Creek receiving environment, leading to negative public conceptions about the quality of water in the Christal Creek watershed, and ultimately, the South
	External health and safety risks of reagents/chemicals
2H	Release of H_2S from the bioreactor with human exposure leading to serious illness or fatality.
3H	Creation of toxic gaseous conditions behind the hydraulic bulkhead as a result of both the creation of a low-oxygen atmosphere and H_2S gas leading to human exposure and death.
6H	Inability to deliver ethanol/methanol safely to treatment facility at GK900 (once a day frequency), leading to a fatal accident.
7H	Inability to deliver ethanol/methanol safely to treatment facility at GK900 (once a year frequency), leading to a fatal accident.

Onek 400 Adit Water Treatment Options Risks

Onek Option 1 - In-Mine Pool Treatment

	Consequence Severity				
Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			1E, 2E, 6R		
Possible		3E	4H, 5E		
Unlikely				7H	
Very Unlikely				8H	

Risks of system failure/design flaws

1E	Incomplete blocking of flow leads to less effective treatment. The result is poor water quality, leading to degradation of aquatic resources.
2E	Incomplete blocking of flow leads to less effective treatment. The result is soil contamination, leading to degradation of plant species.
3E	Water is backed up in the mine pool above the adit leading to seepage along the hillside.

Risks of the natural environment

5E	Uncontrolled seepage from the seeps in the hillside leading to contamination of the hillside, and ultimately the receiving environment.
6R	Uncontrolled seepage from the seeps in the hillside enter the Christal Creek receiving environment, leading to negative public conceptions about the quality of water in the Christal Creek watershed, and ultimately, the South

External health and safety risks of reagents/chemicals

4H	Creation of toxic gaseous conditions behind the hydraulic bulkhead as a result of both the creation of a low-oxygen atmosphere and H_2S gas leading to human exposure and death.
7H	Inability to deliver ethanol/methanol safely to treatment facility at GK900 (once a day frequency), leading to a fatal accident.
8H	Inability to deliver ethanol/methanol safely to treatment facility at GK900 (once a year frequency), leading to a fatal accident.

Onek Option 2 - Ex-situ Bioreactor

	Consequence Severity				
Likelihood	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain					
Likely					
Possible					
Unlikely			3H	2H, 4H	
Very Unlikely			1E	5H	

Risks of bioreactor system failure/design flaws

1E	Wholescale failure of bioreactor treatment facility at a slow rate, leading to release of contaminants into the environment.

External health and safety risks of reagents/chemicals

2H	Release of H_2S from the bioreactor with human exposure leading to serious illness or a fatality.
3H	Line leak (as a result of vandalism) leading to expulsion of methanol/ethanol to environment and exposure causing blindness/bodily harm/toxicity effects.
4H	Inability to deliver ethanol/methanol safely to treatment facility at Onek (once a day frequency), leading to a fatal accident.
5H	Inability to deliver ethanol/methanol safely to treatment facility at Onek (once a year frequency), leading to a fatal accident.

Onek Option 3 - Natural Attenuation

	Consequence Severity				
Likelihood	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain					
Likely					
Possible			1E, 2E		
Unlikely					
Very Unlikely					

1E	Onek discharge is too high for site capacity for attenuation. Result is increase in concentrations of contaminants of concern in water drainages downstream.
2E	Onek discharge is too high for site capacity for attenuation. Result is increase in concentration of contaminants in soils, affecting the ability to vegetation to naturally flourish.

Hector Calumet Mine Water Treatment Options Risks

Hector Calumet Option 1 - Mine Pool Drain, Centralized HDS Plant in Elsa

	Consequence Severity				
Likelihood	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain					
Likely					
Possible			1C, 2E, 4C		
Unlikely			3E		
Very Unlikely				5H	

Risks of the natural environment

1C	Draining the mine results in a variation in the mine pool water level. This leads to exposure of the walls of the workings to oxidation during periods of low water levels, and in turn results in metals flushing and treatment
2E	Water quality worsens over the long term, leading to increased metals leaching in the mine pool.

Physical Hazards

3E	Failure of the pipeline, leading to discharge of very high contaminant concentration water leaking into the receiving environment.
4C	Slope hazard associated with the pipeline occurs, leading to the need for potential mitigative measures to be undertaken on the hillslope and higher construction and/or operation costs.

External health and safety risks of reagents/chemicals

5H	Inability to deliver lime safely to treatment facility in Elsa (once a day frequency), leading to a fatal accident.

Hector Calumet Option 2 - Isolate from GK300 by Hydraulic Plug, Centralized HDS plant in Elsa

	Consequence Severity				
Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain			1E		
Likely					
Possible			5H		
Unlikely			2E, 4C		
Very Unlikely				3E	

Risks of the natural environment

1E	Draining the mine results in a variation in the mine pool water level. This leads to exposure of the walls of the workings to oxidation during periods of lower water levels, and in turn results in metals flushing and treatment higher costs. However, because the pool is already filled to the 400' level, there is going to be less oxidation than there would be if the mine pool were drained because there is less exposed surface.
2E	Water quality worsens over the long term, leading to increased metals leaching in the mine pool.

Physical Hazards

3E	Failure of the pipeline, leading to discharge of very high contaminant concentration water leaking into the receiving environment.
4C	Slope hazard associated with the pipeline occurs, leading to the need for potential mitigative measures to be undertaken on the hillslope and higher construction and/or operation costs.

External health and safety risks of reagents/chemicals

5H	Inability to deliver lime safely to treatment facility in Elsa (once a day frequency), leading to a fatal accident.

Hector Calumet Option 3 - Isolate from GK300, In-Mine Pool Treatment and Attenuation

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			1E, 2E. 6R		
Possible		3E	4E, 5E		9E
Unlikely				7H	
Very Unlikely				8H	

Risks of system failure/design flaws

1E	Incomplete blocking of flow leads to less effective treatment. The result is poor water quality, leading to degradation of aquatic resources.
2E	Incomplete blocking of flow leads to less effective treatment. The result is soil contamination, leading to degradation of plant species.
3E	Water is backed up in the mine pool above the adit leading to seepage along the hillside.

Risks of the natural environment

5E	Uncontrolled seepage from the seeps in the hillside leading to contamination of the hillside, and ultimately the receiving environment.
6R	Uncontrolled seepage from the seeps in the hillside enter the Christal Creek receiving environment, leading to negative public conceptions about the quality of water in the Christal Creek watershed, and ultimately, the South McQuesten River.
9E	The attenuation capacity of the site is overwhelmed through release of contaminants in the waters, leading to high levels of zinc and other contaminants in the soils and plants of the highly sensitive permafrost environment.

External health and safety risks of reagents/chemicals

4E	Creation of toxic gaseous conditions behind the hydraulic bulkhead as a result of both the creation of a low-oxygen atmosphere and H_2S gas leading to human exposure and death.
7H	Inability to deliver ethanol/methanol safely to treatment facility at Hector-Calumet (once a day frequency), leading to a fatal accident.
8H	Inability to deliver ethanol/methanol safely to treatment facility at Hector-Calumet (once a year frequency), leading to a fatal accident.

Galkeno 300 Adit Water Treatment Options Risks

Galkeno 300 - Option #1 - Current Treatment System

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain			4C		
Likely					
Possible			2E, 5E	3C, 6H	
Unlikely			1E		
Very Unlikely					

Risks of the natural environment

1E	Increased flows to ≈20-30L/s making their way all the way down to Christal Creek, leading to an impact on the receiving environment (influx of large volume of water of poor quality negatively impacts on aquatic resources in Christal Creek).
2E	Discharge route changes over time, leading to waters directly reaching the receiving environment.
3C	Increased base flows leading to increased costs (2x)
4C	Increased sludge production leads to significant increase in sludge handling costs.

Physical Hazards

5E	Collapse of the adit leads to an inability to manage the water discharging from it.

External health and safety risks of reagents/chemicals

6H	Inability to deliver lime safely on rough roads (once a day frequency), leading to a fatal accident.

Galkeno 300 Option 2 - Centralized HDS Plant in Elsa

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			1C		
Possible			3C		
Unlikely			2E		
Very Unlikely				4H	

Risks of the natural environment

1C	Increased base flows to ≈20-30L/s leading to a need for increased treatment capacity and higher capital costs.

Physical Hazards

2E	Failure of the pipeline, leading to discharge of very high contaminant concentration water leaking into the receiving environment.
3C	Slope hazard associated with the pipeline occurs, leading to the need for potential mitigative measures to be undertaken on the hillslope and higher construction and/or operation costs.

External health and safety risks of reagents/chemicals

4H	Inability to deliver lime safely to treatment facility in Elsa (once a day frequency), leading to a fatal accident.

Galkeno 300 Option 3 - Isolate Hector Mine Pool

	Consequence Severity				
Likelihood	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain			**3C**		
Likely			**1C**		
Possible		**7C**	**5E, 10C, 11C**	**8C**	
Unlikely		**9C**	**4E**		
Very Unlikely			**2C**	**6H**	

	Risks of the natural environment
1C	Increased flows to ≈20-30L/s leading to a need for increased treatment capacity and higher capital costs.
2C	Increased base flows (2x) leading to increased costs
3C	Increased sludge production leads to significant increase in sludge handling costs.
	Physical Hazards
4E	Failure of the pipeline, leading to discharge of very high contaminant concentration water leaking into the receiving environment.
5E	Collapse of the adit leads to an inability to manage the water discharging from it.
	External health and safety risks of reagents/chemicals
6H	Inability to deliver lime safely to treatment facility at Galkeno 900 (once a day frequency), leading to a fatal accident.
	Risks of system failure/design flaws
7C	Water does not report to Galkeno 900 after installation of the breast-high dam, with an inability even to redirect a small flow down the hillside to GK900 leading to increased costs.
8C	Drain-down is not effective, leading to the need for a bulkhead in the workings and increased costs.
9C	Further changes to the underground flows leads to changes in plans and associated costs (e.g. seeps develop on the hillside).
10C	Pumping requirements at Hector require significant additional expenditures.
11C	Additional treatment requirements at GK900 required if bulkhead cannot adequately isolate water.

Valley Tailings Water Treatment Options Risks

Valley Tailings Area Option 1 - Stabilize in Place - Status Quo

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain			1R		
Likely					
Possible		3C	4E, 5R	2E	
Unlikely		7C			
Very Unlikely				6E	

Risks of tailings dispersion

1R	Windblown tailings are dispersed beyond tailings impoundment leading to an impact on community land use

Risks of failure of Porcupine Diversion system

2E	Breach or failure of the Porcupine Diversion leading to contamination of the Flat Creek drainage
3C	Breach or failure of the Porcupine Diversion leading to need for upgrade/repair/maintenance of the diversion infrastructure

Risks of tailings dam breach

4E	Interruption of active care and maintenance for a period of time as a result of a lack of funding, absence of site presence, etc. leading to untreated, raw effluent discharging into the Flat Creek drainage (1-2mg/L Zn discharge for 1 or 2 years)
5R	Interruption of active care and maintenance for a period of time as a result of a lack of funding, absence of site presence, etc. leading to untreated, raw effluent discharging into the Flat Creek drainage (1-2mg/L Zn discharge for 1 or 2 years)
6E	Major breach of tailings impoundment dams (all 3 dams) leading to large-scale release of tailings downstream into Flat Creek watershed and bog beneath dams.

Risks of contamination of receiving enviroment via tailings porewater

7C	Deterioration of porewater water quality by an order of magnitude, leading to a 3-4x increase in treatment costs.

Valley Tailings Area Option 2 - Cover in Place and Revegetate

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain			1R		
Likely					
Possible		7E	4E, 6E		
Unlikely		3C	5E, 8E	2E	
Very Unlikely					

Risk of tailings dispersion

1R	Windblown tailings are dispersed beyond tailings impoundment leading to an impact on community land use
7E	Failure/erosion of the borrow area leads to release of suspended solids to the immediate natural environment

Risks of failure of Porcupine Diversion system

2E	Breach or failure of the Porcupine Diversion leading to contamination of the Flat Creek drainage
3C	Breach or failure of the Porcupine Diversion leading to need for upgrade/repair/maintenance of the diversion infrastructure

Risks of contamination of receiving enviroment via tailings porewater

4E	Drain-down of tailings porewater, leading to contamination of the receiving environment
5E	Deterioration of porewater water quality by an order of magnitude, leading to contamination of the receiving environment

Risks associated with tailings cover

6E	The cover is not thick enough, leading deep-rooted trees to take up contaminants from the tailings below the cover, or, due to wicking action (net evaporation) contaminants are brought up to the cover from the tailings

Risk of lack of QA/QC

8E	Lack of QA/QC during implementation of this option leads to inadequacies in the final product of the work

Valley Tailings Area Option 3 - Consolidate, Cover, and Revegetate

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain			1R		
Likely					
Possible		7E, 11C	4E, 6E, 9C, 10E, 12C, 13E, 15C		
Unlikely		3C	5E, 8E	2E, 14E	
Very Unlikely					

Risk of tailings dispersion

1R	Windblown tailings are dispersed beyond tailings impoundment leading to an impact on community land use
7E	Failure/erosion of the borrow area leads to release of suspended solids to the immediate natural environment

Risks of failure of Porcupine Diversion system

2E	Breach or failure of the Porcupine Diversion leading to contamination of the Flat Creek drainage
3C	Breach or failure of the Porcupine Diversion leading to need for upgrade/repair/maintenance of the diversion infrastructure

Risks of contamination of receiving enviroment via tailings porewater

4E	Drain-down of tailings porewater, leading to contamination of the receiving environment
5E	Deterioration of porewater water quality by an order of magnitude, leading to contamination of the receiving environment

Risks associated with tailings cover

6E	The cover is not thick enough, leading deep-rooted trees to take up contaminants from the tailings below the

Risks of tailings removal/relocation

9C	Wet tailings are not easily handled, leading to increased costs for tailings consolidation.
10E	Tailings berm failures (failure of the pile) during tailings consolidation leading to contamination/destruction of new creek beds and discharge of contaminants into Flat Creek drainage.
11C	Tailings berm failures (failure of the pile) during tailings consolidation leading to contamination/destruction of new creek beds and increased costs of construction and remediation.
12C	Low estimate of the amount of material the needs to be moved results in higher-than-expected costs.
13E	Residual contamination left behind after removal of the tailings leads to adverse effects on the surface water quality of the new creek beds.
14E	Risk of suspended solids loads from the rehabilitated tailings area before the area is established.
15C	Consolidation time on the relocated tailings is longer than estimated, leading to an increase in the overall cost of the operation (wait time, different contractors may have to be acquired over a number of years).

Risk of lack of QA/QC

8E	Lack of QA/QC during implementation of this option leads to inadequacies in the final product of the work

No Cash 500 Adit Water Treatment Options Risks

No Cash Option 1 - In-Mine Pool Treatment

	Consequence Severity				
Likelihood	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely		4R			
Possible		1E, 2E	3E, 5H, 8E, 10E		
Unlikely			9E	6H	
Very Unlikely			11E	7H	

	Risks of the natural environment
3E	Uncontrolled seepage from the seeps in the hillside leading to contamination of the hillside, and ultimately the receiving environment.
4R	Uncontrolled seepage from the seeps in the hillside enter the Christal Creek receiving environment, leading to negative public conceptions about the quality of water in the Christal Creek watershed, and ultimately, the South
11E	Worsening of water quality over time leading to higher contaminant concentrations
	External health and safety risks of reagents/chemicals
5H	Creation of toxic gaseous conditions behind the hydraulic bulkhead as a result of both the creation of a low-
6H	Inability to deliver ethanol/methanol safely to treatment facility at NC500 (once a day frequency), leading to a
7H	Inability to deliver ethanol/methanol safely to treatment facility at NC500 (once a year frequency), leading to a
	Risks of system failure/design flaws
1E	Incomplete blocking of flow leads to less effective treatment. The result is poor water quality, leading to degradation of aquatic resources.
2E	Incomplete blocking of flow leads to less effective treatment. The result is soil contamination, leading to degradation of plant species.
8E	In-mine pool treatment fails to achieve target concentrations of contaminants leading to degradation of downstream water quality in the NC wetland
9E	In-mine pool treatment fails to achieve target concentrations of contaminants leading to degradation of downstream water quality in the South McQuesten watershed
10E	Mine treatment produces, over time, a significant enough amount of precipitates/solids, leading to high total metals concentrations in the discharge or blockage of discharge and overflow at the input point

No Cash 500 Option 2 - Centralized HDS

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely					
Possible			1C		
Unlikely			2E, 3C		
Very Unlikely					

	Risks of the natural environment
1C	Increased base flows leading to need for increased capacity and increased capital costs
	Physical Hazards
2E	Failure of the pipeline, leading to discharge of very high contaminant concentration water leaking into the receiving environment.
3C	Slope hazard associated with the pipeline occurs, leading to the need for potential mitigative measures to be undertaken on the hillslope and higher construction and/or operation costs.

No Cash Option 3 - Natural Attenuation

Likelihood	Consequence Severity				
	Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely				3L	
Possible	8C		2R, 4E, 6E		
Unlikely			1E, 5E, 7E		
Very Unlikely					

	Risks of the natural environment
6E	Increased base flows leading to need for increased capacity and increased capital costs
7E	Worsening of water quality over time leading to higher contaminant concentrations
	Risks of system failure/design flaws
1E	Natural attenuation is unsuccessful, resulting in full load from No Cash reaching South McQuesten and leading to 15% increase in contamination in the South McQuesten
2R	Natural attenuation is unsuccessful, resulting in full load from No Cash reaching South McQuesten and leading to public concern
3L	Natural attenuation is unsuccessful, resulting in full load from No Cash reaching South McQuesten and leading to 15% increase in contamination in the South McQuesten and breach of regulation under current WUL
4E	Onek discharge is too high for site capacity for attenuation. Result is increase in concentrations of contaminants of concern in water drainages downstream.
5E	Onek discharge is too high for site capacity for attenuation. Result is increase in concentration of contaminants in soils, affecting the ability to vegetation to naturally flourish.
8C	Rerouting flows into pipe changes natural stream flows which causes glaciation and disrupts highway conditions/travel

Keno 700 Adit Water Treatment Options Risks

Keno 700 Option 1 - No Treatment (Mine Flood) with Water Management

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely				4E	
Possible			1E, 2R	3L	
Unlikely				5E	
Very Unlikely					

Risks of the natural environment

5E	Worsening of water quality over time leading to higher contaminant concentrations

Risks of system failure/design flaws

1E	Full load from Keno 700 continues to reach Lightning Creek and leads to heightened problems as a result of the high proportion of contamination in Lightning Creek from Keno 700
2R	Full load from Keno 700 continues to reach Lightning Creek and leads to heightened contamination in Lightning Creek leading to public concern
3L	Full load from Keno 700 continues to reach Lightning Creek and leads to heightened contamination in Lightning Creek leading to breach of regulation under current WUL
4E	Installation of bulkhead causes dissolution of oxidation products which increases mine adit discharge loads temporarily during flooding

Keno 700 Option 2 - Bioreactor

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely					
Possible			6C		
Unlikely			1E, 3H, 5E	2H	
Very Unlikely				4H	

Risks of the natural environment

5E	Worsening of water quality over time leading to higher contaminant concentrations
6C	Increased base flows and/or water quality degradation leading to need for increased capacity and increased capital costs

External health and safety risks of reagents/chemicals

2H	Release of H2S from the bioreactor with human exposure leading to serious illness or a fatality.
3H	Line leak (as a result of vandalism) leading to expulsion of methanol/ethanol to environment and exposure causing blindness/bodily harm/toxicity effects.
4H	Inability to deliver ethanol/methanol safely to treatment facility at Keno 700 (seasonally), leading to a fatal accident.

Risks of system failure/design flaws

1E	Wholescale failure of bioreactor treatment facility at a slow rate, leading to release of contaminants into the environment.

Elsa Village Closure Options Risks

Elsa Village Option 1 - Do Nothing

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			6R	1H, 2E, 3H, 4L, 5C	
Possible					
Unlikely			7H		
Very Unlikely					

1H	Serious accident or fatality in or on a dilapidated building or structure in Elsa
2E	Hazardous chemicals from buildings lead to environmental damage
3H	Hazardous chemicals from buildings lead to health and safety problems
4L	Serious accident or fatality in or on a dilapidated building or structure in Elsa
5C	Serious accident or fatality in or on a dilapidated building or structure in Elsa
6R	Failure to preserve representative heritage values leads to poor reputation
7H	Failure of site infrastructure leads to inaccessibility of roads

Elsa Village Option 2 - Demolish Buildings and Implement Heritage Plan

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely			4E		
Possible			1H		
Unlikely		2E			3H
Very Unlikely					

1H	Hazardous materials and abatement program is ineffective, leading to physical impairment
2E	Hazardous materials and abatement program is ineffective, leading environmental impact
3H	Dismantling of building leads to worker fatality
4E	Demolishing buildings without proper consultation/heritage plan leads to

Mitigated High Risk Closure Options

Likelihood	Consequence Severity: Very Low	Minor	Moderate	Major	Critical
Almost Certain					
Likely		3			
Possible		4, 6, 7, 8, 9, 10	1		
Unlikely		13, 14	2, 5		
Very Unlikely		12, 15, 16		11	

	Tailings - Status Quo
1	Windblown tailings are dispersed beyond tailings impoundment leading to an impact on community land use
2	Breach or failure of the Porcupine Diversion leading to contamination of the Flat Creek drainage
	Tailings - Cover (either with or without consolidation)
3	Windblown tailings are dispersed beyond tailings impoundment during cover construction leading to an impact on community land use
	In-Mine Pool Treatment
4	Draining the mine (**Hector Calumet**) results in a variation in the mine pool water level. This leads to exposure of the walls of the workings to oxidation during periods of lower water levels, and in turn results in metals flushing and higher treatment costs. However, because the pool is already filled to the 400' level, there is going to be less oxidation than there would be if the mine pool were drained because there is less exposed surface.
	Redirect Hector-Calumet Flow Away from Galkeno 300 to Galkeno 900
5	Drain-down is not effective (Hector Calumet isolation from **Galkeno 300** adit to provide closure for GK300), leading to the need for a bulkhead in the workings and increased costs.
	Natural Attenuation (Do Nothing Scenario)
6	The attenuation capacity of the site (from **Hector Calumet**) is overwhelmed through release of contaminants in the waters, leading to high levels of zinc and other contaminants in the soils and plants of the highly sensitive permafrost environment.
7	Natural attenuation is unsuccessful, resulting in full load from **No Cash** reaching South McQuesten and leading to 15% increase in contamination in the South McQuesten and breach of regulation under current WUL
8	Full load from **Keno 700** continues to reach Lightning Creek and leads to heightened contamination in Lightning Creek leading to breach of regulation under current WUL
	Conventional (Local) Lime/HDS Treatment at GK 300
9	Increased base flows leading to increased costs (2x)
10	Increased sludge production leads to significant increase in sludge handling costs.
	Elsa Village Closure
11	Inability to deliver lime safely on rough roads to remote sites (once a day frequency), leading to a fatal accident.
12	Serious accident or fatality in or on a dilapidated building or structure in Elsa
13	Hazardous chemicals from buildings lead to environmental damage
14	Hazardous chemicals from buildings lead to health and safety problems
15	Serious accident or fatality in or on a dilapidated building or structure in Elsa
16	Serious accident or fatality in or on a dilapidated building or structure in Elsa

Once preferred options and residual risks are determined, these options for mine site component closure will be taken to the public to undergo a stakeholder and peer review. With the feedback from this process in mind, final options for each mine site component will be selected and used to develop a final closure option for each site.

A description of this process is illustrated in the attached process diagram. Outstanding items for closure planning include further risk assessment on sites previously not discussed, mitigation and residual risk assessment, stakeholder and peer review and selection of a preferred option for each site. These are the next immediate steps in the process to selecting final closure options and to developing the Closure Plan.

We appreciate your participation in the risk assessment and closure planning process and look forward to continuing our work towards development of a plan for the district. Should you have any particular questions or have feedback on the attached risk summary please contact me.

Sincerely,

Dan Cornett

President

Access Consulting Group

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Meteorological Data
Design Criteria

	Value	Units	Source	Confidence	Comment
Temperature					
Max Recorded	32	deg C	AMC UKH/96/01 (May-05)	70	
Monthly Max	20.8	deg C	Environment Canada, National Climate Data and Information Archive(NCDIA), Canadian Climate Normals 1971-2000, Yukon Territory,	70	Climate Normals are measured in Mayo, elevation 503.8 m.
Monthly Min	-27.6	deg C	Same as Above	70	
Annual Mean	-3	deg C	Same as Above	70	
Minimum Recorded	- 62.2	deg C	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	Mayo is at an elevation of 503.8 m while most of our sites are at higher elevations. Mayo minimum applies.
Max Frost Depth					
Wind					
UBC Basic Wind Speed	7	km/h	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Exposure					
Prevailing Wind Direction	North	-	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Average Barometric Pressure					
Barometric Pressure	95.1	Kpa	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Precipitation					
Annual Average	285	mm	AMC UKH/96/01 (May-05)		
Ave. annual Snowfall	147	cm	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Snow Contribution to Total	0.80		Estimated	50	
Snowload Design	per site	n/a	National Building Code	100	
Evaporation					
Estimated Annual Average Actual Evapotranspiration	200	mm	AMC UKH/96/01 (May-05)	70	
Annual Average Lake	460	mm	AMC UKH/96/01 (May-05)	70	
Monthly Maximum					
Monthly Minimum					
Relative Humidity					
Annual Average	22.9	%	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Monthly Maximum	9.6	%	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Monthly Minimum	38.5	%	Environment Canada, NCDIA, Climate Normals 1971-2000, Yukon Territory, Mayo A	70	
Frost/Freezing					
Frezing Index	4444.0	deg-day Celcius	Dow, Tech Solutions 605	50	
Minimum Buried Depth for Frost Free	2.8	m	Dow, Tech Solutions 605	40	

Design Criteria
Geotechnical

	Value	Unit	Source	Comment
Geotechnical				
Canadian Dam Safety Guidelines - Scoring System				
To be developed/included				
Seismicity				
Design Peak Horizontal Ground Acceleration				
Return Period				
100	0.071g	m/s^2	SRK-G.C.S.(Mar-2008)	· As outlined by: http://earthquakescanada.nrcan.gc.ca/hazard-alea/zoning/haz-eng.php
500	0.138g	m/s^2	SRK-G.C.S.(Mar-2008)	· As outlined by: http://earthquakescanada.nrcan.gc.ca/hazard-alea/zoning/haz-eng.php
1000	0.182g	m/s^2	SRK-G.C.S.(Mar-2008)	· As outlined by: http://earthquakescanada.nrcan.gc.ca/hazard-alea/zoning/haz-eng.php
2475	0.245g	m/s^2	SRK-G.C.S.(Mar-2008)	· As outlined by: http://earthquakescanada.nrcan.gc.ca/hazard-alea/zoning/haz-eng.php
Seismic Coefficient	2/3 of g		DOE, 1989	2/3 of Peak Ha Value for sustained coefficient
Slope Stability Factors of Safety				
Deep Seated				
Static	1.3		EBA-W14101178.003 (Jan.-2010)	Yukon OH&S will be followed
Pseudo-static	1.3		EBA-W14101178.003 (Jan.-2010)	Yukon OH&S will be followed
Static, Long-Term Shallow Face Failure	1.4		EBA-W14101178.003 (Jan.-2010)	Yukon OH&S will be followed
Static, Short-Term Shallow Face Failure	1.7		EBA-W14101178.003 (Jan.-2010)	Yukon OH&S will be followed
Liquefaction Analysis - Probability of Occurrence				
Tailings/Fine Sands				
Return Period				
500	0.138g		No potential under this event	Cyclic loading testing & design to demonstrate
Dams Factors of Safety				
Classification Significant				Dam classification in Accordance with CDA Dam Safety Guidelines (Nov-2007)
Static, Deep Seated	1.5		SRK-G.C.S.(Mar-2008)	
Static, Shallow Face Failure	1.3		SRK-G.C.S.(Mar-2008)	
Pseudo-static, Deep Seated	1.0		SRK-G.C.S.(Mar-2008)	
Classification Low			SRK-G.C.S.(Mar-2008)	Dam classification in Accordance with CDA Dam Safety Guidelines (Nov-2007)
Static, Deep Seated	1.5		SRK-G.C.S.(Mar-2008)	
Static, Shallow Face Failure	1.3		SRK-G.C.S.(Mar-2008)	
Pseudo-static, Deep Seated	1.0		SRK-G.C.S.(Mar-2008)	

	Design Componen	Design Constraint	Method of Analysis	Discussion
Geotechnical				
Slope Stability				
	Deep Seated	Min. FS static and pseudo static, Return Period =500 year	Morgenstern-Price/ Spencer	
	Long-Term Shallow Face Stability	Min. FS static	Morgenstern-Price/ Spencer	
	Short-Term Shallow Face Stability	Min. FS static	Morgenstern-Price/ Spencer	
	Pile Erosion	Minimize Surface Runoff	n/a	Reduce saturated surface, minimize infinite slope failures
	Liquefaction	Probability, Return Period=500 ye	Cyclic Loading Analysis	
Dams				
Significant	Deep Seated	Dam classification=Significant	Morgenstern-Price/ Spencer	
	Shallow Face	Dam classification=Significant	Morgenstern-Price/ Spencer	
Non-Significant	Deep Seated	Dam classification=Low	Morgenstern-Price/ Spencer	
	Shallow Face	Dam classification=Low	Morgenstern-Price/ Spencer	

Keno-Alexco Project Design Criteria
September 24th, 2010

Design Criteria
Hydrologic/Hydraulic

	Value	Unit	Source	Comment
Hydrologic				
Depth of Rainfall for 24 hr Duration				
200 yr	75.6	mm	IDF Curves from 9 surrounding stations, adjusted to site elevation	average elevations of all sites 1260m
100 yr	68.8	mm	IDF Curves from 9 surrounding stations, adjusted to site elevation	average elevations of all sites 1260m
10 yr	TBD			
Freshet	See Separate Document		Clearwater Consultants Memos 1-3	
Curve Number	See Separate Spreadsheet		Natural Resources Conservation Service	
Hydraulic				
Major Diversion & Minor Channels				
Free Board	16	cm		
Culvert Headwater	60	cm		
Detention Ponds				
Free Board	1	m		

	Design Component	Design Constraint	Method of Analysis	Discussion
Hydrologic & Hydraulic				
Major Diversion & Major Existing Channels			HEC-RAS or Manning's Equation	Manning Equation may be used on simple single reach streams with no hydraulic structures, and constant geometry.
	Storm Event	Duration=24hr, Return Period=200 yr NRCS Type IA Distribution*	HEC-HMS	Use Flows from Freshet w/ Return Period of 10 Years, as Base Flow, plus storm event
	Rip Rap	Duration=24hr, Return Period=200 yr NRCS Type IA Distribution*	Slope<2% C.O.E (91), Slope>10% C.O.E.(91) Hydraulic Jump-Bureau of Rec.	Use Flows from Freshet w/ Return Period of 10 Years, as Base Flow, plus storm event
	Culverts	Duration=24hr, Return Period=200 yr NRCS Type IA Distribution*	CulvertMaster/HY-8	Use Flows from Freshet w/ Return Period of 10 Years, as Base Flow, plus storm event
Minor Diversion (Surface and Shallow Flow Diversions)			HEC-RAS or Manning's Equation	Manning Equation may be used on simple single reach streams with no hydraulic structures, and constant geometry.
	Storm Event	Duration=24hr, Return Period=100 yr NRCS Type IA Distribution*	HEC-HMS	
	Rip Rap	Duration=24hr, Return Period=100 yr NRCS Type IA Distribution*	Slope<2% C.O.E (91), Slope 2-8% C.O.E (91) Slope>10% C.O.E.(94), Hydraulic Jump-Bureau of Rec.	
	Culvert Headwater	Duration=24hr, Return Period=100 yr NRCS Type IA Distribution*	CulvertMaster or HY-8	
Stormwater Detention Ponds			HEC-RAS or Manning's Equation	Detention Ponds used to detain peak runoff from storm event that would produce flooding.
	Storm Event	Duration=24hr, Return Period=200 yr NRCS Type IA Distribution	HEC-HMS,SCS/NRCS Method, Pond Pack, or equivalent	
	Rip Rap	Duration=24hr, Return Period=200 yr NRCS Type IA Distribution	Slope<2% C.O.E (91), Slope 2-8% C.O.E (91) Slope>10% C.O.E.(94), Hydraulic Jump-Bureau of Rec.	
	Free Board	75 cm		
	Release Rate	Equal to or less than capacity of receiving water course		

Design Criteria
Erosional Stability/Cover

	Design Component	Design	Source	Discussion
Erosion Stability				
	Erosion	Max. 4.5 tonnes/ha/year	Water Erosion Prediction Project (WEPP) Model, National Soil Erosion Research Lab, USDA	USCS Acceptable 2 ton/ac/year
Cover Design				
Non ARD/ML Potential Areas for Waste Rock Dumps				
	Cover	0.3-0.5 m thick suitable growth medium soil. Reduce infiltration.	n/a - Establish by native vegetation root depth	
ARD/ML Potential Areas for Waste Rock Dumps				
	Cover	0.5-0.7 m thick suitable growth medium soil. Enhance reduction of infiltration.	Maximize evapotranspiration utilizing native vegetation, root depth, establish suitable growth medium - store and	Cover material to store and release water, to provide enhanced reduction of infiltration.
Potential ML Areas for Tailings Sites				
	Cover	Sloped/regraded to stable configuration for long-term stability and to enhance runoff of precipitation and snowmelt. A cover designed to enhance runoff and evapotranspiration including a good quality growth media with appropriate nutrients and organic content to support local flora. This might include a mixture of local, fine grained till material, peat, blended with the tailings material. The final design of the growth media will be based on testing of site-specific materials.		
Potential ML Areas for Tailings Sites				
	Cover	As above but with additional isolation and/or enhanced saturation of the material by encapsulation and/or maintenance of a wet cover. Other methods for mimizing oxidation can be included such as incorporating organic-rich materials into cover system to strip out oxygen from infiltrating waters.		

Keno-Alexco Project Design Criteria
September 24th, 2010

Design Criteria
Table-2

	Design Component	Design	Source	Discussion
Berms & Signage				
Waste Rock Dumps	Berms	2.0 (m) high warning berm 5-10 (m) from crest of slope	Yukon Occupational Heath & Safety Regulations	Tops of dumps sloped away from crest, berms placed at edge - 2m
	Signage	"Closed to Public"	Yukon Occupational Heath & Safety Regulations	
Pits	Berms	2.0 (m) high warning berm 5-10 (m) from pit rim	Yukon Occupational Heath & Safety Regulations	Perimeter of pits double bermed - 2m height
	Signage	XXXX	Yukon Occupational Heath & Safety Regulations	
Roads	Signage	XXXX	Yukon Occupational Heath & Safety Regulations	
Roads				
Private Access Roads				
	Closure	Deter Access/ clean debri/scarify	XXXX	Yukon OH&S will be followed
	Reclamation	Downsized to two-track or completey reclaimed, based on discussions with local agencies - Follow cover design	XXXX	

Specifications:
1. Fill:Random Fill-Max. 60 cm lifts w/water addition as necessary for compaction.
   Structural Fill-Max. 30 cm Lifts +/-5%, Optimum M.C, 90% Modified Proctor
   Liner Compaction-Max. 15 cm Lifts +/- 3%, Optimum M.C., 95% Standard Proctor

Abbreviations

ARD-	Acid Rock Discharge
cm-	Centimeter
C.O.E-	US Army Corp of Engineering
D.C.-	Design Criteria
FS-	Factor of Safety
ha-	Hectares
km-	Kilometer
m-	Meter
Max.-	Maximum
M.C.-	Moisture Content
Min.-	Minimum
ML.-	Metals Leaching

References

Abbreviation	Full Reference
AMC UKH/96/01 (May-05)-	Access Mining Consultants, "Site Characterization," Report NO. UKH/96/01, May 2005
Culvert Master-	
EBA-W14101178.003 (Jan.-2010)-	EBA Engineering Consultants, "Preliminary Engineering and Management Plan Dry-Stacked Tailings Facility Bellekeno Mine Mill Site, Yukon," Report No.W14101178.003, January 2010
HEC-HMS-	U.S. Army Corps of Engineers (2009). Hydraulic Engineering Center (version 3.4)[software]
HEC-RAS-	U.S. Army Corps of Engineers (2010). Hydraulic Engineering Center-River Analysis Sytem (version 4.1.0) [software]
HY-8-	Federal Highway Administration (2010). Culvert Analysis (version HY 8.7.2) [software]
Pond Pack-	
Soilvision-	Murray Fredlund & Robert Thode (2009). Finite Element Modeling.(version 2009)[software]
SRK-G.C.S.(Mar-2008)-	SRK Consulting, "Geotechnical Closure Studies," March 2008
SRK-Geochem(2009)-	SRK Consulting, "Geotechnical Chemical Studies," 2009

SITE DATA

			Geochemical	Implications of Geotechnical Failure (KM to Closest From Toe)							
			(Y/N)	Human Health & Saftey		Ecological		Infrastructure		Visual	
Facilities	**Waste Rock Dump Tonnage[2]**	**Heigth of Waste Rock**	**Is The Site Potenital ARD or ML**	**Homes**	**Public Access**	**High Quality Habitat**	**Creeks**	**Private**	**Public**	**Keno City**	**Hwy 2**
Silver King											
Husky & Husky SW											
Elsa Mine & Mill											
Dixie											
Coral & Wigwan											
Bermingham											
NoCash 500											
Betty											
Hector-Calumet[5]											
Dragon UN & Miller											
Galkeno 300											
Gallkeno 900											
Bluebird											
Tin Can											
Rico											
Flame & Moth											
Onek											
Klondike Keno											
Sadie Ladue (Wernecke)											
Bellekeno											
Kijo											
Croesus No. 1											
Lucky Queen/Black Cap											
Lucky Queen (Shaft)											
Lake											
Shamrock											
Highlander											
Cub & Bunny											
Stone											
Keno 700											
Keno No.9											
Gold Hill No. 2											
Fox											
Divide											
Silver Basin											
Monument & Ladue											
Apex											
Eagle											
Gerlitski											
Christal (Dorothy)											
Townsite											
Sadie Ladue 600											
Elsa Village											
Valley Tailings											
Mackeno											

NOTES:
1. Size Catergory A=<100,000 tonnes; B=10,000 to 100,000 tonnes; D=<1,000 tonnes
2. Tonnage-short tons (Source SRK 2007 Geotechnical Closure Studies, 2007/ SCR, 1996/ PWGSC, 2000 and estimates from SRK inspections)

Keno-Alexco Project Design Criteria
September 24th, 2010
Facility Closure Analysis

Facility	Issue	Design Components To Check	Closure Application Criteria	Method of Analysis	Closure Application		Discussion
					If Facility Meets or Exceeds Criteria.	If Facility Does Not Meets Constraints.	
Waste Rock Dumps							
	Sites w/ARD/ML Potential Per SRK-Geochem. (2009)	Deep Seated Stability	Min. FS static and psuedo static, Return Period =500 year	Morganstern-Price/ Spencer	1,3	1,3,4	
		Long-Term Shallow Face Stability	Min. FS static	Morganstern-Price/ Spencer	1,3	1,3,4	
		Short-Term Shallow Face Stability	Min. FS static	Morganstern-Price/ Spencer	1,3	1,3,4	
		Erosion	Max. 4.5 tonnes/ha/year	WEPP Model	1,3	1,3,4	circumstance where just the cover would be adequate.
	Proximety	Deep Seated Stability	Min. FS static and psuedo static, Return Period =500 year	Morganstern-Price/ Spencer	2	1,4	Should we leave the option open for Alexco to decide if ifrastructure is private?
		Long-Term Shallow Face Stability	Min. FS static	Morganstern-Price/ Spencer	2	1,4	Should we leave the option open for Alexco to decide if ifrastructure is private?
		Short-Term Shallow Face Stability	Min. FS static	Morganstern-Price/ Spencer	2	1,4	Should we leave the option open for Alexco to decide if ifrastructure is private?
		Erosion	Max. 4.5 tonnes/ha/year	WEPP Model	2	1,2,4	Should we leave the option open for Alexco to decide if ifrastructure is private?
Pits	All Pits	Infiltration	infiltration>0	Visual Inspection?	1,5	1	
Tailings	All Tailings	Deep Seated Dam Stability			1,6	1,6,7	
		Shallow Face Dam Stability			1,6	1,6,7	
		Liquefaction	0 Probability, Return Period=500 year	Cyclic Loading Analysis	1,6	1,6,9	
Roads	Private Roads	Use	Not Used for O&M	Per Closure and New Mine Plan	9	10	

Proximity Defentions
1. If an enity from the Human H & S, Ecological, or Infastructure is within a distance equal to or less than the dumps overall height from the dump toe, then the dump is considered within proximity.
2. If a dump is within site of either Highway 2, or Keno City, and there is community concern, then the dump is considered within proximety.

Keno-Alexco Project Design Criteria
September 24th, 2010
Closure Application Reference

Facility	Closure Application#	Application	Design Criteria Reference		Discussion
			Primary	Secondary	
Waste Rock Dumps	1	Berm Along Top of Slope & Caution/Warning Signs	Berms and Signage For W.R. Dumps	_	
	2	Place Cover Per Design Criteria	Cover Design ARD/ML Potential W.R. Dumps	Hydrologic&Hydraulic	
	3	Place Cover Per Design Criteria	Cover Design NON ARD/ML Potential W.R. Dumps	Hydrologic&Hydraulic	May be Placed in areas where it is in visual proximety.
	4	Grade/Reslope to meet or exceed Design Criteria	Slope Stability Deep Seated	Hydrologic&Hydraulic	
	5	Grade/Reslope to meet or exceed Design Criteria	Long-Term Shallow Face Stability	Hydrologic&Hydraulic	
	6	Grade/Reslope to meet or exceed Design Criteria	Short-Term Shallow Face Stability	Hydrologic&Hydraulic	
	7	Grade/Reslope to meet or exceed Design Criteria	Erosion Stability	Hydrologic&Hydraulic	
Pits	8	Berm Along Top of Slope & Caution/Warning Signs	Berms and Signage for Pits	_	
	9	Backfill Pit	Random Fill	-	
Tailings	10	Signage	Berms and Signage for Tailings		
	11	Place Cover Per Design Criteria	Cover Design For Tailings	Hydrologic&Hydraulic	
	12	Stabalize Dam	Dam Deep Seated	Hydrologic&Hydraulic	
	13	Stabalize Dam	Dam Shallow Face	Hydrologic&Hydraulic	
	14	Drain/Load	Liquefaction		
Roads	15	Signage	Signage For Access Roads		
	16	Close/Reclamation	Road Closure & Reclamation		

Keno-Alexco Project Design Criteria
September 24th, 2010

Site Charcteristics

Location Located in the central Yukon Territory, 354 km (220 miles) due north of Whitehorse in the vicinity of the villages of Elsa and Keno City.

Access There is a 407 km long, two lane, paved road from Whitehorse to Mayo followed by a 45 km long all weather gravel road to Keno Hills.

Elevation Extremes (m) (above sea level)

Valley (low)	700
Sourdough Hill	1,370
Galena Hill	1,400
Keno Hill	1,825
Tree line[4]	1350-1500

Sites	Elevations (m)
Silver King	755
Site Max.	765
Site Min.	740
Husky & Husky SW	760
Site Max.	750
Site Min.	735
Elsa Mine & Mill	860
Site Max.	885
Site Min.	840
Dixie	1020
Site Max.	1040
Site Min.	1005
Coral & Wigwan	1285
Site Max.	1250
Site Min.	1220
Bermingham	1255
Site Max.	1270
Site Min.	1235

Keno-Alexco Project Design Criteria
September 24th, 2010

Site Charcteristics

NoCash 500	960
Site Max.	990
Site Min.	935
Betty	1055
Site Max.	1065
Site Min.	1050
Hector-Calumet[5]	1310
Site Max.	1335
Site Min.	1310
Dragon UN & Miller	1280
Site Max.	1290
Site Min.	1270
Galkeno 300	1140
Site Max.	1165
Site Min.	1125
Gallkeno 900	900
Site Max.	935
Site Min.	883
Bluebird	935
Site Max.	940
Site Min.	915
Tin Can	
Site Max.	
Site Min.	
Rico	1000
Site Max.	1025
Site Min.	975
Flame & Moth	
Site Max.	
Site Min.	
Onek	965
Site Max.	980
Site Min.	960
Klondike Keno	1155
Site Max.	1170
Site Min.	1145
Sadie Ladue (Wernecke)	1250
Site Max.	1275
Site Min.	1255

Keno-Alexco Project Design Criteria
September 24th, 2010

Site Charcteristics

Bellekeno	1045
Site Max.	1075
Site Min.	1033
Kijo	1215
Site Max.	1230
Site Min.	1195
Croesus No. 1	1275
Site Max.	1295
Site Min.	1250
Lucky Queen/Black Cap	1415
Site Max.	1440
Site Min.	1390
Lucky Queen (Shaft)	1490
Site Max.	1515
Site Min.	1480
Lake	1190
Site Max.	1205
Site Min.	1175
Shamrock	1500
Site Max.	1545
Site Min.	1480
Highlander	1360
Site Max.	1385
Site Min.	1340
Cub & Bunny	1500
Site Max.	1515
Site Min.	1490
Stone	1195
Site Max.	1225
Site Min.	1170
Keno 700	1475
Site Max.	1500
Site Min.	1465
Keno No.9	1695
Site Max.	1700
Site Min.	1690
Gold Hill No. 2	1780
Site Max.	1800
Site Min.	1750

Keno-Alexco Project Design Criteria
September 24th, 2010

Site Charcteristics

Fox	1620
Site Max.	1635
Site Min.	1595
Divide	1635
Site Max.	1640
Site Min.	1630
Silver Basin	1630
Site Max.	1640
Site Min.	1615
Monument & Ladue	1750
Site Max.	1745
Site Min.	1680
Apex	1460
Site Max.	1470
Site Min.	1445
Eagle	1320
Site Max.	1335
Site Min.	1310
Gerlitski	750
Site Max.	780
Site Min.	730
Christal (Dorothy)	1245
Site Max.	1260
Site Min.	1230
Townsite	1220
Site Max.	1240
Site Min.	1195
Sadie Ladue 600	1110
Site Max.	1120
Site Min.	1105
Elsa Village	
Site Max.	
Site Min.	
Valley Tailings	700
Site Max.	715
Site Min.	700
Mackeno	
Site Max.	
Site Min.	

3. Elevation from topography presented on basemap.

average 1230.414634

Keno-Alexco Project Design Criteria
September 14th, 2010

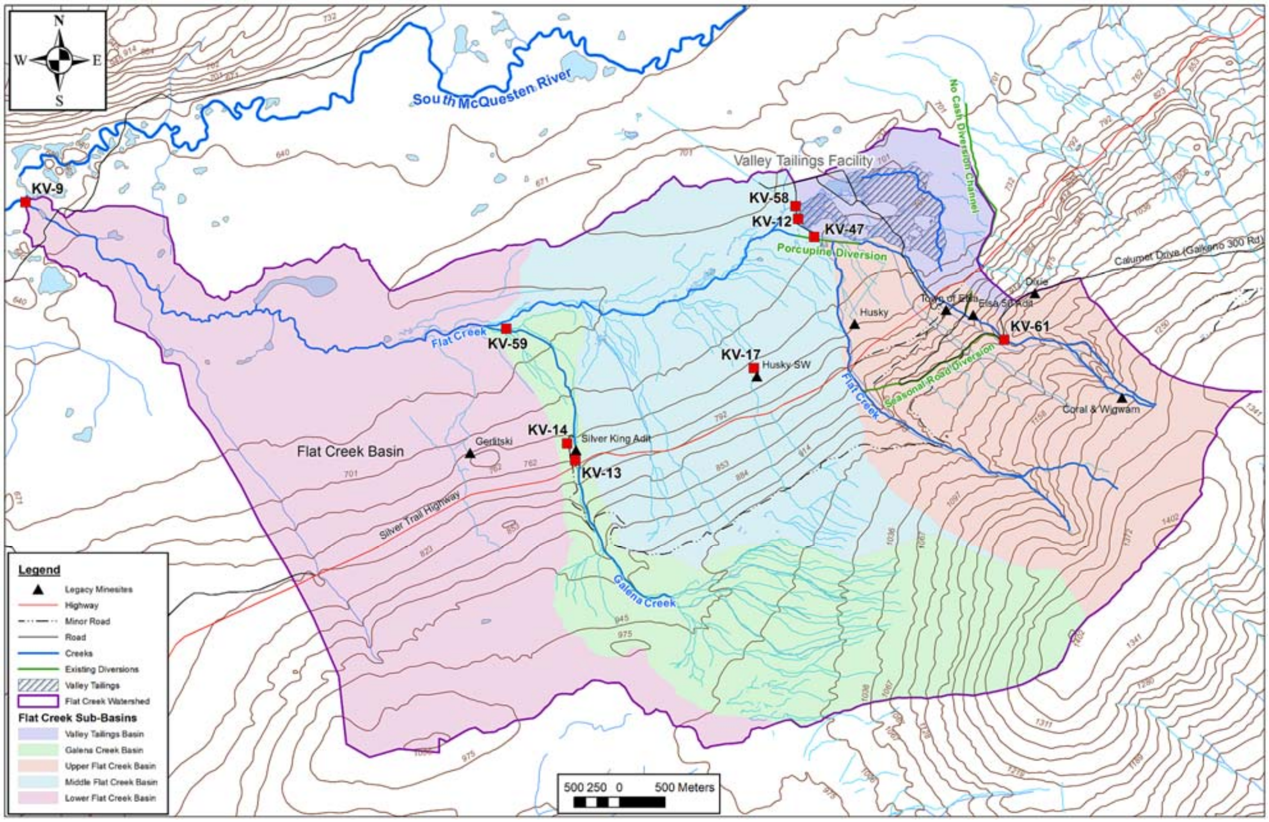
Operation and Construction

	Value	Units	Source	Unit Cost	Comment
Electrical Power					
Yukon Energy Corp.	5	megawatt	1996 Site Characterization & Appendices - Access Mining Consultants.		
UKHM	10.4	megawatt	1996 Site Characterization & Appendices - Access Mining Consultants.		

Mass Load Model for Flat Creek: Description and Results

Draft Report

November 5, 2013



Prepared for:
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Whitehorse, YT

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Fort Collins, Colorado 80525

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1.0 INTRODUCTION

The Flat Creek watershed (Figure 1-1) contains sites impacted by legacy mining activities. These sites have the potential to contribute metal loads to Flat Creek which is a tributary to the South McQuesten River. Legacy mining sites include the following:

- The Husky, Husky Southwest (SW), Dixie, Elsa, and Silver King adits;
- The Valley Tailings impoundment;
- Dispersed tailings throughout the watershed;
- Waste rock used for construction foundations throughout the townsite of Elsa, and
- The Silver King, Husky, and Husky SW, Coral, Wigwam, and Gerlitski waste rock areas.

Reclamation alternatives to reduce metal loads to Flat Creek are being investigated as part of the closure studies for the Keno Hill Silver District. To aid in the evaluation of reclamation alternatives, a simulation model of metal loads to Flat Creek has been developed. Ten constituents have been incorporated into the model. These are cadmium, zinc, sulfate, nitrate, arsenic, copper, nickel, lead, selenium, and silver. Cadmium and zinc are the primary metal contaminants found in Flat Creek; therefore the primary focus of this investigation centers on load contributions from these two constituents. Increased concentrations of zinc and cadmium are a result of release and transport of these metals from mining sites through a combination of geochemical and hydrologic processes that occur in the Flat Creek watershed.

This report provides a description of the Flat Creek mass loading model in the areas of:

- Simulation framework;
- Conceptual model;
- Mathematical descriptions of metal loading and associated key assumptions;
- Calibration procedures; and
- Simulations of potential reductions in metal loads for a range reclamation options.

It is expected that this model will evolve over time as needed to assist in the reclamation evaluation effort and with continued discussion of assumptions and mathematical approaches most appropriate to representing metal loads in Flat Creek. The model's ability to simulate the loading processes in Flat Creek will increase with additional flow and water quality monitoring efforts at key locations within the Flat Creek Watershed.

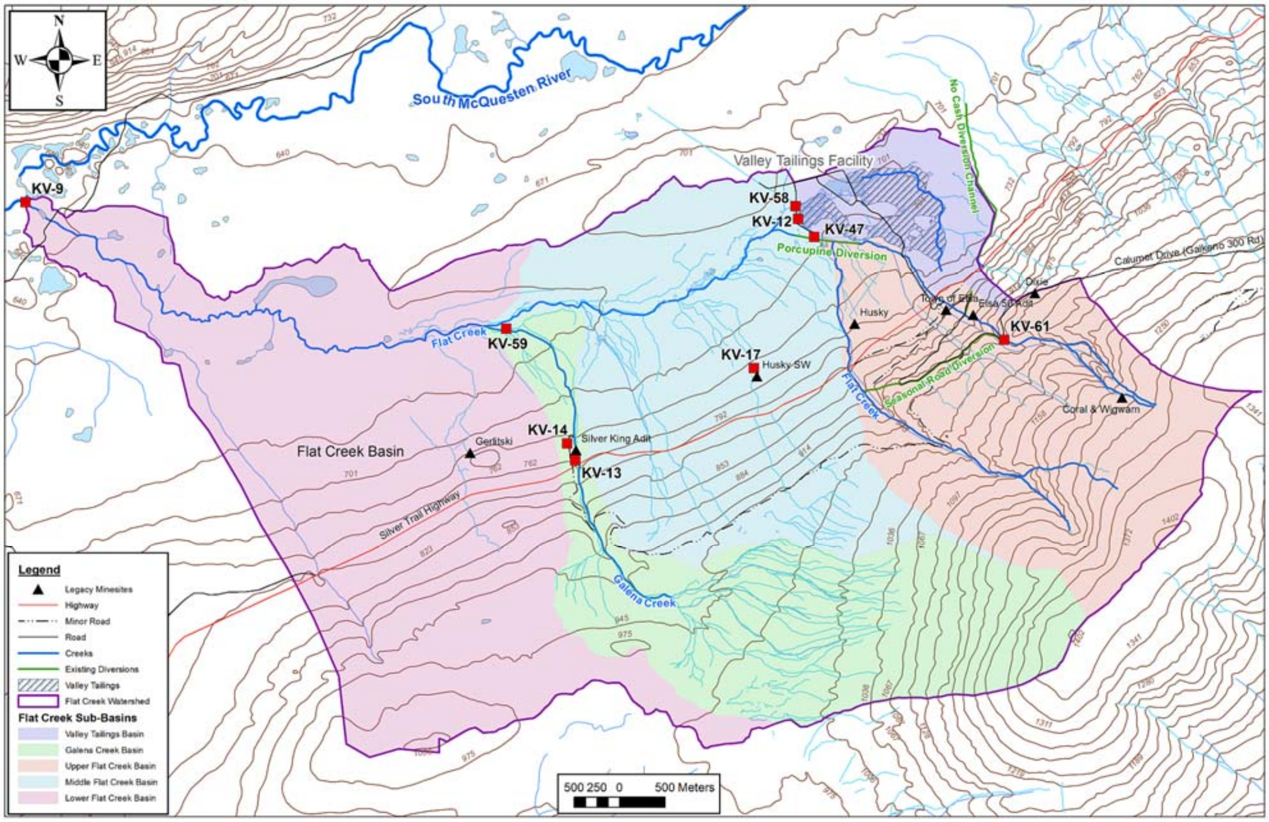


Figure 1-1. Map of Flat Creek Watershed

2.0 SIMULATION FRAMEWORK

The model was developed in the GoldSim simulation framework (www.goldsim.com). GoldSim provides a framework for mathematically representing the dynamics of both water balance and chemical mass balance, which when combined provide the ability to simulate metal mass loadings. The GoldSim framework also provides the capability to represent uncertainties in simulation results through probabilistic calculations.

2.1 Simulation Settings

The simulation settings for the simulation model were as follows:

- **Simulation Length**: The model is configured with a start date of January 1, 2008 and an end date of January 1, 2041 for a total length of 32 years.

- **Simulation time periods:** The simulation period is divided into two components comprised of the following:

    - ***Calibration Period*** from January 1, 2008 through the dates of the most recently available monitoring data: This period utilizes recent historical data from monitoring sites in the Flat Creek watershed to allow for model calibration through iterative adjustment of model parameters in order to obtain a match between observed and simulated results for water balance and metal loads. Each monitoring site has an independent calibration period which is determined by the availability of historical data. Currently, the model utilizes historical monitoring results through July 2013 for the most actively monitored sites. Sites not monitored as frequently typically have their calibration period end in the fall of 2012.

    - ***Future Simulation Period*** from the end of the available historical monitoring results to January 1, 2041: There are two phases of the future simulation period: the first phase is the baseline condition in which no new reclamation options are considered for mitigating metal loads to Flat Creek. The second phase incorporates the potential effects of different reclamation options for decreasing metal loads relative to the baseline condition. Each reclamation option has an independent start date that can be configured via the user interface.

- **Time step**: A time step of one day is used for all simulations. Measured data are typically available on a weekly, monthly, or quarterly basis, although some measurements occur at random intervals. A one-day time step provides a sufficiently small time increment for accurate representation of the measured data while not requiring extensive simulation run time.

3.0 CONCEPTUAL MODEL

Figure 3-1 shows a conceptual model of the sources of constituent loads in the Flat Creek watershed. The simulation model is based on this conceptualization of hydrogeochemical processes depicted in Figure 3-1 in conjunction with available historical data. The loads reporting to Flat Creek are a function of both the rate of release of metals from various sources and the mass flux from these source areas to Flat Creek. The major known sources of metals and transport routes to Flat Creek include the following:

- Discharge from the water treatment plant at Silver King reporting to Flat Creek via overland flow;
- Discharge from non-treated adit discharge at Husky SW reporting to Flat Creek via channelized flow;
- Combined metal loading from the upper Flat Creek watershed resulting from a variety of sources including adit outflow, waste rock piles, and dispersed tailings transported via the upper portion of Flat Creek, Porcupine Creek, Brefault Creek, and the Porcupine Diversion ditch;
- Controlled water releases as well as dam seepage from the Valley Tailings Facility; and
- Natural background sources of metals in surface runoff and groundwater.

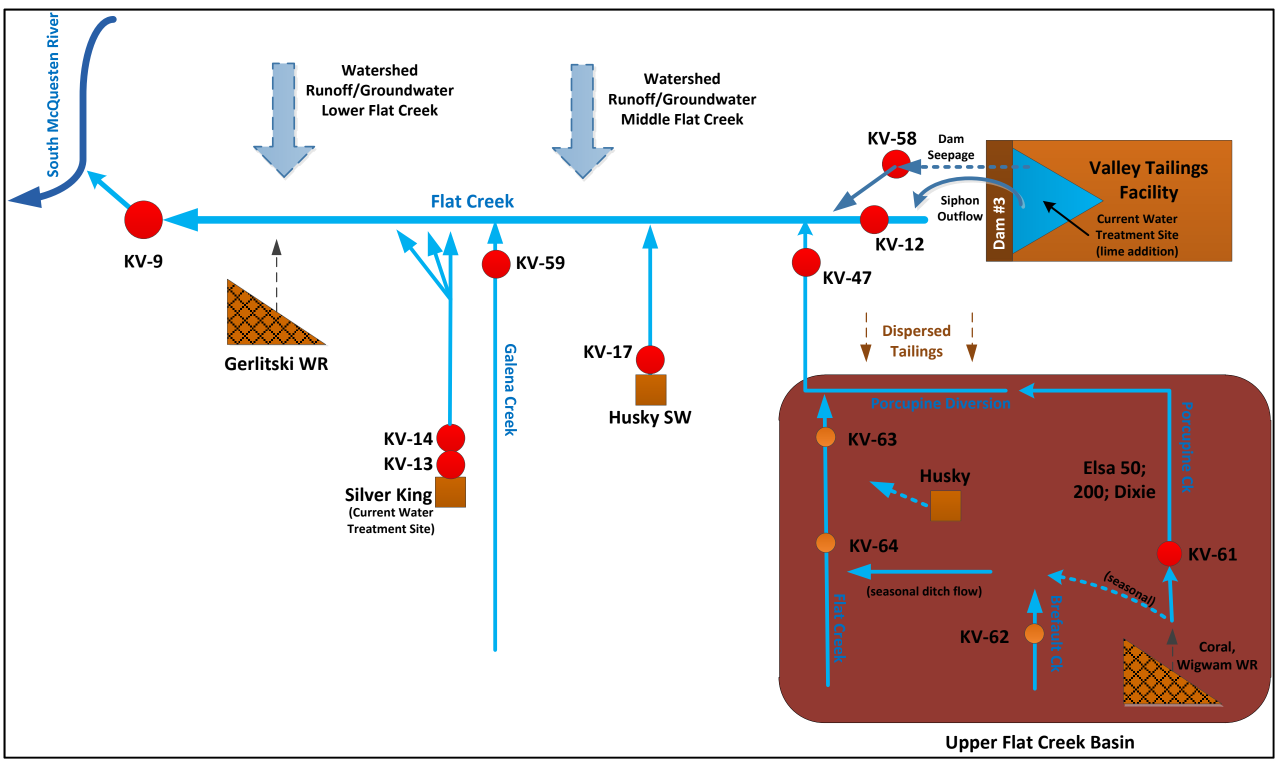


Figure 3-1. Conceptual model of metal loading for the Flat Creek watershed

Due to complex seasonal hydrology and insufficient monitoring data for flow and water quality, the flow and metal load contributions of the upper Flat Creek basin were consolidated into a single element for modeling purposes. These combined flow and metal loading contributions from the upper Flat Creek basin are incorporated into the model at KV-47. Metal loading from waste rock piles in the Flat Creek watershed was not explicitly tracked within the model because the Gerlitski, Coral, and Wigwam waste rock piles are not believed to be significant sources of metals. Metal loading from these piles is tracked indirectly via the combined load contribution at KV-47 (Coral and Wigwam) and through the make-up load added to the lower Flat Creek watershed as part of the model calibration (Gerlitski).

The emphasis of this modeling effort was focused on the determination of metal loading to Flat Creek and subsequently to the South McQuesten River as represented by data for monitoring location KV-9, which is the most downstream sample collection point in the hydrologic system and the key calibration point for the simulation model. Monitoring sites KV-14 at Silver King and KV-17 at Husky SW track water quality at the point of discharge and not at the point where the discharge impacts Flat Creek. Previous field investigations (Interralogic, Inc., 2012) have demonstrated substantial attenuation of metals in transport pathways due to natural geochemical processes. As a result, the model utilizes estimated reduction factors to reflect the reduction in metal loads between these discharge points and Flat Creek.

4.0 Hydrology

4.1 Climatic Data

Average monthly precipitation and lake evaporation data were obtained from a previous site characterization report (Access, 2004). The use of these data in the model was limited to several specific purposes. One use was in the development of a general water balance for the Valley Tailings Facility to help confirm estimated annual siphon outflow volume which was based on inadequate measurements. The second use was in the estimation of the volume of infiltration into tailings covers when modeling reclamation options for the Valley Tailings Facility.

Table 4-1. Monthly precipitation and lake evaporation

Month	Elsa Average Precipitation (mm/month)	Lake Evaporation (mm/month)
Jan	20	0
Feb	28	0
Mar	18	0
Apr	18	40
May	25	90
Jun	40	108
Jul	60	107
Aug	52	85
Sep	42	25
Oct	45	5
Nov	38	0
Dec	35	0
Total (mm):	**421**	**460**

4.2 Watershed Runoff

Many of the hydrologic elements in the model lacked sufficient historical flow measurements to fully characterize seasonal and inter-annual flow contributions. For these hydrologic elements, mean annual runoff (MAR) was used to in lieu of field measurements. Mean annual runoff can be conceptualized as the annual watershed yield reporting to a downstream point. As with precipitation, MAR is expressed in units of depth per unit of time. Expected runoff volume for a watershed is found by multiplying the MAR by the area of the watershed. A MAR of 213 mm/year was used at the starting point for the Flat Creek watershed (Clearwater, 2010) with the annual value adjusted on a year-by-year basis during model calibration to achieve better agreement between simulated and measured cumulative flow volume at KV-9. The distribution of MAR on a monthly basis was also obtained from previous reports (Clearwater, 2010; Access 2008 mass balance spreadsheet model); however the distribution was modified to better match the seasonal runoff pattern of the Flat Creek watershed as measured near the mouth at KV-9. The details of this calibration are described in the following section.

4.3 Daily Flow Series for KV-9

The monitoring site at KV-9 near the mouth of Flat Creek is the most downstream monitoring site on Flat Creek. It serves to integrate the impacts of all upstream flow and load contributions. Because of this, it was used as the reference point for model calibration. Reference points require good estimates of measured values for comparison to model-predicted values. For flow, KV-9 had daily flow gauge data available only for certain periods during years 2008 to 2013. It also had a few periodic, manual stream flow measurements obtained in conjunction with water quality samples. To fill the large gaps in historic flow rates at KV-9, daily watershed runoff values for the calibration period 1/1/2008 – 09/12/2013 were calculated using the MAR and the previously reported monthly distribution of MAR. The calculated daily flow values were calibrated against the measured values by adjusting the MAR value on a yearly basis to match total flow volume and by adjusting the monthly distribution of the MAR to match seasonal flow patterns. When a reasonable fit for most of the measured data was achieved, the resulting calculated daily flow values were used to fill in missing measured daily values in order to create a complete daily baseline flow series for KV-9. The historic flow measurements, calculated runoff, and resulting baseline flow series are presented in Figure 4-1. The resulting monthly distribution of MAR following the calibration process is shown in Table 4-2.

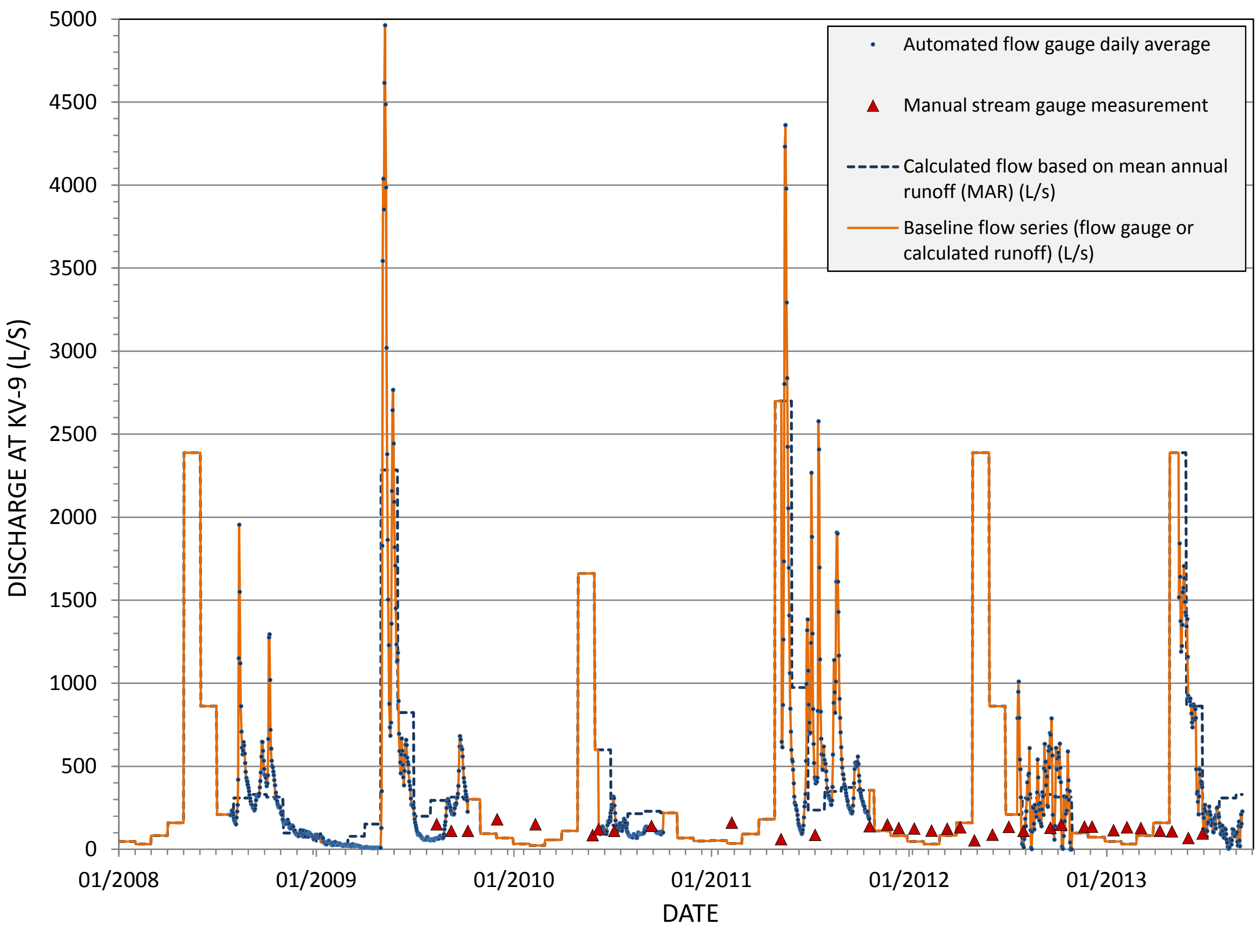


Figure 4-1. Measured flow values and calculated daily baseline flow series at KV-9

Table 4-2. Calibrated monthly distribution of mean annual runoff

Month	Monthly Distribution (%)
Jan	0.97
Feb	0.60
Mar	1.70
Apr	3.19
May	49.22
Jun	17.19
Jul	4.30
Aug	6.36
Sep	6.57
Oct	6.50
Nov	1.97
Dec	1.44
Total:	**100.0**

Table 4-3. Annual runoff values at KV-9 during calibration and future simulation periods

Year	Period	Annual Runoff (mm)
2008	Calibration	230
2009	Calibration	220
2010	Calibration	160
2011	Calibration	260
2012	Calibration	230
2013	Calibration	230
2012 - 2041	Future Simulation	230

4.4 Flow Contributions from Model Components

The methods used to represent flow from various model elements are summarized in Table 4-4. Outflow from components with insufficient historical measurements to characterize historical or future average flow contributions was calculated using the product of the calibrated MAR monthly distribution (Table 4-2) and the area of the region contributing flow to the downstream measurement point (Table 4-5). Model components with outflow calculated using this method are shown in Table 4-4 as “Watershed Runoff Calculation.”

Table 4-4. Methods used to represent flow from model components during calibration and future simulation periods

	Upper Flat Creek Watershed (KV-47)	Valley Tailings - Surface (KV-12)	Valley Tailings - Subsurface (KV-58)	Husky SW (KV-17)	Middle Flat Creek Watershed	Galena Creek (KV-59)	Silver King (KV-14)	Lower Flat Creek Watershed	Flat Creek at Mouth (KV-9)
Calibration Period	Watershed Runoff Calculation	Average Daily Siphon Outflow Schedule	Calculated Seepage Estimate	Average Adit Outflow (constant value)	Watershed Runoff Calculation	Watershed Runoff Calculation minus KV-14 Flow	Historical Measured Values	Watershed Runoff Calculation	Measured and Estimated Daily Flow Series
Future Baseline Simulation Period	Watershed Runoff Calculation	Average Daily Siphon Outflow Schedule	Calculated Seepage Estimate	Average Adit Outflow (constant value)	Watershed Runoff Calculation	Watershed Runoff Calculation minus KV-14 Flow	Monthly Average of Historical Values	Watershed Runoff Calculation	Watershed Runoff Calculation

Table 4-5. Basin areas used in runoff calculations

Basin	Area (km^2)
Upper Flat Creek	10.6
Valley Tailings	2.5
Middle Flat Creek	12.25
Galena Creek	10.05
Lower Flat Creek	19.06
Total:	**54.46**

4.4.1 Valley Tailings Facility Surface Outflow

Surface outflow from the Valley Tailings Facility during the historic calibration and future baseline scenario occurs via a siphon at Dam #3. Siphon operation is generally recorded in care and maintenance spreadsheet logs; however measurements of actual flow rates were not always available. An estimated annual schedule for siphon outflow was developed using historical records of siphon operation for the past several years. Flow rates were set to 0, 10 or 20 L/s based on the number of times historical siphon operation occurred on a given day of the year. The resulting schedule of annual siphon outflow rates is shown in Figure 4-2.

A rough confirmation of the siphon outflow schedule was performed through the development of a simple water balance for solely the Valley Tailings Facility. Precipitation was assumed to be the only source of water to the system. Outflows occurred via surface evaporation and siphon outflow. Surface evaporation calculations assumed one-half of the area of the facility was either ponded water or saturated tailings material subject to surface evaporation loss rates. Siphon outflow rates used the annual schedule shown in Figure 4-2. Over the course of the 30-year simulation, the cumulative difference between the inflows and outflows was less than 5%, providing evidence that the siphon outflow schedule used in the loading model is representative of the hydrologic response of the Valley Tailings Facility to precipitation and runoff patterns.

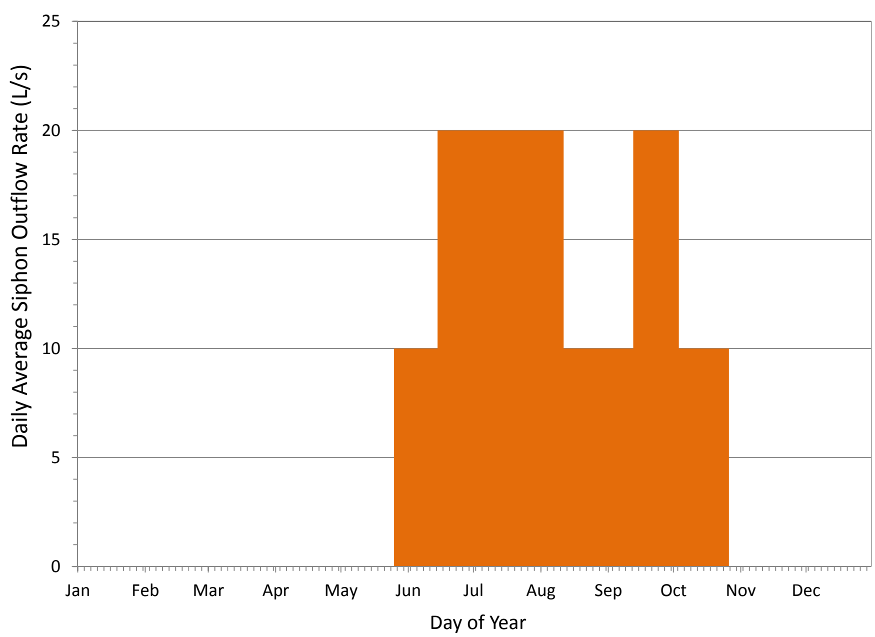


Figure 4-2. Estimated annual Valley Tailings siphon outflow rates

4.4.2 Valley Tailings Facility Sub-Surface Outflow

Subsurface outflow from the Valley Tailings Facility via seepage through Dam #3 was represented by using the calculated groundwater flux reported by Green (SRK, 2008). The best engineering judgment value was 18 m^3/d but the range of estimated values went from 0.1 to 2355 m^3/d. A stochastic element with a distribution spanning this range of values was included in the model so that the user can evaluate the impact of this range of values on downstream loads.

4.4.3 Husky SW Flow

Measured flows from Husky SW have decreased significantly since earlier monitoring efforts during the period 1994 through 1995. Flow measurements were only taken a few times between that period and 2006 when two or three measurements were made per year. Values from 2006 through April 2013 were used to develop an average outflow value of 0.2 L/s. These values were used for both baseline and future flow representation.

4.4.4 Galena Creek Flow

Only four flow measurements were available for Galena Creek, therefore the watershed runoff calculation method was used to develop estimated flow contributions. It is likely that at least a portion of the flow emanating from Silver King results from infiltration of precipitation received on the Galena Creek watershed. Evidence of a seasonal pattern can be found in the Silver King outflow measurements. To avoid double-counting Silver King outflow, the calculated daily watershed runoff for the Galena Creek watershed was reduced by the equivalent of 50% of the daily outflow value for Silver King (Section 4.4.5) before routing it to Flat Creek.

4.4.5 Silver King Flow

Silver King outflow is typically measured daily, so these daily values were used to represent outflow during the calibration period. Flow conditions during the future simulation period were represented by average monthly flow values.

5.0 Water Quality

Metal concentrations used to calculate load contributions from each model component were obtained from a compilation of historical water quality sampling results provided by Access Consulting Group. Use of these data to characterize historic and simulated future concentrations is described in the following sections.

5.1 Historical Calibration Period

Historical metal concentrations occurring during the calibration period were used to represent the water quality conditions at each monitoring site used in the model. The concentration at each site was assumed to remain at the most-recently measured concentration until the next water quality measurement was taken. Historical values for cadmium, zinc, sulfate and arsenic during the calibration period are plotted in Figure 5-1 through Figure 5-4.

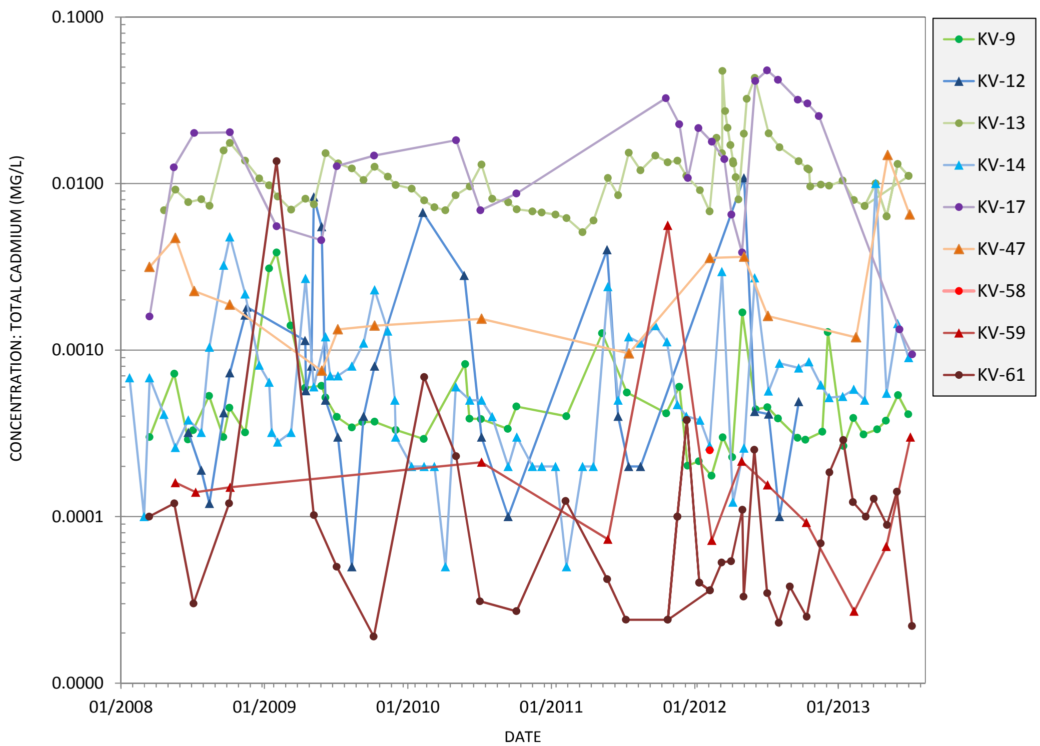


Figure 5-1. Historical concentrations of total cadmium used in model during calibration period

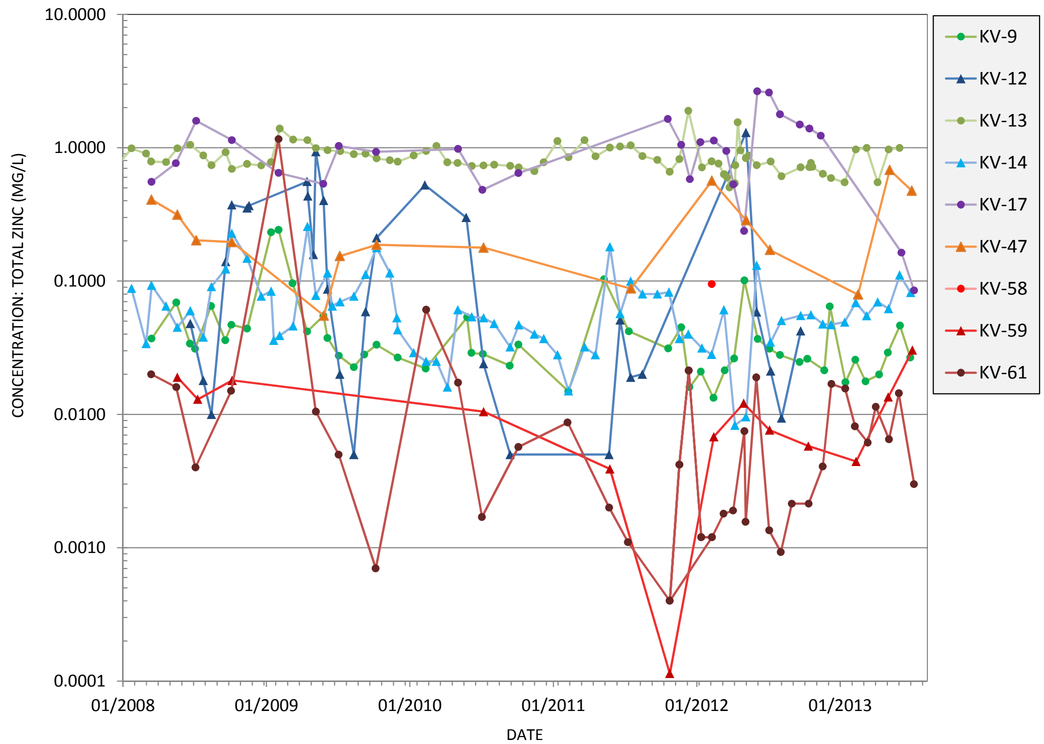


Figure 5-2. Historical concentrations of total zinc used in model during calibration period

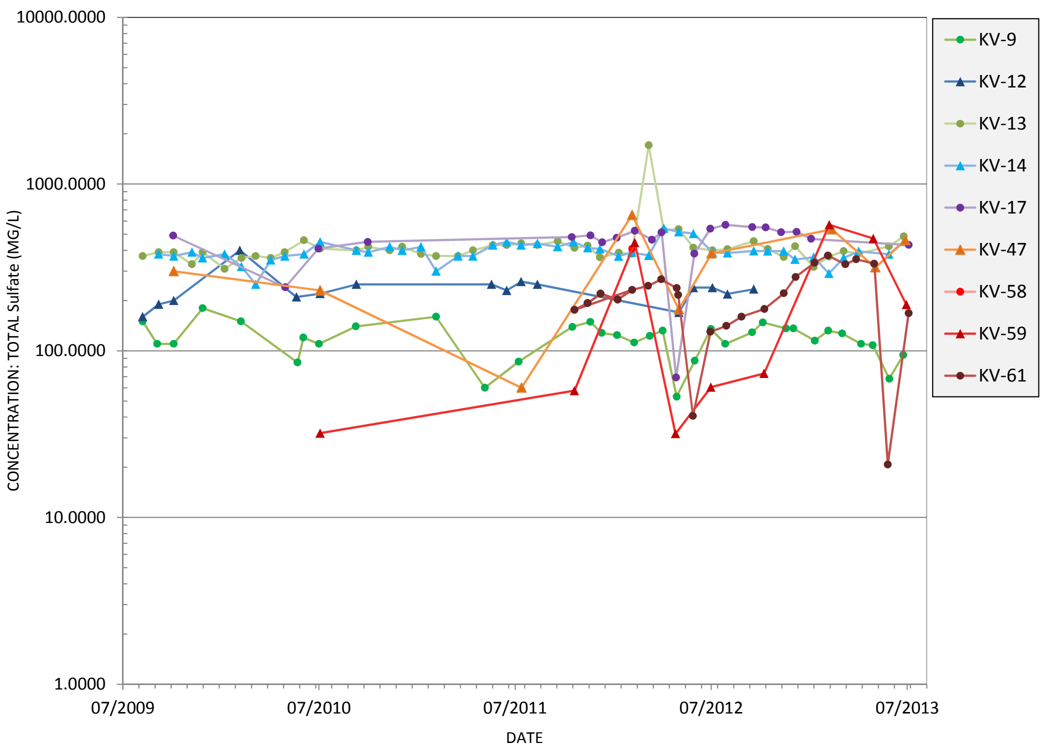


Figure 5-3. Historical concentrations of total sulfate used in model during calibration period

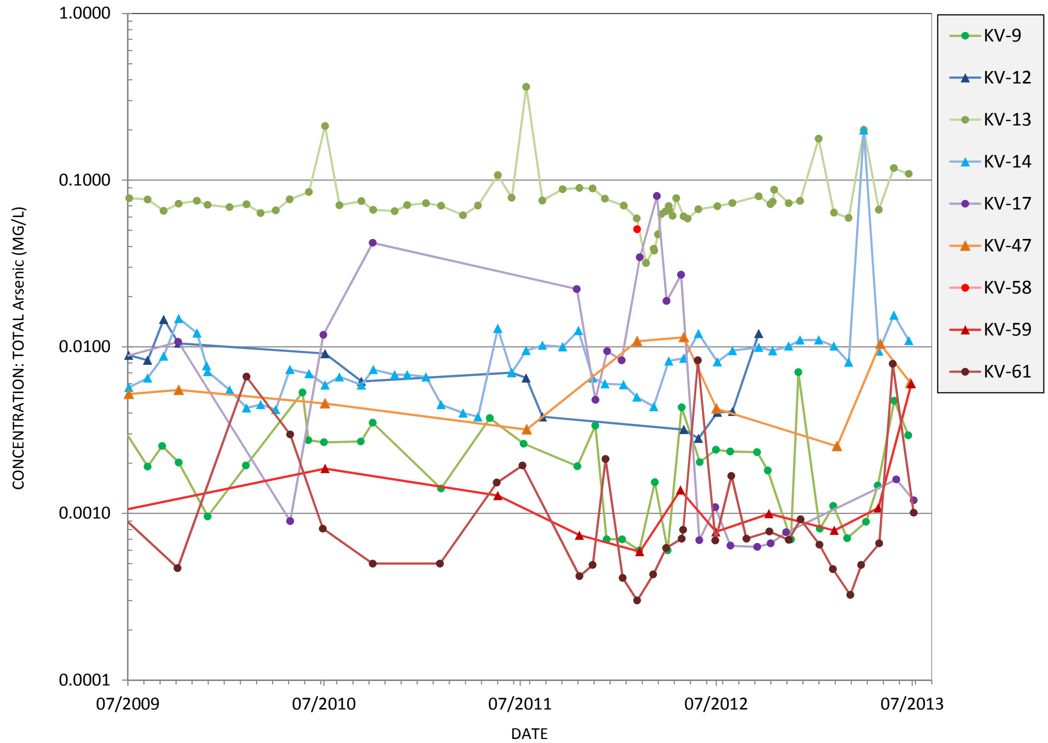


Figure 5-4. Historical concentrations of total arsenic used in model during calibration period

5.2 Simulated Future Concentrations

For monitoring sites with sufficient data points (KV-9, KV-12, KV-13, KV-17, KV-14, and KV-61), monthly average values were calculated. Monthly averages utilized all historic monitoring data including values obtained before beginning of the model calibration period (1/1/2008). Data from samples before 2008 were included in order to provide additional observations to provide sufficient values for the calculation of an average for each month of the year. All historic values were checked to ensure that values from before 2008 were not markedly difference from values measured in 2008 or later. When sufficient historic monitoring results were not available to calculate monthly averages, a single overall average was calculated for just the calibration period (KV-47, KV-58 and KV-59). The resulting average values were used to simulate future concentrations at various sites within the model. The average values used for cadmium, zinc, sulfate, and arsenic are shown in Table 5-1 through Table 5-4.

Table 5-1. Average total cadmium concentrations used to simulate future baseline concentrations

Average Conc. Cd (total) (mg/L)	Upper Flat Creek Watershed (KV-61)*	Upper Flat Creek Watershed (KV-47)**	Valley Tailings - Surface (KV-12) *	Valley Tailings - Subsurface (KV-58)	Husky SW (KV-17)*	Galena Creek (KV-59)**	Silver King (KV-13) *	Silver King (KV-14) *	Flat Creek at Mouth (KV-9) *
Annual	0.00042	0.00328	0.00168	(assumed	0.01763	0.00056	0.01189	0.00095	0.00060
January	0.00012	--	0.00089	same	0.02150	--	0.00887	0.00042	0.00079
February	0.00243	--	0.00396	as	0.01167	--	0.00869	0.00028	0.00079
March	0.00008	--	0.00149	KV-12)	0.00780	--	0.01462	0.00114	0.00050
April	0.00009	--	0.00113	--	0.00650	--	0.00987	0.00210	0.00033
May	0.00010	--	0.00485	--	0.00978	--	0.01255	0.00070	0.00087
June	0.00117	--	0.00040	--	0.01671	--	0.01504	0.00171	0.00041
July	0.00003	--	0.00026	--	0.01966	--	0.01290	0.00203	0.00048
August	0.00002	--	0.00012	--	0.04190	--	0.01178	0.00105	0.00041
September	0.00009	--	0.00031	--	0.02735	--	0.01254	0.00127	0.00036
October	0.00004	--	0.00061	--	0.02180	--	0.01206	0.00193	0.00040
November	0.00009	--	0.00147	--	0.02405	--	0.01135	0.00141	0.00042
December	0.00031	--	0.00100	--	0.01080	--	0.00909	0.00040	0.00060

* sufficient data available for monthly average values to be used

** no data - estimated value

-- insufficient data for monthly averages

Table 5-2. Average total zinc concentrations used to simulate future baseline concentrations

Average Conc. Zn (total) (mg/L)	Upper Flat Creek Watershed (KV-61)*	Upper Flat Creek Watershed (KV-47)**	Valley Tailings - Surface (KV-12) *	Valley Tailings - Subsurface (KV-58)	Husky SW (KV-17)*	Galena Creek (KV-59)**	Silver King (KV-13) *	Silver King (KV-14) *	Flat Creek at Mouth (KV-9) *
Annual	0.0351	0.2694	0.2186	(assumed	1.0329	0.0112	0.8457	0.0678	0.0449
January	0.0060	--	0.1850	same	1.1000	--	0.8329	0.0494	0.0617
February	0.2067	--	0.3625	as	0.8885	--	0.7986	0.0415	0.0499
March	0.0093	--	0.1780	KV-12)	0.7500	--	0.8888	0.1026	0.0384
April	0.0067	--	0.3807	--	0.5300	--	0.6847	0.0826	0.0270
May	0.0088	--	0.4554	--	0.6288	--	0.8166	0.0675	0.0679
June	0.1544	--	0.0468	--	1.1067	--	1.0997	0.1214	0.0371
July	0.0032	--	0.0190	--	1.3197	--	1.0201	0.1335	0.0434
August	0.0009	--	0.0137	--	1.7800	--	0.9400	0.0831	0.0396
September	0.0111	--	0.0494	--	1.6050	--	0.9960	0.0859	0.0316
October	0.0041	--	0.2155	--	1.1858	--	0.8921	0.1309	0.0342
November	0.0042	--	0.3547	--	1.1400	--	0.9179	0.1142	0.0368
December	0.0198	--	0.3500	--	0.5800	--	0.8151	0.0493	0.0358

Table 5-3. Average dissolved sulfate concentrations used to simulate future baseline concentrations

Average Conc. SO4 (total) (mg/L)	Upper Flat Creek Watershed (KV-61)*	Upper Flat Creek Watershed (KV-47)**	Valley Tailings - Surface (KV-12) *	Valley Tailings - Subsurface (KV-58)	Husky SW (KV-17)*	Galena Creek (KV-59)**	Silver King (KV-13) *	Silver King (KV-14) *	Flat Creek at Mouth (KV-9) *
Annual	217	346	233	(assumed	456	215	432	396	119
January	248	--	232**	same	448	--	0	325	130
February	279	--	400	as	524	--	370	339	139
March	288	--	232**	KV-12)	464	--	712	414	129
April	311	--	232**	--	512	--	418	424	127
May	262	--	210	--	155	--	452	445	89
June	110	--	217	--	382	--	432	446	97
July	149	--	240	--	460	--	434	421	123
August	141	--	210	--	569	--	402	399	130
September	160	--	225	--	552	--	424	402	126
October	177	--	200	--	493	--	408	405	132
November	202	--	232**	--	503	--	381	380	143
December	239	--	232**	--	482	--	399	383	148

* sufficient data available for monthly average values to be used

** no data - estimated value

-- insufficient data for monthly averages

Table 5-4. Average total arsenic concentrations used to simulate future baseline concentrations

Average Conc. As (total) (mg/L)	Upper Flat Creek Watershed (KV-61)*	Upper Flat Creek Watershed (KV-47)**	Valley Tailings - Surface (KV-12) *	Valley Tailings - Subsurface (KV-58)	Husky SW (KV-17)*	Galena Creek (KV-59)**	Silver King (KV-13) *	Silver King (KV-14) *	Flat Creek at Mouth (KV-9) *
Annual	0.00218	0.00745	0.01056	(assumed	0.01570	0.00143	0.07816	0.01085	0.00350
January	0.00053	--	0.05230	same	0.00830	--	0.08783	0.00735	0.00724
February	0.00171	--	0.04500	as	0.02855	--	0.05738	0.00581	0.00621
March	0.00038	--	0.04030	KV-12)	0.06300	--	0.05603	0.00797	0.00315
April	0.00056	--	0.02690	--	0.01880	--	0.07929	0.03637	0.00168
May	0.00364	--	0.00925	--	0.01965	--	0.08065	0.00815	0.00377
June	0.00830	--	0.00700	--	0.00596	--	0.08778	0.00880	0.00287
July	0.00105	--	0.00719	--	0.00883	--	0.12968	0.00751	0.00279
August	0.00168	--	0.00490	--	0.00064	--	0.06963	0.00761	0.00237
September	0.00225	--	0.00910	--	0.01507	--	0.07520	0.00830	0.00277
October	0.00187	--	0.00728	--	0.01468	--	0.07396	0.01071	0.00233
November	0.00059	--	0.00567	--	0.00279	--	0.08261	0.01148	0.00186
December	0.00152	--	0.00720	--	0.00940	--	0.06316	0.00769	0.00290

6.0 METAL LOAD COMPUTATION

The loading model is based on a series of mathematical equations to calculate metal loads as a function of the dynamics of the watershed and effects expected to occur as a result of implementation of different reclamation options. As detailed above, the metal load calculations are split into two main simulation periods: the calibration period and the future simulation period. The calibration period was selected to begin on 1/1/2008 and extend through the end of available data on a site-by-site basis; however measured metal concentrations for earlier years were sometimes used to provide sufficient data for the development of monthly average concentrations at selected sites when deemed appropriate. The future simulation period includes simulation of metal loads for both the current baseline (average) conditions and optionally for scenarios under which various reclamation options are hypothetically implemented.

6.1 Load Source: Upper Flat Creek Watershed

Model inputs used to simulate metal loading from the upper Flat Creek watershed during future baseline and treatment options are summarized in Table 6-1. Metal loading at KV-47 under the calibration period and future baseline period was calculated using the average metal concentrations at KV-47. Under all three Valley Tailings reclamation options the water quality of the Porcupine Diversion is expected to be improved through the creation of a new diversion in non-tailings material and through the addition of a cover or transfer of exposed hillside tailings. The improvement in water quality and therefore reduction in metal load under each of the options was represented by using a function of the average metal concentrations found upstream of this area along Porcupine Creek at KV-61.

Table 6-1. Summary of model inputs under future baseline and treatment options: Upper Flat Creek Watershed

Upper Flat Creek Watershed (at KV-47)			***Water Quality (mg/L)***									
Scenario	**Description**	**Flow**	**Cd**	**Zn**	**SO4**	**NH3**	**As**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**
0	Baseline (current treatment through lime addition)	MAR * Upper Flat Creek Area (10,580,000 m^2)	0.00316	0.276	348	0.059	0.0074	0.0041	0.0511	0.0031	0.00062	0.00073
	Notes: WQ values are based on mean of recent measured values at KV-47.											
1	Close in place	MAR * Upper Flat Creek Area (10,580,000 m^2)	0.00084	0.072	434	0.000	0.0044	0.0030	0.0056	0.0031	0.00096	0.00007
	Notes: New diversion installed in non-tailings material. Cover exposed hillside tailings. Assume WQ at KV-47 becomes similar to 2X WQ in Porcupine Creek at KV-61.											
2	Combine exposed tailings	MAR * Upper Flat Creek Area (10,580,000 m^2)	0.00042	0.036	217	0.000	0.0022	0.0015	0.0028	0.0015	0.00048	0.00003
	Notes: New diversion installed in non-tailings material. Hillside tailings moved to VTF. Assume WQ at KV-47 becomes similar to WQ in Porcupine Creek at KV-61.											
3	Combine tailings into lined facility	MAR * Upper Flat Creek Area (10,580,000 m^2)	0.00042	0.036	217	0.000	0.0022	0.0015	0.0028	0.0015	0.00048	0.00003
	Notes: New diversion installed in non-tailings material. Hillside tailings moved to VTF. Assume WQ at KV-47 becomes similar to WQ in Porcupine Creek at KV-61.											

6.2 Load Source: Valley Tailings Surface Runoff

Model inputs and assumptions used to simulate metal loading from the Valley Tailings Facility (VTF) during future baseline and treatment options are summarized in Table 6-2 for surface outflows and Table 6-3 for subsurface seepage outflows. Three reclamation scenarios are under consideration for the VTF:

1. Close in place;
2. Combine exposed tailings, and;
3. Combine exposed tailings into a lined tailings facility.

These options will result in changes to the hydrology and to metal concentrations in outflows from the VTF. Additionally, with respect to water quality of VTF outflows, each of the three reclamation options involves an implementation phase and graduated response phase. It was assumed each option would take ten years to establish long-term conditions. During the five-year project implementation phase, all runoff and seepage from the VTF area would be collected and treated on-site by a plant with efficiency similar to the Galkeno 900 site. After this five-year phase, water outflows would no longer be captured and treated. During the next five year period, metal concentrations in the outflows are assumed to decline in a gradual manner until they reach their final estimated concentrations at the beginning of the eleventh year after initiation of reclamation.

Under the baseline future scenario, surface outflows from the VTF continue to be modeled as siphon outflow. Under each reclamation option, surface runoff flows from non-covered and covered areas are calculated separately. Each calculation of runoff volume is based on the mean annual runoff depth multiplied by the respective surface area (covered –vs. - non-covered area). Under reclamation scenario 1, the entire area of the VTF would be covered. Under scenarios 2 and 3, the entire area of the VTF is reclaimed but not covered and an additional area representing the covered tailings facility is created. The area used by the covered tailings facility is subtracted from the area of the Middle Flat Creek Watershed and the runoff from that watershed area is reduced accordingly. Changes in outflow volume due to reclamation scenarios are assumed to occur upon commencement of the reclamation efforts (i.e. no graduated implementation phase).

Metal concentrations in surface outflows under future baseline conditions are assumed to continue to be similar to average values at KV-12. Post-reclamation, non-covered reclaimed VTF areas (options 2 and 3) are assumed to produce runoff with metal concentrations similar to average values at KV-61. Areas receiving clean cover material (options 1, 2, and 3) are assumed to generate runoff bearing no metal load after establishment of long-term conditions.

Table 6-2. Summary of model inputs under future baseline and treatment options: Valley Tailings surface runoff

Scenario	Component	Time Period	Non-Covered Area	Covered Area
Baseline (continue current treatment through lime addition)	Flow	Baseline Conditions and all Pre-Reclamation Time Periods	siphon outflow schedule	n/a (no cover under baseline conditions)
	Water Quality	Baseline Conditions and all Pre-Reclamation Time Periods	avg @ KV-12	n/a (no cover under baseline conditions)
Option 1 (close in place)	Flow	Post-Reclamation (entire period)	n/a (all areas covered)	MAR * VTF area (2,500,000 m^2)
	Water Quality	Post-Reclamation Years 1-5	n/a (all areas covered)	avg @ Galkeno 900
		Post-Reclamation Years 6-10	n/a (all areas covered)	avg @ Galkeno 900 * (100% -> 0%)
		Post-Reclamation Years 11 -	n/a (all areas covered)	0 mg/L (assume no load contributed by runoff from covered areas)
Option 2 (combine tailings and cover)	Flow	Post-Reclamation (entire period)	MAR * VTF area (2,500,000 m^2)	MAR * covered tailings area (286,580 m^2)
	Water Quality	Post-Reclamation Years 1-5	avg @ Galkeno 900	avg @ Galkeno 900
		Post-Reclamation Years 6-10	avg @ KV-61 * (150% -> 100%)	avg @ Galkeno 900 * (100% -> 0%)
		Post-Reclamation Years 11 -	avg @ KV-61	0 mg/L (assume no load contributed by runoff from covered areas)
Option 3 (combine tailings into lined facility and cover)	Flow	Post-Reclamation (entire period)	MAR * VTF area (2,500,000 m^2)	MAR * covered tailings area (286,580 m^2)
	Water Quality	Post-Reclamation Years 1-5	avg @ Galkeno 900	avg @ Galkeno 900
		Post-Reclamation Years 6-10	avg @ KV-61 * (150% -> 100%)	avg @ Galkeno 900 * (100% -> 0%)
		Post-Reclamation Years 11 -	avg @ KV-61	0 mg/L (assume no load contributed by runoff from covered areas)

6.3 Load Source: Valley Tailings Subsurface Seepage

Subsurface outflow from the VTF is assumed to continue as seepage from Dam #3 under the future baseline scenario. As with surface outflows, all reclamation options assume capture and treatment of all subsurface outflow for the first five years and a graduated implementation of long-term conditions over the next five years. Subsurface seepage rates and quality are also calculated separately for non-covered and covered areas. Future baseline conditions assume the continuation of currently-observed seepage rates through Dam #3 and that seepage water quality is similar to measurements at KV-12. Subsurface outflows are assumed to be equal to 22% of average precipitation for the covered areas and 30% of precipitation for the reclaimed areas not receiving a cover.

Under scenario 1, the tailings are covered in place so there is less opportunity for complete incorporation of lime amendments. This scenario is assumed to result in a 75% reduction of metal concentrations in subsurface outflow compared to baseline conditions. Scenarios 2 and 3 include physical removal of tailings material to a separate facility. Because of the increased opportunity for complete incorporation of lime under these scenarios, a 90% reduction in metal concentrations is assumed for outflow from covered areas. Reclaimed former tailings areas are conservatively assumed to continue producing seepage with water quality equal to historical average values at KV-12. The assumptions used to model scenarios 2 and 3 are exactly the same and will produce identical estimates of subsurface outflow and metal loads in this model. The only difference is the assumption of a liner under the tailings facility included in scenario 3. The presence of a liner would provide more options should additional capture and treatment of subsurface outflow be desired.

Table 6-3. Summary of model inputs under future baseline and treatment options: Valley Tailings subsurface outflow

Scenario	Component	Time Period	Non-Covered Area	Covered Area
Baseline (continue current treatment through lime addition)	Flow	Baseline Conditions and all Pre-Reclamation Time Periods	0.208 L/s through Dam #3 (SRK report)	n/a (no cover under baseline conditions)
	Water Quality	Baseline Conditions and all Pre-Reclamation Time Periods	avg @ KV-12	n/a (no cover under baseline conditions)
Option 1 (close in place)	Flow	Post-Reclamation (entire period)	n/a (all areas covered)	22% infiltration into covered tailings area (286,580 m^2)
	Water Quality	Post-Reclamation Years 1-5	n/a (all areas covered)	avg @ Galkeno 900
		Post-Reclamation Years 6-10	n/a (all areas covered)	avg @ KV-12 * 25% * (150% -> 100%)
		Post-Reclamation Years 11 -	n/a (all areas covered)	avg @ KV-12 * 25%
Option 2 (combine tailings and cover)	Flow	Post-Reclamation (entire period)	30% infiltration into reclaimed VTF area (2,500,000 m^2)	22% infiltration into covered tailings area (286,580 m^2)
	Water Quality	Post-Reclamation Years 1-5	avg @ Galkeno 900	avg @ Galkeno 900
		Post-Reclamation Years 6-10	avg @ KV-12 * (150% -> 100%)	avg @ KV-12 * 10% * (150% -> 100%)
		Post-Reclamation Years 11 -	avg @ KV-12	avg @ KV-12 * 10%
Option 3 (combine tailings into lined facility and cover)	Flow	Post-Reclamation (entire period)	30% infiltration into reclaimed VTF area (2,500,000 m^2)	22% infiltration into covered tailings area (286,580 m^2)
	Water Quality	Post-Reclamation Years 1-5	avg @ Galkeno 900	avg @ Galkeno 900
		Post-Reclamation Years 6-10	avg @ KV-12 * (150% -> 100%)	avg @ KV-12 * 10% * (150% -> 100%)
		Post-Reclamation Years 11 -	avg @ KV-12	avg @ KV-12 * 10%

6.4 Load Source: Husky SW

Model inputs used to simulate metal loading from Husky SW adit discharge during future baseline and treatment options are summarized in Table 6-4. Under the baseline scenario, average values at KV-17 are used to represent initial water quality. These concentrations are reduced by fixed percentages in order to represent the impact of natural attenuation that occurs between KV-17 and Flat Creek. Minimum values are used to ensure that concentrations used to calculate loading to Flat Creek do not drop below concentrations reported in the natural attenuation study (Interralogic, Inc., 2012).

Similar approaches are used to estimate future loading impacts from Husky SW under the five different treatment options in the simulation model. Options that include treatment near the source utilize fixed percentage reduction in concentrations at KV-17 or assume treatment effluent concentrations similar to other treatment plants such as at Galkeno 900 (Table 6-5) or KV-14. These scenarios assume no additional reduction in concentration due to natural attenuation between the source and Flat Creek occurs.

Table 6-4. Summary of model inputs under future baseline and treatment options: Husky SW

Husky SW (KV-17)

Scenario	Description	Flow	Conc. At Source (mg/L) Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
0	Baseline (no active treatment)	no impact	KV-17 Monthly average value for each constituent									
1	Managed natural attenuation	no impact	KV-17 Monthly average value for each constituent									
2	Mine pool treatment	no impact	0.1*(KV-17 Monthly average value for each constituent)									
3	Bioreactor treatment	no impact	Galkeno 900 average									
4	Mechanical treatment	no impact	KV-14 Monthly average value for each constituent									
5	Reclamation only	no impact	KV-14 Monthly average value for each constituent									

Scenario	Description	Flow	Natural Attenuation * Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
0	Baseline (no active treatment)	no impact	98%	97%	0%	41%	65%	64%	90%	65%	72%	91%
1	Managed natural attenuation	no impact	98%	97%	0%	41%	65%	64%	90%	65%	72%	91%
2	Mine pool treatment	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	Bioreactor treatment	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	Mechanical treatment	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	Reclamation only	no impact	98%	97%	0%	41%	65%	64%	90%	65%	72%	91%

Scenario	Description	Flow	Conc. At Flat Creek (mg/L) Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
0	Baseline (no active treatment)	no impact	KV-17 Monthly Average*(1-Natural Attenuation Percentage) Minimum Values Given									
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005
1	Managed natural attenuation	no impact	KV-13 Monthly Average*(1-Natural Attenuation Percentage) Minimum Values Given									
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005
2	Mine pool treatment	no impact	KV-17 Average Value*0.1 Minimum Values Given Below									
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005
3	Bioreactor treatment	no impact	Galkeno 900 average									
4	Mechanical treatment	no impact	KV-14 average value Minimum Values Given Below									
			0.00002	0.002	230	0.01800	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005
5	Reclamation only	no impact	KV-17 Monthly Average*(1-Natural Attenuation Percentage) Minimum Values Given									
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005

Scenario	Description	Flow	Notes
0	Baseline (no active treatment)	no impact	Historical avg of KV-17 (2008 to last sampling date - insuff. data for monthly avg). Minimum values based on natural attenuation study average values near Flat Creek.
1	Managed natural attenuation	no impact	Same performance as current baseline with natural attenuation between source and Flat Creek, but with modifications to enhance long-term sustainability
2	Mine pool treatment	no impact	90% reduction in adit outflow as measured at KV-17 (treatment estimate based on Platoro case study as relayed by J. Harrington). No additional reduction due to
3	Bioreactor treatment	no impact	Assumes results similar to Galkeno 900 bioreactor pilot test. No additional reduction due to natural attenuation expected.
4	Mechanical treatment	no impact	Assumes results similar to current Silver King mechanical treatment (as measured at KV-14).
5	Reclamation only	no impact	Same performance as baseline scenario with current natural attenuation performance between source and Flat Creek, but with modifications to enhance long-

* Natural attenuation reduction between KV-14 and Flat Creek is based on Interralogic natural attenuation study conducted after implementation of current treatment system. As a result, starting concentrations at KV-14 were already low and minimal additional reduction in concentration due to natural attenuation was observed.

Table 6-5. Average measured constituent concentrations at Galkeno 900

Constituent	Concentration (mg/L)
Cd	0.00022
Zn	0.15
SO4	988.3
NH3	0.026
As	0.021
Cu	0.0014
Pb	0.0017
Ni	0.070
Se	0.0027
Ag	0.00019

6.5 Load Source: Middle Flat Creek Watershed

Although the middle Flat Creek watershed area was used as part of the calculation of flow emanating from the entire Flat Creek watershed, no metal load contributions were assigned to this component.

6.6 Load Source: Galena Creek

Load contributions from Galena Creek were calculated as the product of the calculated watershed runoff as described above (Section 4.4.4) and the metal concentrations described in Section 5.0. No changes to load contributions are expected to occur as a result of any reclamation options.

6.7 Load Source: Silver King

Model inputs used to simulate metal loading from Silver King during future baseline and treatment options are summarized in Table 6-6. Under the baseline scenario, average concentrations of treatment plant effluent at KV-14 are used to represent initial water quality. Under the baseline and active treatment scenarios, it is assumed no additional reduction in metal concentration due to natural attenuation occurs between the treatment plant effluent discharge and Flat Creek. Alternate treatment and natural attenuation scenarios utilize average metal concentrations measured at KV-13 which reflect Silver King outflow before treatment by the existing system.

Table 6-6. Summary of model inputs under future baseline and treatment options: Silver King

Silver King (KV-14)

Scenario	Description	Flow	Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
			Conc. At Source (mg/L)									
0	Baseline (current treatment plant)	no impact	KV-14 Monthly average value for each constituent									
1	Managed natural attenuation	no impact	KV-13 Monthly average value for each constituent									
2	Mine pool treatment	no impact	0.1 *(KV-13 Monthly average value for each constituent)									
3	Bioreactor treatment	no impact	Galkeno 900 average									
4	Continue current treatment	no impact	KV-14 Monthly average values for each constituent									

Scenario	Description	Flow	Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
			Natural Attenuation *									
0	Baseline (current treatment plant)	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1	Managed natural attenuation	no impact	98%	97%	0%	41%	65%	64%	90%	65%	72%	91%
2	Mine pool treatment	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	Bioreactor treatment	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	Continue current treatment	no impact	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Scenario	Description	Flow	Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
			Conc. At Flat Creek (mg/L)									
0	Baseline (current treatment plant)	no impact	KV-14 Monthly Average				Minimum Values Given Below					
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005
1	Managed natural attenuation	no impact	KV-13 Monthly Average*(1-Natural Attenuation Percentage)						Minimum Values Given			
			0.00002	0.002	230	0.018	0.00360	0.00560	0.0016	0.0037	0.0002	0.000005
2	Mine pool treatment	no impact	KV-13 Monthly Average*0.1				Minimum Values Given Below					
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.000005
3	Bioreactor treatment	no impact	Galkeno 900 Average									
4	Continue current treatment	no impact	KV-14 Monthly Averages				Minimum Values Given Below					
			0.00002	0.002	230	0.018	0.0036	0.0056	0.0016	0.0037	0.0002	0.00001

Scenario	Description	Flow	Notes
0	Baseline (current treatment plant)	no impact	Monthly average of historical treatment plant effluent values as measured at KV-14. No additional reduction due to natural attenuation expected (based on previous
1	Managed natural attenuation	no impact	No treatment of adit outflow. Starting concentrations based on KV-13. Natural attenuation values estimated based on Husky SW study.
2	Mine pool treatment	no impact	90% reduction in adit outflow as measured at KV-13 (treatment estimate based on Platoro case study as relayed by J. Harrington). No additional reduction due to natural
3	Bioreactor treatment	no impact	Assumes results similar to Galkeno 900 bioreactor pilot test. No additional reduction due to natural attenuation expected.
4	Continue current treatment	no impact	Monthly avg of historical treatment values as measured at KV-14. No additional reduction due to natural attenuation expected.

* Natural attenuation reduction between KV-14 and Flat Creek is based on Interralogic natural attenuation study conducted after implementation of current treatment system. As a result, starting concentrations at KV-14 were already low and minimal additional reduction in concentration due to natural attenuation was observed.

6.8 Load Source: Lower Flat Creek Watershed

Metal concentrations of surface and sub-surface flow contributions from Flat Creek watershed areas not impacted by legacy mining activity are not well characterized but are expected to be comparatively low. A make-up load calculated as part of the model calibration process was added to Flat Creek at this point. Additional details of the calibration process are presented in Section 7.0 below.

7.0 STOCHASTIC PARAMETERS

Two types of stochastic elements were incorporated into the model to represent the uncertainties of future metal loads in probabilistic simulations:

- Simple multipliers
- Direct values

Table 7-1 gives a list of all of the stochastic elements used in the model. The majority of these elements were simple multipliers that are applied as a percentage of uncertainty to specific inputs used in model calculations. For example, the stochastic element named *Chem_Uncertainty* has a truncated normal distribution that is described in Figure 7-1. In a probabilistic simulation, a new value is selected from this distribution for each model realization. The future chemical constituent concentrations are multiplied by this new value, which is a percentage range with a mean of 100% such that the mean value of the input parameter is always equal to the best estimate defined by the equations in Section 4. After a large number of realizations (e.g., 200 to 500), a range of concentrations for each constituent will have been produced with a distribution that is the same as that shown in Figure 7-1. The simple multipliers provide a means to estimate uncertainties based on variability observed in measured data and professional judgment.

Table 7-1. Stochastic elements used to define uncertainties in metal loads, precipitation and seepage

Element Name in Model	Use in Model	Probability Distribution	Mean	Standard Deviation	Minimum	Maximum
Seepage_Outflow_Stochastic	Represent uncertainty in the seepage rate through Valley Tailings Dam 3	Truncated Log-Normal	18 m3/day (geometric mean)	18 (geometric s.d.)	0.1 m3/day	2000 m3/day
MAR_Uncertainty	Multiplier for the mean annual runoff in calculations catchment surface runoff rate	Cumulative Distribution	1.002	0.201	NA	NA
Chem_Uncertianty	Multiplier for the future concentrations of all constituents for all sampling stations.	Truncated Normal	100%	60%	25%	175%

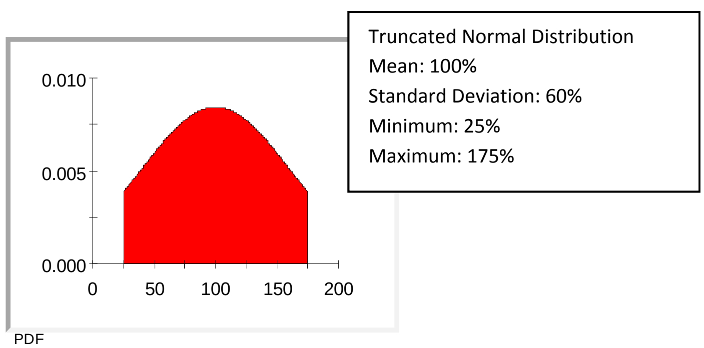


Figure 7-1. Example of probability distribution function for a simple multiplier stochastic element

The second type of stochastic element, direct values, represents an uncertainty distribution that is a direct result of statistical analyses of measured data. This type of element is used specifically in the model to represent uncertainty in the seepage rate through Valley Tailings Dam 3. The data used to develop this distribution was developed by SRK (2008). Figure 7-2 shows an example of the direct value stochastic element that is used in this case.

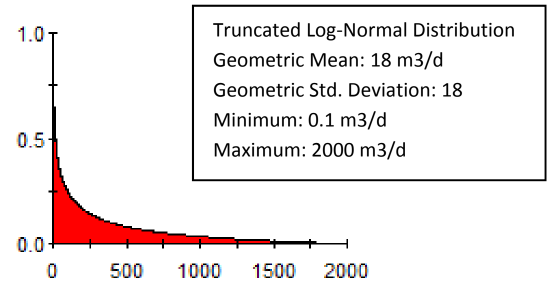


Figure 7-2. Example of probability distribution function for a direct value stochastic element

8.0 Model Calibration

Because of its location at the mouth of Flat Creek and the availability of daily flow rates for at least a portion of the calibration period, KV-9 was designated as the calibration point for the model. Calibration involved examining the difference between the model-simulated flow and loads contributed by all known upstream sources and the flow and loads measured at KV-9. This difference reflects the net impact of any unknown sources and unknown sinks plus errors in measurement or estimation. The calibration process provides the opportunity to adjust the way model-simulated values are derived in order to provide a better match between model output and measured values. The calibration process can also be used to determine contributions or losses from unknown or unmeasured sources or sinks.

8.1 Water Balance Calibration

Model-simulated flow and measured flow at KV-9 were found to be quite similar; however that finding is not unexpected due to the fact that flow at KV-9 and model-simulated flow from model components are not independent. Development of a complete daily flow series at KV-9 involved filling in missing time segments with flow calculated using the MAR (Figure 4-1). This technique also was used to estimate flow contributions from many components of the model which contribute to the simulated flow values. Because of the close agreement between values and lack of independence, no further calibration adjustment was performed for flow.

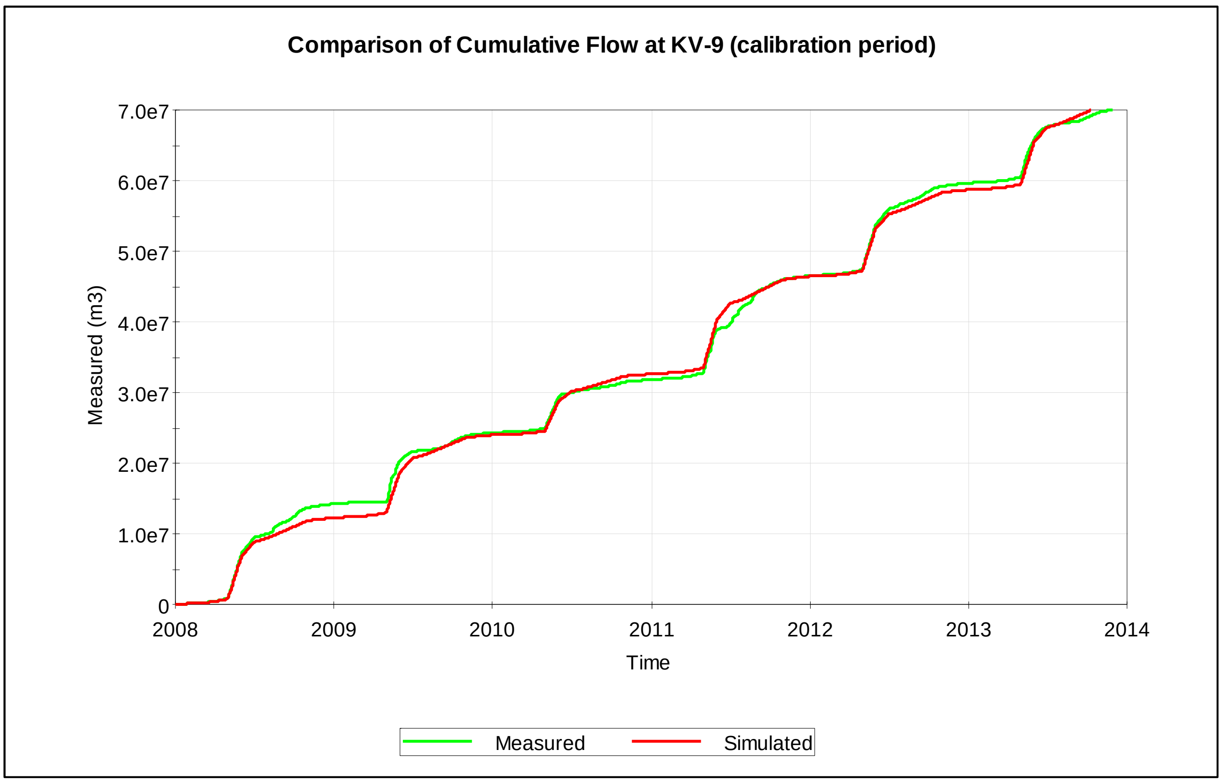


Figure 8-1. Measured and modeled cumulative flow at KV-9

8.2 Metal Load Balance Calibration

Before calibration, there were already relatively small differences in the model-simulated cumulative load at KV-9 and measured cumulative load at KV-9 for both cadmium (Figure 8-2 –upper plot) and zinc (Figure 8-3 – upper plot). The differences in load fluctuated between positive and negative values indicating over-prediction of load in some periods and under-prediction in other periods. When the model under-predicts the load at KV-9 based on measured values, it suggests the possibility of additional sources of metal in the watershed that were not included in the model. An under-prediction would suggest the presence of additional natural attenuation processes somewhere along the stream. Fluctuating over- and under-prediction of loads suggests the presence of a high amount of variability in the underlying measurement data used to build the model, or the possibility of seasonal or annual variation in contribution from additional unknown loads or natural attenuation processes.

Larger differences were found for arsenic (Figure 8-4 – upper plot) where the model-predicted values were under-estimating the calculated load based on measured values. This suggests the possibility of additional sources of arsenic load within the stream system or incomplete characterization of known sources of arsenic load.

In the calibration process, a combination of additional natural attenuation and load contributions were added to the model on an annual basis to provide better agreement between simulated and measured metal loads at KV-9. The result of the model calibration efforts can be seen in the lower plots presented Figure 8-2 (cadmium) Figure 8-3 (zinc), and Figure 8-4 (arsenic). The resulting calibrated model was used to provide base-case future values for comparison to the various treatment alternatives.

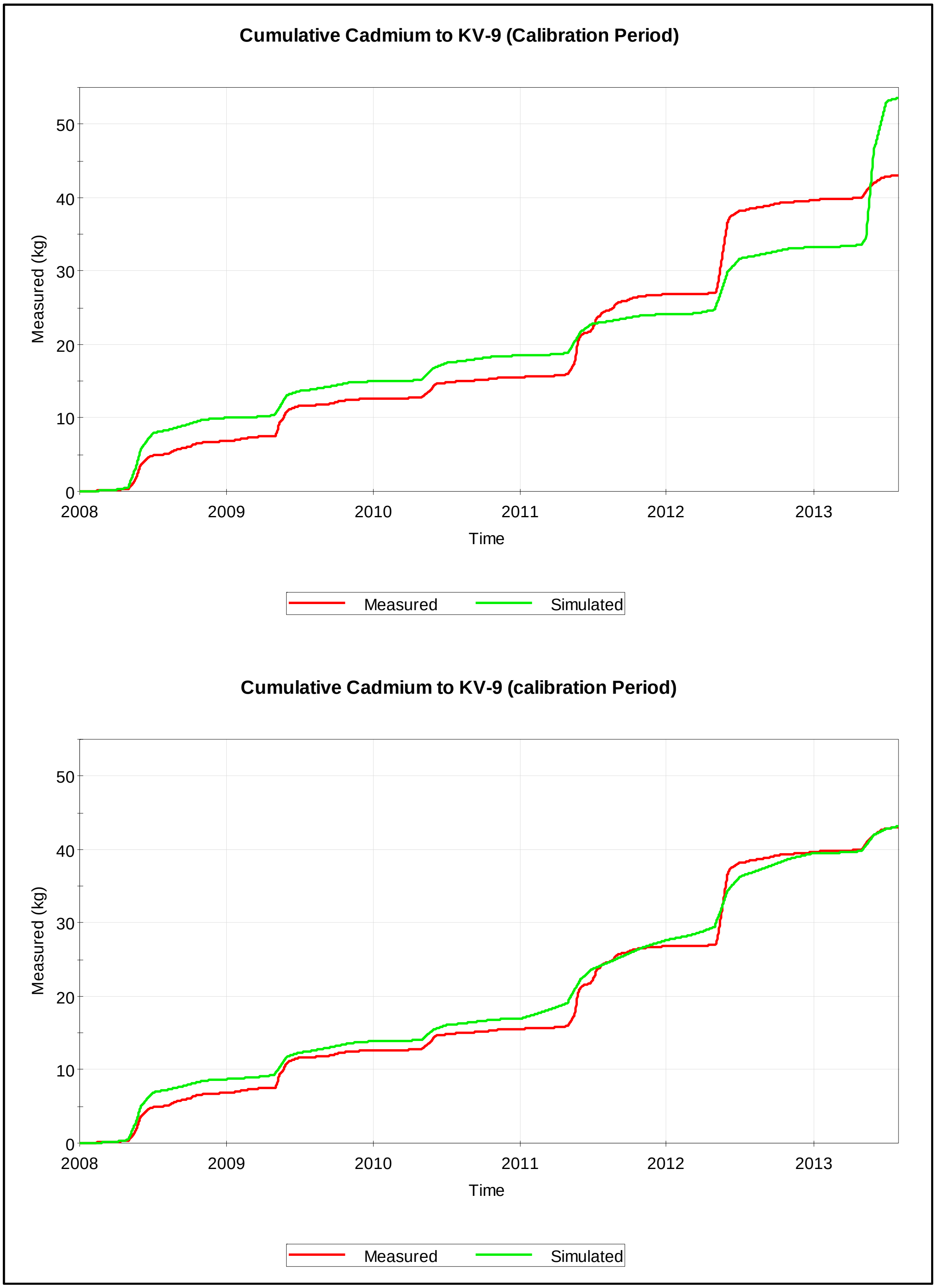


Figure 8-2. Measured and modeled cumulative cadmium at KV-9 before and after model calibration

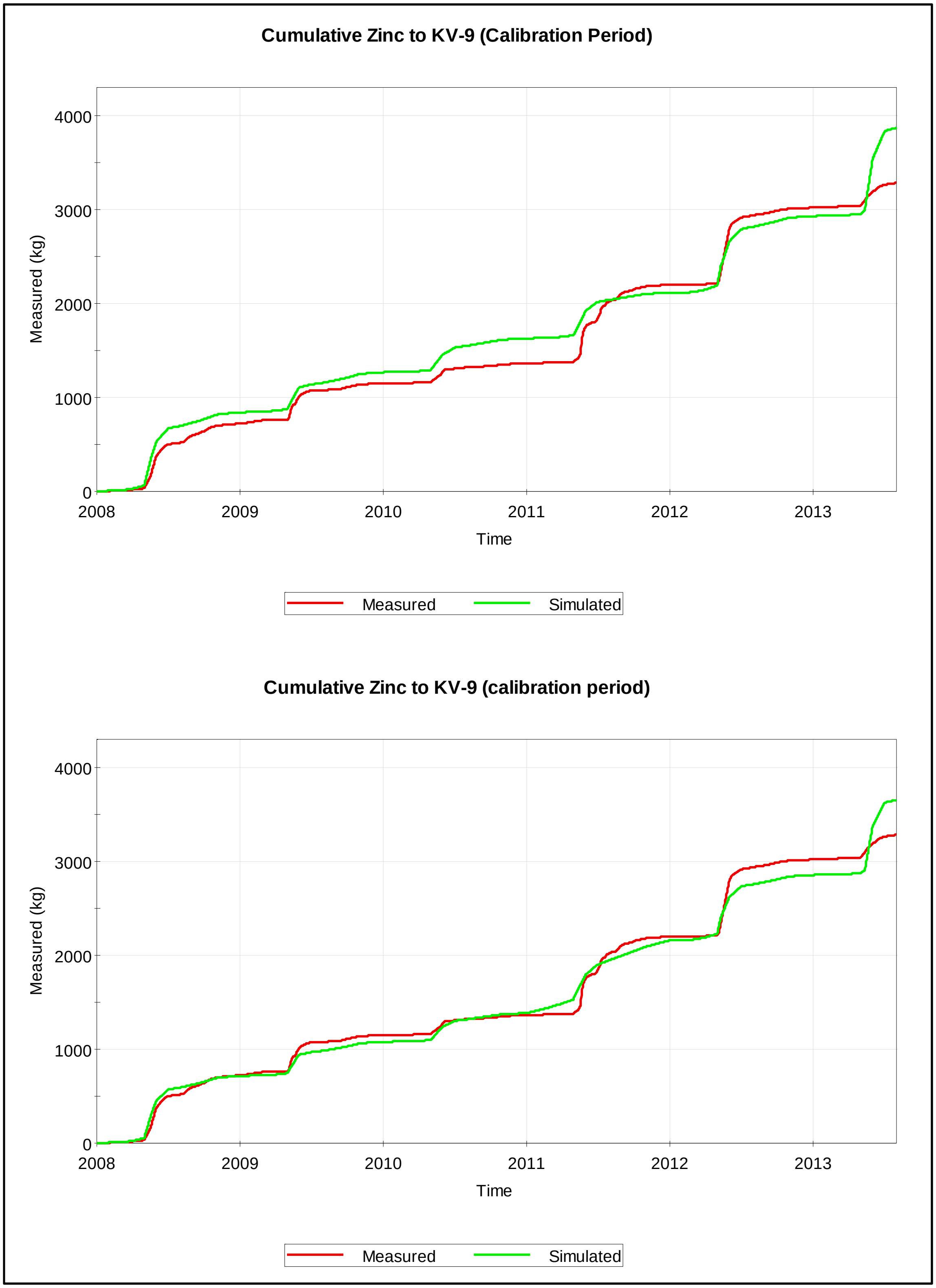
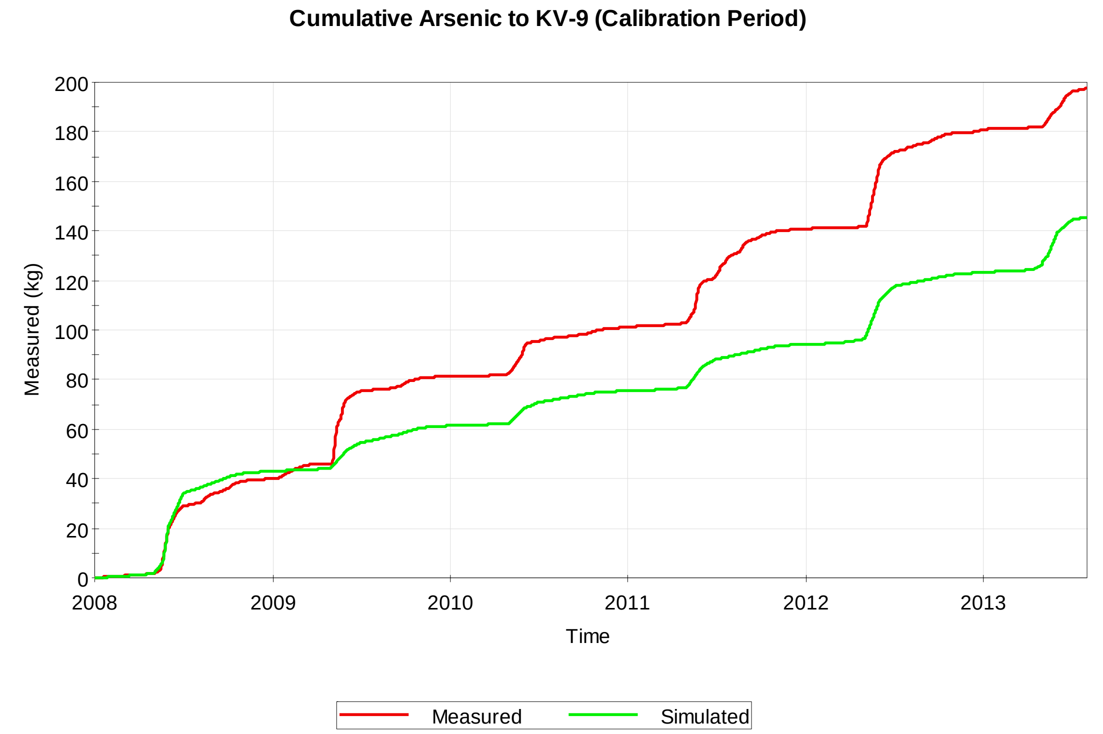


Figure 8-3. Measured and modeled cumulative zinc at KV-9 before and after model calibration



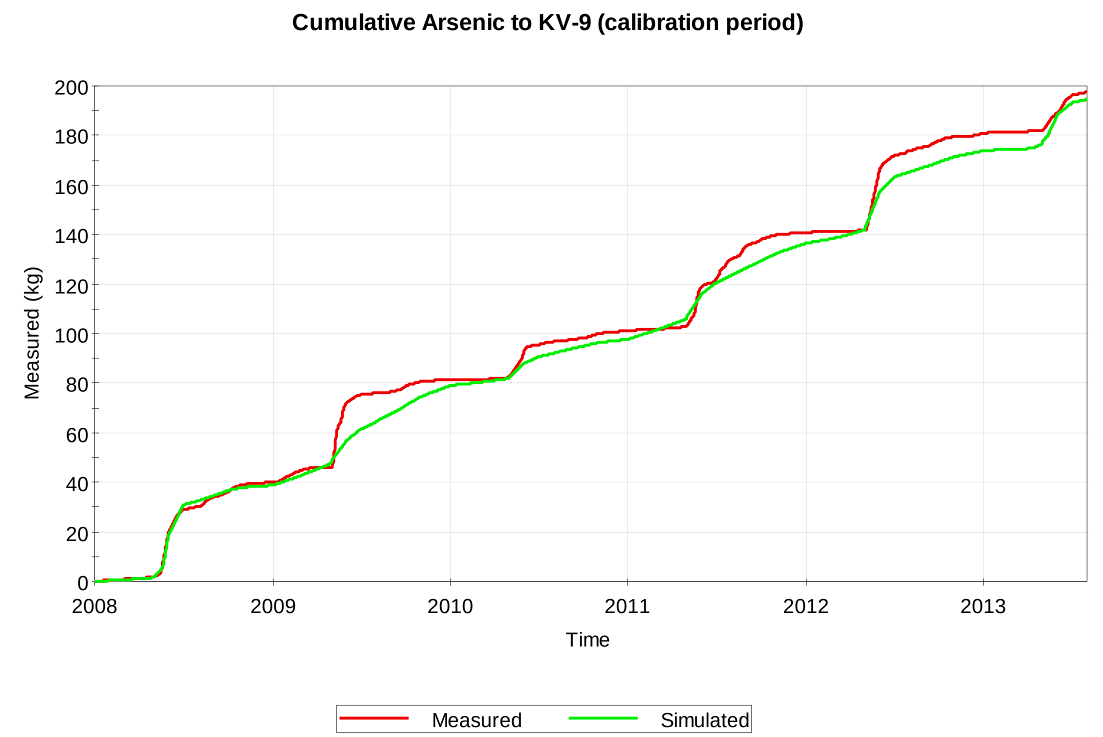


Figure 8-4. Measured and modeled cumulative arsenic at KV-9 before and after model calibration

9.0 Model Results

9.1 Metal Loading Under Baseline Scenario

The simulated annual average metal loads for the baseline scenario (no change in current management practices) are summarized in Table 9-1 for cadmium, zinc, arsenic, and copper for previous years 2009 – 2012 and future year 2025. The 2025 values are representative of average conditions of flow and concentrations of metals projected into the future based on currently available calibration data. The metal loads for the baseline scenario provide a reference for comparing the predicted effects of various reclamation options.

Table 9-1. Simulated annual metal load contributions under baseline conditions

Annual Load Contributions (kg/yr)											
Metal	KV -47	Valley Tailinngs Runoff NCA	Valley Tailings Runoff Covered	Seepage NCA	Seepage CA	Husky SW at Flat Creek	Middle Flat Creek Watershed Runoff	Galena Creek	Silver King at Flat Creek	Lower Flat Creek Watershe d Runoff	Total Simulated Load at KV-9	Measured Load at KV-9
2009												
Cd	3.44	0.12	0.00	0.01	0.00	0.00	0.00	1.12	0.23	0.82	5.73	5.170
Zn	360.57	14.84	0.00	1.42	0.00	0.16	0.00	21.98	22.11	0.38	421.46	363.83
As	11.25	1.85	0.00	0.12	0.00	0.03	0.00	2.80	2.18	22.93	41.16	41.29
Cu	9.61	0.52	0.00	0.02	0.00	0.04	0.00	4.00	1.60	10.71	26.49	26.49
2010												
Cd	2.45	0.19	0.00	0.01	0.00	0.00	0.00	0.81	0.06	0.00	3.52	3.061
Zn	315.21	19.48	0.00	1.42	0.00	0.14	0.00	15.89	7.67	0.00	359.81	305.53
As	8.98	1.75	0.00	0.12	0.00	0.04	0.00	2.02	1.13	5.81	19.85	19.86
Cu	1.95	0.66	0.00	0.02	0.00	0.04	0.00	2.89	1.01	7.34	13.92	13.93
2011												
Cd	3.87	0.16	0.00	0.01	0.00	0.00	0.00	1.32	0.25	5.61	11.24	10.71
Zn	432.52	4.99	0.00	1.42	0.00	0.14	0.00	25.99	19.84	349.72	834.63	775.40
As	11.75	1.11	0.00	0.12	0.00	0.08	0.00	3.31	2.36	21.02	39.75	39.78
Cu	4.85	0.40	0.00	0.02	0.00	0.04	0.00	4.73	1.52	27.37	38.92	38.96
2012												
Cd	7.51	0.16	0.00	0.01	0.00	0.00	0.00	1.14	0.30	3.75	12.87	11.82
Zn	746.03	12.42	0.00	1.43	0.00	0.26	0.00	22.47	14.79	8.63	806.02	696.15
As	22.91	0.87	0.00	0.12	0.00	0.04	0.00	2.86	2.48	10.61	39.89	39.93
Cu	5.66	0.29	0.00	0.02	0.00	0.04	0.00	4.08	1.65	23.02	34.76	34.67
2025*												
Cd	7.75	0.08	0.00	0.01	0.00	0.00	0.00	1.17	0.30	0.00	9.32	8.197
Zn	677.25	13.09	0.00	1.42	0.00	0.20	0.00	23.04	21.93	0.00	736.93	660.91
As	18.16	1.44	0.00	0.12	0.00	0.03	0.00	2.93	2.39	15.76	40.84	41.08
Cu	10.06	0.50	0.00	0.02	0.00	0.04	0.00	4.19	1.33	18.90	35.03	35.07

* representative future year

Under the average conditions of the baseline scenario, the upper Flat Creek watershed is typically the largest contributor of both metal loads. The upper Flat Creek watershed includes tailings deposits on the Elsa hillside, Porcupine Diversion, and associated historic mine sites in the vicinity of Elsa (Figure 3-1). The second-largest load source is generally Galena Creek. All other sources contribute significantly less cadmium load with the exception of the make-up load added to the lower Flat Creek watershed to calibrate the model. This result suggests several possibilities:

- Dispersed tailings located in the middle and lower reaches of Flat Creek comprise a significant source of metal load;
- The assumptions used to represent load contributions from known sources may be underestimates;

- Monitoring data at some sites might not be providing an adequate representation of average metal concentrations throughout all flow conditions.

9.2 Metal Loading Under Future Reclamation Scenarios

A summary of the effects of various reclamation options for reducing metal loads to Flat Creek is provided in Table 9-2 (Valley Tailings), Table 9-7 (Husky SW), and Table 9-8 (Silver King). The results are presented as average load reduction (in kg per year) at KV-9 that might potentially be achieved assuming a proportional response between load reduction at contributing sources and the downstream load reduction at KV-9. Values shown reflect the expected values after the respective reclamation option has been completely implemented and is producing the assumed final conditions.

9.2.1 Valley Tailings Facility Reclamation Scenarios

Simulated load reduction results of various reclamation options for the Valley Tailings Facility (Table 9-2) indicate the potential for significant reduction in downstream load under all three reclamation options. Identical assumptions for improvements in water quality under reclamation Options 2 and 3 resulted in identical load reductions results under both scenarios with the only difference between the options being the presence of a liner under the consolidated tailings. As mentioned above, a liner allows for more options should capture and additional treatment of subsurface seepage be desired. Sulfate was used as a conservative tracer not subjected to reduction via any of the treatment scenarious. Any changes to sulfate concentrations are the result of changes to the underlying assumptions regarding average concentrations used as inputs to the treatment scenarios.

Table 9-2. Simulated impact to long-term average annual metal loads at KV-9 under potential reclamation options for the Valley Tailings Facility and upper Flat Creek watershed

		Average Annual Load at KV-9 (kg/yr)									
	Reclamation Option	**Cd**	**Zn**	**SO4**	**NH3**	**As**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**
0	Baseline	8.12	626.6	1,448,283	129.1	39.16	34.51	370.03	31.04	2.39	2.01
1	Close in place	3.09	190.0	1,616,016	4.1	31.21	31.56	279.09	30.28	3.01	1.10
2	Combine exposed tailings (partial consolidation)	2.71	182.3	1,282,393	9.4	31.51	29.91	286.67	29.13	2.36	1.15
3	Combine tailings into lined facility	2.71	182.3	1,282,393	9.4	31.51	29.91	286.67	29.13	2.36	1.15

		Reduction at KV-9 Compared to Baseline Conditions (kg/yr and %)									
	Reclamation Option	**Cd**	**Zn**	**SO4**	**NH3**	**As**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**
0	Baseline	--	--	--	--	--	--	--	--	--	--
1	Close in place	5.03 (61.9%)	436.6 (69.7%)	-167,733 -(11.6%)	125.0 (96.8%)	7.95 (20.3%)	2.94 (8.5%)	90.95 (24.6%)	0.76 (2.4%)	-0.62 -(25.9%)	0.91 (45.2%)
2	Combine exposed tailings (partial consolidation)	5.41 (66.6%)	444.3 (70.9%)	165,890 (11.5%)	119.7 (92.7%)	7.65 (19.5%)	4.60 (13.3%)	83.36 (22.5%)	1.91 (6.2%)	0.03 (1.1%)	0.86 (42.7%)
3	Combine tailings into lined facility	5.41 (66.6%)	444.3 (70.9%)	165,890 (11.5%)	119.7 (92.7%)	7.65 (19.5%)	4.60 (13.3%)	83.36 (22.5%)	1.91 (6.2%)	0.03 (1.1%)	0.86 (42.7%)

	Reclamation Option	**Description**
0	Baseline	a) Current treatment through lime addition
1	Close in place	a) create stable water channels through and around tailings b) cover unvegetated tailings with growth media c) monitor for % cover objectives d) cover system optimization and evaluation
2	Combine exposed tailings (partial consolidation)	a) create stable water channels through and around tailings b) move exposed tailings on hillside to valley bottom, place behind dams to minimize ponded water and limit phreatic surface buildup c) cover combined tailings to meet revegetation objectives d) combination of consolidation based on existing tailings characteristics e) cover system optimization and evaluation
3	Combine tailings into lined facility	a) move tailings into lined facility capable of maintaining saturated tailings with appropriate cover system b) scarify and seed existing tailings footprint c) re-establish native drainages d) re-processing as a mechanism for closure cost offset e) cover system optimization and evaluation f) potential for some residual tailings deposits to be left after consolidation

Scenarios 1, 2, and 3 are all expected to produce a greater than 60% reduction in Cd loads and approximately a 70% reduction in Zn loads at KV-9. These estimates reflect the combined impact of reclamation efforts for both the VTF directly and reclamation of the upper Flat Creek watershed. The individual contributing model elements under each scenario are shown in Table 9-3 (flow), Table 9-4 (cadmium load), Table 9-5 (zinc load), and Table 9-6 (arsenic load). These tables show that the load reduction achieved under all three scenarios is solely a result of the reclamation efforts performed for the upper Flat Creek watershed. Under the current model assumptions, reclamation scenarios for the VTF do result in a reduction in the concentration of Cd and Zn in surface and subsurface outflows. However, reclamation activities at the VTF also result in increased outflow volumes and consequently cause a slight increase in metal loads compared to baseline conditions. Outflow volumes increase under all three reclamation scenarios due to a reduction in evaporative losses when the ponds and elevated phreatic surface are eliminated. A simple water balance for just the VTF under current operating conditions was added to the model in order to confirm the finding that a significant portion of water received at the VTF is lost via surface evaporation from ponds and saturated tailings material.

Table 9-3. Contributions from individual model components under baseline conditions and Valley Tailings reclamation scenarios: flow

	Long-Term Average Flow (L/s)										
Scenario	Upper Flat Creek Water-shed	VTF Runoff: Non-Covered Area	VTF Runoff: Covered Area	VTF Seepage: Non-Covered Area	VTF Seepage: Covered Area	Husky SW	Middle Flat Creek Water-shed	Galena Creek	Silver King	Lower Flat Creek Watershed	Flat Creek at KV-9
Baseline	77.8	6.4	0.0	0.2	0.00	0.40	90.1	66.4	7.5	140.2	388.8
VT Option 1	77.8	0.0	18.4	0.0	0.84	0.40	90.1	66.4	7.5	140.2	401.5
VT Option 2	77.8	18.4	2.1	10.0	0.84	0.40	88.0	66.4	7.5	140.2	411.5
VT Option 3	77.8	18.4	2.1	10.0	0.84	0.40	88.0	66.4	7.5	140.2	411.5

Table 9-4. Contributions from individual model components under baseline conditions and Valley Tailings reclamation scenarios: cadmium load

	Long-Term Average Annual Cd Load (kg/yr)										
Scenario	Upper Flat Creek Water-shed	VTF Runoff: Non-Covered Area	VTF Runoff: Covered Area	VTF Seepage: Non-Covered Area	VTF Seepage: Covered Area	Husky SW	Middle Flat Creek Water-shed	Galena Creek	Silver King	Lower Flat Creek Watershed (calibration inputs)	Flat Creek at KV-9
Baseline	7.75	0.08	0.00	0.01	0.00	0.00	0.00	1.17	0.30	0.00	8.115
VT Option 1	2.06	0.00	0.00	0.00	0.01	0.00	0.00	1.17	0.30	0.00	3.090
VT Option 2	1.03	0.24	0.00	0.35	0.00	0.00	0.00	1.17	0.30	0.00	2.707
VT Option 3	1.03	0.24	0.00	0.35	0.00	0.00	0.00	1.17	0.30	0.00	2.707

Table 9-5. Contributions from individual model components under baseline conditions and Valley Tailings reclamation scenarios: zinc load

	Long-Term Average Annual Zn Load (kg/yr)										
Scenario	Upper Flat Creek Water-shed	VTF Runoff: Non-Covered Area	VTF Runoff: Covered Area	VTF Seepage: Non-Covered Area	VTF Seepage: Covered Area	Husky SW	Middle Flat Creek Water-shed	Galena Creek	Silver King	Lower Flat Creek Watershed (calibration inputs)	Flat Creek at KV-9
Baseline	677.25	13.09	0.00	1.42	0.00	0.20	0.00	23.04	21.93	0.00	626.58
VT Option 1	176.67	0.00	0.00	0.00	1.20	0.20	0.00	23.04	21.93	0.00	189.96
VT Option 2	88.34	20.87	0.00	57.10	0.48	0.20	0.00	23.04	21.93	0.00	182.25
VT Option 3	88.34	20.87	0.00	57.10	0.48	0.20	0.00	23.04	21.93	0.00	182.25

Table 9-6. Contributions from individual model components under baseline conditions and Valley Tailings reclamation scenarios: arsenic load

	Long-Term Average Annual As Load (kg/yr)										
Scenario	Upper Flat Creek Water-shed	VTF Runoff: Non-Covered Area	VTF Runoff: Covered Area	VTF Seepage: Non-Covered Area	VTF Seepage: Covered Area	Husky SW	Middle Flat Creek Water-shed	Galena Creek	Silver King	Lower Flat Creek Watershed (calibration inputs)	Flat Creek at KV-9
Baseline	18.16	1.44	0.00	0.12	0.00	0.03	0.00	2.93	2.39	15.76	39.16
VT Option 1	10.80	0.00	0.00	0.00	0.09	0.03	0.00	2.93	2.39	15.76	31.21
VT Option 2	5.40	1.28	0.00	4.37	0.04	0.03	0.00	2.93	2.39	15.76	31.51
VT Option 3	5.40	1.28	0.00	4.37	0.04	0.03	0.00	2.93	2.39	15.76	31.51

9.2.2 Husky SW Reclamation Scenarios

At Husky SW, the low outflow rate results in small load contributions to Flat Creek even under baseline conditions without reclamation (as shown in Table 9-1). As a result, reducing or even completely eliminating load contributions from Husky SW would not result in appreciable reduction in downstream loads at KV-9. This is shown by the results for each of the various Husky SW treatment options summarized in Table 9-7.

Table 9-7. Simulated impact to long-term average annual metal loads at KV-9 under potential reclamation options for Husky SW

		Average Annual Load at KV-9 (kg/yr)									
	Reclamation Option	Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
0	Baseline	8.12	626.6	1,448,283	129.1	39.16	34.51	370.03	31.04	2.39	2.01
1	Managed natural attenuation	8.12	626.6	1,448,283	129.1	39.16	34.51	370.03	31.04	2.39	2.01
2	Mine pool treatment	8.12	627.0	1,448,283	128.9	39.15	34.51	370.03	30.99	2.39	2.01
3	Bioreactor treatment	8.11	627.2	1,448,283	128.9	39.25	34.48	370.03	31.34	2.40	2.01
4	Mechanical treatment	8.18	630.0	1,448,283	129.1	39.17	34.48	369.59	31.09	2.40	2.01
5	Reclamation only	8.12	626.6	1,448,283	129.1	39.16	34.51	370.03	31.04	2.39	2.01

		Reduction at KV-9 Compared to Baseline Conditions (kg/yr and %)									
	Reclamation Option	Cd	Zn	SO4	NH3	As	Cu	Pb	Ni	Se	Ag
0	Baseline	--	--	--	--	--	--	--	--	--	--
1	Managed natural attenuation	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)
2	Mine pool treatment	-0.01 -(0.1%)	-0.41 -(0.1%)	0.00 (0.0%)	0.22 (0.2%)	0.01 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.04 (0.1%)	0.00 (0.0%)	0.00 (0.0%)
3	Bioreactor treatment	0.00 (0.0%)	-0.66 -(0.1%)	0.00 (0.0%)	0.18 (0.1%)	-0.09 -(0.2%)	0.03 (0.1%)	0.00 (0.0%)	-0.30 -(1.0%)	-0.01 -(0.6%)	0.00 (0.0%)
4	Mechanical treatment	-0.06 -(0.8%)	-3.47 -(0.6%)	0.00 (0.0%)	-0.05 (0.0%)	-0.02 (0.0%)	0.03 (0.1%)	0.44 (0.1%)	-0.05 -(0.2%)	-0.01 -(0.4%)	0.00 (0.0%)
5	Reclamation only	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)	0.00 (0.0%)

	Reclamation Option	Description
0	Baseline	a) no active treatment - natural attenuation only
1	Managed natural attenuation	a) engineered water management structure as part of shaft closure passively aerates water, settles precipitates, and disperses water onto hillside; b) study program to confirm NA is performing adequately; c) ongoing monitoring at shaft and within Flat Creek to demonstrate treatment; d) define thresholds for source and receiving environment that define acceptable treatment e) note: engineered water management structure could be used as an injection point for carbon source for in situ bioreactor f) note MNA may allow for reclamation-only alternative
2	Mine pool treatment	a) alkaline and/or carbon source injection and mixing into shaft mine pool that creates clean discharge; b) ongoing monitoring at shaft to demonstrate treatment c) note: could be used to pretreat for MNA alternative
3	Bioreactor treatment	a) could be a lined facility or an injection gravel-filled trench; b) carbon source addition in both solid phase and dissolved phase; c) ongoing monitoring at bioreactor discharge to demonstrate treatment d) note: could be used to pretreat for MNA alternative
4	Mechanical treatment	a) treatment plant using active water mixing with reagents and recovery of treatment sludge (range of treatment substrates include lime, sodium hydroxide, sodium hydrosulfide) b) note: could be stand alone small plant, or combined with common plant for instance in Elsa
5	Reclamation only	a) minimal reclamation aimed at reducing shaft discharge contact with mineralized waste rock downgradient of the shaft.

9.2.3 Silver King Reclamation Scenarios

At Silver King (Table 9-8), the existing treatment plant provides a significant reduction in metal loads. Alternate treatment options provide little additional benefit in terms of load reduction. It is unlikely that managed natural attenuation (Option 1) would provide a greater load reduction than the current treatment plant. The assumption that the current treatment plant effluent is not subject to additional reduction through natural attenuation or the amount of simulated reduction in metal concentrations due to natural attenuation under Option 1 might need to be revisited. Negative percent reduction values (i.e. an increase over baseline conditions) occur for some constituents due to underlying assumptions regarding average and minimum values used as inputs for the various treatment alternatives. As such, they are an artifact of the modeling process and are not intended to imply that metal loads would increase under these treatment options compared to baseline conditions.

Table 9-8. Simulated impact to long-term average annual metal loads at KV-9 under potential reclamation options for Silver King

		Average Annual Load at KV-9 (kg/yr)									
	Reclamation Option	**Cd**	**Zn**	**SO4**	**NH3**	**As**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**
0	Baseline	8.12	626.6	1,448,283	129.1	39.16	34.51	370.03	31.04	2.39	2.01
1	Managed natural attenuation	7.89	613.1	1,453,501	129.1	42.91	35.32	369.87	31.53	1.91	1.98
2	Mine pool treatment	7.87	609.4	1,448,283	129.1	37.58	34.51	369.87	27.28	1.86	1.98
3	Bioreactor treatment	7.89	638.6	1,591,002	130.7	41.40	33.57	369.89	40.20	2.33	2.01

		Reduction at KV-9 Compared to Baseline Conditions (kg/yr and %)									
	Reclamation Option	**Cd**	**Zn**	**SO4**	**NH3**	**As**	**Cu**	**Pb**	**Ni**	**Se**	**Ag**
0	Baseline	--	--	--	--	--	--	--	--	--	--
1	Managed natural attenuation	0.22 (2.7%)	13.4 (2.1%)	-5,218 -(0.4%)	0.00 (0.0%)	-3.75 -(9.6%)	-0.82 -(2.4%)	0.16 (0.0%)	-0.50 -(1.6%)	0.48 (20.2%)	0.03 (1.4%)
2	Mine pool treatment	0.24 (3.0%)	17.1 (2.7%)	0.00 (0.0%)	0.00 (0.0%)	1.58 (4.0%)	0.00 (0.0%)	0.16 (0.0%)	3.76 (12.1%)	0.52 (21.9%)	0.03 (1.3%)
3	Bioreactor treatment	0.22 (2.8%)	-12.0 -(1.9%)	-142,719 -(9.9%)	-1.64 -(1.3%)	-2.24 -(5.7%)	0.94 (2.7%)	0.14 (0.0%)	-9.16 -(29.5%)	0.06 (2.5%)	0.01 (0.3%)

	Reclamation Option	**Description**
0	Baseline	a) Current treatment plant
1	Managed natural attenuation	a) Engineered water management structure passively aerates water at adit, settles precipitates, and disperses water onto hillside b) Study program to confirm NA is performing adequately c) Ongoing monitoring at adit and within Flat Creek to demonstrate treatment; d) Define thresholds for source and receiving environment that define acceptable treatment e) Note: engineered water management structure could be used as an injection point for carbon source for in situ bioreactor
2	Mine pool treatment	a) alkaline and/or carbon source injection and mixing into pool that creates clean discharge b) ongoing monitoring at adit to demonstrate treatment c) note: could be used to pretreat for MNA alternative
3	Bioreactor treatment	a) use existing lined facility in existing settling ponds b) carbon source addition in both solid phase and dissolved phase c) ongoing monitoring at bioreactor discharge to demonstrate treatment d) note: could be used to pretreat for MNA alternative

9.3 Simulated Concentrations

Annual statistics for measured concentrations of metals at KV-9 for the period of available data are shown in Table 9-9 in order to document recent measured concentrations and for comparison to model-simulated concentrations.

Table 9-9. Historical instantaneous metal concentrations at KV-9

	Cd				Zn				As			
Year	N	Avg (mg/L)	Min(mg/L)	Max(mg/L)	N	Avg (mg/L)	Min(mg/L)	Max(mg/L)	N	Avg (mg/L)	Min(mg/L)	Max(mg/L)
2004	2	0.00050	0.00030	0.00069	2	0.062	0.039	0.085	0	na	na	na
2005	4	0.00017	0.00056	0.00033	4	0.005	0.048	0.028	4	0.0022	0.0005	0.0036
2006	5	0.00015	0.00066	0.00031	5	0.020	0.065	0.033	5	0.0015	0.0006	0.0037
2007	3	0.00025	0.00065	0.00047	3	0.026	0.077	0.050	3	0.0028	0.0008	0.0042
2008	8	0.00029	0.00072	0.00041	8	0.031	0.069	0.045	8	0.0024	0.0006	0.0050
2009	11	0.00033	0.00385	0.00108	11	0.023	0.242	0.077	11	0.0093	0.0010	0.0356
2010	6	0.00029	0.00082	0.00045	6	0.022	0.054	0.032	6	0.0031	0.0019	0.0053
2011	6	0.00020	0.00126	0.00057	6	0.015	0.103	0.042	6	0.0023	0.0007	0.0037
2012	12	0.00051	0.00018	0.00168	12	0.035	0.013	0.101	12	0.0022	0.0006	0.0070

The structure of the GoldSim simulation model described in this report was designed to estimate chemical loads and is most suited to evaluating reclamation options in terms of changes in chemical loads. However, ERDC has requested estimates of metal concentrations (Cd, Zn, As) in Flat Creek from the model resulting from the various reclamation alternatives for us as an aid in the evaluation of reclamation options. However, these predicted concentrations should be viewed with caution; while the simulation model is capable of making estimates of concentrations based on calculations of loads and water flow rates, those calculations do not take into account potential variability in hydrogeochemical, biological, and physical processes that can affect concentrations in natural stream systems particularly over short time frames such as seasons. The concentrations produced by the model should be understood to be indicative of approximate ranges expected to occur over yearly to longer time-scales rather than precise predictions of day-to-day concentrations.

Model-derived estimates of mean, median, and maximum concentrations for zinc, cadmium, and arsenic for the year 2025 are shown in Table 9-10 for the various reclamation options. This year was chosen because it reflects a period when the effects of the reclamation options are expected to be fully implemented and reach steady state conditions. These concentrations should be considered as estimates that provide a relative measure of the potential concentrations and ranges potentially achievable for the simulated reductions in chemical loads.

Table 9-10. Mean, median, and maximum estimated concentrations of Cd, Zn, and As at KV-9 based on probabilistic simulation results for 100 realizations of reclamation alternatives.

		Simulated Concentration at KV-9 (mg/l)								
		Cd			Zn			As		
		Mean	Median	Max*	Mean	Median	Max*	Mean	Median	Max*
Baseline (no reclamation)		0.00067	0.00067	0.00074	0.055	0.053	0.067	0.0075	0.0072	0.0098
Valley Tailings Reclamation Option:										
1	Close in place	0.00025	0.00025	0.00026	0.017	0.017	0.019	0.0063	0.0061	0.0083
2	Combine exposed tailings	0.00028	0.00028	0.00032	0.027	0.026	0.032	0.0069	0.0067	0.0089
3	Combine tailings into lined facility	0.00028	0.00028	0.00032	0.027	0.026	0.032	0.0069	0.0067	0.0089
Huskey SW Reclamation Option:										
1	Managed natural attenuation	0.00067	0.00067	0.00074	0.055	0.053	0.067	0.0074	0.0072	0.0097
2	Mine pool treatment	0.00068	0.00067	0.00074	0.055	0.053	0.067	0.0074	0.0072	0.0097
3	Bioreactor treatment	0.00067	0.00067	0.00074	0.055	0.054	0.067	0.0074	0.0072	0.0097
4	Mechanical treatment	0.00068	0.00067	0.00074	0.055	0.053	0.067	0.0074	0.0072	0.0097
5	Reclamation only	0.00067	0.00067	0.00074	0.055	0.053	0.067	0.0074	0.0072	0.0097
Silver King Reclamation Option:										
1	Managed natural attenuation	0.00064	0.00063	0.00070	0.052	0.051	0.064	0.0084	0.0081	0.0110
2	Mine pool treatment	0.00063	0.00062	0.00070	0.051	0.050	0.063	0.0071	0.0069	0.0093
3	Bioreactor treatment	0.00064	0.00063	0.00070	0.059	0.058	0.070	0.0081	0.0079	0.0106

*95th percentile upper limits from probabilistic model simulations

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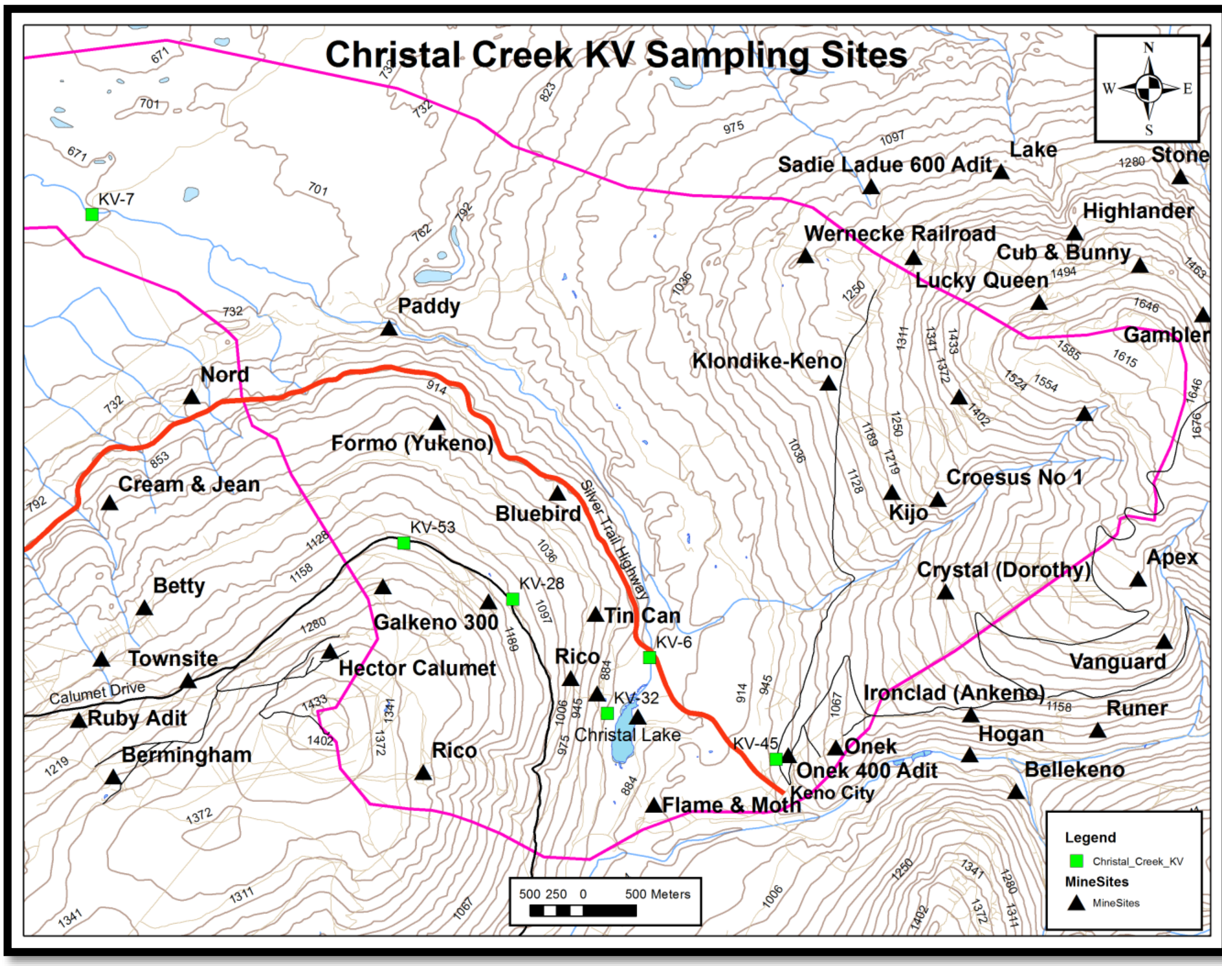
Chemical Mass Load Model for Christal Creek: Description and Results: 2013 Update

Draft Report

November 12, 2013



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1.0 INTRODUCTION

Christal Creek receives chemical loads from a number of legacy mine sites. The types of sites that contribute chemical loads to Christal Creek include:

- Galkeno 300 and 900 water treatment plant discharge
- Untreated discharge from the Onek 400, Lucky Queen, and UN adits
- Mackeno tailings and dispersed tailings along Christal Creek
- Waste rock from both open pit and underground mine development on Keno Hill, Erikson Gulch, and Galena Hill
- Formo and Paddy mine sites located outside the United Keno Hill Mine (UKHM) reclamation boundaries

Reclamation alternatives to reduce chemical loads to Christal Creek are being investigated as part of closure studies for the UKHM. A simulation model of chemical loads to Christal Creek has been developed for the purpose of assisting in the evaluation of reclamation options.

Our original model was focused on cadmium, zinc, and sulphate (Interralogic, 2012a). In this 2013 update of the model, we have added input data and calculations to simulate loads of arsenic, copper, lead, nickel, silver, and selenium in a similar manner as previously developed for cadmium, zinc, and sulphate. While the focus of this report remains with cadmium and zinc, we also present results for the arsenic, copper, lead, and silver as part of this updated report on simulation modeling to estimate chemical loading effects of potential reclamation options. The purpose of this report is to present the results developed from a simulation model of the Christal Creek watershed designed to explore the potential reductions in chemical loads that could be achieved by different reclamation alternatives. The modeling framework, conceptual model, input data, calculation approaches, key assumptions, calibration procedures, are also presented.

The model has evolved over time as reclamation alternatives are developed and refined. The numerical results provided in this report for loads and concentrations differ slightly from Interralogic (2012a) because we were able to take advantage of an additional year and a half of monitoring data for Christal Creek and monitoring locations for inflows to Christal Creek for calibration and calculations of average monthly concentrations to represent future chemistry. In addition, we have made refinements in the water quality expectations for different water treatment approaches associated with the reclamation options.

2.0 Simulation Framework

The model was developed in the GoldSim simulation framework (www.goldsim.com). GoldSim provides a framework for mathematically representing the dynamics of both water balance and chemical mass balance, which are the components needed to simulate chemical loadings in a watershed. GoldSim also provides capabilities to represent uncertainties in simulation results through probabilistic calculations. GoldSim relies on *Stochastic* elements to represent a range of possible uncertainties in an input parameter as a probability distribution. In a probabilistic simulation, GoldSim uses a Monte Carlo algorithm to select input parameters according to the specified uncertainty distribution during multiple runs of the simulation model, that is, the model is run many (e.g., 250 times) each time with a new set of input values for the uncertain parameters. The multiple runs are referred to as realizations of the simulation model. GoldSim assembles the results from the multitude or realizations and converts them to probability distribution outputs that describe the level of uncertainty in model results.

2.1 Simulation Settings

The simulation settings for the simulation model were:

- **Simulation type and length**: Calendar time with a start date of January 1, 2008 and end date of January 1, 2041 for a total length of 33 years. These dates were selected to provide a 30-year simulation period beyond current time.
- **Simulation time periods**: The simulation period is broken into two portions comprised of the following:
  - *Calibration Period* from January 1, 2008 through July 3, 2013: This period is when measured data are available for monitoring locations in the Christal Creek watershed, allowing for iterative adjustment of model parameters to obtain a match between observed and simulated results for water balance and chemical loads.
  - *Future Simulation Period* from July 3, 2013 to January 1, 2041: There are two aspects to the future simulation period: the first is the baseline condition in which no reclamation options are considered for mitigating chemical loads to Christal Creek, and the second is the representation of the potential effects of different reclamation options for decreasing chemical loads relative to the baseline condition.
- **Time step**: A time step of one day is used for all simulations. Most measured data are available on a weekly to monthly to quarter-year basis, although some data are at random intervals. A one-day time step provides a sufficiently small time increment for accurate representation of the measured data while not requiring extensive simulation run time.
- **Probabilistic simulations**: Generally, 250 realizations were run for probabilistic simulations to provide a sufficient population of results for statistically accurate representations of ranges of uncertainty in model simulation results.

3.0 Conceptual Model

Figure 3-1 shows a conceptual model of the hydrogeochemical processes controlling chemical loads in the Christal Creek watershed. The simulation model is based on the conceptualization of hydrogeochemical processes and available data depicted in Figure 3-1. The loads are a function of both rates of releases of chemical constituents from various sources and rates of flow in the transport routes from source areas to Christal Creek. The major known sources of chemical constituents and transport routes include included in the model are:

- Discharge from the water treatment plants at Galkeno 300 and Galkeno 900 through surface channels to Christal Lake and Christal Creek
- Discharge from non-treated adit discharge sources, including the Onek 400 Adit and UN Adit, and transport as surface water and groundwater
- Leaching of tailings in the Mackeno Mill area adjacent to the northeast side of Christal Lake and transport through the vadose and saturated zones to Christal Lake and Christal Creek
- Leaching of waste rock at legacy mine sites on Keno Hill and Galena Hill and transport through surface water and groundwater to Christal Lake and Christal Creek
- Natural background sources of chemicals in surface runoff and groundwater
- Discharge from the historical Lucky Queen mine and waste rock
- Discharge from the Formo and Paddy Mine areas, which are privately owned sites outside of the reclamation boundary and not subject to evaluation and reclamation measures

There are two other potential sources of chemical constituents that are not currently included in the model. These are:

- Tailings deposited in Christal Lake and
- Dispersed tailings located in sediments along Christal Creek downstream of Christal Lake.

These two potential sources are not included in the model at the current time for two reasons. First, there is a lack of information available to quantify their relative importance as contributors to metal loads. Second, measured data indicate much smaller masses of Zn and Cd are exiting the system at monitoring point KV-7 than known to be entering the watershed via the major load sources listed above. Thus, the excess in chemical loads from known sources masks the potential contributions from tailings in Christal Lake dispersed tailings in sediments, making it difficult to discern their importance. The excess of loading from known sources also indicates there is substantial attenuation of metals in the transport pathways. The effect of attenuation for reducing metal loads is taken into account in the model through the calibration process described below.

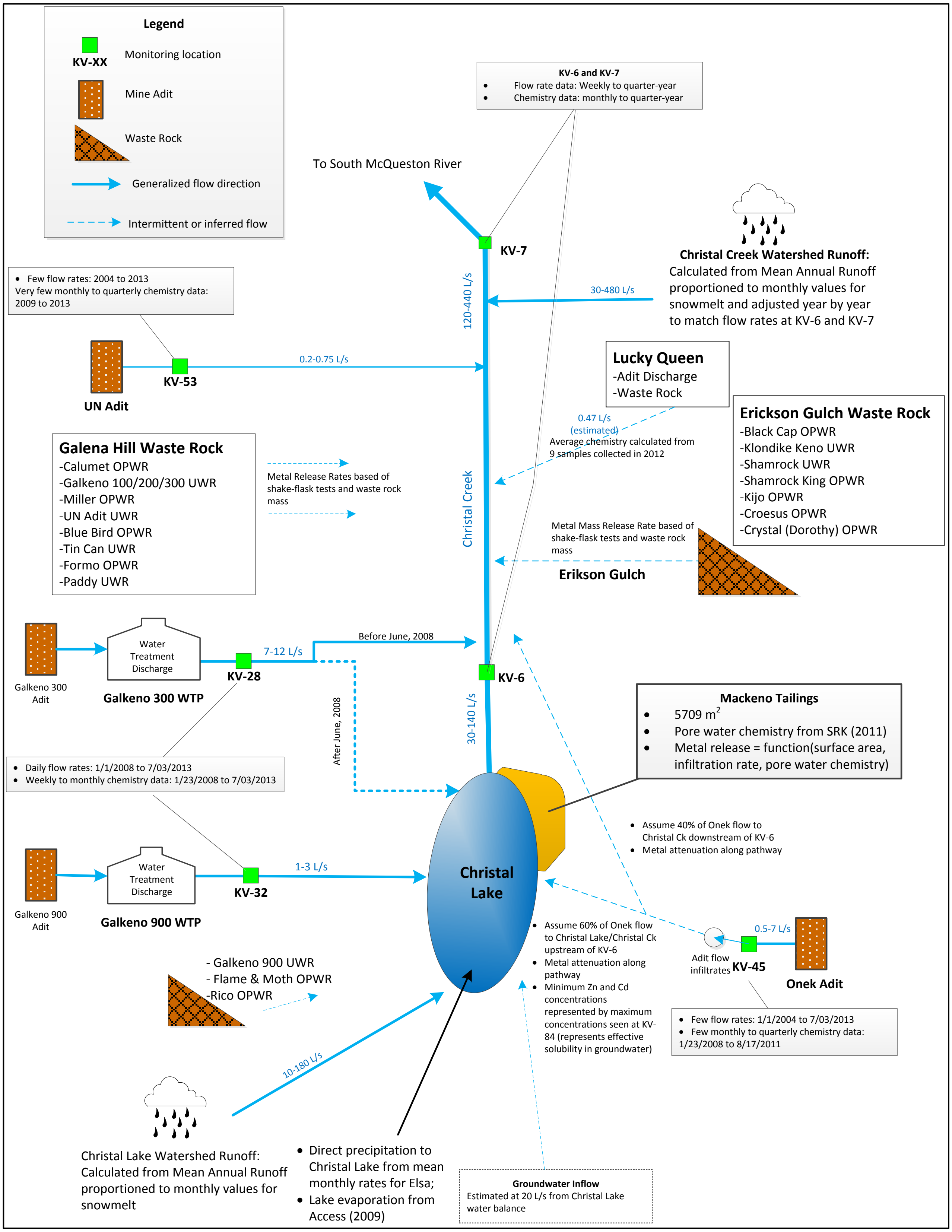

Figure 3-1: Conceptual model of metal loads for the Christal Creek watershed

4.0 MATHEMATICAL FORMULATIONS

The GoldSim simulation model is based on a series of mathematical equations to calculate chemical loads as a function of the dynamics of the watershed and effects expected to occur as a result of implementation of different reclamation options. The load calculations are split into two main simulation periods:

- Calibration period
- Future simulation period

The calibration period is the time for which measured data on concentrations and flow rates are available for model calibration. When measured concentrations were reported to be less than detection levels, concentrations were set equal to the detection concentration in calculations of chemical loads for the calibration period. Measured concentrations of lead, silver, and selenium were commonly less than detection levels.

The future simulation period refers to the simulation time after the availability of measured data during which extrapolations and estimates are used to predict future chemical loads based on the model calibration and estimated effects of different hypothetical reclamation options. The potential reclamation options considered in the model are described in more detail Section 9.

4.1 Load Source: Galkeno 300 Discharge

Calibration Period: Chemical loads ($L_{chemical}$) in units of mass per unit of time are calculated from:

$$L_{chemical} = C_{meas} \times F_{meas} \quad \text{(Eq. 1)}$$

where C_{meas} is the measured concentrations of chemical constituents in mg/L and F_{meas} is the measured flow rate in L/s. Measured flow rates are available on a daily basis from monitoring point KV-28 for the time period of 1/1/2008 to 7/3/2013. Measured concentrations are available on a weekly to monthly basis for the same time period from KV-28. Monthly average flow rates and concentrations are given in Table 4-1 and Table 4-2, respectively.

Future Simulation Period: Chemical loads ($L_{chemical}$) in units of mass per unit of time are calculated from:

$$L_{chemical} = C_{yr\_ave} \times F_{mon\_ave} \quad \text{(Eq. 2)}$$

where C_{yr_ave} is the average of measured concentrations for the last year of Galkeno 300 operation (August 2010 to August 2011), and F_{mon_ave} is the monthly average flow rate calculated from the period of record for discharge from the Galkeno 300 water treatment plant (Table 4-1). The averages are used repeatedly for the entirety of the future simulation period (Table 4-1 and Table 4-2).

Reclamation Option of Improved Water Treatment for the Future Simulation Period: Chemical loads are calculated according to:

$$L_{chemical} = C_{treatment} \times F_{mon\_ave} \quad \text{(Eq. 3)}$$

In Eq. 3, $C_{treatment}$ is the target concentration that would be achieved if improved water treatment measures were implemented at Galkeno 300. Target concentrations for improved water treatment are provided in Section 9.0.

4.2 Load Source: Galkeno 900 Discharge

Calibration Period: Chemical loads ($L_{chemical}$) in units of mass per unit of time are calculated in the same manner as for Galkeno 300 (Eq. 1) except that measured data from KV-32 are used. Measured flow rates are available on a daily basis from monitoring point KV-32 for the time period of 1/1/2008 to 7/3/2013. Measured concentrations are available on a weekly to monthly basis for the same time period from KV-28. Monthly average flow rates and concentrations are given in Table 4-1 and Table 4-3, respectively.

Future Simulation Period: Chemical loads ($L_{chemical}$) in units of mass per unit of time are calculated in the same manner as for Galkeno 300 (Eq. 2) except that average concentrations and average monthly flow rates are derived from KV-32 data. The averages are used repeatedly for the entirety of the future simulation period (Table 4-1 and Table 4-3).

Reclamation Option of Improved Water Treatment for the Future Simulation Period: Chemical loads are calculated according to Eq. 3 with target concentrations for improved treatment. Target concentrations for water treatment are provided in Section 9.0.

Table 4-1: Monthly average flow rates for Galkeno 300 (KV-28) and Galkeno 900 (KV-32) water treatment plant discharges

Month	Galkeno 300 Average Flow Rate (L/s) (2008-2013 Data)	Galkeno 900 Average Flow Rate (L/s) (2008-2013 Data)
Jan	10.85	2.91
Feb	9.65	2.87
Mar	9.29	2.76
Apr	8.79	2.79
May	10.00	2.82
Jun	12.52	2.76
Jul	11.30	2.77
Aug	11.73	2.82
Sep	12.47	2.84
Oct	12.70	2.69
Nov	12.43	2.75
Dec	11.77	2.78

Table 4-2: Monthly average chemistry (mg/L) observed for Galkeno 300 (KV-28) water treatment plant discharges

Month	Zn	Cd	SO_4	NH_3*	As	Cu	Pb	Ni	Se	Ag
Jan	0.237	0.0094	875	0.06	0.0002	0.0002	0.0001	0.0010	0.00012	0.00001
Feb	0.274	0.0054	913	0.10	0.0012	0.0009	0.0002	0.0048	0.00057	0.00006
Mar	0.279	0.0080	933	0.10	0.0010	0.0009	0.0002	0.0052	0.00060	0.00006
Apr	0.241	0.0060	872	0.10	0.0343	0.0022	0.0086	0.0118	0.03366	0.00171
May	0.218	0.0055	824	0.10	0.0010	0.0015	0.0002	0.0048	0.00077	0.00007
Jun	0.991	0.0235	871	0.10	0.0011	0.0015	0.0010	0.0071	0.00074	0.00008
Jul	0.478	0.0168	877	0.10	0.0014	0.0015	0.0025	0.0041	0.00064	0.00014
Aug	0.166	0.0113	896	0.10	0.0010	0.0009	0.0006	0.0044	0.00062	0.00007
Sep	0.254	0.0090	941	0.10	0.0012	0.0009	0.0004	0.0052	0.00072	0.00008
Oct	0.195	0.0083	954	0.10	0.0008	0.0008	0.0001	0.0040	0.00056	0.00006
Nov	0.280	0.0074	933	0.10	0.0016	0.0008	0.0039	0.0040	0.00054	0.00007
Dec	0.199	0.0061	925	0.10	0.0011	0.0009	0.0012	0.0022	0.00058	0.00007

*No measured concentrations available (0.1 mg/L is estimated)

Table 4-3: Monthly average chemistry (mg/L) observed for Galkeno 900 (KV-32) water treatment plant discharges

Month	Zn	Cd	SO_4	NH_3*	As	Cu	Pb	Ni	Se	Ag
Jan	0.142	0.00006	962	0.026	0.015	0.0008	0.0032	0.0675	0.0004	0.000056
Feb	0.214	0.00014	1017	0.026	0.015	0.0009	0.0002	0.0653	0.0007	0.000058
Mar	0.145	0.00011	980	0.026	0.015	0.0008	0.0016	0.0484	0.0005	0.000054
Apr	0.110	0.00172	988	0.026	0.045	0.0022	0.0085	0.0516	0.0337	0.001706
May	0.081	0.00009	969	0.026	0.011	0.0024	0.0021	0.0480	0.0006	0.000093
Jun	0.128	0.00020	996	0.026	0.012	0.0015	0.0028	0.0593	0.0006	0.000221
Jul	0.292	0.00011	989	0.026	0.010	0.0019	0.0027	0.0468	0.0007	0.000076
Aug	0.076	0.00008	951	0.026	0.014	0.0013	0.0002	0.0621	0.0006	0.000067
Sep	0.443	0.00016	988	0.026	0.020	0.0009	0.0004	0.0797	0.0006	0.000101
Oct	0.144	0.00010	1015	0.026	0.015	0.0007	0.0002	0.0564	0.0005	0.000053
Nov	0.080	0.00007	983	0.026	0.015	0.0008	0.0002	0.0440	0.0005	0.000044
Dec	0.211	0.00010	1004	0.026	0.014	0.0008	0.0002	0.0665	0.0005	0.000057

*Only one measured concentration available (0.026 mg/L)

4.3 Load Source: Onek 400 Adit Discharge

Calibration Period: Chemical loads ($L_{chemical}$) in units of mass per unit of time are calculated from:

$$L_{chemical} = C_{mon\_ave} \times F_{mon\_ave} \times A_f \qquad \text{(Eq. 4)}$$

where C_{mon_ave} is the monthly average of measured concentrations in mg/L, F_{mon_ave} is the monthly average of measured flow rates in L/s or estimates for months with no measured data (Table 4-5), and A_f is an attenuation factor specific to each chemical constituent. Monthly averages for concentrations and flow rates were used to represent seasonal patterns observed for Onek 400 Adit flows and chemistry (Table 4-4 and Table 4-5). The monthly averages are used repeatedly for the entirety of the future simulation period.

We assume that 40% of the chemical load from the Onek 400 Adit enters the groundwater system and eventually reaches Christal Lake or Christal Creek upstream of KV-6 and 60% enters Christal Creek downstream of KV-6. The travel time is estimated at about 4 years. The chemical loads from the Onek 400 Adit are decreased due to attenuation processes in the groundwater system by processes such as solubility, cation exchange, and adsorption with the minimum concentration constrained by the expected presence of elevated levels of some metals, such as zinc and cadmium, in the groundwater path below the Adit. The values of specific attenuation factors were determined through the calibration process (discussed in Section 6.2).

Future Simulation Period: Chemical loads are also calculated according to Eq. 4.

Reclamation Option of Onek 400 Adit Water Treatment for the Future Simulation Period: The possible reclamation options for the Onek 400 Adit discharge include water treatment or reclamation of the Onek pit to decrease the rate of discharge. For options that continue to discharge the Onek 400 Adit discharge water at or near the current adit location, we assume the minimum possible loads specifically for zinc and cadmium are constrained by various geochemical processes (e.g., solubility, adsorption, ion exchange) in the flow path directly below the adit during the past years of discharge. We used the average concentrations of zinc (1.08 mg/L) and cadmium (0.01 mg/L) measured at well KV-84, which is located immediately downgradient of the Onek 400 Adit, as approximations of the effective solubilities of zinc and cadmium in the groundwater flow path. These concentrations are substantially lower than those in the Onek 400 discharge water (see Table 4-5). For reclamation options that involve continued discharge of adit water to the current location, we assume that zinc and cadmium concentrations in the groundwater flow path downgradient of the Onek 400 Adit cannot be lower than these maximum concentrations measured for KV-84 in calculations of chemical loads. In addition, we assume that and decrease in load due to reclamation would not be instantaneous but would occur gradually over a four year time span because of the distance between the Onek 400 Adit and Christal Creek. The time for Onek 400 Adit water to travel through the groundwater zone to Christal Creek is estimated to be about 4 years.

Table 4-4: Average flow rates for the Onek 400 Adit

Month	Onek 400 Adit Flow Rate (L/s)
Jan	1.84
Feb	0.50
Mar	1.00
Apr	1.50
May	0.92
Jun	2.93
Jul	1.22
Aug	0.63
Sep	2.20
Oct	2.42
Nov	1.84
Dec	1.84

Table 4-5: Monthly average chemistry (mg/L) for the Onek 400 Adit (KV-45) discharge

Month	Zn	Cd	SO_4	NH_3*	As	Cu	Pb	Ni	Se	Ag

Jan	34.4	0.389	292	0.025	0.0321	0.0044	0.0011	0.0202	0.0008	0.00007
Feb	32.0	0.351	283	0.025	0.0334	0.0027	0.0019	0.0182	0.0008	0.00008
Mar	32.6	0.348	303	0.025	0.0320	0.0036	0.0009	0.0188	0.0008	0.00008
Apr	29.4	0.314	287	0.025	0.0842	0.0040	0.0170	0.0283	0.0672	0.00340
May	112.1	3.901	416	0.025	0.0354	0.0376	0.0120	0.0255	0.0011	0.00016
Jun	117.4	2.555	462	0.025	0.0360	0.0195	0.0062	0.0305	0.0014	0.00015
Jul	84.1	1.373	424	0.025	0.0600	0.0240	0.0085	0.0285	0.0007	0.00009
Aug	71.2	1.035	382	0.025	0.0346	0.0076	0.0047	0.0253	0.0008	0.00010
Sep	48.3	0.537	337	0.025	0.0290	0.0026	0.0010	0.0210	0.0008	0.00010
Oct	56.8	0.747	351	0.025	0.0746	0.0082	0.0068	0.0227	0.0005	0.00008
Nov	41.2	0.516	358	0.025	0.0320	0.0025	0.0011	0.0210	0.0005	0.00006
Dec	36.5	0.439	308	0.025	0.0288	0.0018	0.0013	0.0204	0.0008	0.00010

*Only two measured concentration available (average = 0.025 mg/L)

4.4 Load Source: UN Adit Discharge (KV-53)

Calibration Period: Chemical loads are calculated according to Eq. 1. There are few data available for measured flow rates (13 measurements made during May to August between 2010 and July 2013). Flow rates for the winter months were estimated from the average of the measured rates at 0.3 L/s. Table 4-6 gives a summary of the monthly average flow rates for the UN Adit. Concentration data were available from 17 samples collected between October 2009 and July 2013. Table 4-7 gives the monthly average concentrations determined from the available data for the UN Adit. The flow rate and concentration data in Table 4-6 and Table 4-7 were used to calculate chemical loads for the entirety of the simulation period, assuming that the entire chemical load enters Christal Creek downstream of KV-6.

Future Simulation Period: Chemical loads are also calculated according to Eq. 1.

Reclamation Option of UN Adit Water for the Future Simulation Period: The chemical loads from the UN adit are low; hence a specific reclamation option for the discharge is not currently being considered. Reclamation of waste rock at the UN Adit and nearby sites (Miller) is included in the representation of the waste rock reclamation option.

Table 4-6: Average flow rates for the UN Adit (KV-53)

Month	UN Adit Flow Rate (L/s)
Jan	0.30
Feb	0.30
Mar	0.30
Apr	0.30
May	0.13
Jun	0.22
Jul	0.47
Aug	0.50
Sep	0.60
Oct	0.30
Nov	0.30
Dec	0.30

Table 4-7: Monthly Average concentrations (mg/L) for the UN Adit (KV-53)

Month	Zn	Cd	SO_4	NH_3	As	Cu	Pb	Ni	Se	Ag
Jan	0.044	0.0002	104	No data	0.0104	0.0010	0.0010	0.0020	0.0008	0.00010
Feb	0.159	0.0010	97	No data	0.0263	0.0015	0.0026	0.0034	0.0006	0.00010
Mar	0.159	0.0010	97	No data	0.0263	0.0015	0.0026	0.0034	0.0006	0.00010
Apr	0.159	0.0010	97	No data	0.0263	0.0015	0.0026	0.0034	0.0006	0.00010
May	0.017	0.0001	76	No data	0.0079	0.0010	0.0006	0.0030	0.0008	0.00010
Jun	0.028	0.0002	13	No data	0.0038	0.0030	0.0049	0.0033	0.0005	0.00015
Jul	0.065	0.0011	96	No data	0.0084	0.0019	0.0007	0.0037	0.0005	0.00010
Aug	0.044	0.0002	113	No data	0.0074	0.0010	0.0020	0.0026	0.0008	0.00010
Sep	0.093	0.0004	105	No data	0.0107	0.0010	0.0010	0.0040	0.0009	0.00010
Oct	0.567	0.0030	110	No data	0.0870	0.0014	0.0065	0.0041	0.0006	0.00008
Nov	0.131	0.0006	100	No data	0.0371	0.0002	0.0014	0.0020	0.0001	0.00002
Dec	0.030	0.0001	97	No data	0.0100	0.0010	0.0005	0.0030	0.0008	0.00010

4.5 Load Source: Mackeno Mill Tailings

Calibration Period: Approximately, 8440 tons of tailings from historic operations at the Mackeno were deposited in an undammed pile near the northeast side of Christal Lake (Access, 2009). These tailings contain sulfide minerals that are exposed to oxidative weathering processes. A sample of porewater from the tailings collected in September 2011 had 0.299 mg Cd/L and 195 mg Zn/L (Table 4-8). We used these concentrations to calculate the rate of chemical loads with the following equation:

$$L_{chemical} = A_{tail} \times Precip_{mon\_ave} \times I_{fraction} \times C_{porewater} \qquad \text{(Eq. 5)}$$

where A_{tail} is the surface area (5709 m^2), $Precip_{mon\_ave}$ is the monthly average rate of precipitation (Table 4-9), $I_{fraction}$ is the fraction of precipitation that infiltrates through the tailings (estimated at 45%), and $C_{porewater}$ are the recently SRK-measured porewater concentrations. We assume the entire chemical load from the Mackeno tailings enters Christal Lake or Christal Lake upstream of KV-6.

Future Simulation Period: Equation (5) is also used for the future simulation period.

Reclamation Option of Removal and/or Cover for the Future Simulation Period: The potential effects of reclamation on chemical loads require a number of assumptions about future performance. The key assumptions are:

- The reclamation of the Mackeno tailings would result in a decrease in chemical loads to Christal Creek due to decreased exposure to weathering, decreased infiltration, and potentially fewer tailings in the event that the tailings were removed.
- If lime is tilled into the tailings as part of the reclamation process, then chemical loads would be decreased by 90% due to the acid neutralizing effects of the lime and associated precipitation of stable metal oxyhydroxides and sulfate minerals.
- Re-grading and placement of clean soil cover will reduce the infiltration rate to 22% of mean annual precipitation based on experience at Brewery Creek (J. Harrington, personal communication).
- Reductions in chemical releases will take place over about three years.

- For the option of removal of the Mackeno tailings to the Valley Tailings facility at Elsa, the disruption of the surface during the removal process will lead to a temporary doubling of chemical releases for one year with loads decreasing to 5% of the current estimated non-reclaimed load over a period of 4 years. The minimum value of 5% is assumed to be due to residual tailings located in areas not accessible to excavation and areas of unknown tailings mixed in with natural soils.

Table 4-8: Porewater chemistry for Mackeno Tailings (sample MDP-3 collected Oct 6, 2011; D. MacGregor, SRK personal communication)

Constituent	Concentration (mg/L)
Zn	195
Cd	0.299
SO_4	1290
NH_3	0.1
As	0.565
Cu	0.004
Pb	0.339
Ni	0.308
Se	0.0008
Ag	0.0002

Table 4-9: Climate data (Access, 2004)

Month	Elsa Average Precipitation (mm/mon)	Lake Evaporation (mm/mon)
Jan	20	0
Feb	28	0
Mar	18	0
Apr	18	40
May	25	90
Jun	40	108
Jul	60	107
Aug	52	85
Sep	42	25
Oct	45	5
Nov	38	0
Dec	35	0

4.6 Load Source: Waste Rock

Calibration Period: The rates of metal leaching from waste rock were based on the procedure developed by SRK (2007/08) from shake flask leaching tests on various waste rock samples. The leaching data for open pit waste rock were averaged together and data for underground mine waste rock were averaged together. This averaging yielded two sets of rates of metal release (R_{metal}) in units of kg metal/kg rock/yr for each of open pit waste rock and underground mine waste rock. Table 4-10 gives a summary of the waste rock tonnages and types. Table 4-11 gives the rates of metal leaching determined for waste rock.

The rates of metal loadings for open pit waste rock sites (L_{WR_Pit}) in units of kg/yr are calculated using the data in Table 4-10 and Table 4-11 according to:

$$L_{WR\_Pit} = R_{metal} \times M_{WR\_Pit} \qquad \text{(Eq. 6)}$$

where M_{WR_Pit} is the tonnage of open pit waste rock. Likewise, for underground waste rock, the rates of metal loading ($L_{WR\_Undergroud}$) are defined by:

$$L_{WR\_Undergroud} = R_{metal} \times M_{WR\_Underground} \qquad \text{(Eq. 7)}$$

where $M_{WR\_Underground}$ is the tonnage of underground mine waste rock.

Future Simulation Period: Equations 6 and 7 are also used for the future simulation period.

Reclamation Option of Cover and Re-grading for the Future Simulation Period: For the scenario where the waste rock sites would potentially re-graded and covered with clean soil to reduce exposure to weathering processes and water, the rates of metal loading were decreased to 22% of current levels defined by Eqs. 6 and 7. The total decrease to 22% is based on experience at Brewery Creek where cover performance has been assessed. The decrease in loading was assumed to occur over a 4-year period.

Table 4-10: Summary of waste rock sites in the Christal Creek watershed

Waste Rock Location	Metric tons	Type
Calumet Pit	1000000	Open Pit
Onek Pit	402000	Open Pit
BlackCap	390000	Open Pit
Galkeno100_200_300	150000	Adit
Lucky Queen	61900	Adit
Miller	63000	Open Pit
Formo	27800	Open Pit
Galkeno_900	20800	Adit
Shamrock_King	16200	Open Pit
Shamrock	9000	Adit
UN_Adit	7500	Adit
Klondike-Keno	3200	Adit
Paddy	2000	Adit
Flame&Moth	1562	Open Pit
Tin Can	1000	Adit
Kijo	100	Open Pit
Croesus	100	Open Pit
Bluebird	240	Open Pit
Rico	100	Open Pit

Table 4-11: Rates of chemical release from mine waste rock based on Shake-Flask Extraction tests from SRK (2007/08)

Constituent	Open Pit Waste Rock Release Rates (mg/kg/yr)*	Adit Waste Rock Release Rates (mg/kg/yr)
As	1.22E-04	0.0062
Cd	8.34E-04	0.0229
Cu	3.98E-04	0.014
Pb	0.048	0.029
Ni	8.57E-05	0.021
Ag	2.53E-05	4.80E-05
Zn	0.0093	0.208
SO_4	150*	150*
Se	1.51E-04	0.0019

*Averaged from 28 shake flask leaching tests

** Averaged from 18 shake flask leaching tests

4.7 Load Source: Natural Background Surface Runoff

The rate of surface runoff (S_{runoff}) in L/s was represented in the simulation model from the product of the watershed area ($A_{watershed}$) and the mean annual runoff (MAR) proportioned according to an estimate of the seasonal runoff pattern month by month (SR_{month}) in units of percent of total runoff:

$$S_{runoff} = A_{watershed} \times MAR \times SR_{month} \qquad \text{(Eq. 8)}$$

The mean annual runoff rates were 240 mm/yr for the watershed upstream of KV-6 based on the value used in the spreadsheet mass load model developed by Access Consulting and 213.3 mm/yr for the watershed draining to the KV-6 to KV-7 stretch of Christal Creek reported in Clearwater (2010). The seasonal runoff monthly pattern was also obtained from the Access Consulting spreadsheet model (Table 4-12). The chemical loads from surface runoff were calculated by multiplying the flow rate from Eq. 8 times the estimate concentrations for surface runoff in Table 4-13. The concentrations in Table 4-13 were estimated through the calibration process.

Table 4-12: Values used to represent a seasonal pattern of surface runoff

Month	Percent of Mean Annual Runoff
Jan	1.6%
Feb	1.6%
Mar	1.6%
Apr	18.3%
May	18.3%
Jun	18.3%
Jul	9.5%
Aug	9.5%
Sep	9.5%
Oct	4.0%
Nov	4.0%
Dec	4.0%

Table 4-13: Estimated concentrations for surface runoff

Constituent	Surface Runoff to KV-6 (mg/L)	Surface Runoff to KV-7 (mg/L)
As	0.002	0.00001
Cd	0	0
Cu	0.002	0.001
Pb	0.001	0.0005
Ni	0.0004	0.0008
Ag	7.8E-06	2.0E-05
Zn	0	0
SO_4	200	120
Se	0.00065	0.0006
NH_3	0.01	0.01

4.8 Load Source: Natural Background Groundwater

Calibration Period: Calibration of the water balance for Christal Lake indicated a deficit of about 20 L/s compared to the sum of all measured inflows to Christal Lake and Christal Creek upstream of KV-6 (discussed below). Consequently, we assumed that this deficit was most likely to be groundwater entering Christal Lake from the upgradient catchment that extends to the southeast area of Keno City. The chemical load from groundwater was calculated from the following equation:

$$L_{chemical} = C_{KC\_ave} \times 20\ L/s \qquad \text{(Eq. 9)}$$

where C_{KC_ave} is the average concentration from monitoring well KC-MW-2 (Table 4-14). This well is located outside the expected flowpath between the Onek 400 Adit and Christal Creek and is assumed to provide a reasonable approximation of background groundwater chemistry.

Future Simulation Period: Equation 9 was also used for the future simulation period.

Reclamation Option of Removal and/or Cover for the Future Simulation Period: There are no reclamation options under consideration for natural groundwater.

Table 4-14: Estimated chemistry of groundwater

Constituent	Average Concentration (mg/L)
As	0.00084
Cd	0.0013
Cu	0.0009
Pb	0.0010
Ni	0.0015
Ag	7.8E-06
Zn	0.062
SO_4	163
Se	0.0014
NH_3	0.01

4.9 Load Source: Formo and Paddy Mines

The Formo and Paddy Mines are privately held properties not located within the UKHM reclamation planning area. They have open areas of mining-related disturbances where elevated concentrations of zinc and sulfate have been reported. There are few flow rate and concentration data available to quantify the loads from these sources; hence the load calculation approaches presented below are estimations based on available information.

Calibration Period: Chemical loads from the Paddy Mine are based on concentration data reported for a small tributary near the access road by Graff and Burns (2011 - site PMRD TRIB) (Table 4-15). Graff and Burns (2011) did not measure a flow rate for this tributary. We used a flow rate of 1 L/s for the tributary based on visual estimation of the stream multiplied by the concentrations (Table 4-15) to estimate the load from Paddy.

Chemical loads from the Formo Mine are based on concentration data reported for a seep located about 10 m from Christal Creek (location 57-WQ-SCD-01 in PWGSC, 2000) (Table 4-15) and an estimated rate of runoff for the area around the seep from the location map in PWGSC (2000).

Table 4-15 Formo and Paddy concentration and flow rate data

Constituent	Formo Mine Area Concentrations (mg/L)	Paddy Mine Area Concentrations (mg/L)
As	0.01	0.0011
Cd	1.25	0.000006
Cu	0.0024	0.0011
Pb	0.0003	0.00032
Ni	0.1	(0.0) No data
Ag	0.00024	(0.0) No data
Zn	25.6	0.0025
SO_4	2030	28
Se	0.019	(0.0) No data
NH_3	(0.0) No data	(0.0) No data
Source	PWGSC (2000) Location: 57-WQ-SCD-01	Graff and Burns (2011); Location PMRD-TRIB
Flow Rate (L/s)	1.0	0.01 to 0.03*

* Drainage area of 9600 m^2 multiplied monthly precipitation rate and runoff coefficient of 15%

Future Simulation Period: Chemical loads are also calculated in the same manner as for the calibration period.

Reclamation Option of UN Adit Water for the Future Simulation Period: Chemical loads are also calculated in the same manner as for the calibration period because the Formo and Paddy Mines are not subject to future reclamation for the purposes of this report.

5.0 Stochastic Parameters

Stochastic elements were incorporated into the model to estimate the uncertainties future chemical loads in probabilistic simulations. Table 5-1 gives a list of the stochastic elements used in the model. These elements were simple multipliers that are applied as a percentage of uncertainty to specific inputs used in model calculations. For example, the stochastic element named *Stoch_Onek_FlowRate* has a truncated normal distribution that is described in Figure 5-1. In a probabilistic simulation, a new value is selected from this distribution for each model realization. The monthly average flow rate for the Onek 400 Adit is multiplied by this new value, which is a percentage range with a mean of 100% such that the mean value of the input parameter is always equal to the best estimate defined by the equations in Section 4. After a large number of realizations (e.g., 250), a range of flow rate for the Onek 400 Adit will have been produced with a distribution that is the same as that shown in Figure 5-1. The effects of this range of flow rates will be incorporated into a set of results for chemical loads that are also probability distributions. The simple multipliers provide a means to estimate uncertainties based on variability observed in measured data and professional judgment.

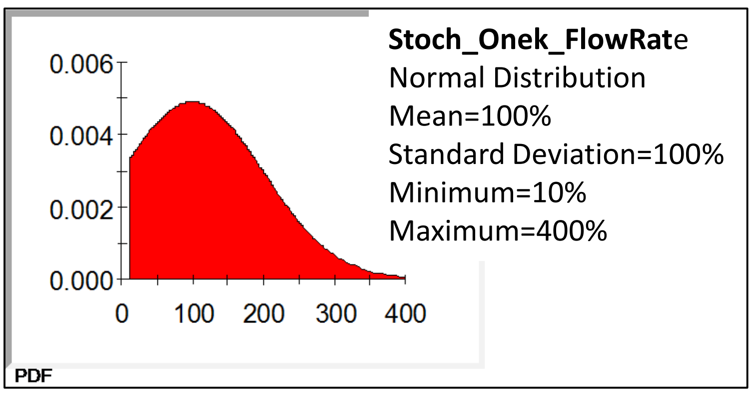

Figure 5-1 Example of probability distribution function for a simple multiplier stochastic element

Table 5-1 Stochastic elements used to define uncertainties in metal loads

Element Name in Model	Use in Model	Probability Distribution	Mean	Standard Deviation	Minimum	Maximum
Stoch_WR_ReleaseUncert	Directly applied to release rate from open pit and adit waste rock	Truncated Normal	100%	50%	25%	200%
Stoch_Gk300_900_FlowRate	Multiplier for rates of discharge from the Galkeno 300 and 900 water treatment plants	Truncated Normal	100%	10%	75%	125%
Stoch_GWInflowToChristalLake	Multiplier for the rate groundwater inflow to Christal Lake	Truncated Normal	100%	25%	50%	150%
Stoch_MAR	Multiplier for the mean annual runoff in calculations catchment surface runoff rate	Truncated Normal	100%	10%	75%	125%
Stoch_Onek_FlowRate	Multiplier for to the rate of discharge from the Onek 400 Adit	Truncated Normal	100%	100%	50%	400%
Stoch_AveKV_28_Chem	Multiplier for concentrations in discharge from the Galkeno 300 water treatment plant	Truncated Normal	100%	15%	50%	150%
Stoch_AveKV_32_Chem	Multiplier for concentrations in discharge from the Galkeno 900 water treatment plant	Truncated Normal	100%	15%	50%	150%
Stoch_AveKV_45_Chem	Multiplier for concentrations in discharge from the Onek 400 Adit	Truncated Normal	100%	50%	25%	200%
Stoch_MTInfiltrationUncert	Multiplier for the potential rate of infiltration into the Mackeno Tailings	Truncated Normal	100%	15%	50%	150%
Stock_GW_Chem	Multiplier for concentrations in background groundwater entering Christal Lake; also applied to runoff chemistry	Truncated Normal	100%	25%	50%	150%

6.0 Model Calibration

Measured data are available for flow rates and chemical concentrations at the monitoring locations shown in Figure 3-1 at varying levels of detail. Monitoring locations KV-6 and KV-7 on Christal Creek, in particular, provide an opportunity to calibrate the model against measured data through iterative adjustment of input parameters. Calibration of the model was conducted for the following two main components of the simulation model:

- Water balance at KV-6 and KV-7 and
- Chemical balances for loads at KV-6 and KV-7.

The parameters adjusted for calibration of the water and chemical balances are described in the following two sections.

6.1 Water Balance Calibration at KV-6 and KV-7

The focus of the water balance was to achieve agreement between simulated and measured cumulative volumes of water flowing down Christal Creek at KV-6 and KV-7. Location KV-6 represents the water balance for Christal Lake watershed and upper reach of Christal Creek (Figure 3-1). Location KV-7 represents the water balance for the reach of Christal Creek between KV-6 and KV-7 (Figure 3-1).

Figure 6-1 shows a comparison of simulated to observed cumulative volume of water at KV-6 after calibration. Two model parameters were adjusted to achieve agreement between the simulated and measured flow volumes. First, an inflow of groundwater at a rate of 20 L/s was added to the model to provide an overall increase in cumulative flow volume. Second, the mean annual rate of runoff (MAR) for 2009 was increased to 150% of the average value to represent the high runoff for 2009. The calibration adjustments improved agreement for runoff in 2009 and achieved a much closer match to total volume for the entirety of the calibration period, indicating the model produced a reasonable representation of the water balance for Christal Lake and the upper reach of Christal Creek upstream of KV-6.

After calibration of the upper portion of the watershed, the reach of Christal Creek between KV-6 and KV-7 was examined. This calibration shown in Figure 6-2 was achieved by decreasing the mean annual runoff (MAR) for the watershed area draining to the KV-6 to KV-7 reach of Christal Creek to 70-80% of the mean annual value for 2008 through 2010. No other parameters in the model were changed.

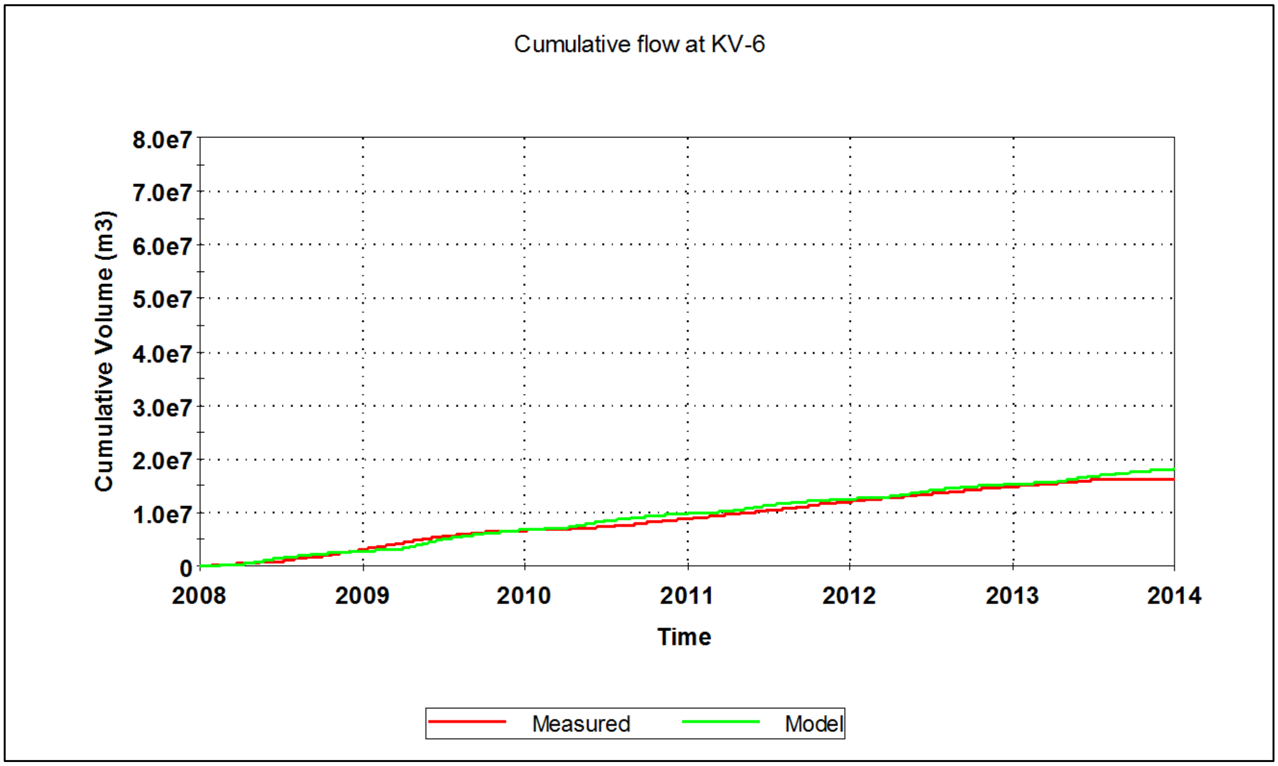

Figure 6-1 Comparison of simulated and measured cumulative volumes of water at KV-6 after model calibration

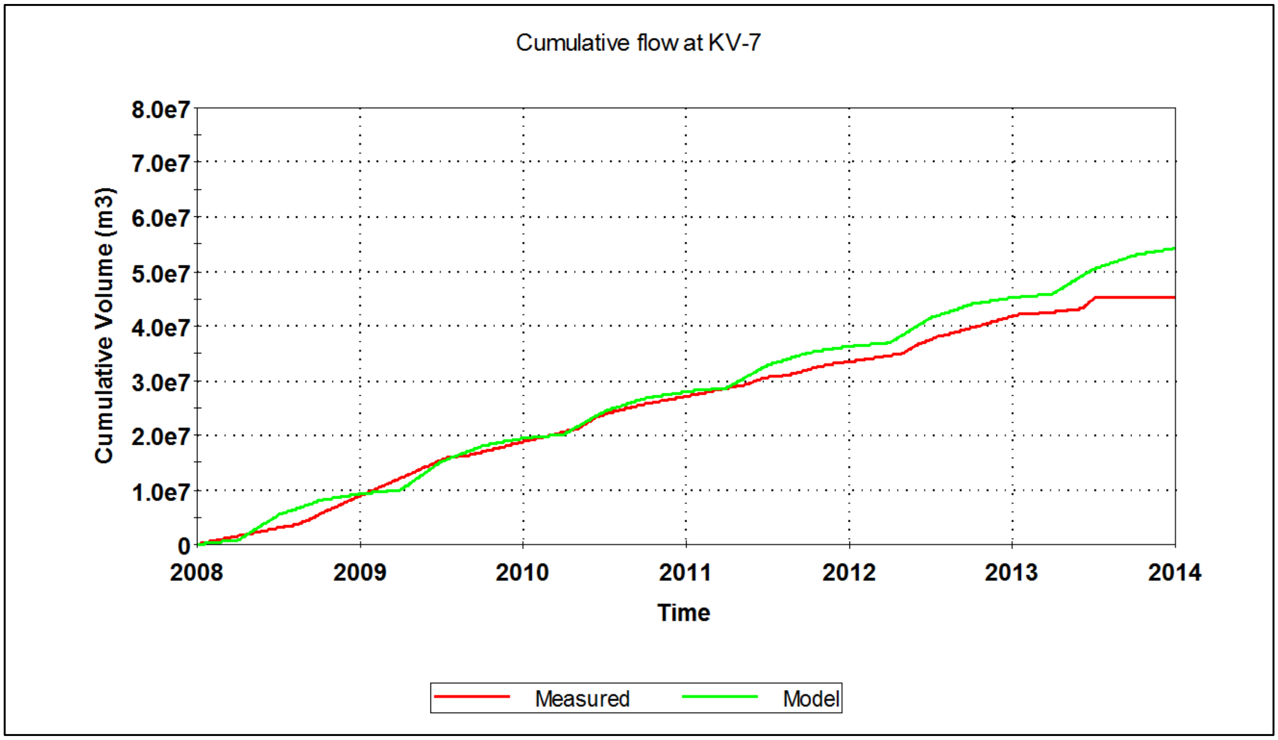

Figure 6-2 Comparison of simulated and measured cumulative volumes of water at KV-7 after model calibration

A check of the calibration for cumulative water flow at KV-6 and KV-7 was made by comparing simulated cumulative masses of sulfate to measured data at KV-6 and KV-7, assuming that sulfate would be conservatively transported through the watershed. Comparison of the simulated and measured cumulative sulfate loads are shown in Figure 6-3 and Figure 6-4. The good agreement between the simulation and measured results provides additional assurance that the model is producing a reliable estimation of flow rates in Christal Creek.

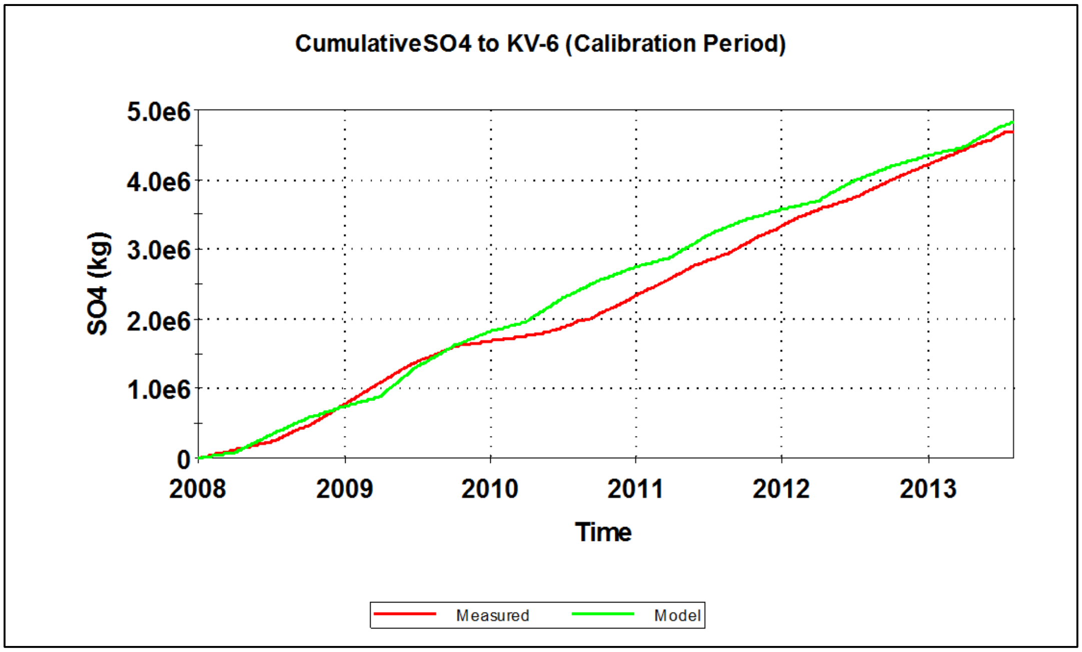

Figure 6-3: Measured and modeled cumulative sulfate at KV-6

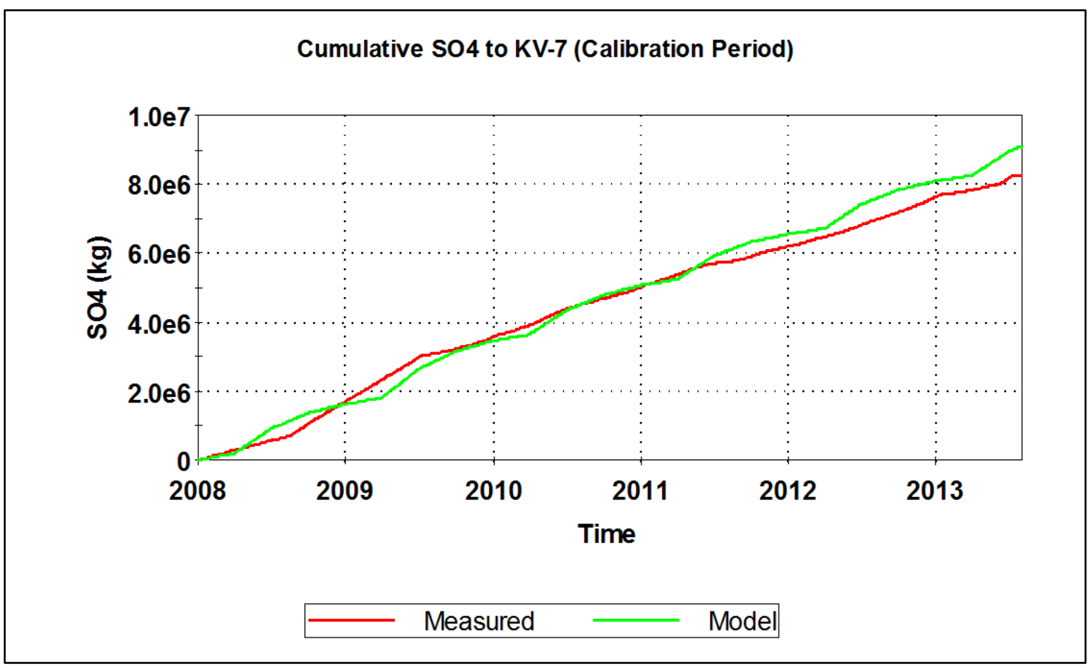

Figure 6-4 Measured and modeled cumulative sulfate at KV-7

6.2 Calibration of the Chemical Balance for Cadmium, Zinc, and Arsenic Loads at KV-6 and KV-7

Initial simulations of cadmium, zinc, and arsenic cumulative loads at KV-6 and KV-7 indicated higher loads than calculated from measured flow rates and concentrations. For example, the simulated cumulative cadmium load at KV-6 was about 7 to 8 times greater than the measured data and about 4 to 5 times greater than measured for zinc over the calibration period. Likewise, for KV-7, simulated cumulative cadmium loads were about 10 to 12 times greater and zinc loads from 3 to 4 times greater than measured over the calibration period.

To obtain agreement between the simulated and measured loads, attenuation factors were added to the model as part of the calibration process. These attenuation factors were applied to two pathways:

- Pathway 1: Groundwater flow path between the Onek 400 Adit and Christal Creek
- Pathway 2: Groundwater flow path leading to Christal Creek downstream of KV-6

The values of the attenuation factors determined by the calibration process are given in Table 6-1. The concentrations at the source location, such as the Onek 400 Adit, were multiplied by the attenuation factors to reduce chemical loads to match the observed data for Christal Creek at KV-6 and KV-7. However, in the case of Pathway 1 for the Onek 400 Adit discharge, specifically cadmium and zinc concentrations were not allowed to become lower than the effective limits determined from the KV-84 data (see Section 4.3), based on the assumption there is some amount of mineral solid phases containing these elements that will continue to leach into the groundwater in the future. Overall, the comparisons of simulated and observed loads examined during the calibration process indicate there is significant loss of cadmium and zinc in the transport pathways between the potential sources of these metals and Christal Creek.

Comparisons of measured and modeled loads for zinc, cadmium, arsenic, and copper for Christal Creek at monitoring locations KV-6 and KV-7 are shown in Figure 6-5 to Figure 6-8. In these comparisons, measured loads refer to loads calculated directly from measured flow rates and concentrations at KV-6 and KV-7, whereas modeled loads refer to loads simulated by the GoldSim model for Christal Creek based on the various inputs and transport pathways to Christal Creek from the surrounding watershed. The comparisons show that the model can reproduce the observed chemical loads in Christal Creek after the application of calibration factors.

Table 6-1: Attenuation factors used to calibrate chemical loads

	Attenuation Factors (%)	
Constituent	**Pathway 1: Groundwater flow path between the Onek 400 Adit and Christal Creek**	**Pathway 2: Groundwater flow path leading to Christal Creek downstream of KV-6**
As	100	5
Cd	2.5	15
Cu	100	100
Pb	100	100
Ni	100	100
Ag	100	100
Zn	11.9	100
SO_4	100	100
Se	100	100
NH_3	100	100

*100% indicates no attenuation effect

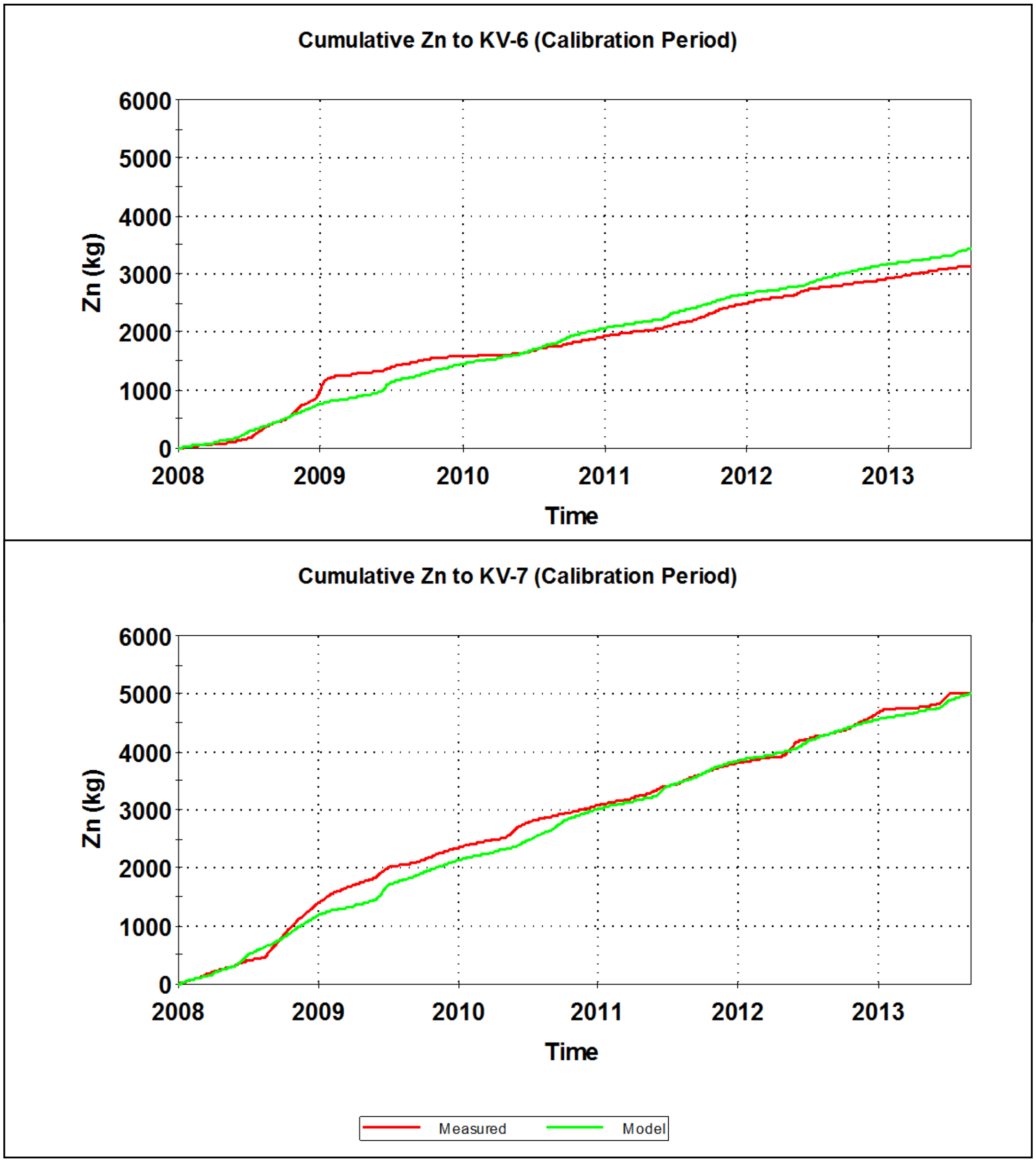

Figure 6-5: Measured and modeled zinc loads at KV-6 and KV-7 after calibration

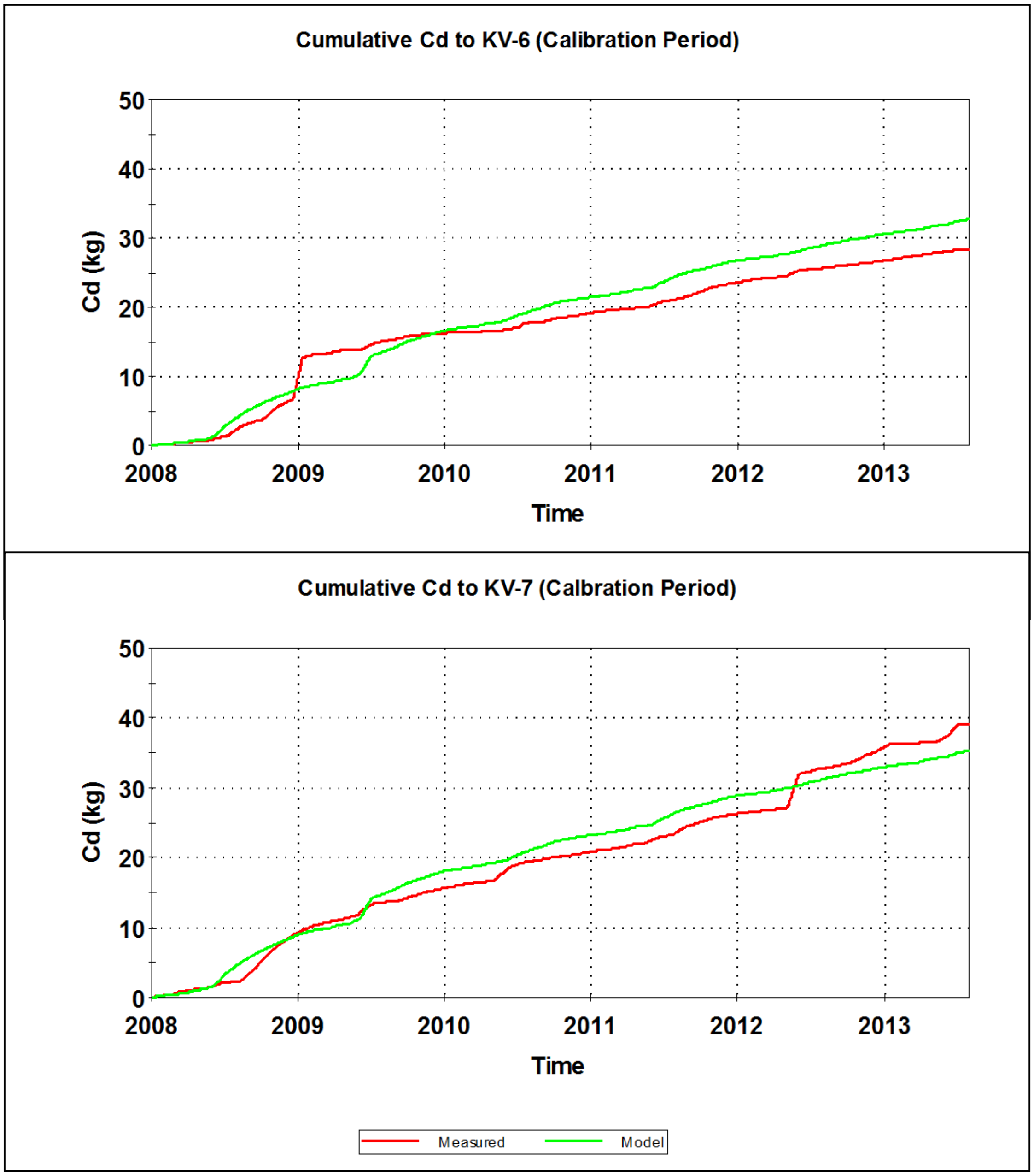

Figure 6-6: Measured and modeled cadmium loads at KV-6 and KV-7 after calibration

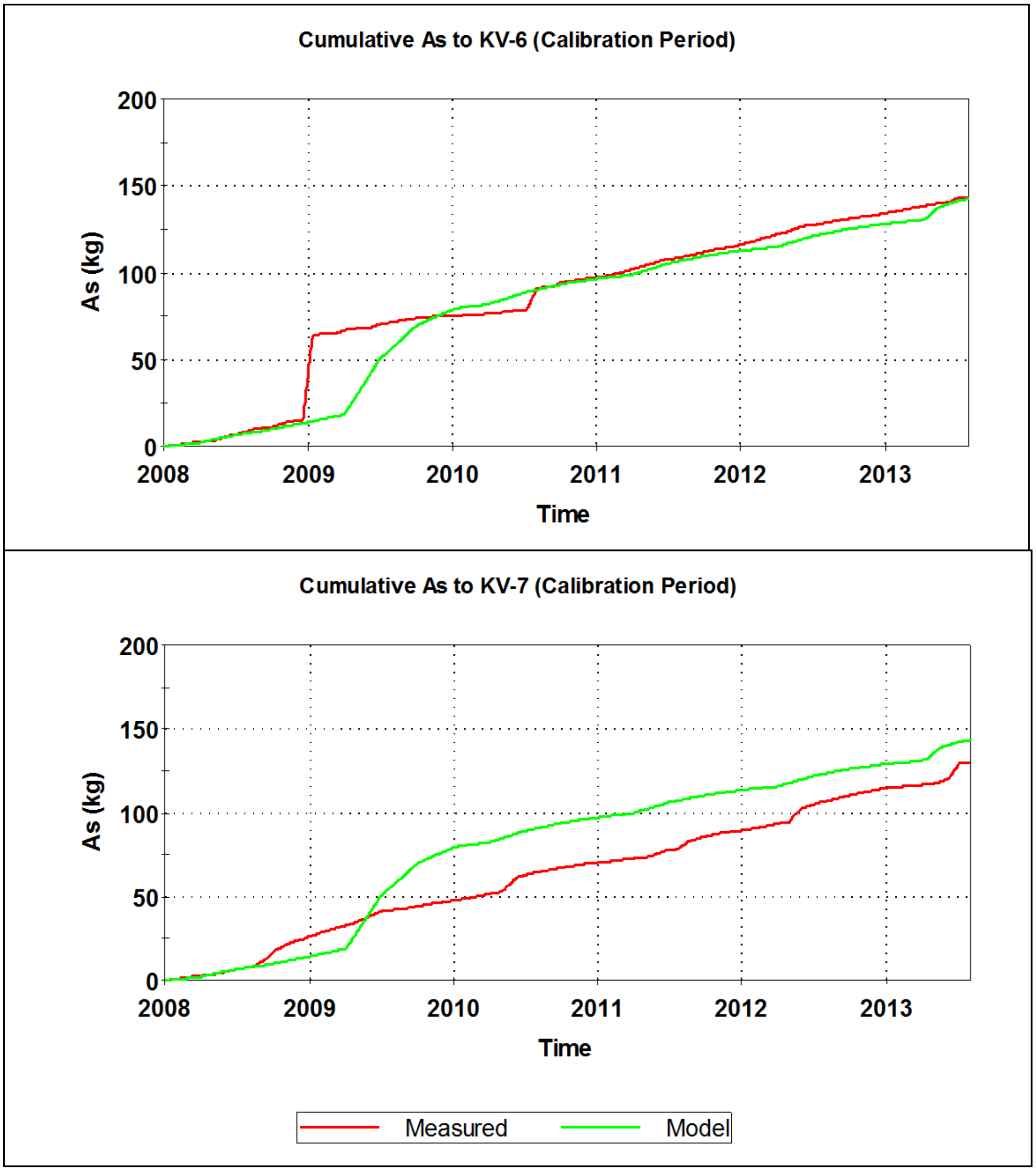

Figure 6-7: Measured and modeled arsenic loads at KV-6 and KV-7 after calibration

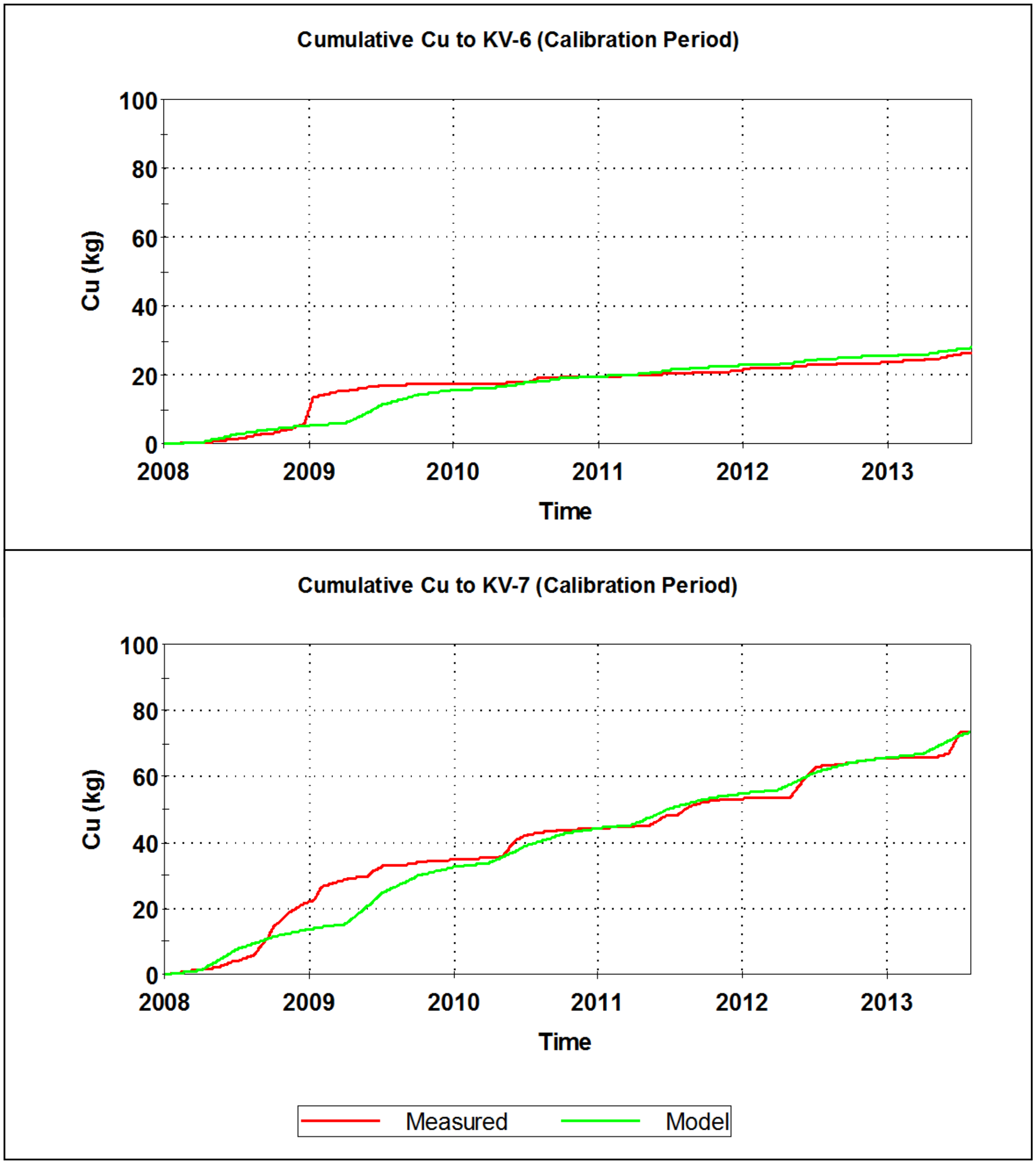

Figure 6-8: Measured and modeled copper loads at KV-6 and KV-7 after calibration

7.0 SUMMARY OF CHEMICAL LOAD SOURCES

Results from probabilistic simulations of chemical loads at KV-7 for the Base Case condition of no reclamation in the future are shown in Figure 7-1 to Figure 7-4. The probabilistic results in these figures provide a depiction of the expected ranges of probable future loads for the future based on the uncertainty distributions given in Table 5-1. The Base Case simulations show a steady upward trend in loads for cadmium, zinc, arsenic, and copper at KV-7.

The yearly average loads for the Base Case of no future reclamation are summarized in Table 7-1 for the calibration period when measured data are available and a representative future year. The summary in Table 7-1 is representative of average conditions of flow and concentrations projected into the future based on the data for the calibration period. The metal loads for the Base Case provide a baseline for comparing the predicted effects of reclamation options in Section 9.0.

Table 7-1: Base Case chemical loads at KV-7 for the calibration period and a representative future year (2015)

	Galkeno 300	Galkeno 900	Mackeno Tailings	Onek 400 Adit	Waste Rock	UN Adit	Surface Runoff	Groundwater	DCR Seep	Formo & Paddy	Lucky Queen Adit	Totals
2009												
Zn	146.58	11.84	187.68	474.30	32.85	4.78	0.00	39.24	10.41	20.87	10.63	939
Cd	3.48	0.01	0.29	6.22	0.13	0.02	0.00	0.84	0.08	1.01	0.13	12.2
As	0.54	1.92	0.54	4.24	0.03	0.52	55.53	0.53	4.16	0.08	0.54	68.6
Cu	0.34	0.11	0.00	1.36	1.55	0.01	14.43	0.57	0.14	0.07	0.29	18.9
Pb	1.16	0.03	0.33	0.67	28.64	0.05	5.83	0.65	0.12	0.00	3.26	40.7
Ag	0.041	0.006	0.000	0.006	0.018	0.001	0.144	0.005	0.001	0.000	0.057	0.28
2010												
Zn	83.62	7.09	187.68	478.72	32.85	6.73	0.00	39.24	10.41	20.87	10.63	878
Cd	2.18	0.01	0.29	2.28	0.13	0.04	0.00	0.84	0.08	1.01	0.13	7.0
As	0.31	0.78	0.54	2.53	0.03	0.96	9.30	0.53	4.16	0.08	0.54	19.8
Cu	0.37	0.09	0.00	1.33	1.55	0.02	7.20	0.57	0.14	0.07	0.29	11.6
Pb	0.10	0.20	0.33	0.41	28.64	0.07	4.52	0.65	0.12	0.00	3.26	38.3
Ag	0.037	0.009	0.000	0.005	0.018	0.001	0.121	0.005	0.001	0.000	0.057	0.26
2011												
Zn	65.01	30.69	187.68	435.12	32.85	2.91	0.00	39.24	10.41	20.87	10.63	835
Cd	3.01	0.02	0.29	1.87	0.13	0.02	0.00	0.84	0.08	1.01	0.13	7.4
As	0.26	1.35	0.54	1.59	0.03	0.64	8.37	0.53	4.16	0.08	0.54	18.1
Cu	0.29	0.08	0.00	0.47	1.55	0.01	7.01	0.57	0.14	0.07	0.29	10.5
Pb	0.10	0.30	0.33	0.15	28.64	0.05	4.34	0.65	0.12	0.00	3.26	37.9
Ag	0.029	0.013	0.000	0.004	0.018	0.001	0.120	0.005	0.001	0.000	0.057	0.25
2012												
Zn	48.66	12.92	188.09	345.27	32.94	0.35	0.00	39.35	10.44	20.92	10.66	710
Cd	1.78	0.01	0.29	1.34	0.13	0.00	0.00	0.84	0.08	1.01	0.13	5.6
As	0.19	0.82	0.54	1.49	0.03	0.10	8.39	0.53	4.17	0.08	0.54	16.9
Cu	0.08	0.02	0.00	0.39	1.55	0.01	7.78	0.57	0.14	0.07	0.29	10.9
Pb	0.15	0.09	0.33	0.16	28.72	0.01	4.72	0.65	0.12	0.00	3.27	38.2
Ag	0.008	0.003	0.000	0.006	0.018	0.001	0.135	0.005	0.001	0.000	0.057	0.23
2025*												
Zn	113.81	14.68	187.68	356.00	32.85	1.29	0.00	39.24	10.41	20.87	10.63	787
Cd	3.43	0.02	0.29	1.32	0.13	0.01	0.00	0.84	0.08	1.01	0.13	7.3
As	1.11	1.45	0.54	2.17	0.03	0.22	9.32	0.53	4.16	0.08	0.54	20.2
Cu	0.43	0.11	0.004	0.48	1.55	0.01	9.49	0.57	0.14	0.07	0.29	13.2
Pb	0.38	0.16	0.33	0.25	28.64	0.02	5.67	0.65	0.12	0.00	3.26	39.5
Ag	0.062	0.019	0.000	0.018	0.018	0.001	0.167	0.005	0.001	0.000	0.057	0.35

***Representative future simulation year**

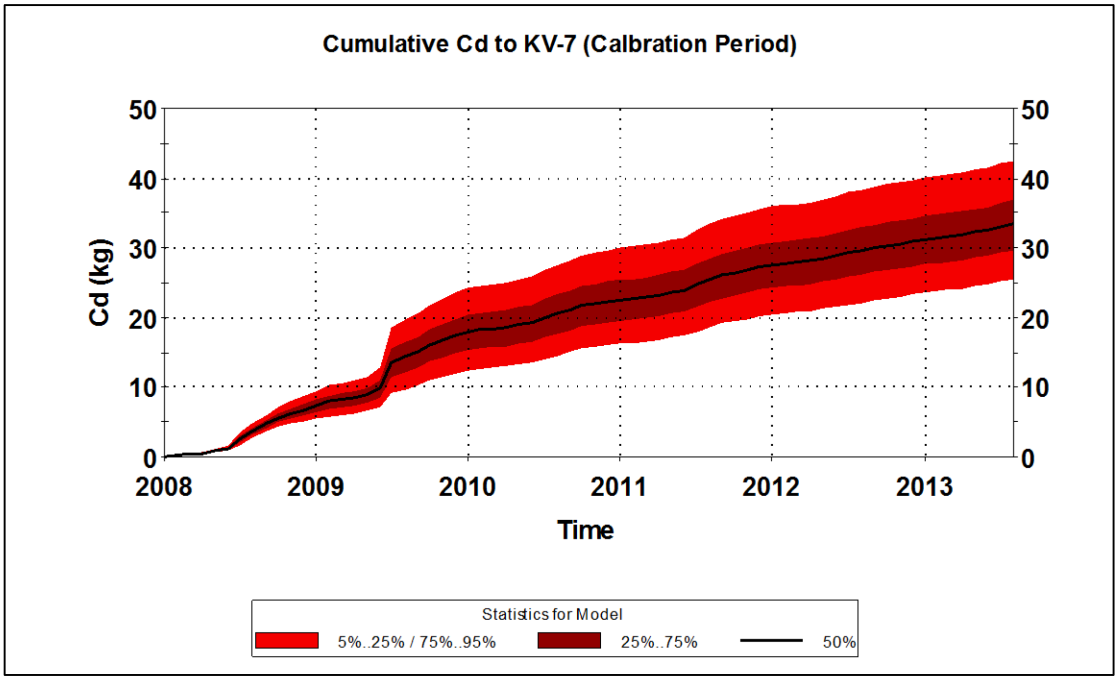

Figure 7-1: Base Case probabilistic simulation of cumulative cadmium total load at KV-7

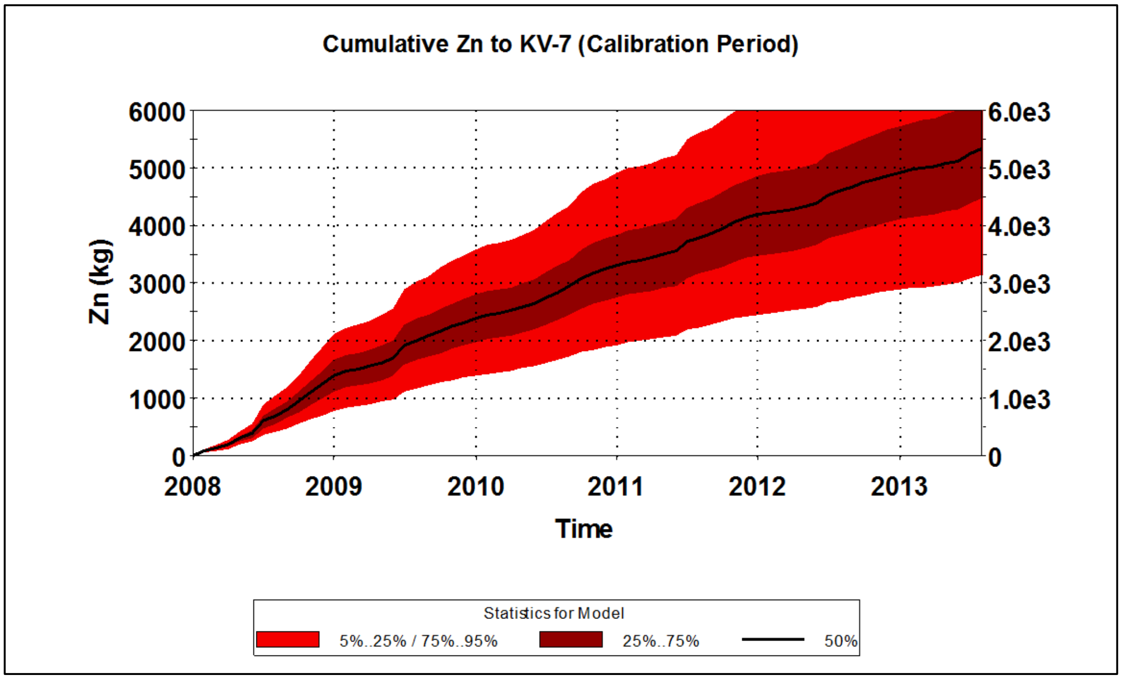

Figure 7-2: Base Case probabilistic simulation of cumulative zinc total load at KV-7

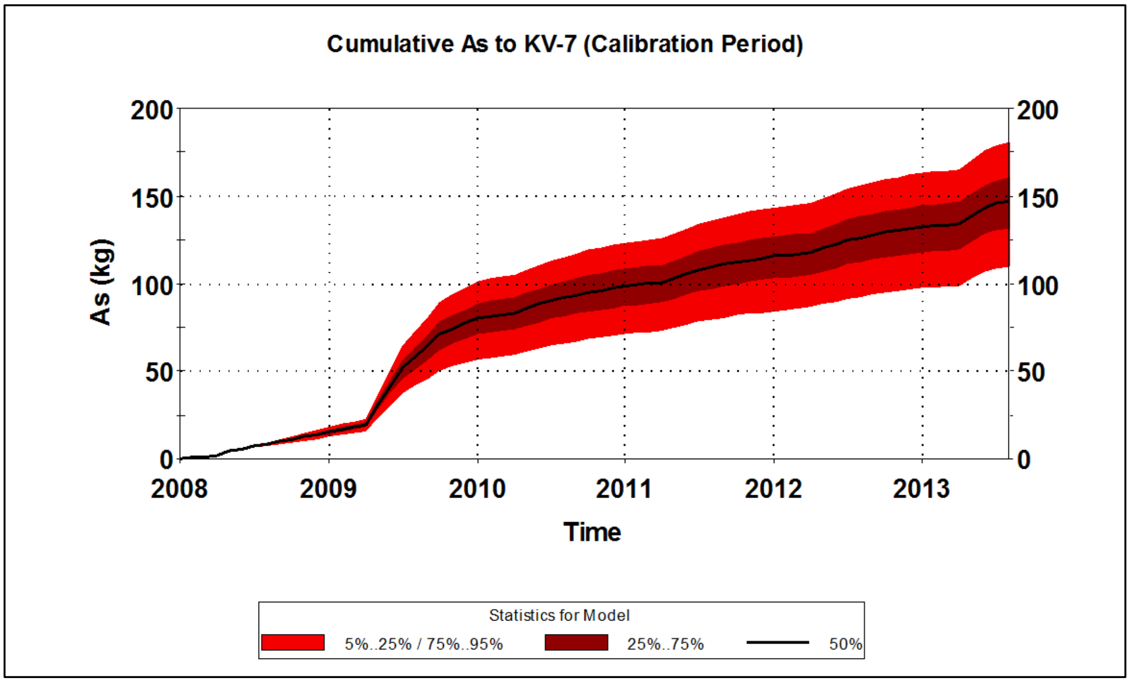

Figure 7-3: Base Case probabilistic simulation of cumulative arsenic load at KV-7

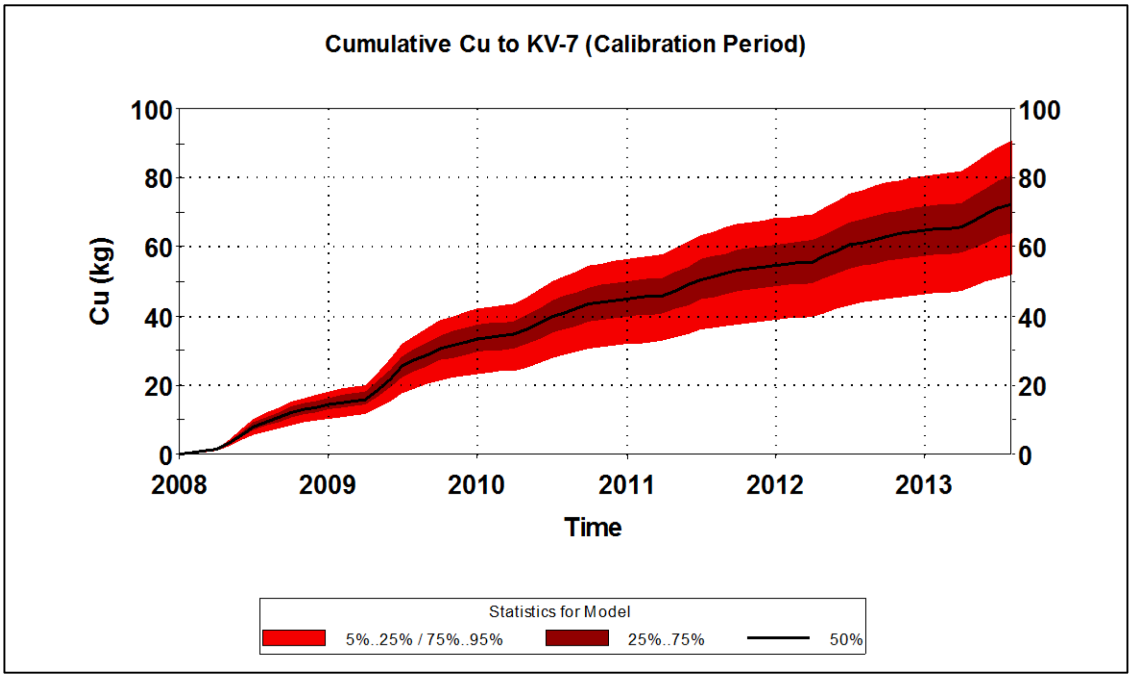

Figure 7-4: Base Case probabilistic simulation of cumulative copper load at KV-7

8.0 Previous Reclamation Effects

Previous reclamation efforts in the Christal Creek watershed included construction and operation of water treatment plants to reduce metal loads from adit discharges at Galkeno 900 and Galkeno 300.

8.1 Galkeno 900 Water Treatment

In October 1993, concerns about the high zinc concentrations and loadings in the Galkeno drainage water led to the installation of a hydraulic bulkhead in the Galkeno 900 adit and the establishment of a water treatment system. Discharge from the Galkeno 900 adit treatment plant travels via an underground pipe from the adit to the settling pond. After passing through the treatment pond, discharges flow downgradient and over energy dispersion sheeting before entering the vegetative area between the settling pond and Christal Lake. The flow path travels through approximately 190 m of surface vegetation and marshes before draining into Christal Lake. We do not have sufficient flow rate and concentration data for the time period before and shortly after 1993 to determine the decrease in metal loads achieved by operation of the Galkeno 900 water treatment plant.

8.2 Galkeno 300 Water Treatment

Adit discharge from Galkeno 300 was originally another large source of chemical loads to Christal Creek; hence, a water treatment plant was constructed to reduce chemical loads from the Galkeno 300 Adit. Plant construction was completed in December 2007. Optimization of the system for zinc removal was completed in February 2008. Consistent compliance (<0.5 mg/l zinc) was reached on February 15, 2008 and Galkeno 300 discharge has consistently met compliance standards since that time.

Figure 8-1 shows the decrease in annual zinc loads that occurred after operation of the treatment plant at Galkeno 300 and the associated decrease at KV-7. Water treatment reduced the zinc load discharged from Galkeno 300 from 4332 kg/yr in 2007 to a range of 64 to 147 kg/yr during 2008 to 2012. These reductions are equivalent to a percentage range of decrease of greater than 95%.

A reduction in zinc loads occurred in Christal Creek at KV-7 in response to water treatment but the reduction was not directly proportional to the decreases at Galkeno 300 (Figure 8-1). For example, the zinc load at KV-7 prior to water treatment was 2092 kg/yr in 2007. In subsequent years of 2009 to 2012, zinc loads decreased to 958 to 728 kg/yr, which is equivalent to a percentage range of decrease of 54 to 65% relative to the 2007 load of 2092 kg. The average load for the most recent five year time span of 2008 through 2013[1] is 787 kg Zn/yr, which is a 62% decrease relative to the pre-treatment value of 2092 kg/yr in 2007.

[1] Load for 2013 is estimated from measured data through July 2, 2013 plus model simulation for the remainder of the year

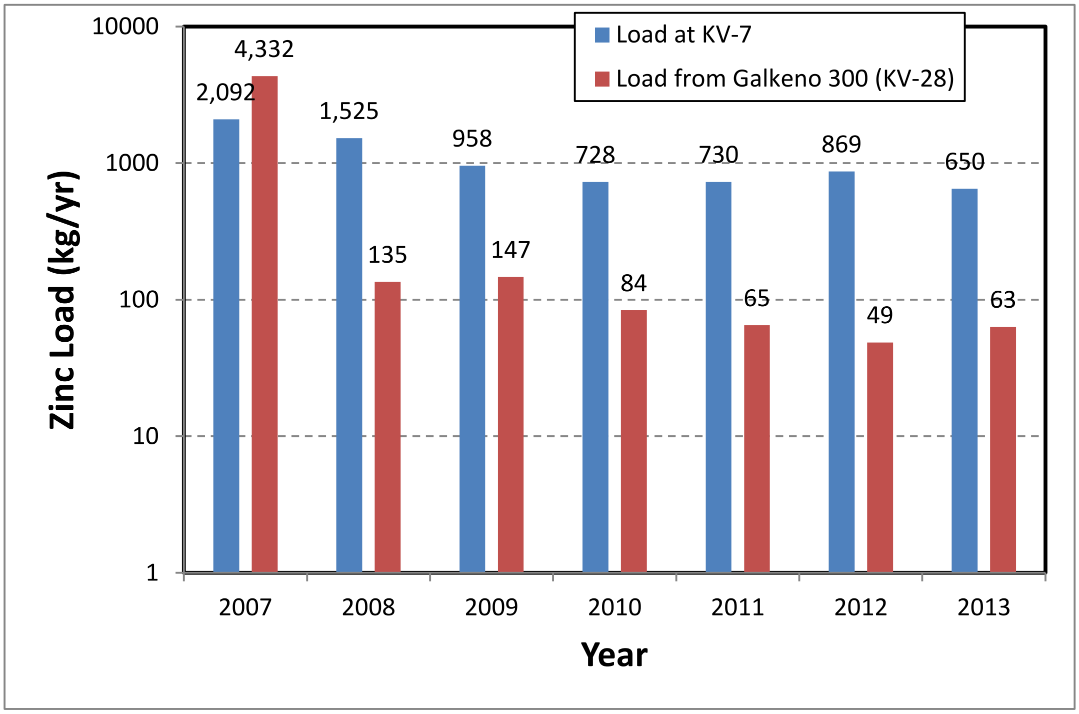

Figure 8-1 History of annual zinc loads from Galkeno 300 and response at KV-7

9.0 Simulation Results for Future Reclamation Scenarios

9.1 Chemical Loads for Reclamation Options

A summary of the effects of various reclamation options for reducing chemical loads to Christal Creek is provided in Table 9-1 along with the assumptions used to develop the options. The reclamation options for reducing loads from point sources, such as Galkeno 300, are assumed to result in a rapid response of reduced loads in Christal Creek. However, reclamation options for non-point sources (e.g., Mackeno Tailings) are expected to take a number of years before a complete response is observed in Christal Creek. The chemical loads in Table 9-1 are annual values obtained from the simulation model for year 2025. Year 2025 is used because it is after the time period when the potential effects of reclamation options are predicted to reach steady-state, assuming a start date of August 2016 for initiation of reclamation effects for all of the options in Table 9-1.

The results are presented as average loads in kg per year at KV-7 that might potentially be achieved, assuming a proportional effect between load reduction at sources and response in Christal Creek. The assumption of a proportional response is important consideration because past behavior observed in Christal Creek after the startup of the Galkeno 300 indicates that a proportional response may not occur (Figure 8-1). We also assume that some amount of residual loading will always be present due to tailings remaining in the sediments of Christal Lake and Christal Creek as well as the transport path downgradient of the Onek 400 Adit that are not included in viable reclamation scenarios. These residual loads are described in the assumptions given in Table 9-1.

Table 9-1 Average zinc and cadmium loads predicted for implementation of potential reclamation options

Reclamation Option	Operational Objectives and Assumptions	Zinc Average Predicted Load at KV-7 (kg Zn/yr)	Cadmium Average Predicted Load at KV-7 (kg Cd/yr)	Arsenic Average Predicted Load at KV-7 (kg As/yr)	Lead Average Predicted Load at KV-7 (kg Pb/yr)	Silver Average Predicted Load at KV-7 (kg Ag/yr)
Base Case	Current conditions (averages from measured data for 2008 to 2013 at KV-7)	Model=787; Measured = 787	Model = 7.3; Measured = 7.5	Model = 20.2; Measured = 27.3	Model = 39.5; Measured = 38.8	Model = 0.35; Measured =0.27
Galkeno 300 Options						
1) Existing facility at Galkeno 300 is upgraded to: a) Enhance sludge management b) Improve adit water collection management c) Provide redundant water recovery from Hector Calumet c) Improve winter access d) Improve reagent handling facilities	**A)** Galkeno 300 treatment results remain the same as those established for 2009 and later: averages of 0.22 mg Zn/L; 0.007 mg Cd/L (0.322 mg Zn/L and 0.01 mg Cd/L - effective flow-weighted averages) (*Discharge load enters Christal Lake through Hinton Creek as currently configured.*) **B)** Galkeno 300 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L. (*Discharge load enters Christal Lake through Hinton Creek as currently configured.***)**	**A) 787** **B) 709**	**A) 7.3** **B) 4.2**	**A) 20.1** **B) 20.1**	**A) 39.5** **B) 39.5**	**A) 0.34** **B) 0.32**
2) New treatment facility at Elsa: a) Pipeline from G300 or well into Hector Calumet to Elsa, capacity for other mine discharges b) New water treatment plant including reagent handling and mixing, treatment plant, sludge handling facilities c) Capacity of treatment plant sufficient to handle No Cash additional flow (adaptive management alternative)	**A)** Galkeno 300 treatment results same as established at Galkeno 300 for 2009 and later: averages of 0.22 mg Zn/L; 0.007 mg Cd/L (0.322 mg Zn/L and 0.01 mg Cd/L - effective flow-weighted averages) (*Discharge load is removed from Christal Creek and added to Flat Creek***.)**	**A) 674**	**A) 3.8**	**A) 19.0**	**A) 39.1**	**A) 0.29**
3) New treatment facility at Silver Trail Highway near Galkeno 300: a) Pipeline from G300 or well into Hector Calumet to Silver Trail area b) New water treatment plant including reagent handling and mixing, treatment plant, sludge handling facilities c) Capacity of treatment plant sufficient to handle Onek 400, Galkeno 300, and Galkeno 900 additional flow (adaptive management alternative)	**A)** Galkeno 300 treatment results same as currently established averages of 0.22 mg Zn/L; 0.007 mg Cd/L (0.322 mg Zn/L and 0.01 mg Cd/L - effective flow-weighted averages) (*Discharge load is moved downstream to enter at KV-6.*) **B)** Galkeno 300 treatment improved to reduce zinc to average of 0.1 mg Zn/L and Cd average of 0.001 mg Cd/L. (*Discharge load is moved downstream to enter at KV-6***.)**	**A) 787** **B) 709**	**A) 7.3** **B) 4.2**	**A) 20.1** **B) 20.1**	**A) 39.5** **B) 39.5**	**A) 0.34** **B) 0.32**

Reclamation Option	Operational Objectives and Assumptions	Zinc Average Predicted Load at KV-7 (kg Zn/yr)	Cadmium Average Predicted Load at KV-7 (kg Cd/yr)	Arsenic Average Predicted Load at KV-7 (kg As/yr)	Lead Average Predicted Load at KV-7 (kg Pb/yr)	Silver Average Predicted Load at KV-7 (kg Ag/yr)
Galkeno 900 Options						
1) Bioreactor treatment with the following design: a) Lined facility at Galkeno 900 adit built into hillside on contour b) Carbon source addition in both solid phase and dissolved phase; c) Ongoing monitoring at bioreactor discharge to demonstrate treatment	A) Average concentrations in bioreactor effluent are 0.02 mg Zn/L and 0.0001 mg Cd/L. *Assume bioreactor treatment assumes achievement of results similar to the 0.75 L/s operational phase of the Galkeno 900 bioreactor pilot test and passive filtration will remove suspended solids and yield discharge effluent similar to the bioreactor "dissolved" effluent concentrations. (Discharge load remains at current location.)*	A) 775	A) 7.3	A) 20.0	A) 39.5	A) 0.36
(2) Stand-alone small mechanical plant similar to Galkeno 300 plant to provide: a) Improved clarifier b) Improved options for reagents b) New sludge management facilities c) Discharge to bog at edge of Christal Lake	A) Galkeno 900 treatment plant improved performance to achieve averages of 0.12 mg Zn/L, 0.00005 mg Cd/L; Note that current averages at Galkeno 900 are 0.15 mg Zn/L and 0.00013 mg Cd/L. *Assume mechanical plant achieves same performance as Galkeno 300 plant.* (*Discharge load remains at current location.)*	A) 783	A) 7.3	A) 20.0	A) 39.5	A) 0.36
3) New treatment facility at Silver Trail Highway near Galkeno 900: a) Pipeline from Galkeno 900 to Silver Trail area b) New water treatment plant including reagent handling and mixing, treatment plant, sludge handling facilities c) Capacity of treatment plant designed initially to handle Galkeno 300, Onek 400, and Galkeno 900 flow (adaptive management alternative)	A) Galkeno 900 treatment results same as established at Galkeno 300 for 2009 and later: averages of 0.22 mg Zn/L; 0.007 mg Cd/L. Note that current averages at Galkeno 900 are 0.15 mg Zn/L and 0.00013 mg Cd/L. (*Discharge load remains at current location.)* B) Galkeno 900 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L. Note that current averages at Galkeno 900 are 0.15 mg Zn/L and 0.00013 mg Cd/L. (*Discharge load remains at current location.)*	A) 792 B) 781	A) 7.9 B) 7.3	A) 20.0 B) 20.0	A) 39.5 B) 39.5	A) 0.36 B) 0.36

Reclamation Option	Operational Objectives and Assumptions	Zinc Average Predicted Load at KV-7 (kg Zn/yr)	Cadmium Average Predicted Load at KV-7 (kg Cd/yr)	Arsenic Average Predicted Load at KV-7 (kg As/yr)	Lead Average Predicted Load at KV-7 (kg Pb/yr)	Silver Average Predicted Load at KV-7 (kg Ag/yr)
Onek 400 Adit Options						
1) Bioreactor treatment with the following design features (natural attenuation assumed to continue) a) Lined facility at Onek 400 adit area b) Carbon source addition in both solid phase and dissolved phase; c) Ongoing monitoring at bioreactor discharge to demonstrate sufficient pre-treatment for MNA d) Natural attenuation by aeration after bioreactor, settling pond, distribution on north side of Christal creek in peat beds e) Natural attenuation monitoring at settling pond, and in Christal creek upstream and downstream of expected discharge zone	A) Bioreactor effluent achieves 90% reduction in metal concentrations in Onek 400 Adit discharge to produce averages of 9.8 mg Zn/L and 0.15 mg Cd/L. *(Assume that bioreactor treatment assumes conservatively that a 90% reduction in metal concentrations can be achieved. The target concentrations are assumed to be greater than those achieved for the Galkeno 900 pilot test bioreactor, because the starting concentrations at Onek 400 are comparatively much higher than at Galkeno 900. Natural attenuation continues to occur but only to minimum concentrations defined by hydrozincite and otavite solubilities.)*	**A) 488**	**A) 6.4**	**A) 18.2**	**A) 39.3**	**A) 0.33**
2) Stand-alone small mechanical plant with the following design: a) Similar to Galkeno 300 plant with clarifier and option of reagents b) New sludge management facilities c) Discharge directly to Christal Creek	A) Onek 400 treatment results same as averages established for 2009 and later at Galkeno 300 - averages of 0.22 mg Zn/L; 0.007 mg Cd/L. *(Assume no additional natural attenuation in flow path to Christal Creek because discharge is directly to Christal Creek; assume that residual load from accumulated zinc and cadmium in the groundwater pathway continues to contribute load at 5% of current flow rate multiplied by solubility concentrations.)*	**A) 460**	**A) 6.4**	**A) 18.2**	**A) 39.3**	**A) 0.34**
	B) Onek 400 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L. *(Assume no additional natural attenuation in flow path to Christal Creek because discharge is directly to Christal Creek; assume that residual load from accumulated zinc and cadmium in the groundwater pathway continues to contribute load at 5% of current flow rate multiplied by solubility concentrations.)*	**B) 454** (Note: Onek load controlled by residual load)	**B) 6.1** (Note: Onek load controlled by residual load)	**A) 18.2**	**A) 39.3**	**A) 0.34**

Reclamation Option	Operational Objectives and Assumptions	Zinc Average Predicted Load at KV-7 (kg Zn/yr)	Cadmium Average Predicted Load at KV-7 (kg Cd/yr)	Arsenic Average Predicted Load at KV-7 (kg As/yr)	Lead Average Predicted Load at KV-7 (kg Pb/yr)	Silver Average Predicted Load at KV-7 (kg Ag/yr)
3) Treat in new treatment facility at Silver Trail Highway near Galkeno 900: a) Pipeline from Galkeno 900 to Silver Trail area b) New water treatment plant including reagent handling and mixing, treatment plant, sludge handling facilities c) Discharge to Christal Creek above KV-6 d) Capacity of treatment plant designed initially to handle Galkeno 300, Onek and Galkeno 900 flow (adaptive management alternative)	A) Assume similar results to averages achieved at Galkeno 300 since 2009 of 0.22 mg Zn/L and 0.007 mg Cd/L. *(Assume no additional natural attenuation in flow path to Christal Creek because discharge is directly to Christal Creek; assume that residual load from accumulated zinc and cadmium in the groundwater pathway continues to contribute load at 5% of current flow rate multiplied by solubility concentrations.)*	A) 460	A) 6.4	A) 18.2	A) 39.3	A) 0.34
4) Enhancement and monitoring of existing natural attenuation through: a) Source control to reduce metal loadings b) Route flows to areas downgradient of Keno City c) Discharge flows to ground in exfiltration channel d) Monitoring program downgradient of discharge area	A) Flow reduction from Onek 400 adit by 70% due to cover in pit and diversions. *(Assume existing processes of attenuation continue to operate with minimum concentrations of Zn and Cd controlled by solubilities of hydrozincite and otavite remaining in transport path.)*	A) 538	A) 6.6	A) 18.6	A) 39.3	A) 0.34
Mackeno Tailings						
1) Close in place with the following design features: a) Create stable water channel through and around tailings, remove tailings from watercourse if required b) Cover un-vegetated tailings with growth media c) Optimize cover performance by contouring and lime addition c) Monitor after remediation to determine if load reductions are achieved	A) Lime is tilled into the tailings before re-grading. *Assume that 90% reduction in porewater concentrations relative to concentrations in pore water measured by SRK in 2011) is achieved by lime. Infiltration is reduced to 22% of mean annual rainfall (based on experience at Brewery Creek) by re-grading and placing clean soil cover over the existing footprint of the tailings.* B) Lime not tilled into the tailings. *Assume infiltration is reduced to 22% of mean annual rainfall (based on experience at Brewery Creek) by re-grading and placing clean soil cover over the existing footprint of the tailings.*	A) 614 B) 746	A) 7.0 B) 7.2	A) 19.7 B) 20.0	A) 39.2 B) 39.4	A) 0.35 B) 0.35

Reclamation Option	Operational Objectives and Assumptions	Zinc Average Predicted Load at KV-7 (kg Zn/yr)	Cadmium Average Predicted Load at KV-7 (kg Cd/yr)	Arsenic Average Predicted Load at KV-7 (kg As/yr)	Lead Average Predicted Load at KV-7 (kg Pb/yr)	Silver Average Predicted Load at KV-7 (kg Ag/yr)
(2) Consolidate and cover a) isolate work site from stream b) excavate tailings from shoreline c) install new shoreline with barrier/riprap d) grade tailings and cover e) cover system optimization	A) Lime is tilled into the tailings before re-grading. *Assume that 90% reduction in porewater concentrations relative to concentrations in pore water measured by SRK in 2011) is achieved by lime. Infiltration is reduced to 22% of mean annual rainfall (based on experience at Brewery Creek) by re-grading and placing clean soil cove. Assume that consolidation reduces footprint to 60% of current area thereby reducing infiltration by 60%.*	**A) 606**	**A) 7.0**	**A) 19.6**	**A) 39.2**	**A) 0.35**
3) Source removal by combining with Valley Tailings a) Remove un-vegetated tailings and transport to Valley Tailings b) Scarify and seed existing tailings areas c) Closure by combination with Valley tailings	A) Tailings removed results in increased loading in year 2015 when the removal action is undertaken. *Assume that disruption of tailings area results in a doubling of load due to construction effects during removal year. Assume 5 year decay to 5% or current loading from Mackeno Tailings is achieved starting in 2016. The residual 5% load assumed to be due to remnant pockets of tailings not easily removed or hidden and remaining tailings in Christal Lake.*	**A) 609**	**A) 7.0**	**A) 19.6**	**A) 39.2**	**A) 0.35**
Waste Rock						
1) Re-grade and cover all waste rock sites a) Waste rock sites re-graded to consolidate and blend into surroundings b) Covers placed to reduce infiltration and leaching of metals 2) **Re-grade and optimize cover all waste rock sites** a) Waste rock sites re-graded to consolidate and blend into surroundings b) Optimized covers placed to reduce infiltration and leaching of metals by maximum amount technically feasible	A) Waste rock covered. *Assume that loads are reduced to 40% of mean annual rainfall over a 4-year period by reduction in infiltration through waste rock and associated reduction in leaching of metals.* B) Waste rock cover optimized to reduce infiltration to full extent possible. *Assume that loads are reduced to 22% of mean annual rainfall (based on experience at Brewery Creek) over a 4-year period by reduction in infiltration through waste rock and associated reduction in leaching of metals.*	**A) 767** **B) 761**	**A) 7.2** **B) 7.2**	**A) 20.0** **B) 20.0**	**A) 22.3** **B) 17.1**	**A) 0.34** **B) 0.33**

9.2 Chemical Loads for Reclamation Alternatives

The load results in Table 9-1 are specific to individual reclamation options. Combinations of options to create Reclamation Alternatives may also be considered. For example, the Onek 400 Adit and Mackeno tailings are the largest sources of zinc and cadmium; hence reclamation of both of those two sites may be a reasonable alternative. Table 9-2 gives a summary of the zinc and cadmium loads for the options that provide the greatest reductions in loads and also two alternatives that involve implementation of multiple options. The results in Table 9-2 show that Alternatives 4 and 5 that involved reclamation of both the Onek 400 Adit discharge and Mackeno tailings have the greatest potential to reduce zinc and cadmium loads in Christal Creek.

Table 9-2: Average zinc and cadmium loads in Christal Creek at KV-7 predicted for implementation of potential Reclamation Alternatives

Reclamation Alternatives (Combinations of Options)	Zinc Average Predicted Load at KV-7 (kg Zn/yr)	Cadmium Average Predicted Load at KV-7 (kg Cd/yr)	Arsenic Average Predicted Load at KV-7 (kg As/yr)	Lead Average Predicted Load at KV-7 (kg Pb/yr)	Silver Average Predicted Load at KV-7 (kg Ag/yr)
Base Case: Current conditions (averages from measured data for 2008 to 2013 at KV-7)	Model=787; Measured = 787	Model = 7.3; Measured = 7.5	Model = 20.2; Measured = 27.3	Model = 39.5; Measured = 38.8	Model = 0.35; Measured =0.28
Alternative 1: Treat Galkeno 300 & 900: Galkeno 300 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L. Galkeno 900 treatment plant improved performance to achieve averages of 0.12 mg Zn/L, 0.00005 mg Cd/L; Note that current averages at Galkeno 900 are 0.15 mg Zn/L and 0.00013 mg Cd/L.	704	4.2	21.5	39.5	0.34
Alternative 2: Treat Onek: Onek 400 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L.	454	6.1	18.2	39.3	0.34
Alternative 3: Reclaim Mackeno Tailings (Consolidate and cover): Lime is tilled into the tailings before re-grading. Assume that 90% reduction in porewater concentrations relative to concentrations in pore water measured by SRK in 2011) is achieved by lime. Infiltration is reduced to 22% of mean annual rainfall by re-grading and placing clean soil cover. Assume that consolidation reduces footprint to 60% of current area thereby reducing infiltration by 60%.	606	7.0	19.6	39.2	0.35
Alternative 4: Reclaim Waste Rock Sites: Waste rock cover optimized to reduce infiltration to full extent possible. Assume that loads are reduced to 22% of mean annual rainfall (based on experience at Brewery Creek) over a 4-year period by reduction in infiltration through waste rock and associated reduction in leaching of metals.	761	7.2	20.0	17.1	0.33
Alternative 5: Treat Onek and reclaim Mackeno: (same as above)	272	5.8	17.7	39.0	0.34
Alternative 6: All of the above (Options 1 to 5) (same as above)	163	2.6	17.3	16.6	0.31

9.3 Concentrations

Trends in measured concentrations in Christal Creek at KV-6 and KV-7 are shown in Figure 9-1 and Figure 9-2, respectively. The measured data typically show approximately a tenfold variation between winter and summer with lowest concentrations typically occurring during January to March and highest concentrations occurring during July to September.

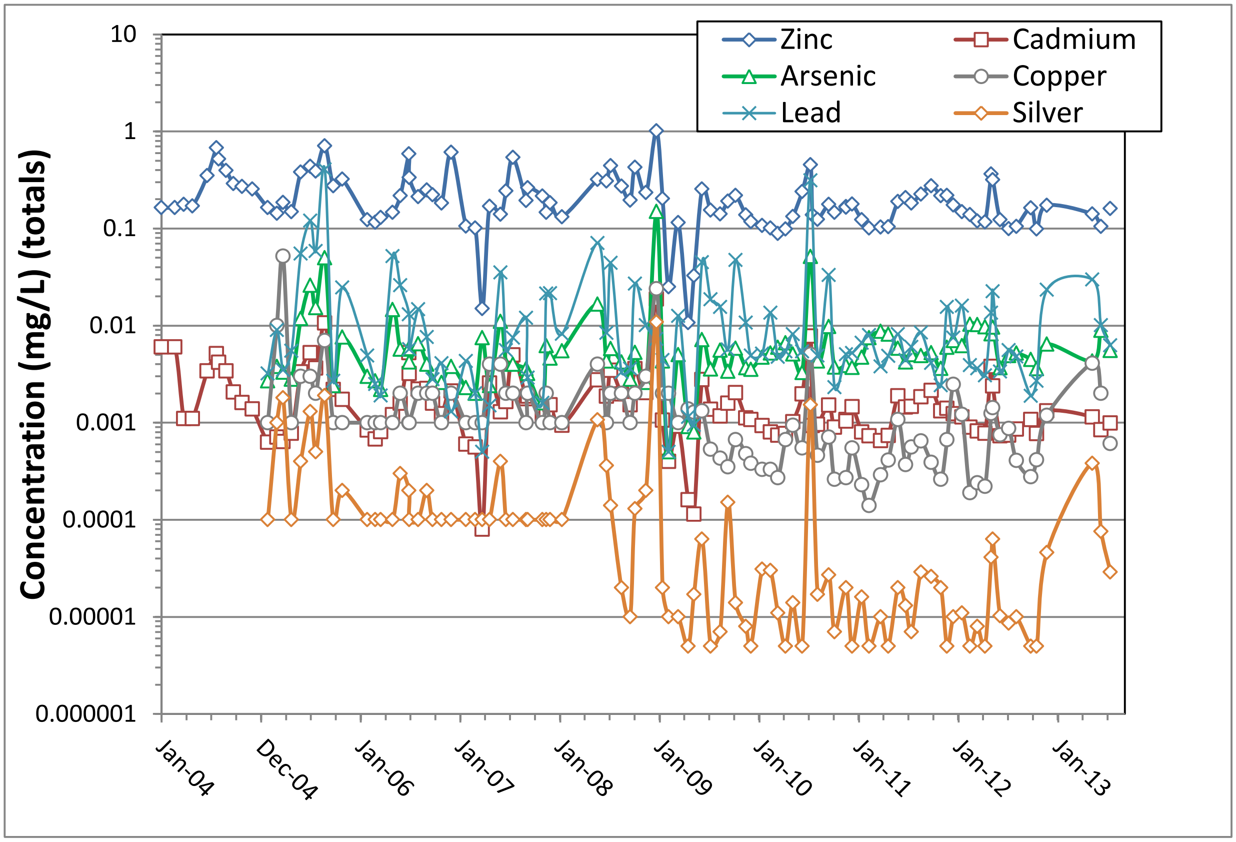

Figure 9-1: Measured cadmium, zinc, arsenic, copper, lead and silver concentrations (totals) at KV-6

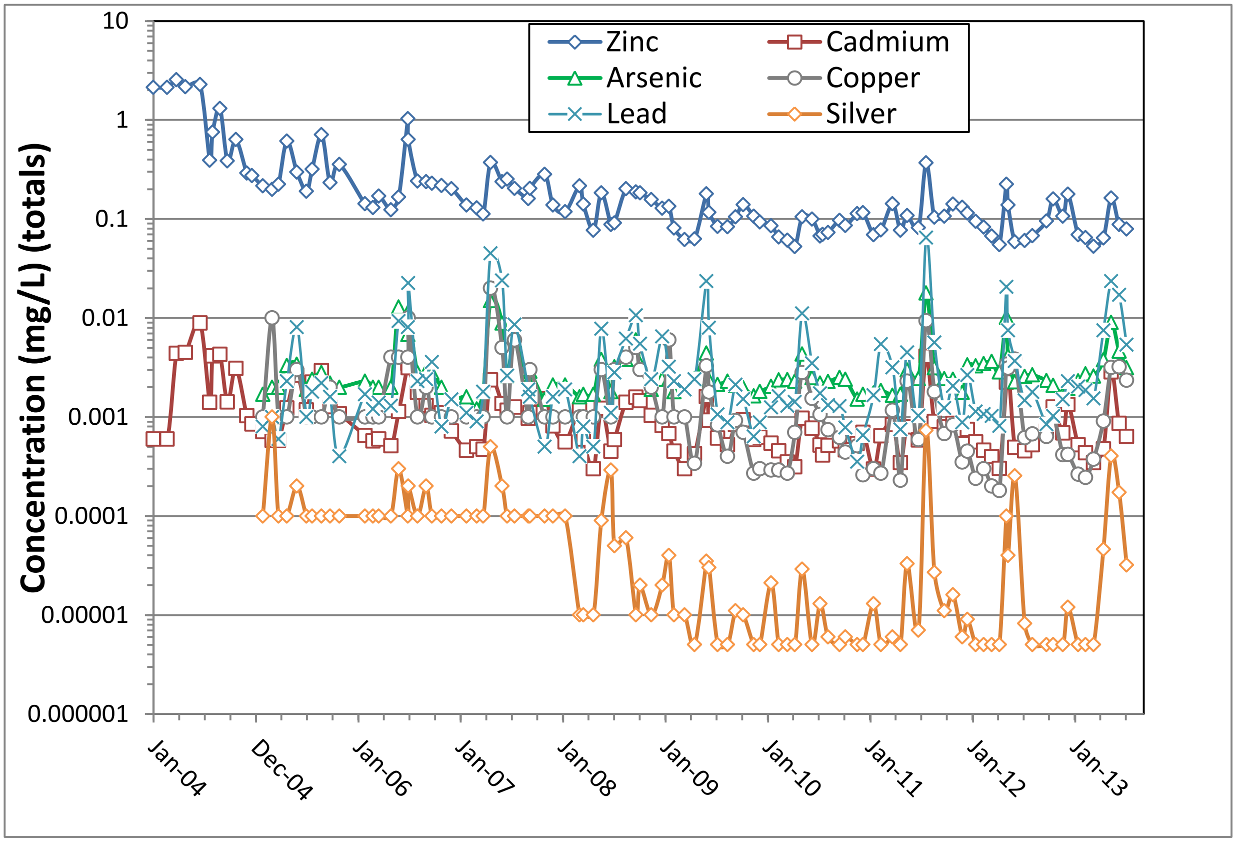

Figure 9-2: Measured cadmium, zinc, arsenic, copper, lead, and silver concentrations (totals) at KV-7

The structure of the GoldSim simulation model described in this report was designed to estimate chemical loads and is most suited to evaluating reclamation options in terms of changes in chemical loads. However, ERDC has requested estimates of metal concentrations (Cd, Zn) in Christal Creek from the model to aid in the evaluation of reclamation options. Figure 9-3 and Figure 9-4 show the results for zinc and cadmium from probabilistic simulations for Reclamation Alternative 6 (see Table 9-2). The predicted concentrations vary by about 10 times over the course of each year when considering the outer percentile limits of the probability distributions, which is approximately similar to the range observed in the measured data (Figure 9-1 and Figure 9-2). However, these predicted concentrations should be viewed with caution; while the simulation model is capable of making estimates of concentrations based on calculations of loads and water flow rates, those calculations do not take into account potential variability in hydrogeochemical, biological, and physical processes that can affect concentrations in natural stream systems particularly over short time frames. The concentrations produced by the model should be understood to be indicative of approximate ranges expected to occur over yearly to longer time-scales rather than precise predictions of day-to-day concentrations that might occur.

Estimates of average, median, and maximum concentrations for zinc and cadmium are shown in Table 9-3 for the Reclamation Alternatives (see Table 9-2) for the year 2025, which is 9 years after the initiation of reclamation, when the effects of those options are expected to reach steady state. The median concentration estimates in Table 9-3 were calculated by averaging the daily median concentrations predicted by the probabilistic model for the year 2025. The 95th percentile concentrations represent the single maximum daily concentration predicted by the probabilistic model for year 2025. These concentrations should be considered as estimates that provide a relative measure of the potential concentrations and ranges potentially achievable for the simulated reductions in chemical loads.

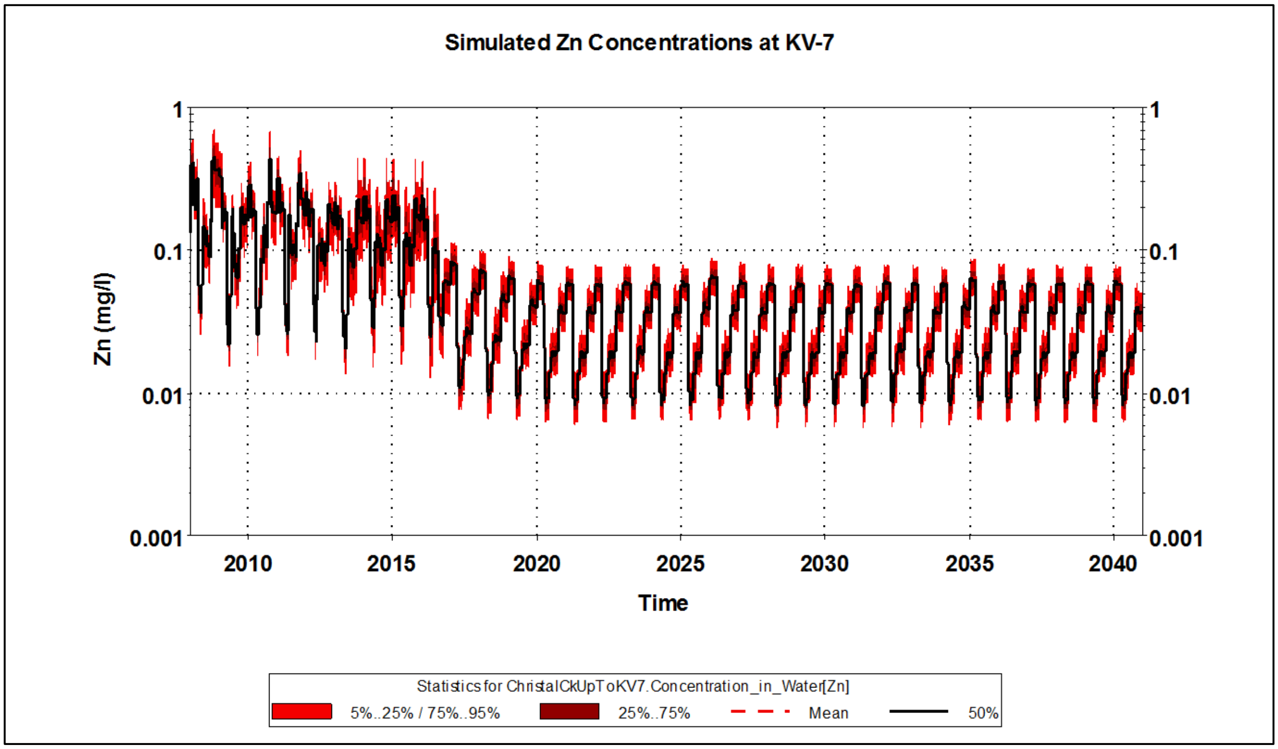

Figure 9-3: Probabilistic results for zinc concentration at KV-7

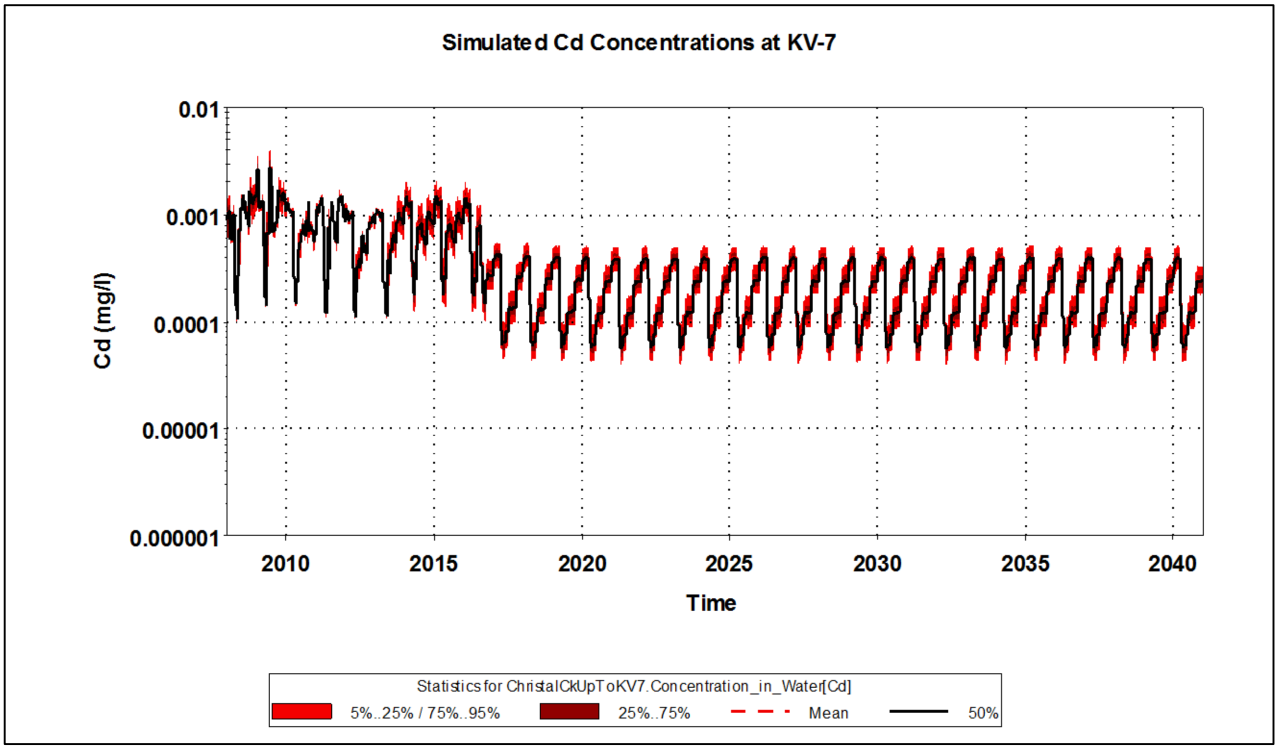

Figure 9-4: Probabilistic results for cadmium concentration at KV-7

Table 9-3: Mean, median, and maximum estimated concentrations of Cd and Zn in Christal Creek at monitoring location KV-7 based on probabilistic simulations results for 250 realizations for Reclamation Alternatives

	Cadmium at KV-7 (mg/L)		Zinc at KV-7 (mg/L)	
Reclamation Alternatives (Combinations of Option)	**Average: Median**	**Maximum 95th Percentile**	**Average: Median**	**Maximum 95th Percentile**
Base Case: No reclamation	0.0010*: 0.0007*(0.0008**)	0.0031* (0.0021**)	0.11*: 0.09*(0.11**)	0.20* (0.43**)
Option 1: Treat Galkeno 300 & 900: Galkeno 300 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L. Galkeno 900 treatment plant improved performance to achieve averages of 0.12 mg Zn/L, 0.00005 mg Cd/L; Note that current averages at Galkeno 900 are 0.15 mg Zn/L and 0.00013 mg Cd/L.	0.0004: 0.0004	0.0010**	0.11: 0.10	0.42**
Option 2: Treat Onek: Onek 400 treatment improved to reduce zinc and cadmium concentrations to averages of 0.1 mg Zn/L; 0.001 mg Cd/L.	0.0007: 0.0007	0.0018**	0.07: 0.07	0.20**
Option 3: Reclaim Mackeno Tailings (Consolidate and cover): Lime is tilled into the tailings before re-grading. Assume that 90% reduction in porewater concentrations relative to concentrations in pore water measured by SRK in 2011) is achieved by lime. Infiltration is reduced to 22% of mean annual rainfall by re-grading and placing clean soil cover. Assume that consolidation reduces footprint to 60% of current area thereby reducing infiltration by 60%.	0.0007: 0.0007	0.0020**	0.09: 0.08	0.37**
Option 4: Reclaim Waste Rock Sites: Waste rock cover optimized to reduce infiltration to full extent possible. Assume that loads are reduced to 22% of mean annual rainfall (based on experience at Brewery Creek) over a 4-year period by reduction in infiltration through waste rock and associated reduction in leaching of metals.	0.0008: 0.0007	0.0021**	0.12: 0.11	0.42**
Option 5: Treat Onek and reclaim Mackeno: (same as above)	0.0006: 0.0006	0.0018**	0.04: 0.04	0.10**
Option 6: All of the above (Options 1 to 5) (same as above)	0.0002: 0.0002	0.0007**	0.025: 0.024	0.065**

*Based on measured data for Cd(T) and Zn(T) at KV-7 from Jan 2011 to July 2013 (32 analyses)

**95th percentile upper limits from probabilistic model simulations

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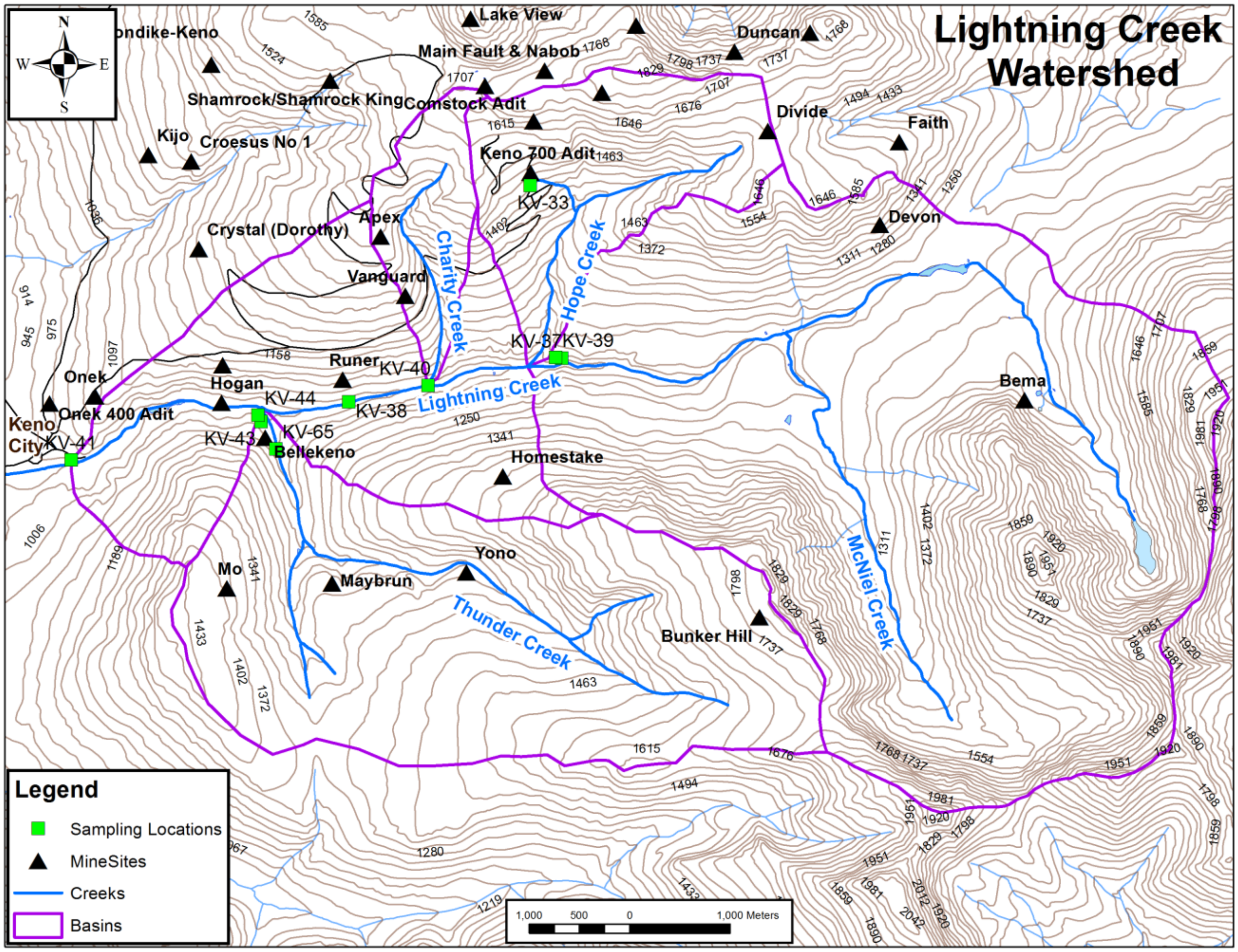
Mass Load Model for Lightning Creek: Description and Results: 2013 Update

Draft Report

November 12, 2013



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1.0 INTRODUCTION

The Elsa Reclamation and Development Company (ERDC) is investigating closure options for historical mine sites associated with the former United Keno Hill Mining (UHKM) Company claims. Closure options are being evaluated to reduce metal loadings to the receiving environment from inactive mine sites through hydrogeochemical processes.

Our original model was focused on cadmium, zinc, and sulphate (Interralogic, 2012a). In this 2013 update of the model, we have added input data and calculations to simulate mass loads of arsenic, copper, lead, nickel, silver, and selenium in a similar manner as previously developed for cadmium, zinc, and sulphate. While the focus of this report remains with cadmium and zinc, we also present results for arsenic, lead ad silver as part of this updated report on simulations of metal loading effects of reclamation options.

The purpose of this report is to present the results of a simulation model developed for the Lightning Creek watershed to explore the potential reductions in chemical constituent loads that could be achieved by different reclamation alternatives for the Keno 700 mine. The modeling framework, conceptual model, input data, calculation approaches, key assumptions, calibration procedures, are also presented.

The model has evolved over time as reclamation alternatives are developed and refined. The numerical results provided in this report for loads and concentrations differ slightly from Interralogic (2012a) because we were able to take advantage of an additional year and a half of monitoring data for Lightning Creek for calibration and calculations of average monthly concentrations to represent future chemistry. In addition, we have made refinements in the water quality expectations for different water treatment approaches associated with the reclamation options.

2.0 SIMULATION FRAMEWORK

The model was developed in the GoldSim simulation framework (www.goldsim.com). GoldSim provides a framework for mathematically representing the dynamics of both water balance and chemical mass balance, which are the components needed to simulate metal mass loadings.

2.1 Simulation Settings

The simulation settings for the model were:

- **Simulation type and length**: Calendar time with a start date of January 1, 2008 and an end date of January 1, 2041, for a total length of 33 years, was used. These dates were selected to provide a 30-year simulation period beyond the original model construction date.
- **Simulation time period**: The simulation period is split into a calibration period and a future simulation period as described below:
    - Calibration Period - January 1, 2008 through July 1, 2013: Measured data are available for monitoring locations in the Lightning Creek watershed during this period, allowing for iterative adjustment of unmeasured model parameters to obtain a match between observed and simulated results for water balance and metal loads.
    - Future Simulation Period – July 1, 2013 to January 1, 2041: There are two aspects to the future simulation period. The first is the baseline condition in which no reclamation options are considered for mitigating metal loads to Lightning Creek. The second is the representation of the potential effects of different reclamation options for decreasing metal loads relative to the baseline condition.
- **Time step**: A time step of one day was used. Most measured data are available on a weekly to quarter-year basis. A one-day time step provides a sufficiently small time increment for accurate representation of the measured data while not requiring extensive simulation run time.

3.0 CONCEPTUAL MODEL

Figure 3-1 shows a conceptual model of the hydrogeochemical processes controlling chemical loads and the locations of available measured data in the Lightning Creek watershed. The layout of the simulation model was based on this conceptual model. The chemical loads are functions of rates of release from various sources and rates of flow in the transport routes from source areas to Lightning Creek. Our original model was included simulations for cadmium, zinc, and sulphate (Interralogic, 2012a). In this 2013 update of the model, we have added input data and calculations to simulate mass loads of arsenic, copper, lead, nickel, silver, and selenium.

There three major sources of chemical constituents in the Lightning Creek watershed:

- Untreated adit discharge from the Keno 700 adit transported as surface water;
- Natural background sources of chemical constituents in surface runoff from sub-basins within the Lightning Creek watershed, including Hope Creek upstream of Keno 700 adit, upper Lightning Creek Basin, and Charity Creek; and
- Discharge from the water treatment plant at the Bellekeno 625 adit to Thunder Creek and then to Lightning Creek.

There are two other potential sources of chemical constituents, whose loads are contained within the measured data collected at the major source contributors, but are not analyzed separately in the model. These are:

- Leaching of placer mining waste rock materials in the stream of Lightning Creek and on the hillsides;
- Historic mine sites other than Keno 700;
- Leaching of waste rock along the surface channel downstream of the Keno 700 adit; and
- Leaching of waste rock downstream of the Bellekeno Mine.

Potential placer mining and historic mining sites other than Keno 700 are not directly included in the model due to an absence of information that might indicate that one or more of them are point sources of chemical constituents. The magnitudes of the releases from Keno 700 waste rock source were estimated through a calibration process (discussed below in Section 5.2). A short-term but significant release of constituents was added as a loading source for the stream reach below the Keno 700 adit for late 2008 to 2009 and again for middle to late 2011 and 2012. The load source was added based on our assumption that disruption of the area during demolition work conducted during that time period (Access, 2010) had the potential to result in short-term increases in the rates of releases of chemical constituents.

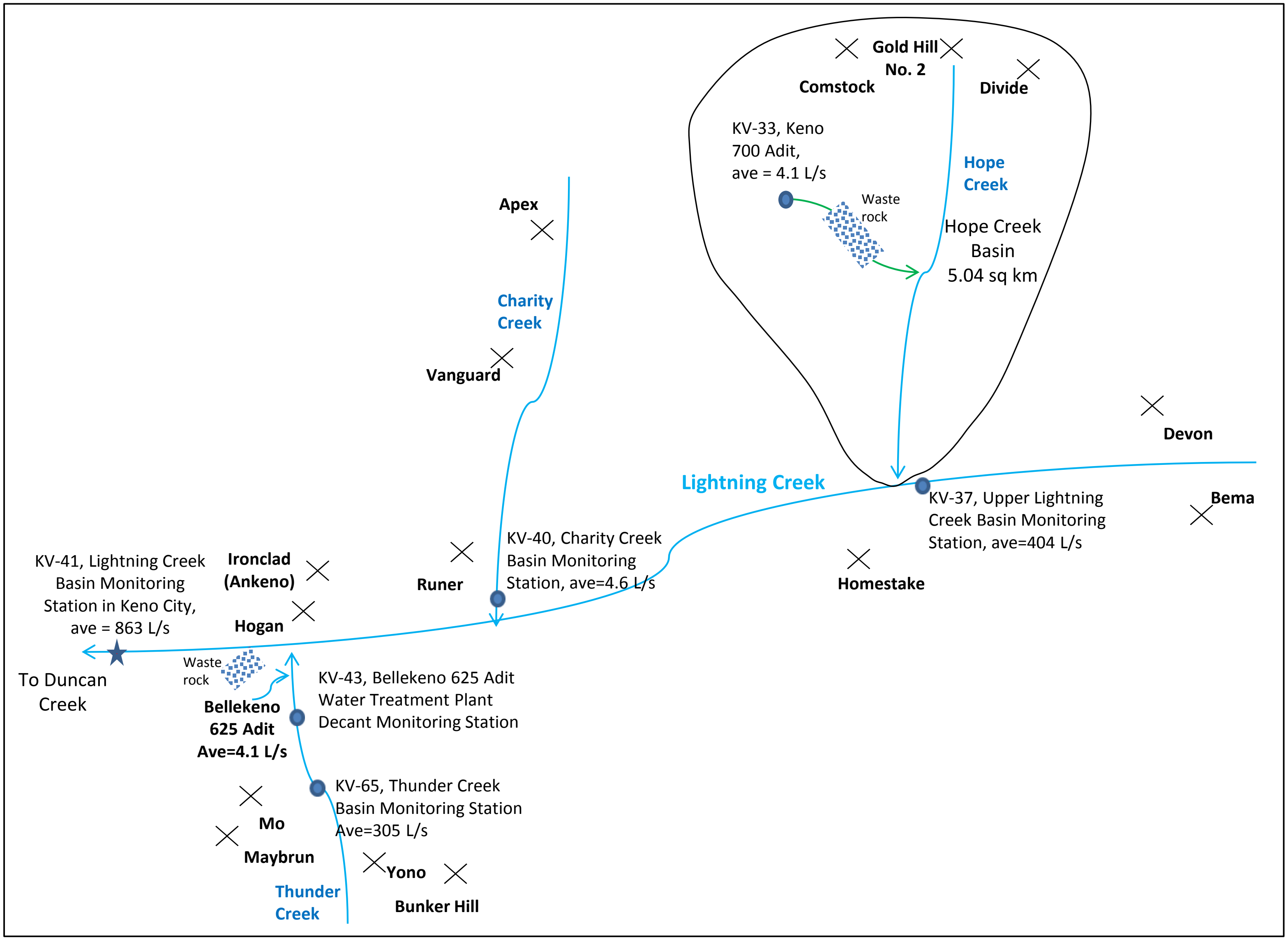


Figure 3-1: Conceptual model of the Lightning Creek watershed

3.1 Calibration Period Inputs

The conceptual model, Figure 3-1, shows the monitoring stations in which measured data were used in the calibration phase of the model. The following is a description of each station and how the available data was utilized.

KV-37:

- *Flow Data* - Flow and chemistry data were directly used from this station, which represents all flow leaving the upper catchments of the Lighting Creek Basin. Flow rate measurements were available for 13 dates between July 5, 2008 and July 4, 2013. Two much earlier flow rate measurements were also available; one in August 2003 and one in July 2004.
- *Chemistry Data* - Water chemistry data were available for 53 samples collected between July 30, 2004 and July 4, 2013.

KV-33: Keno 700 adit flow and chemistry data.

- *Flow Data* – Keno 700 adit water travels into Hope Creek mixing with water from the Hope Creek Basin. The total amount of water reaching Lightning Creek from this area was represented by the sum of the Hope Creek basin runoff plus the measured adit flow. Measured adit flow rates were available from 17 measurements between June 25, 1997 and July 4, 2013. The basin runoff was calculated by multiplying an estimated mean annual runoff (MAR) by the Hope Creek Basin area. The mean annual runoff was 352.5 mm/yr determined for the entire Lightning Creek watershed above KV-41 (Clearwater, 2010). The seasonal pattern of runoff from snowmelt was included in the calibration process (discussed below). The basin area was determined by delineating the plan view area in Arc GIS.
- *Chemistry Data* - Water chemistry data for the Keno 700 adit discharge were available from 40 samples collected between October 25 2006 and July 4, 2013. These chemistry data and the measured flow rates were directly used to calculate loads for the Keno 700 adit discharge. We assumed the water derived from the Hope Creek Basin contributes no additional metal load beyond that calculated for the Keno 700 adit discharge.
- *Waste Rock Leaching* – The surface channel of the Keno 700 adit discharge consists of waste rock from the mine. We assumed that metals are released from the waste rock by geochemical leaching processes. The magnitudes of metal releases were estimated by adding chemical constituent masses into the stream segment representing the Keno 700 adit discharge until agreements between measured and simulated cumulative metal loads were achieved for the downstream KV-41 location. This calibration approach is based on the assumption that the waste rock below Keno 700 is the most likely source of additional metals in the watershed other than the flow from the Keno 700 adit.

KV-40:

- *Flow Data* - KV-40 represents all flow from the Charity Creek Basin into Lighting Creek. Twelve flow rate measurements were available between August 2, 2003 and July 4, 2013.

- *Chemistry Data* – Chemistry date for KV-40 were available from 19 samples collected between July 19, 2005 and July 4, 2013.

KV-65:

- *Flow Data* – KV-65 represents all flow from the Thunder Creek Basin entering Lighting Creek. Twenty seven flow rate measurements were available from December 31, 2007 to July 12, 2013.
- *Chemistry Data* - Water chemistry data for KV-65 from 57 samples collected between July 15, 2007 and July 12, 2013.

KV-43:

- *Flow Data* - This station monitors decant water from the Bellekeno 625 adit treatment facility, which flows to Thunder Creek just upstream from its confluence with Lightning Creek. Both flow and chemistry data from this station were used for load calculations. Flow rates are measured daily since November 2007.
- *Chemistry Data* - Samples for chemical analyses have been collected on a weekly basis since the end of June 2006 to July 23, 2013.

Overall, there are not enough data available to develop a detailed depiction of short-term fluctuations or long-term trends in chemical loads in Lightning Creek. The simulation model uses a one-day timestep, which is a much smaller time increment than present in the available data with the exception of the KV-43 data for the Bellekeno 625 adit treatment plant discharge. Because the simulation timestep is one day and measured values were not always available on a daily basis during the calibration period, each measured value was held constant until the date of the next measured value. In addition, all measured concentrations determined to be less than the detection limit were set to the detection limit concentrations. If a measurement was not taken before or on the start of the model calibration period, the average value for that constituent was substituted for the start date (1/1/2008).

3.2 Future Simulation Period

The available data were used to calculate monthly average flow rates and monthly average concentrations. These monthly average data were used repeatedly for each year to represent future conditions in simulations. This method allows the future values to be comparable to values seen in the calibrated, measured values while accounting for natural, seasonal variation.

In several cases, there were insufficient flow and/or chemistry data to calculate an average value for a given month. For months for which no flow data were available, the value was estimated using neighboring monthly values and estimated seasonal variations. Calculated monthly values for each source or measuring station are given in the following section.

4.0 LOAD SOURCE DATA AND CALCULATIONS

The following sections describe the equations and data used to represent metal loads in the model for both the calibration period and future simulation period.

4.1 Load Source: Bellekeno 625 Adit Water Treatment Discharge (KV-43)

Calibration Period: Chemical loads ($L_{chemical}$) for the calibration period, in units of mass per unit time, were calculated using Equation 1. Measured flow rates at KV-43 were available on a near daily basis between 11/1/2007 and 2/15/2012, and measured chemical concentrations were available on a quarterly basis between 1/27/2005 and 2/15/2012.

$$L_{chemical} = C_{meas} \times FR_{meas} \qquad \text{(Eq. 1)}$$

where C_{meas} is the measured concentration of the chemical constituent (mg/L) and FR_{meas} is the measured flow rate (L/s).

Future Simulation Period: Chemical loads ($L_{chemical}$) for the future simulation period, in units of mass per unit of time, were calculated using Equation 2.

$$L_{chemical} = C_{yr\_ave} \times FR_{mon\_ave} \qquad \text{(Eq. 2)}$$

where C_{yr_ave} is the average of the measured chemical concentrations from 2008 to 2012 (mg/L) and FR_{mon_ave} is the average monthly flow rate calculated from the period of record (L/s).

The average monthly discharge flow rate and chemical concentrations were calculated from the Bellekeno 625 water treatment plant data (KV-43) (Table 4-1). These values are used each year for the entirety of the future simulation period.

Table 4-1: Bellekeno 625 treatment plant (KV-43) monthly average flow rates and concentrations

Month	Discharge (L/s)	As (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Ag (mg/L)	Zn (mg/L)	SO_4 (mg/L)	Se (mg/L)
1	4.15	0.0043	0.00025	0.0010	0.0219	0.0102	0.00011	0.049	626.8	0.00104
2	4.37	0.0049	0.00067	0.0011	0.0345	0.0136	0.00017	0.336	627.7	0.00088
3	4.17	0.0049	0.00050	0.0014	0.0176	0.0131	0.00015	0.223	626.5	0.00082
4	4.23	0.0078	0.00034	0.0021	0.0203	0.0092	0.00023	0.091	555.8	0.00074
5	4.32	0.0099	0.00056	0.0048	0.0416	0.0118	0.00079	0.127	531.6	0.00090
6	4.32	0.0066	0.00049	0.0032	0.0240	0.0112	0.00053	0.113	492.5	0.00316
7	4.79	0.0077	0.00048	0.0059	0.0312	0.0100	0.00154	0.077	466.3	0.00290
8	4.43	0.0049	0.00052	0.0018	0.0190	0.0100	0.00023	0.071	479.5	0.00293
9	4.42	0.0043	0.00024	0.0012	0.0093	0.0097	0.00016	0.043	554.8	0.00289
10	4.34	0.0083	0.00083	0.0018	0.0419	0.0133	0.00026	0.141	590.9	0.00234
11	3.96	0.0087	0.00084	0.0029	0.0571	0.0119	0.00044	0.125	622.6	0.00196
12	3.41	0.0078	0.00033	0.0012	0.0281	0.0113	0.00020	0.051	621.8	0.00117

4.2 Load Source: Keno 700 Untreated Adit Discharge (Station KV-33)

Calibration Period: The total water contributed to Lightening Creek from the Hope Creek Basin and the Keno 700 adit flow is equal to the sum of those two flows. The cumulative chemical load reaching Lightning Creek from the Hope Creek basin and the Keno 700 adit flow was set equal to the adit flow, assuming the contribution from the Hope Creek Basin is negligible. The rate of surface runoff (S_{runoff}) in units of L/s was represented in the simulation model by the product of the watershed area ($A_{watershed}$) and MAR proportioned according to an estimate of the seasonal runoff pattern month by month (SR_{month}) (Table 4-2) in units of percent of total runoff:

$$S_{runoff} = A_{watershed} \times MAR \times SR_{month} \qquad \text{(Eq. 3)}$$

The initial estimate of the mean annual runoff rate was 352.5 mm/yr for the watershed draining to the station KV-41 on Lightning Creek (Clearwater, 2010). The starting values for the seasonal runoff pattern were obtained from the Access Consulting spreadsheet model but were modified during the calibration process to those given in Table 4-2.

Chemical loads were calculated using Equation 1 using the available measured data for KV-33 and watershed runoff rates from Equation 3.

Table 4-2: Values used to represent a seasonal pattern of surface runoff

Month	Percent of Mean Annual Runoff
Jan	7%
Feb	7%
Mar	8%
Apr	11%
May	11%
Jun	10%
Jul	8%
Aug	9%
Sep	8%
Oct	7%
Nov	7%
Dec	7%

Future Simulation Period: Chemical loads for the future simulation period were calculated using Equation 2. Table 4-3 contains the average monthly discharge and concentrations used to represent the future conditions for KV-33.

Table 4-3: Keno 700 (KV-33) and Hope Creek Basin monthly average flow rates and concentrations

Month	Keno 700 (KV-33) Average Flow Rate (L/s)	Hope Creek Basin Average Flow Rate (L/s)	As (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Ag (mg/L)	Zn (mg/L)	SO_4 (mg/L)	Se (mg/L)
Jan	3.0	7.36	0.0704	0.01400	0.0014	0.0023	0.0073	0.00010	1.380	179.0	0.0008
Feb	3.0	7.36	0.0544	0.01180	0.0017	0.0060	0.0069	0.00010	1.360	179.0	0.0008
Mar	4.0	7.36	0.0813	0.01120	0.0035	0.0329	0.0083	0.00054	1.315	188.0	0.0008
Apr	5.0	83.99	0.1215	0.01130	0.0014	0.0023	0.0073	0.00010	1.380	179.0	0.0008
May	6.0	83.99	0.0382	0.00948	0.0053	0.0085	0.0077	0.00026	1.306	124.3	0.0008
Jun	6.0	83.99	0.0301	0.00792	0.0035	0.0035	0.0054	0.00022	0.922	179.0	0.0008
Jul	5.0	43.68	0.0336	0.01313	0.0023	0.0059	0.0075	0.00013	1.388	148.8	0.0008
Aug	4.0	43.68	0.0367	0.01240	0.0014	0.0023	0.0073	0.00010	1.380	179.0	0.0008
Sep	5.0	43.68	0.0308	0.01843	0.0010	0.0011	0.0083	0.00010	2.263	179.0	0.0008
Oct	4.0	18.24	0.0333	0.02064	0.0055	0.0031	0.0077	0.00010	2.100	172.3	0.0007
Nov	3.0	18.24	0.0390	0.01610	0.0014	0.0023	0.0073	0.00010	1.380	179.0	0.0008
Dec	3.0	18.24	0.0445	0.01445	0.0014	0.0023	0.0073	0.00010	1.380	179.0	0.0008

4.3 Load Source: Natural Background Surface Runoff from Lightning Creek Sub-basins

Calibration Period: Equation 1 was used to calculate chemical loads based on measured data for KV-37 (upper Lightning Creek) and KV-40 (Charity Creek).

Future Period: Equation 2 was used to calculate chemical loads for the future period. Table 4-4 through

Table 4-6 contain the average monthly discharge and chemical concentrations used for each of the sub-basins included in the model to represent this portion of the watershed.

Table 4-4: Upper Lightning Creek (KV-37) sub-basin monthly average flow rates and concentrations

Month	Upper Lightning Creek Sub-basin Average Flow Rate (L/s)	As (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Ag (mg/L)	Zn (mg/L)	SO_4 (mg/L)	Se (mg/L)
Jan	119.7	0.0030	0.00002	0.0005	0.0003	0.0003	0.00004	0.003	24.9	0.0005
Feb	115.7	0.0030	0.00002	0.0006	0.0003	0.0005	0.00003	0.003	26.6	0.0005
Mar	184.4	0.0043	0.00001	0.0007	0.0004	0.0007	0.00003	0.004	26.5	0.0008
Apr	68.7	0.0026	0.00001	0.0004	0.0002	0.0003	0.00001	0.002	28.7	0.0005
May	344.4	0.0039	0.00004	0.0015	0.0008	0.0009	0.00002	0.004	19.9	0.0004
Jun	1496.1	0.0034	0.00007	0.0014	0.0010	0.0005	0.00002	0.007	19.3	0.0003
Jul	587.7	0.0024	0.00001	0.0007	0.0002	0.0005	0.00005	0.003	33.3	0.0004
Aug	242.9	0.0026	0.00001	0.0004	0.0002	0.0003	0.00001	0.002	28.7	0.0005
Sep	367.4	0.0025	0.00002	0.0005	0.0003	0.0005	0.00004	0.003	28.7	0.0006
Oct	325.5	0.0019	0.00001	0.0005	0.0001	0.0004	0.00001	0.001	34.5	0.0006
Nov	162.0	0.0025	0.00001	0.0003	0.0001	0.0002	0.00001	0.001	29.0	0.0006

Dec	92.1	0.0028	0.00001	0.0003	0.0002	0.0004	0.00001	0.002	26.4	0.0005

Table 4-5: Charity Creek Sub-basin (KV-40) monthly average flow rates and concentrations

Month	Charity Creek Sub-basin Average Flow Rate (L/s)	As (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Ag (mg/L)	Zn (mg/L)	SO_4 (mg/L)	Se (mg/L)
Jan	1.0	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Feb	0.0	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Mar	1.7	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Apr	4.0	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
May	6.3	0.0004	0.00008	0.0025	0.0003	0.0043	0.00002	0.008	139.0	0.0003
Jun	5.2	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Jul	4.1	0.0009	0.00005	0.0007	0.0003	0.0012	0.00003	0.004	144.3	0.0015
Aug	0.8	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Sep	1.0	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Oct	1.7	0.0008	0.00007	0.0012	0.0001	0.0026	0.00001	0.007	139.0	0.0020
Nov	1.0	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015
Dec	1.0	0.0007	0.00005	0.0009	0.0002	0.0015	0.00001	0.005	139.0	0.0015

Table 4-6: Thunder Creek Sub-basin (KV-65) monthly average flow rates and concentrations

Month	Thunder Creek Sub-basin Average Flow Rate (L/s)	As (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Ag (mg/L)	Zn (mg/L)	SO_4 (mg/L)	Se (mg/L)
Jan	45.4	0.0004	0.00015	0.0005	0.0009	0.0002	0.00001	0.003	60.3	0.00092
Feb	32.4	0.0004	0.00010	0.0004	0.0006	0.0004	0.00001	0.003	59.8	0.00085
Mar	52.1	0.0005	0.00018	0.0007	0.0022	0.0005	0.00001	0.010	66.8	0.00093
Apr	132.4	0.0005	0.00019	0.0006	0.0027	0.0003	0.00002	0.005	65.8	0.00093
May	212.6	0.0029	0.00036	0.0051	0.0549	0.0027	0.00019	0.028	35.0	0.00052
Jun	714.4	0.0006	0.00035	0.0015	0.0045	0.0008	0.00003	0.004	13.5	0.00035
Jul	227.3	0.0008	0.00023	0.0014	0.0161	0.0008	0.00015	0.009	21.6	0.00049
Aug	277.5	0.0005	0.00017	0.0007	0.0039	0.0005	0.00003	0.005	27.4	0.00075
Sep	239.7	0.0006	0.00013	0.0008	0.0018	0.0006	0.00003	0.005	25.2	0.00066
Oct	266.3	0.0004	0.00011	0.0005	0.0009	0.0004	0.00001	0.003	35.0	0.00077
Nov	159.4	0.0004	0.00018	0.0006	0.0014	0.0003	0.00001	0.004	47.2	0.00093
Dec	52.6	0.0004	0.00012	0.0003	0.0015	0.0002	0.00001	0.003	55.5	0.00093

4.4 Load Source: Bellekeno Mine Waste Rock

Mining operations at the Bellekeno and Onek Mines have deposited waste rock in areas that drain to Lightning Creek. Table 4-7 gives the estimated rates of deposition of waste rock for these two recent mining operations. We have represented rates of chemical loading from these waste rock areas based on the procedure developed by SRK (2007/08) from shake flask leaching tests on waste rock samples from adits (Table 4-8). The rates of chemical loading in units of kg metal/yr are calculated using the data in Table 4-7and Table 4-8 according to:

$$L_{WR\_Pit} = R_i \times M_{WR} \qquad \text{(Eq. 4)}$$

where M_{WR} is the tonnage of deposited waste rock and R_i is the release rate for each chemical constituent. We assume that the waste rock will be reclaimed by mid-2016, at which point we assume that reclamation will reduce infiltration through the waste rock by 78% over the time period from mid-2016 to mid-2020.

Table 4-7: Waste rock deposition from Bellekeno and Onek (New) mines

Date	Bellekeno (tonnes)	Onek (tonnes)
1/1/2008	0	0
1/1/2009	46,000	0
1/1/2010	74,500	0
1/1/2011	79,500	0
8/1/2012	140,000	0
1/1/2013	200,000	25,000
1/1/2014	260,000	50,000
1/1/2015	260,000	75,000
1/1/2050	260,000	75,000

Table 4-8: Rates of chemical release from underground mine waste rock based on Shake-Flake Extractions tests in SRK (2007/08)

Constituent	Release Rate (mg/kg/yr)
As	0.0062
Cd	0.0229
Cu	0.014
Pb	0.029
Ni	0.021
Ag	4.80E-05
Zn	0.208
SO_4	150*
Se	0.0019

*Estimated – not reported for Shake Flask Leaching tests

5.0 Model Calibration

Different amounts of data for flow rate and chemical concentrations were available for the monitoring locations in the Lightning Creek watershed. Station KV-43 had a large amount of data (daily to weekly frequencies for flow and chemistry), whereas the rest of the stations had sparse data ranging from a few scattered values in time to monthly values. In addition, no data were available for the Hope Creek Basin, requiring an estimation of runoff from the MAR and basin area.

We conducted a calibration process to adjust estimated model variables iteratively, such as the MAR and chemical release rates from waste rock, until agreement was achieved between simulated and measured cumulative water volume and cumulative metal load at the KV-41 monitoring location. Once the model reproduced the measured data for KV-41 as well as possible, simulations of the future were conducted to assess the potential effects of different reclamation alternatives for reducing metal loads in Lightning Creek. KV-41 was used as the calibration target because it has a relatively large amount of flow and chemistry data and is the most downstream monitoring station on Lightning Creek in the Keno Silver District. The following two sections describe the water balance and chemical balance calibration methods.

5.1 Water Balance Calibration at KV-41

Figure 5-1 shows a comparison of the measured and simulated cumulative volumes of water at KV-41 achieved by the calibration process. To achieve the agreement shown in Figure 5-1, the seasonal runoff pattern was defined by proportioning the MAR by month of year (Table 4-2).

Sulphate should be conservatively transported in dissolved form in the Lightning Creek watershed. Thus, we also compared the simulated and measured cumulative sulphate loads at KV-41 (Figure 5-2), as well as concentrations (Figure 5-3), as a second check of the water balance. There are variances between the measured and modeled SO_4 loads and concentrations at different time periods. But, given the sparse data available for some of the upstream monitoring locations on Lightning Creek, the model produces a reasonable depiction of the overall water balance at KV-41.

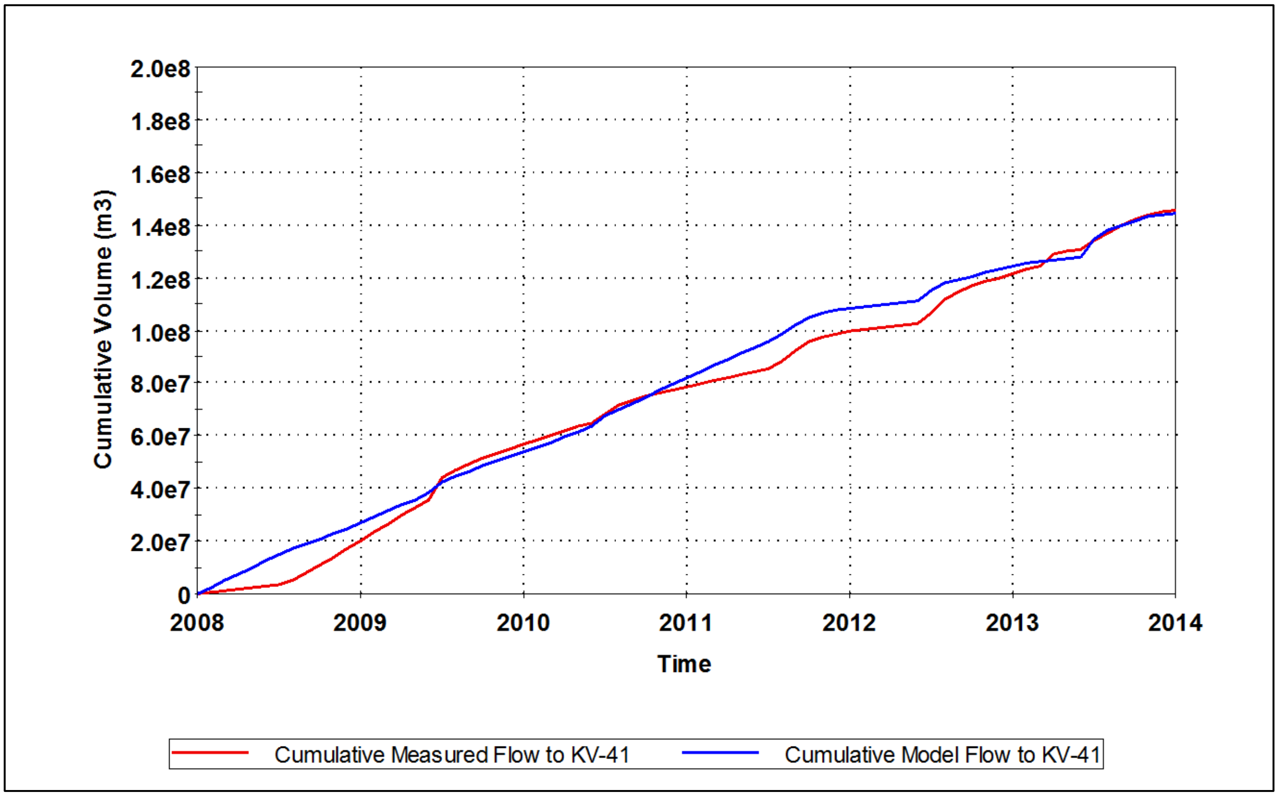


Figure 5-1: Cumulative flow volume comparison at Station KV-41

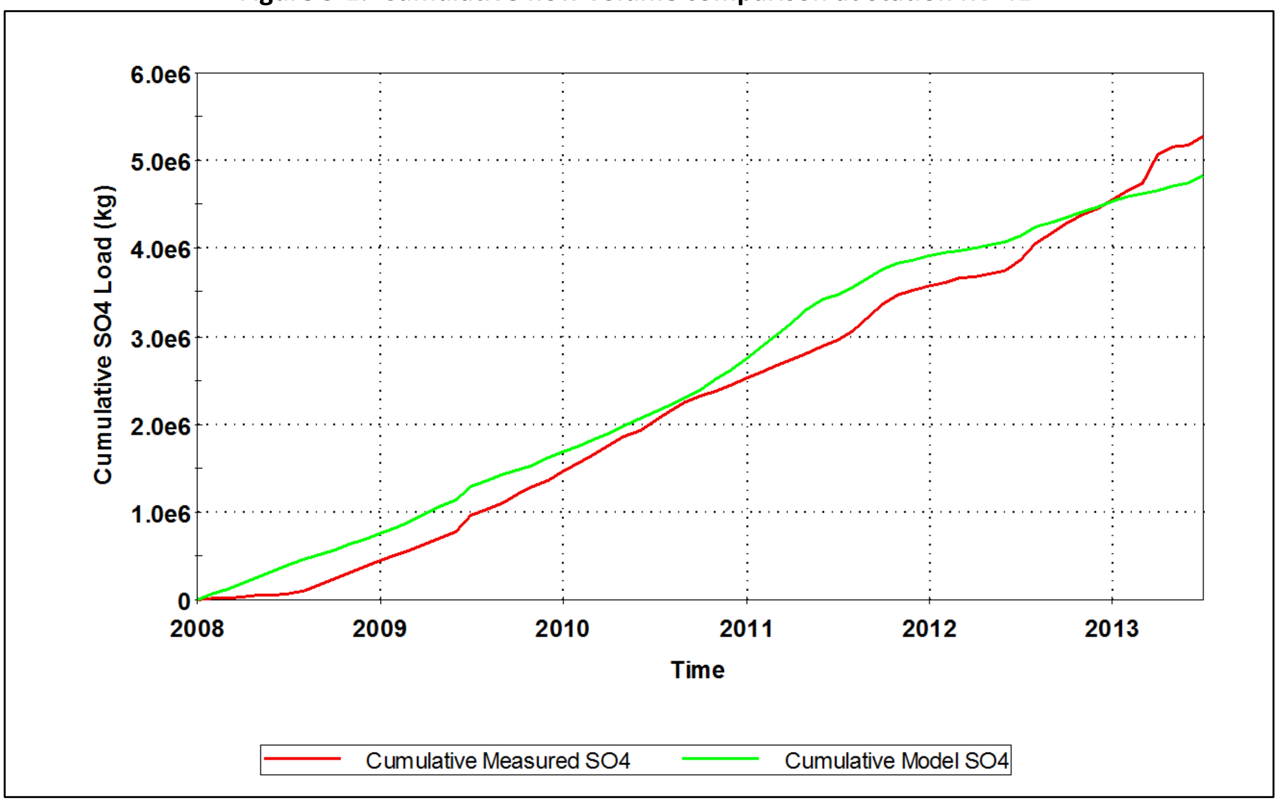


Figure 5-2: Comparison of cumulative sulphate at Station KV-41

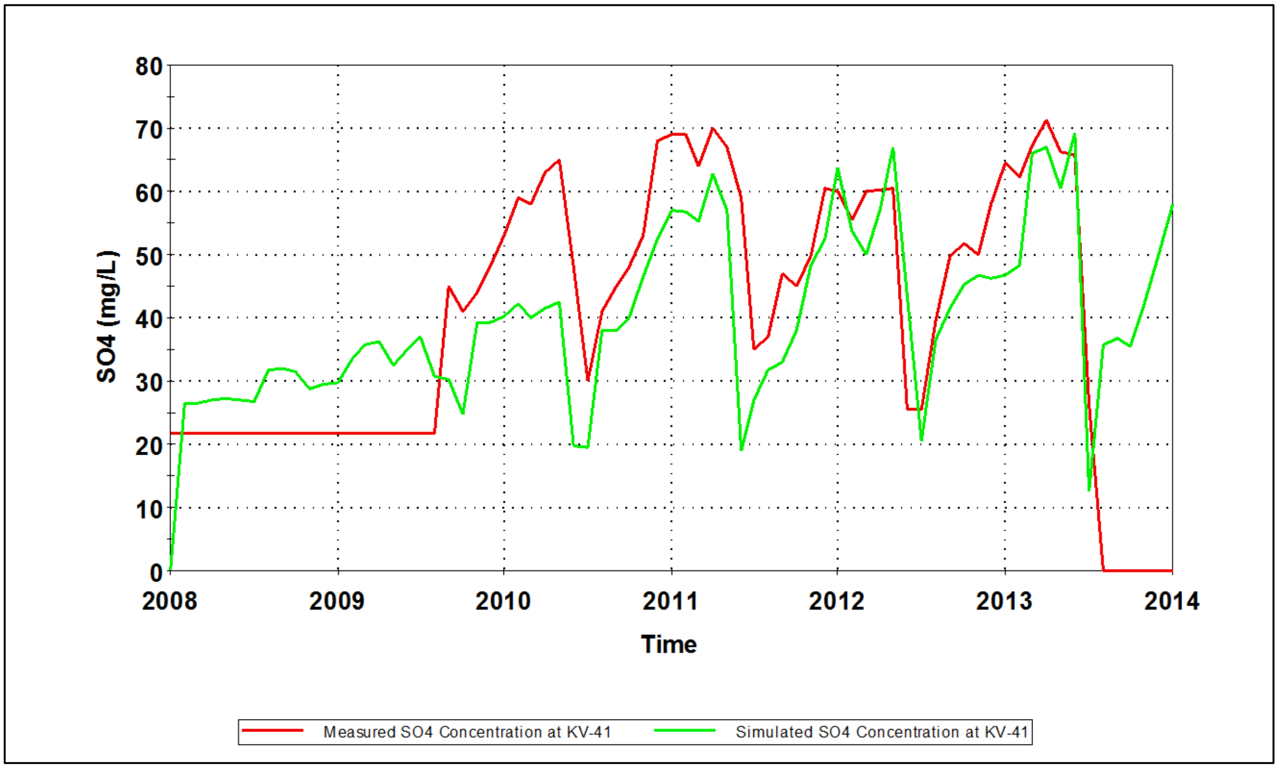


Figure 5-3: Comparison of sulphate concentrations at Station KV-41

5.2 Chemical Balance Calibration of Loads

Initial simulations of cumulative loads for KV-41 were substantially less than loads based on measured concentrations and flow rates, possibly starting in the 4th quarter of 2008 at the earliest and clearly occurring throughout 2009 (Figure 5-4 and Figure 5-6). The precise reason for the increase in metal loads moving through the system in 2008 and 2009 is not known, but the timing matches the period of demolition that occurred at Keno 700 (Access, 2010). Also, stream flow at KV-41 was very high in spring 2009 at 3590 L/s compared to freshet peak flows of 1675 and 1713 L/s in 2010 and 2011 possibly exacerbating the release of metals from the disrupted ground around Keno 700. The rate of metal loading source appears to have diminished substantially in 2010 as indicated by the substantial lessening of the slopes for the cumulative masses of metals and sulphate with time in 2010 to 2011 compared to 2009. This pattern suggests that the increase in metal loads in 2009 may be due primarily to high spring runoff and erosion in 2009 compared to other years in the data record. A similar pattern occurred in 2011 and 2012 when high spring runoff flows of 1960 L/s and 1900 L/s occurred respectively and chemical loads increased correspondingly.

We have assumed the source of the additional metal mass in 2009 was release from disrupted ground that occurred as a result of the demolition and re-contouring of the land surface during the Keno 700 demolition work. It is possible that other factors may also be involved but the Keno 700 activities would seem to represent the most likely documented cause. To represent this release process in the model, a chemical mass release function was inserted into the model. Release rates were adjusted in terms of mass and timing until agreement between the simulated and measured cumulative loads was achieved. Table 5-1 gives the mass release rates determined from the calibration process.

The figures below (Figures 5-4 to 5-19) show comparisons of simulated loads and measured loads for each of the remaining constituents at KV-41 before and after calibration. In each case, the addition of extra mass results in improved agreement between simulation results and measured values. The calibrated model was used as the basis for comparing the potential reductions in metal loads that may be achieved be reclamation options.

Table 5-1: Mass release rates determined through the model calibration process

Date	Arsenic (kg)	Cadmium (kg)	Copper (kg)	Lead (kg)	Nickel (kg)	Silver (kg)	Zinc (kg)	Sulfate (kg)	Selenium (kg)
1/1/2008	0	0	0	0	0	0	40	0	0
4/1/2008	0	0	0	0	0	0	40	0	1
7/1/2008	50	5	450	180	0	0	800	0	2
10/1/2008	370	5	100	1150	190	21	800	0	0
1/1/2009	50	5	0	70	0	0	850	0	0
4/1/2009	50	5	60	200	0	3	1000	0	0
6/1/2009	270	18	250	670	165	2	1000	0	7
10/1/2009	45	0	50	150	50	4	700	150000	2
1/1/2010	0	0	50	0	0	0	0	150000	3
4/1/2010	0	0	50	0	0	0	0	0	0
8/1/2011	110	0	0	0	215	8	0	0	0
9/1/2011	60	0	300	150	50	5	0	20000	2
11/1/2011	0	0	0	0	0	0	0	20000	0
6/1/2012	0	0	450	200	450	0	0	0	18
7/1/2012	15	0	700	300	450	11	40	0	15
8/1/2012	0	0	200	425	50	5	0	0	10
10/1/2012	0	0	5	50	10	0	0	0	10
6/1/2013	0	0	0	0	0	0	0	0	0

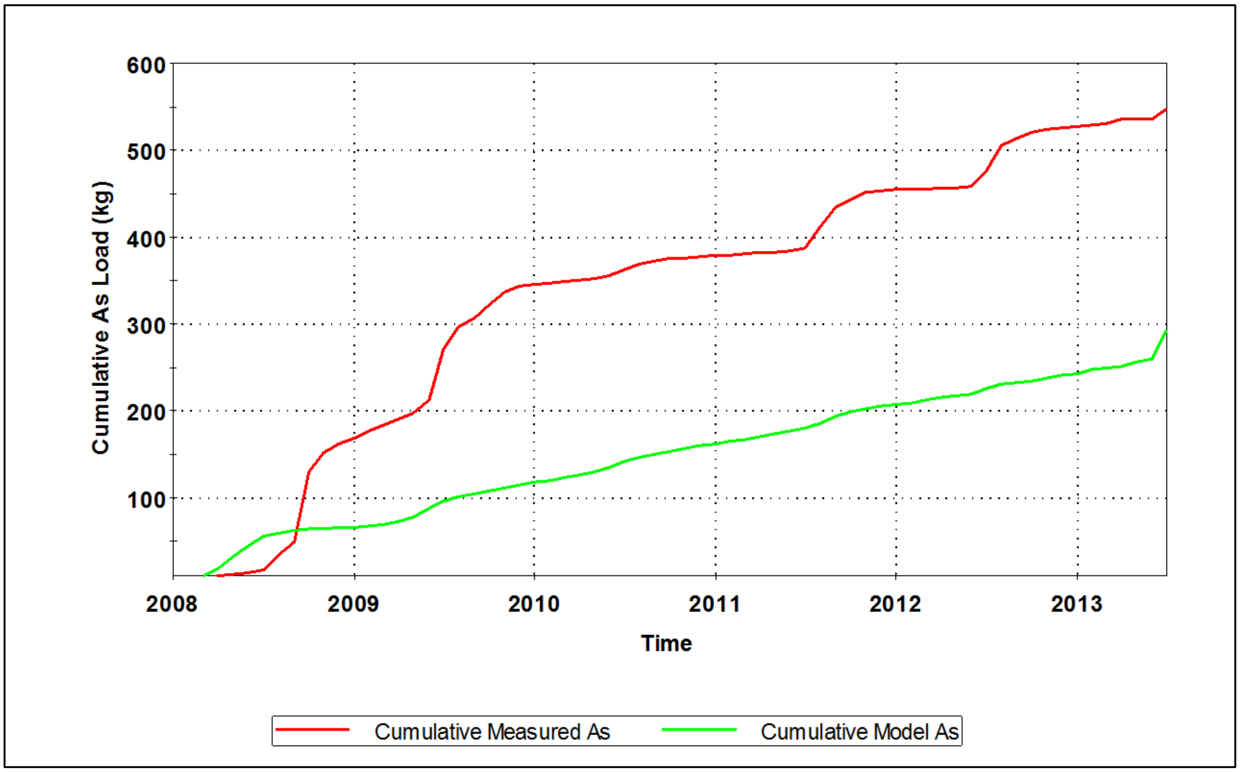


Figure 5-4: Comparison of cumulative arsenic at KV-41 before calibration

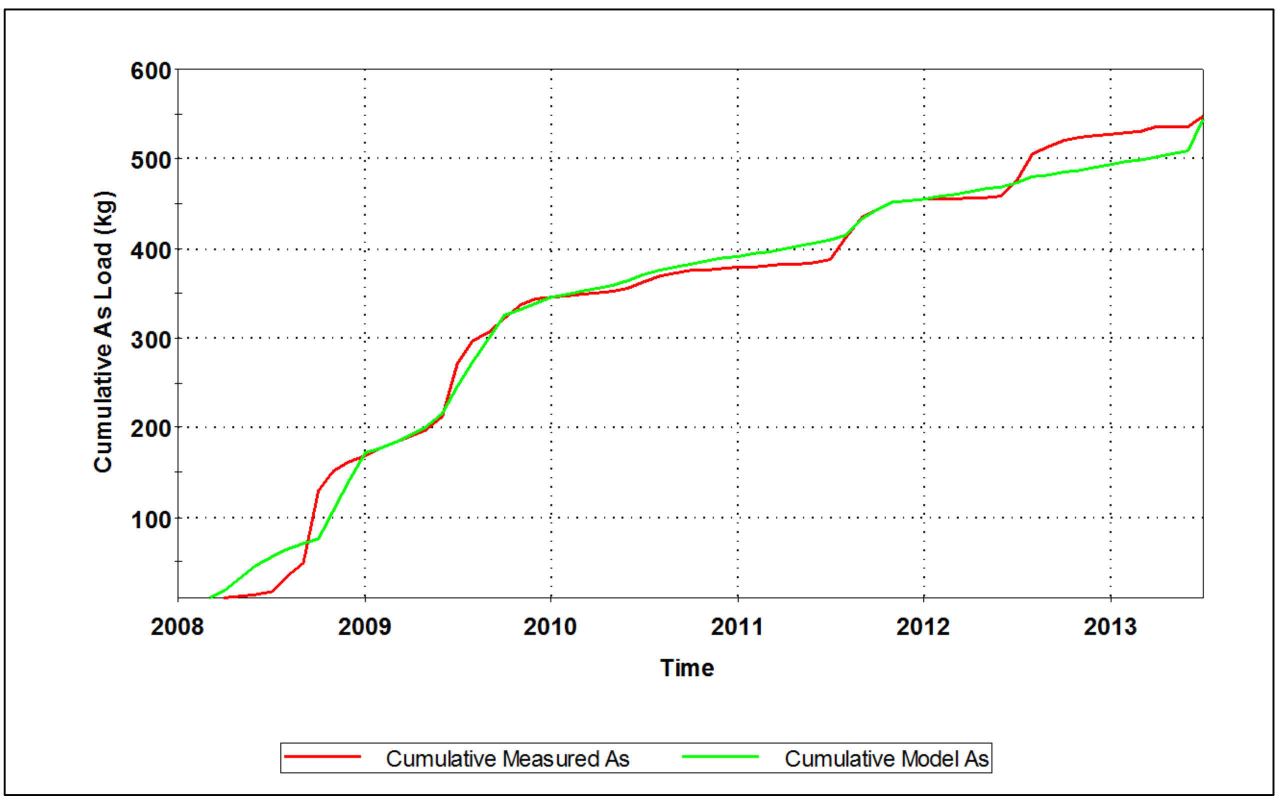


Figure 5-5: Comparison of cumulative arsenic at KV-41 after calibration

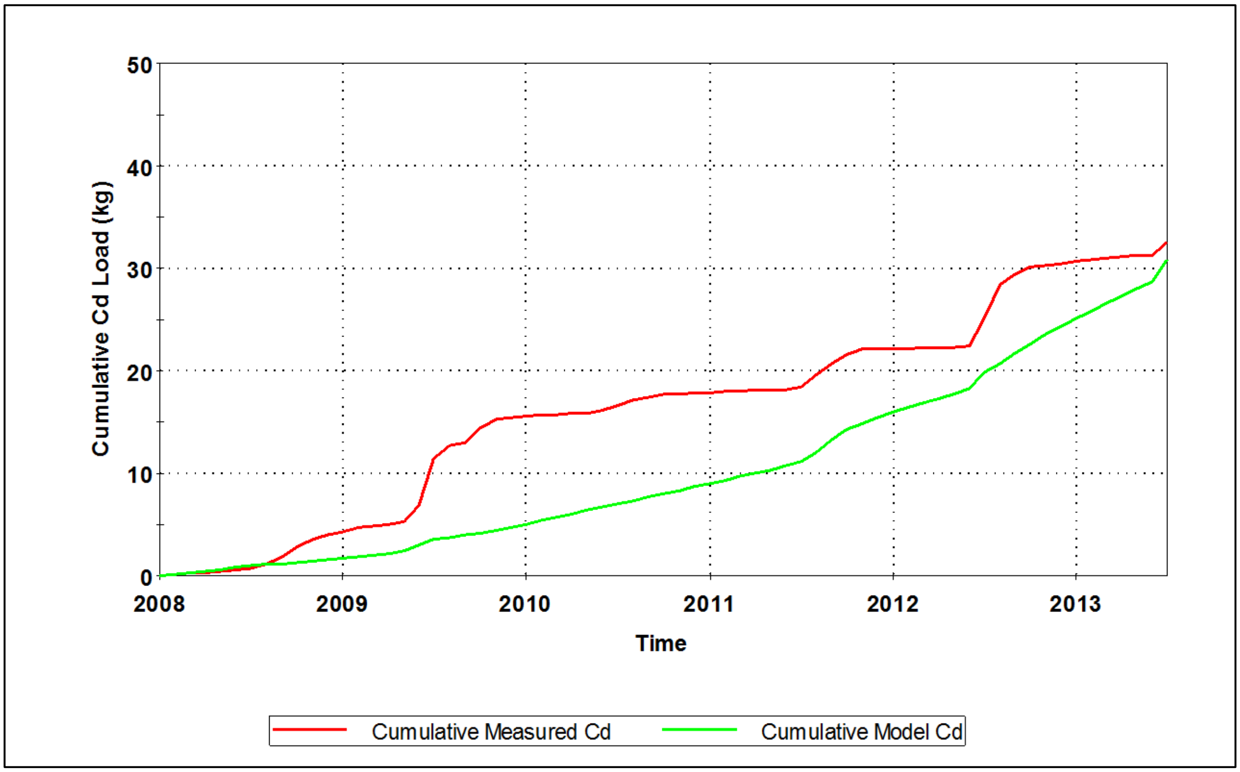


Figure 5-6: Comparison of cumulative cadmium at KV-41 before calibration

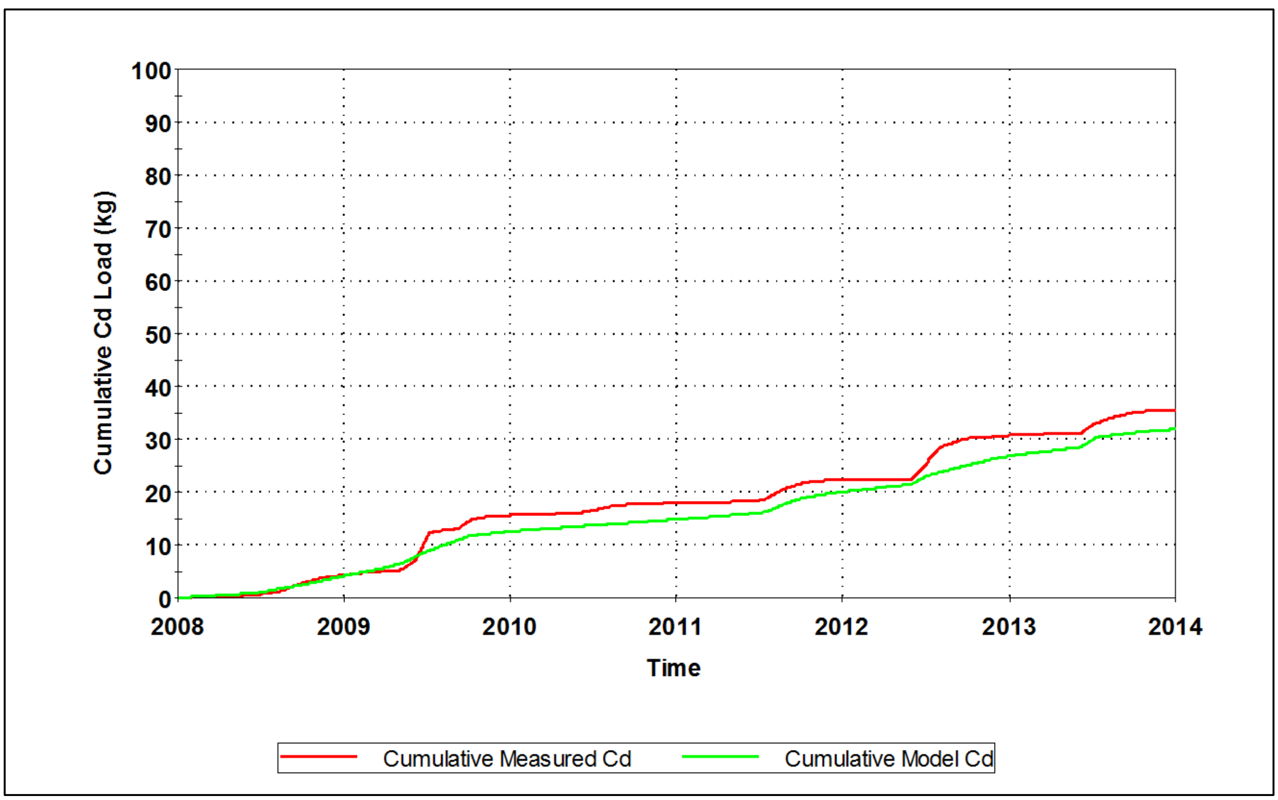


Figure 5-7: Comparison of cumulative cadmium at KV-41 after calibration

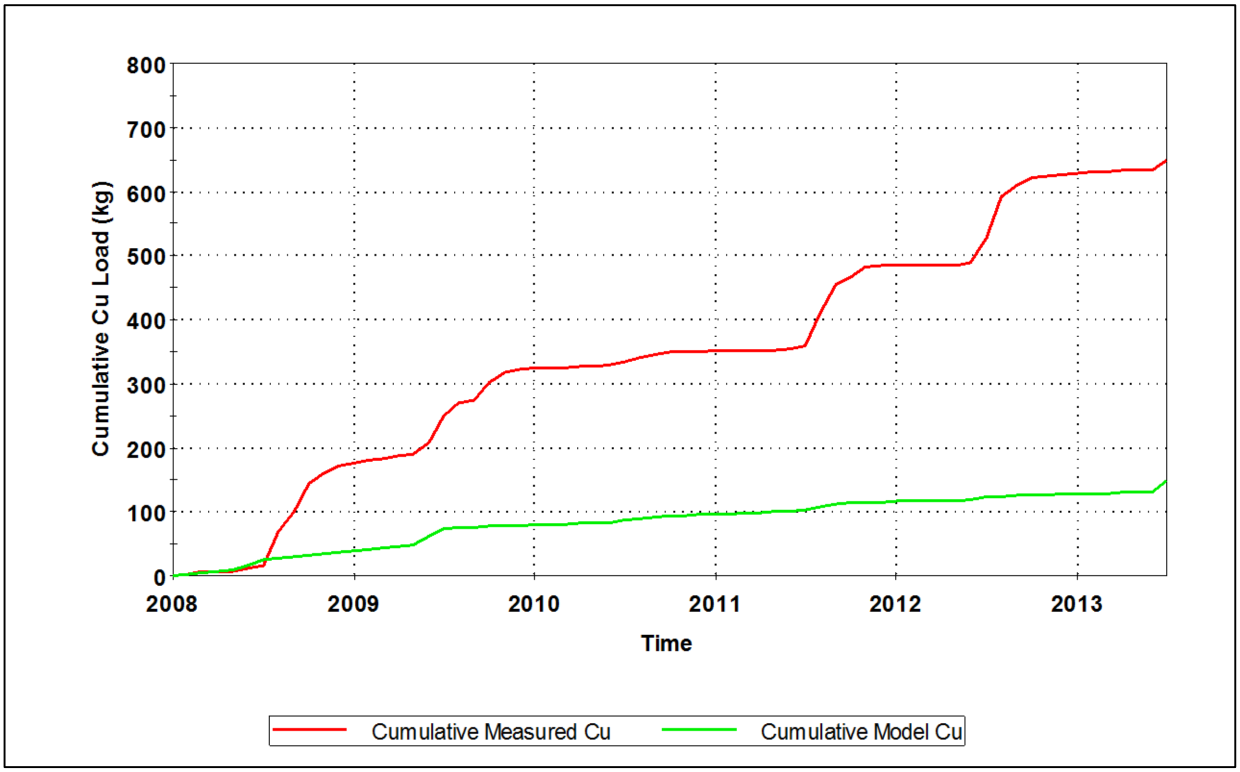


Figure 5-8: Comparison of cumulative copper at KV-41 before calibration

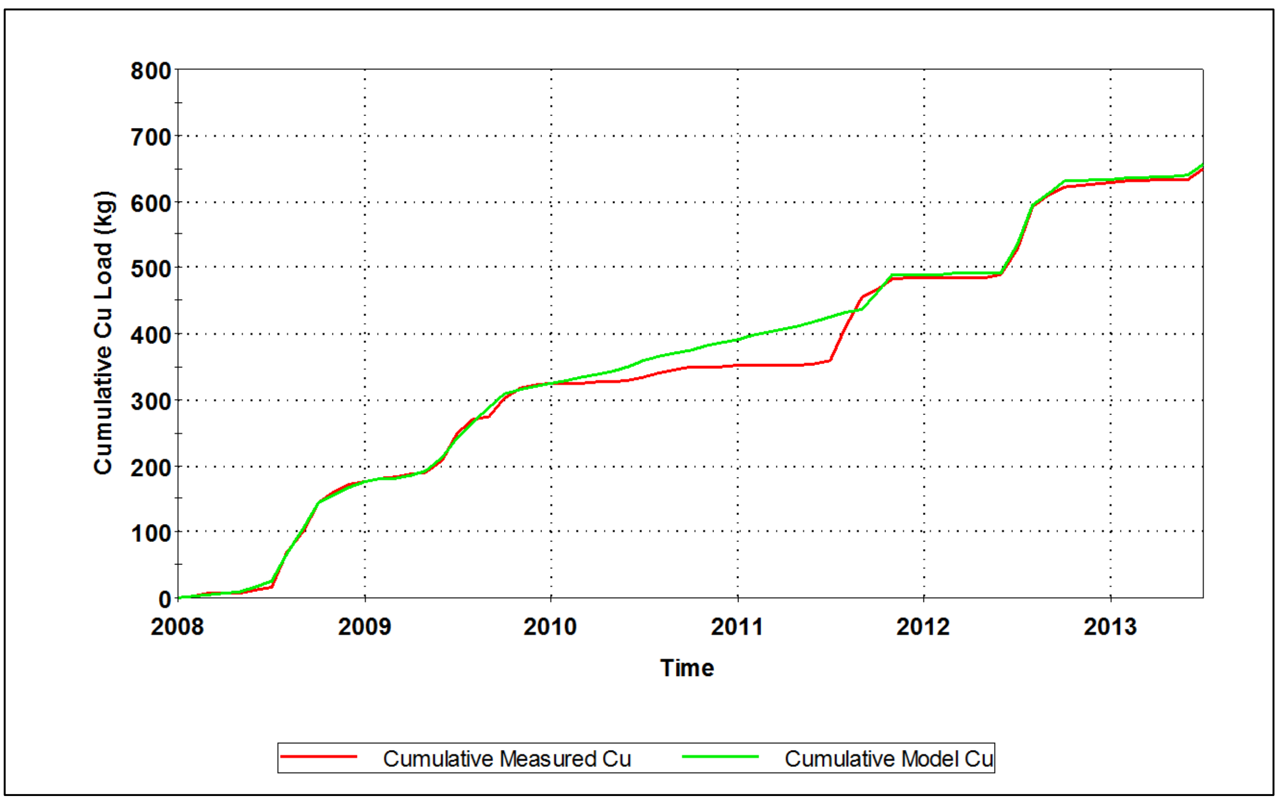


Figure 5-9: Comparison of cumulative copper at KV-41 after calibration

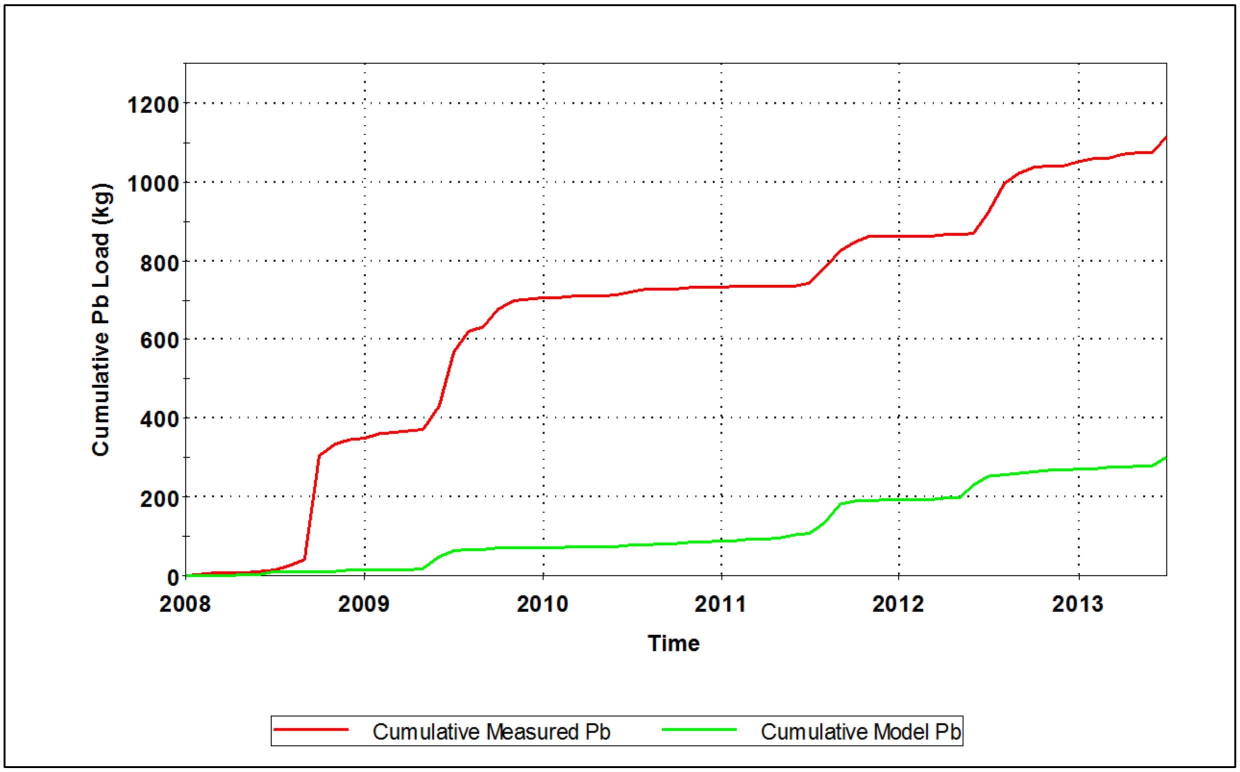


Figure 5-10: Comparison of cumulative lead at KV-41 before calibration

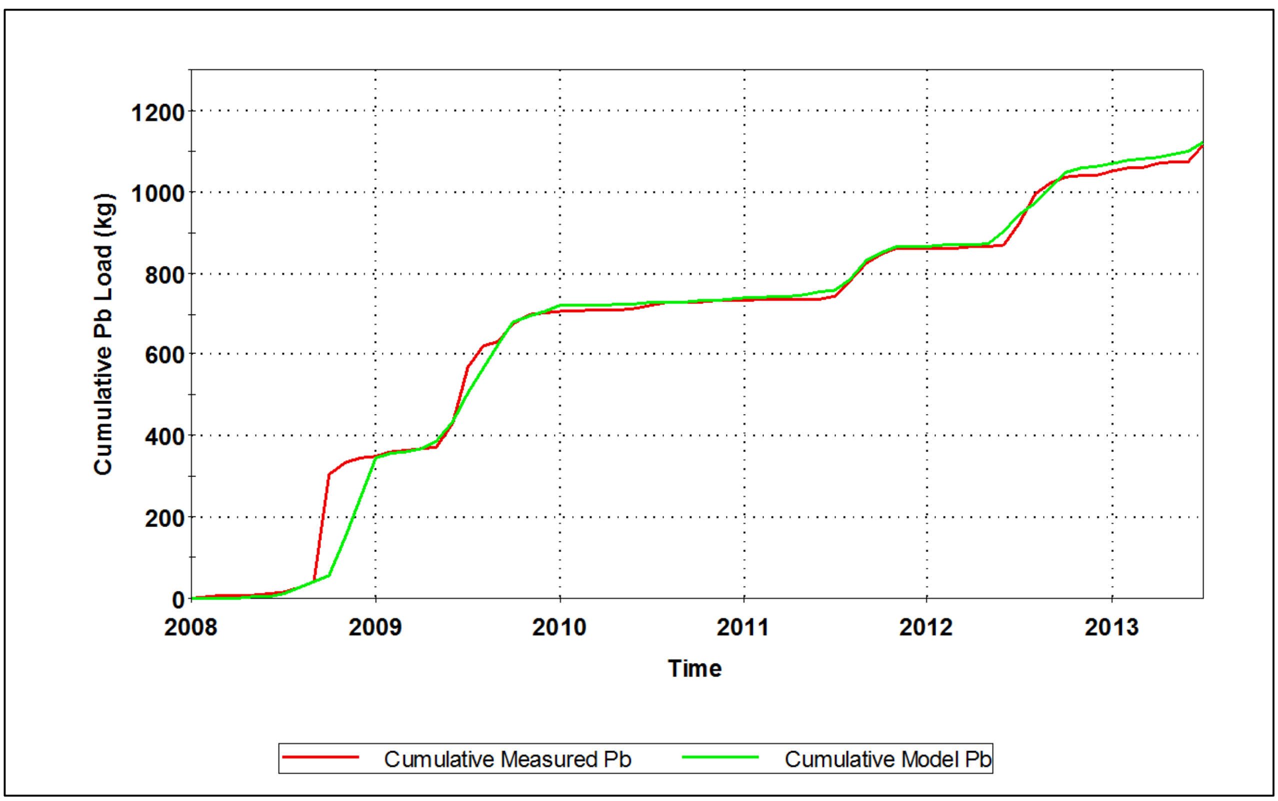


Figure 5-11: Comparison of cumulative lead at KV-41 after calibration

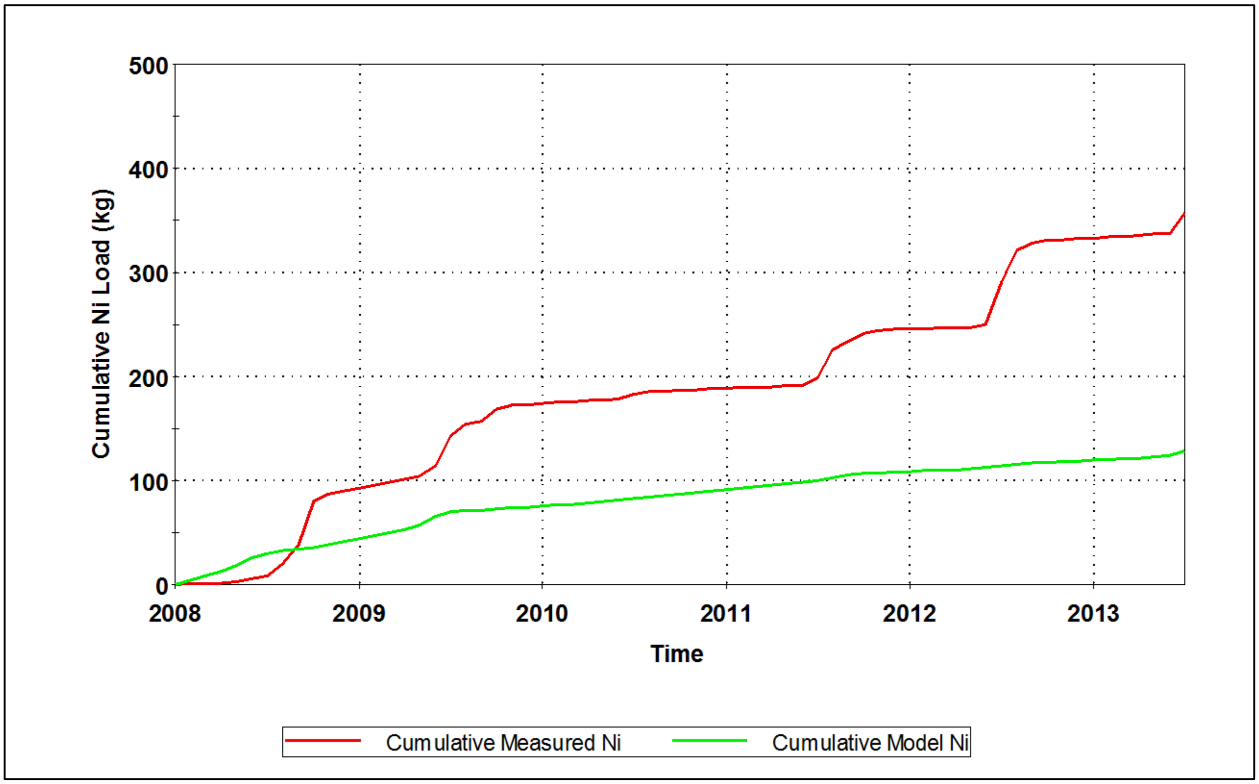


Figure 5-12: Comparison of cumulative nickel at KV-41 before calibration

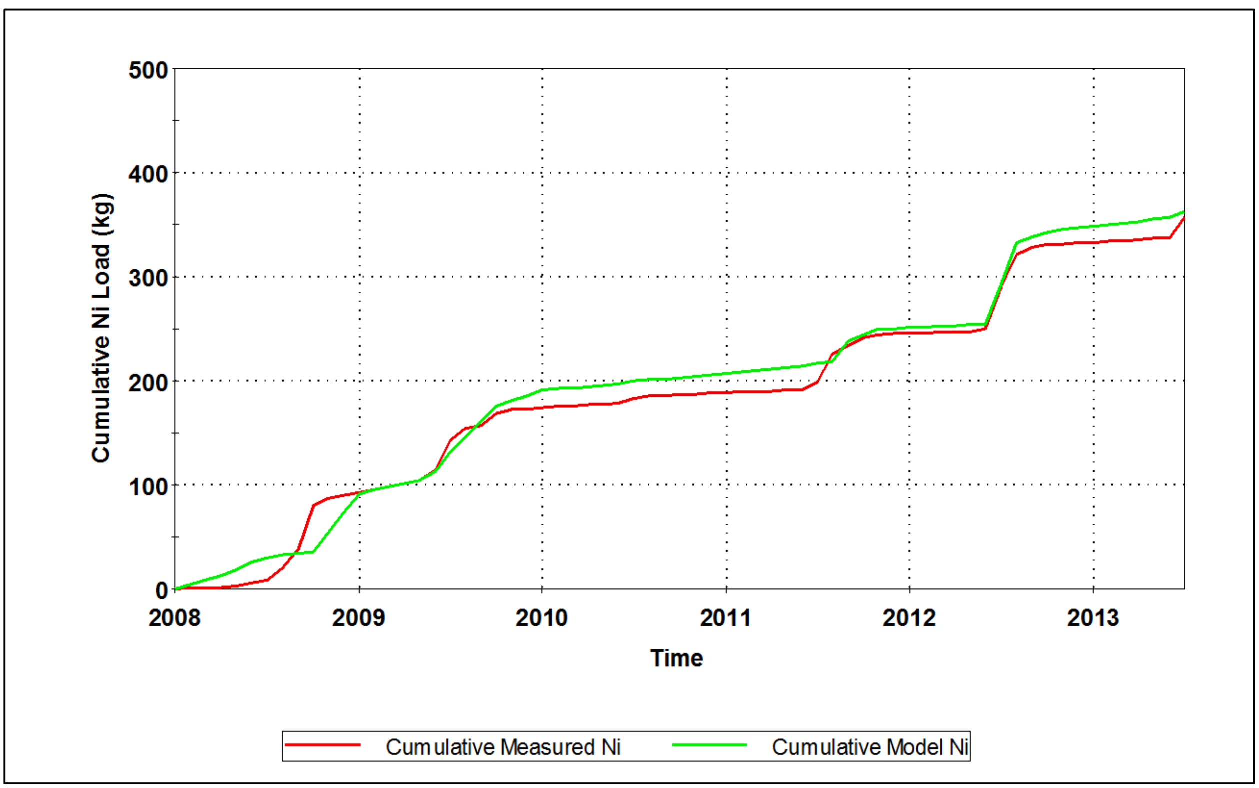


Figure 5-13: Comparison of cumulative nickel at KV-41 after calibration

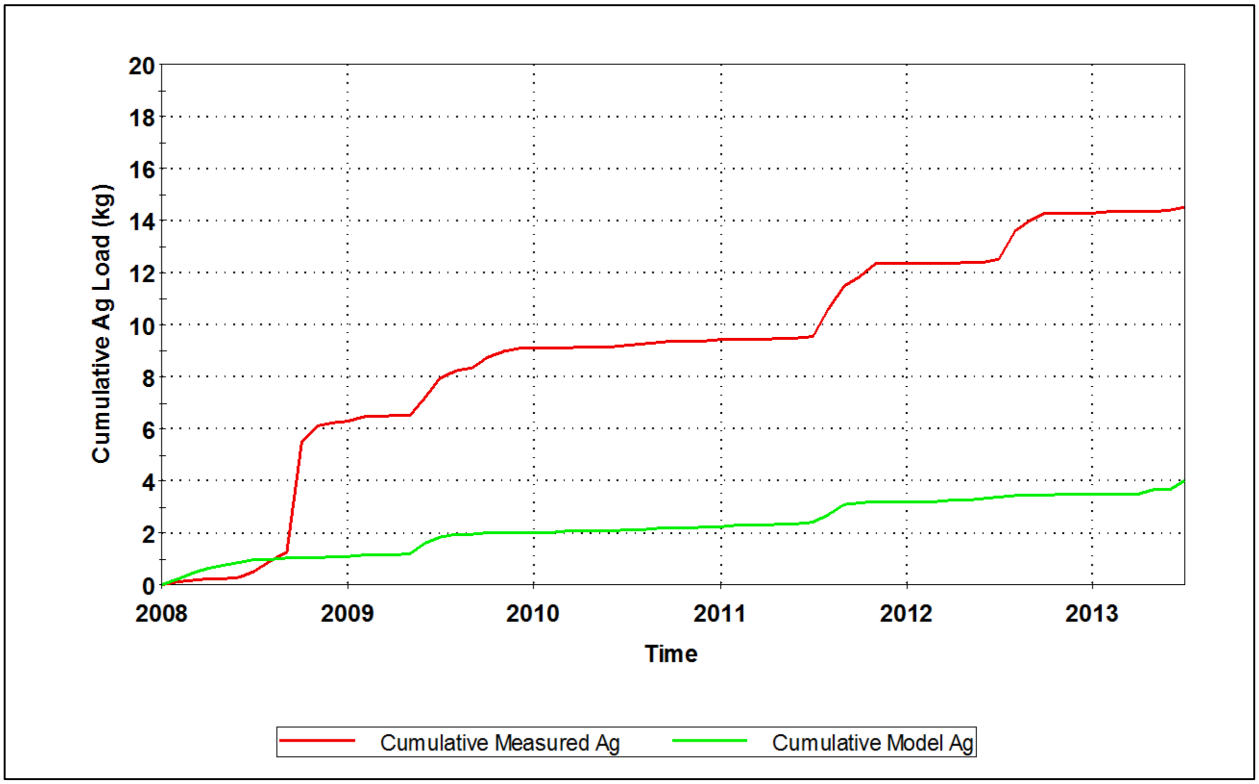


Figure 5-14: Comparison of cumulative silver at KV-41 before calibration

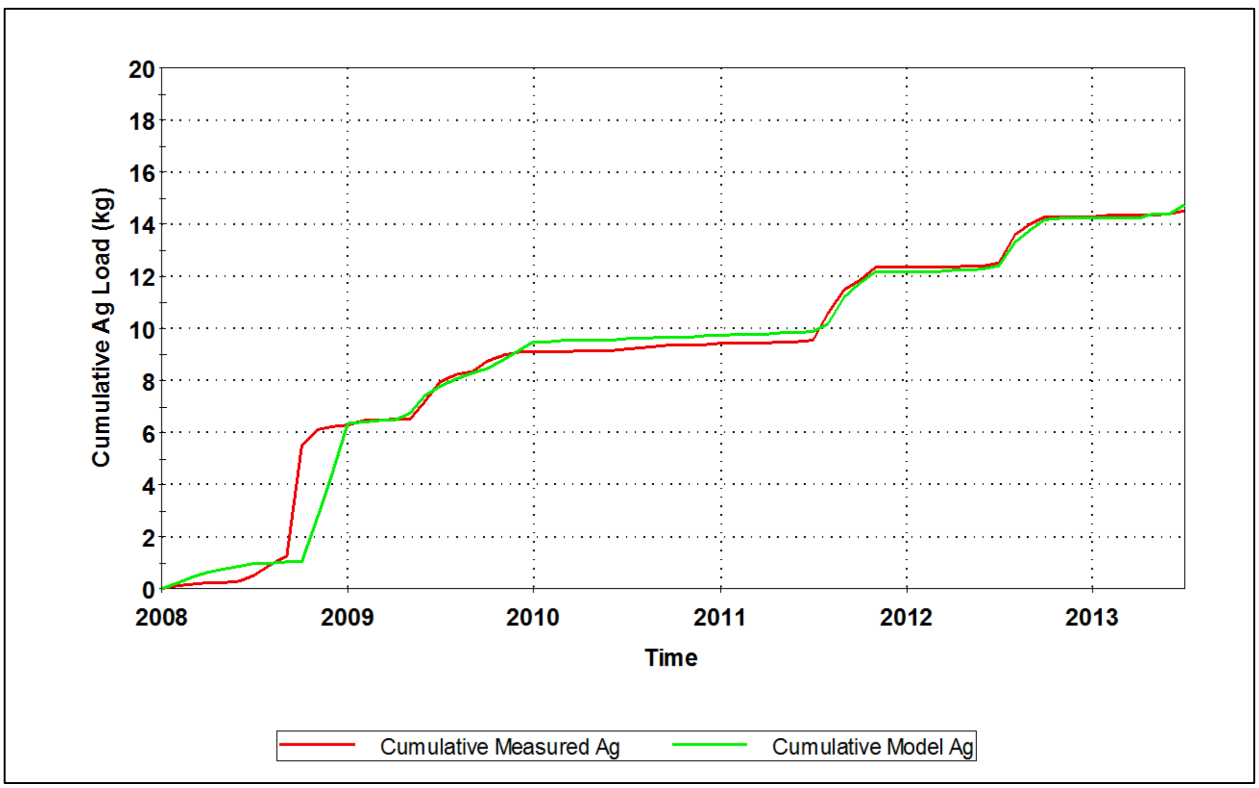


Figure 5-15: Comparison of cumulative silver at KV-41 after calibration

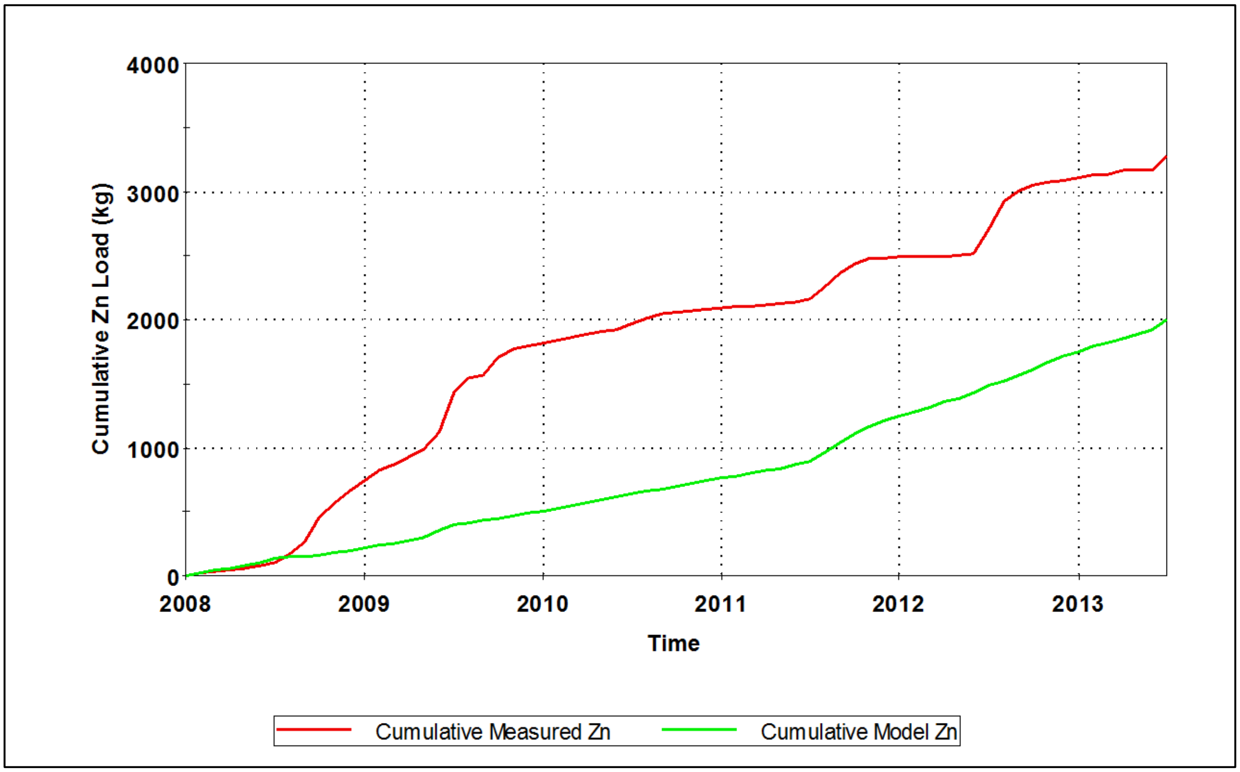


Figure 5-16: Comparison of cumulative zinc at KV-41 before calibration

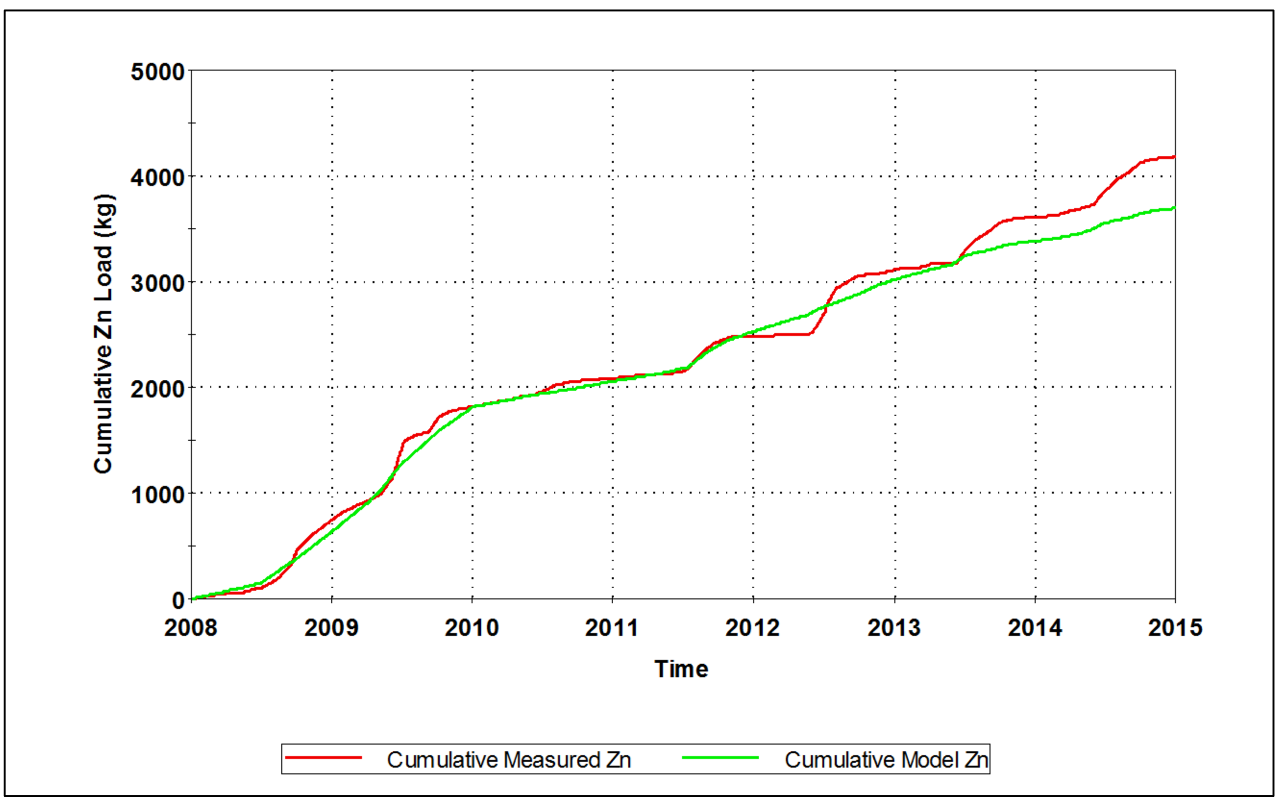


Figure 5-17: Comparison of cumulative zinc at KV-41 after calibration

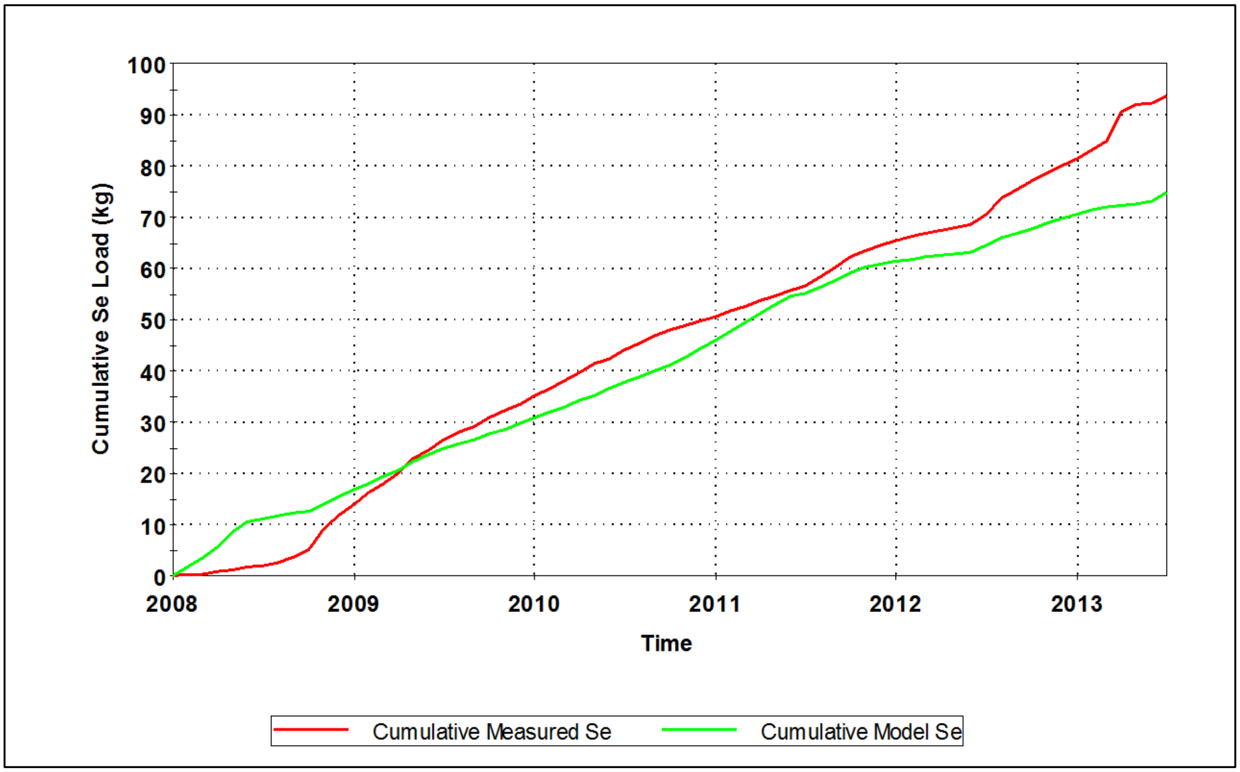


Figure 5-18: Comparison of cumulative selenium at KV-41 before calibration

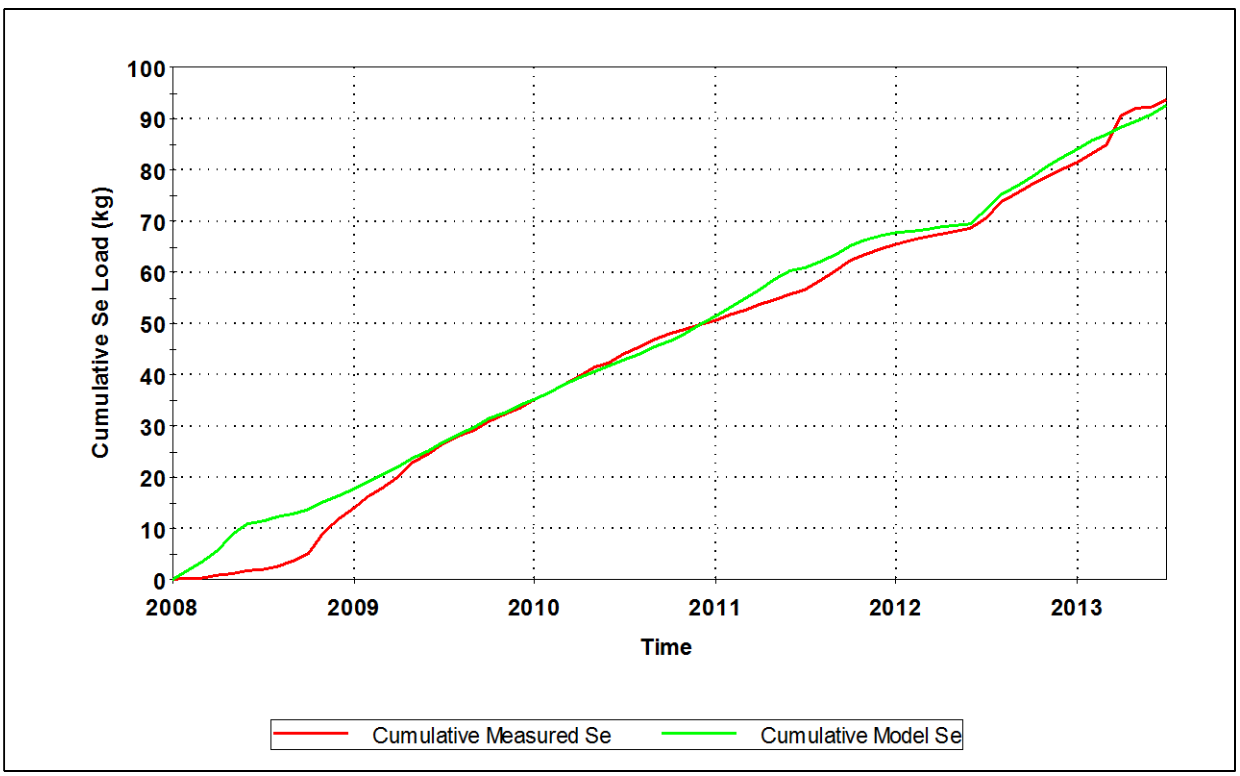


Figure 5-19: Comparison of cumulative selenium at KV-41 after calibration

6.0 Simulation Results for Future Reclamation Scenarios

A number of reclamation options for the Keno 700 adit flows are under consideration. The simulation model was used to determine the potential reduction in mass loads that could be achieved for potential reclamation options. These reductions in mass loads are based on estimates of the effects of the reclamation on the concentrations of metals from the Keno 700 adit, which is the major source of metals in the upper Lightning Creek watershed. Table 6-1 gives the estimates of the concentrations estimated to be achievable by the different reclamation options and basis for the estimations.

The concentration data in Table 6-1 differ from the approach used in the previous model report (Interralogic, 2012a) where we based estimates of some reclamation effects on the basis of percentages of load reduction. However, we now have an additional year and half of water quality data from the bioreactor test at Galkeno 900, water treatment at Galkeno 300 and 900, and No Cash Creek that we believe provide a more reliable basis for making estimates of potential reclamation effects; hence we have used those data to define concentration estimates for the reclamation options.

The reclamation options and basis for estimation of concentration targets are provided below:

- **Base Case – No Reclamation**: Simulation of the current set of metal loading conditions based on the calibrated model with future dates represented by average values for hydrology, climate, and metal concentrations and release rates for all sources.

- **Option 1 - Bioreactor**: A bioreactor would be installed and begin running in August of 2016[1] that will lower the average concentrations in discharges to averages values achieved with the Galkeno 900 bioreactor test site (Table 6-1).

- **Option 2 – Mine Pool Treatment**: A mine pool would be created using a low pressure hydraulic adit plug, alkaline and/or carbon source injection and mixing into mine pool to improve the quality of discharge water. We assumed water treatment will gradually reduce metal concentrations to concentrations that are estimated as twice those achievable for the bioreactor option over a 4-year period starting in 2016 (Table 6-1).

- **Option 3 – Managed Natural Attenuation**: An engineered adit plug would capture and route water to the nearby catchment where passive aeration tumbling devices buried in hillside will attenuate metals. A settling pond or similar structure will be used to remove any Fe, Mn, and Al precipitates with adsorbed trace metals in the new drainage. An injection/distribution surface trench will distribute creek drainage across the hillside. Future concentrations for this option are based on the average concentrations observed at locations NC-3 and NC-4 on No Cash Creek. These two

[1] Dates for treatment implementation are conceptual in nature for the purpose determining potential effects of the different options and are not meant to indicate scheduled construction; it is currently assumed implementation could occur about three years in the future.

locations are at the bottom of Galena Hill downstream of the zone where water is aerated by cascading down the hillside (Table 6-1).

- **Option 4 – Water Treatment Plant**: A water treatment plant will be installed and begin running in August 2016 that will lower the average concentrations in discharges to those observed at the Galkeno 900 water treatment plant (Table 6-1).

Table 6-1: Concentrations estimated to be achievable for water exiting the Keno 700 adit (location KV-33) for potential reclamation options

	Concentrations (mg/L)				
Constituent	**Base Case**	**Option 1 (Bioreactor)**	**Option 2 (Mine Pool Treatment)**	**Option 3 (Managed Natural Attenuation)**	**Option 4 (Water Treatment Plant)**
Ag	N/A	0.0001	0.0002	0.0001	0.0003
As	N/A	0.01	0.02	0.001	0.016
Cd	N/A	0.0001	0.0002	0.007	0.0003
Cu	N/A	0.001	0.002	0.002	0.001
Ni	N/A	0.01	0.02	0.004	0.005
Pb	N/A	0.001	0.002	0.005	0.003
Se	N/A	0.001	0.002	0.0008*	0.0008*
Zn	N/A	0.1	0.2	0.74	0.17
SO_4	N/A	120	120	170*	170*

*We assume these options will result in little to no reduction in concentrations of Se and SO_4

6.1 Simulation Results for Metal Loads for the Reclamation Options

Approximately 4 to 6 years after the initiation of the reclamation options in 2016, simulated metal loads reach a steady state level that can be directly compared among the different reclamation options. Steady state results for simulated cadmium, zinc, and arsenic loads at KV-41 for the four reclamation options are given in Table 6-2 and shown in Figure 6-1, Figure 6-2, and Figure 6-3, respectively.

The simulation results can summarized as follows:

- Zinc: Option 1 (Bioreactor) is predicted to result in the greatest reduction in annual load due to the low concentration of zinc expected to be achievable in a bioreactor water treatment system.
- Cadmium: Options 1 (Bioreactor), Option 2 (Mine Pool Treatment), and Option 3 (Water Treatment Plant) are all predicted to produce the same amount load reduction.
- Arsenic: Option 3 (Managed Natural Attenuation) is predicted to result in the largest reduction in annual load, although there is not a much difference between any of Options 1 to 4.
- Lead and Silver: Both lead and silver concentrations are very low throughout the Lightning Creek basis; hence reclamation options are not expected to have a significant effect on their loads or concentrations.

Table 6-2 Simulated Annual Metal Loads at KV-41 4 to 6 years after initiation of reclamation

Option	Total Cd Load at KV-41 (kg/yr)	Total Zn Load at KV-41 (kg/yr)	Total As Load at KV-41 (kg/yr)	Total Pb Load at KV-41 (kg/yr)	Total Ag Load at KV-41 (kg/yr)
No Treatment	3.7	303	45.8	68.1	0.68
Option 1: Bioreactor	2.0	124	40.2	67.4	0.67
Option 2: Mine Pool Treatment	2.0	137.6	41.5	67.5	0.68
Option 3: Managed Natural Attenuation	2.9	209.4	39.2	67.9	0.67
Option 4: Water Treatment Plant	2	133.6	41.2	67.7	0.70

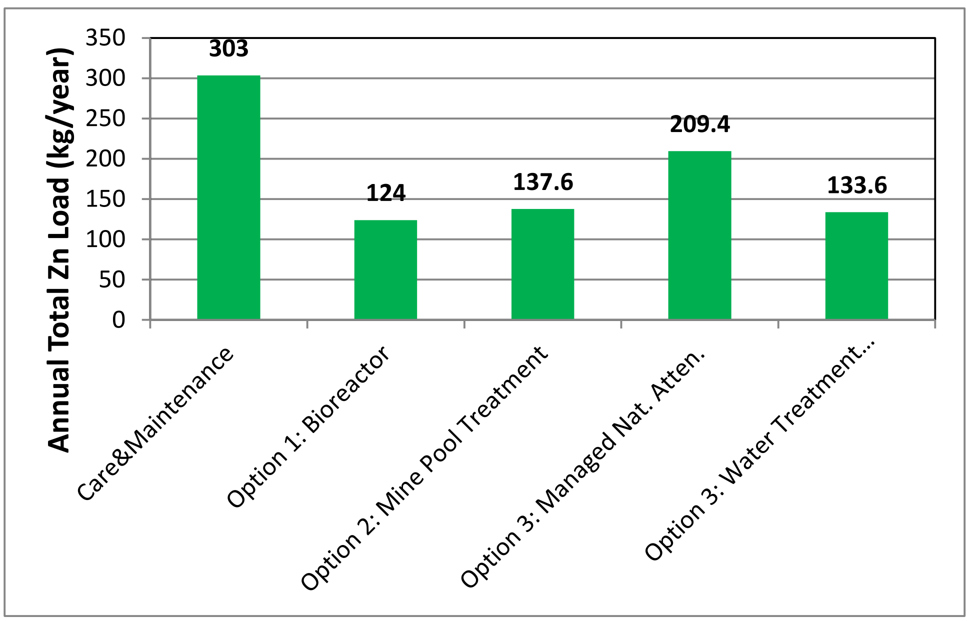


Figure 6-1: Simulated annual steady-state zinc loads at KV-41 for reclamation options

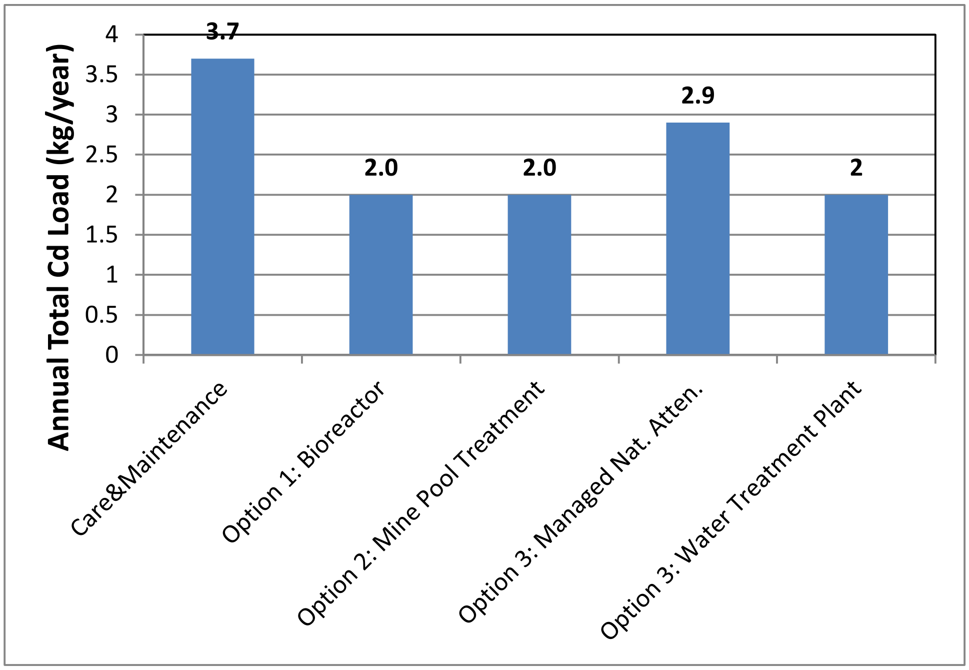


Figure 6-2: Simulated steady-state annual cadmium loads at KV-41 for reclamation options

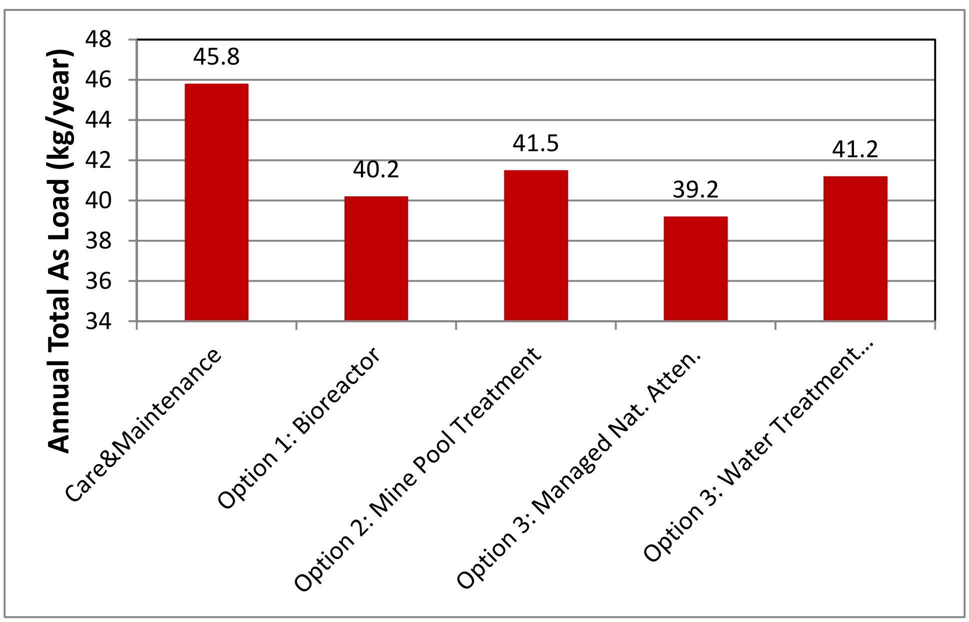


Figure 6-3: Simulated steady-state annual arsenic loads at KV-41 for reclamation option

6.2 Simulated Concentrations for Reclamation Options

Trends in measured concentrations of cadmium, zinc, and arsenic in Lightning Creek at KV-41 are shown in Figure 6-4. The measured data show approximately a tenfold variation between winter and summer with lowest concentrations typically occurring during January to March and highest concentrations occurring during July to September. The structure of the GoldSim simulation model described in this report was designed to estimate chemical loads and is most suited to evaluating reclamation options in terms of changes in chemical loads. However, ERDC has requested estimates of metal concentrations (Cd, Zn, As) in Lightning Creek from the model to aid in the evaluation of reclamation options. While the simulation model is capable of making estimates of concentrations based on calculations of loads and water flow rates, those calculations do not take into account potential variability in hydrogeochemical, biological, and physical processes that can affect concentrations in natural stream systems particularly over short time frames. The concentrations produced by the model should be understood to be indicative of approximate ranges expected to occur over yearly to longer time-scales rather than precise predictions of day-to-day concentrations that might occur.

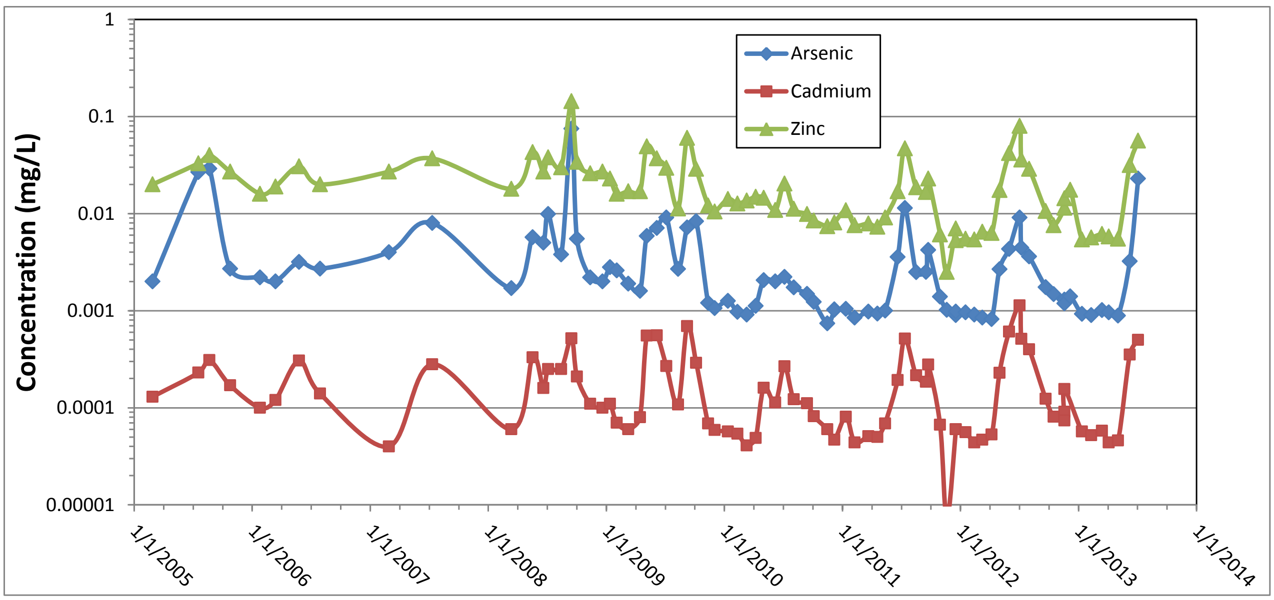
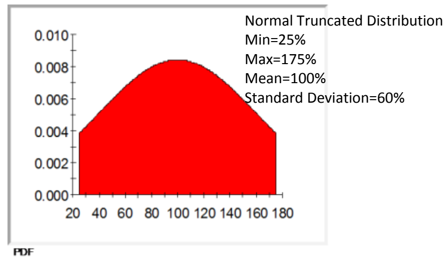


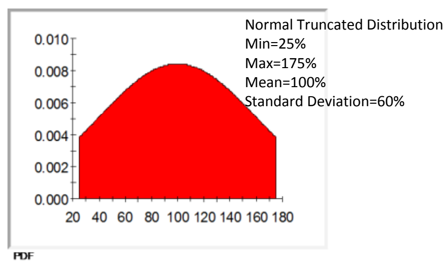
Figure 6-4: Measured cadmium, zinc, and arsenic concentrations in Lightning Creek at KV-41

In making estimates of concentrations, we used a probabilistic approach where have assigned estimated uncertainty ranges to represent the potential range of chemical effects of the reclamation options and range of natural variability inherent in the stream dynamics. The uncertainties were defined as follows:

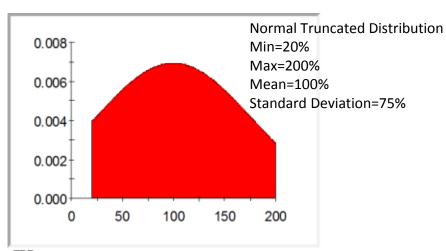
Reclamation Options (Options 1 to 4): Plus and minus 75% about a mean value of 100% with a normal distribution and standard deviation of 60%. This distribution is based on professional judgment.



- Natural Stream Chemistry Dynamics: Plus and minus 75% about a mean value of 100% with a normal distribution and standard deviation of 60%. This distribution is based on measured data for KV-41 and other water quality monitoring locations.



- Waste rock release rates: Plus 100% and minus 80% about a mean value of 100% with a normal distribution and standard deviation of 75%. This distribution approximates the range determined for waste rock leaching in SRK (2007/08).



Estimates of metal concentrations are shown in Table 6-3 for the year 2024, which is 8 years after the initiation of reclamation options, when the effects of those options are expected to reach steady state. The median concentration estimates in Table 6-3 were calculated by averaging the monthly median concentrations predicted by the probabilistic model for the year 2024. The 95th percentile concentrations represent the single maximum monthly concentration predicted by the probabilistic model for year 2024.

The relative differences in estimated concentrations among the reclamation options are consistent with the load simulation results provided in Table 6-2.

Table 6-3: Summary of predicted concentration ranges for year 2024 for the different options

	Concentrations (mg/L)									
	Base Case		Option 1 (Bioreactor) (Yr 2024)		Option 2 (Mine Pool Treatment) (Yr 2024)		Option 3 (Managed Natural Attenuation) (Yr 2024)		Option 4 (Water Treatment Plant) (Yr 2024)	
	Median	95th	Median	95th Percentile	Median	95th Percentile	Median	95th Percentile	Median	95th Percentile
Cd	0.0002	0.0004	0.00007	0.00026	0.00007	0.00026	0.00015	0.00033	0.00007	0.00026
Zn	0.021	0.038	0.005	0.021	0.006	0.022	0.012	0.031	0.006	0.022
As	0.0023	0.0057	0.0018	0.0052	0.0019	0.0053	0.0018	0.0051	0.0019	0.0052

7.0 REFERENCES

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Interralogic (2012a) Mass Load Model for Lightning Creek: Description and Results. Draft Report Prepared for Access Consulting, Whitehorse, YT; prepared by Interralogic, Inc., Fort Collins, Colorado, May 9, 2012.

Interralogic (2012b) Mass Load Model for Christal Creek: Description and Results. Draft Report prepared by Interralogic, Inc., prepared for Access Consulting, February 28, 2012.

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Closure Options and Metal Loading Reduction Comparisons for Flat Creek, Christal Creek and Lightning Creek Sites

		Average Annual Load at KV-9		Reduction at KV-9 Compared to Baseline	
		Zn load kg/yr	Cd load kg/yr	Zn % Decrease	Cd % Decrease
Valley Tailings F	Current Treatment	626.6	8.12	0.0%	0.0%
	Close in Place	190	3.09	69.7%	61.9%
	Combine Exposed Tailings (partial consolidation)	182.3	2.71	70.9%	66.6%
	Combine Tailings into Lined Facility	182.3	2.71	70.9%	66.6%
Husky SW	Status Quo	626.6	8.12	0.0%	0.0%
	Managed Natural Attenuation	626.6	8.12	0.0%	0.0%
	Mine Pool Treatment	627	8.12	-0.1%	0.0%
	Bioreactor Treatment	627.2	8.11	-0.1%	0.1%
	Mechanical Treatment	630	8.18	-0.5%	-0.7%
	Reclamation Only	626.6	8.12	0.0%	0.0%
Silver King	Existing Treatment Facility (status quo)	626.6	8.12	0.0%	0.0%
	Managed Natural Attenuation	613.1	7.89	2.2%	2.8%
	Mine Pool Treatment	609.4	7.87	2.7%	3.1%
	Bioreactor Treatment	638.6	7.89	-1.9%	2.8%

Base Condition Established		Average Annual Load at KV-7		Reduction at KV-7 Compared to Baseline	
		Zn load kg/yr	Cd load kg/yr	Zn % Decrease	Cd % Decrease
Base Case		787	7.3	-	-
Galkeno 300	Existing Treatment Facility (status quo)	787	7.3	0.0%	0.0%
	Existing Facility (improved performance)	709	4.2	9.9%	42.5%
	Elsa Treatment Facility	674	3.8	14.4%	47.9%
	Silver Trail Facility (current GK300 performance)	787	7.3	0.0%	0.0%
	Silver Trail Facility (improved performance)	709	4.2	9.9%	42.5%
Galkeno 900	Existing Treatment Facility (status quo)	787	7.3	0.0%	0.0%
	Bioreactor	775	7.3	1.5%	0.0%
	Upgrade Existing Treatment Facility	783	7.3	0.5%	0.0%
	Silver Trail Facility (current GK300 performance)	792	7.9	-0.6%	-8.2%
	Silver Trail Facility (improved performance)	781	7.3	0.8%	0.0%
Onek 400	Bioreactor & Managed Natural Attenuation	488	6.4	38.0%	12.3%
	Small Facility at Onek Site (current GK300 performanc	460	6.4	41.6%	12.3%
	Small Facility at Onek Site (improved performance)	454	6.1	42.3%	16.4%
	Silver Trail Facility (current GK300 performance)	460	6.4	41.6%	12.3%
	Reclamation & Managed Natural Attenuation	538	6.6	31.6%	9.6%
Mackeno Tailin	Close in Place with Lime	614	7	22.0%	4.1%
	Close in Place no Lime	746	7.2	5.2%	1.4%
	Consolidate and cover	606	7	23.0%	4.1%
	Remove Tailings	609	7	22.6%	4.1%
Waste Rock	Re-grade and Cover	767	7.2	2.5%	1.4%
	Re-grade and Optimize Cover	761	7.2	3.3%	1.4%

		Average Annual Load at KV-41		Reduction at KV-41 Compared to Baseline	
		Zn load kg/yr	Cd load kg/yr	Zn % Decrease	Cd % Decrease

Closure Options and Metal Loading Reduction Comparisons for Flat Creek, Christal Creek and Lightning Creek Sites

Base Case		303	3.7	0.0%	0.0%
Keno 700	Bioreactor Treatment	124	2	59.1%	45.9%
	Mine Pool Treatment	137.6	2	54.6%	45.9%
	Managed Natural Attenuation	209.4	2.9	30.9%	21.6%
	Water Treatment Plant	133.6	2	55.9%	45.9%

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Draft Technical Memorandum

TO: ERDC Project File

FROM: Interralogic, Inc.

DATE: March 31, 2011

SUBJECT: Reclamation Description and Costing
Waste Rock Storage Areas and Open Pits
Keno Hills Mining District, Elsa, YT

Introduction

At the request of Elsa Reclamation and Development Company, Ltd. (ERDC), this memorandum has been prepared by Interralogic, Inc. (Interralogic) to describe reclamation activities being considered for waste rock storage areas (WRSAs) and open mine pits (pits) located within the Keno Hills Mining District near Elsa, YT. Provided for each activity is a Level 5 cost estimate considered accurate to -50% / +100% of actual cost.

As shown in Table 1 and displayed on Figure 1, 68 WRSA sites have been identified within the District, and of these, there are 16 sites with pits. Note that the list does not include the Flame & Moth and Bellekeno 625 sites, which are operational facilities and not being considered for near-term reclamation under this closure and reclamation program.

As required by site conditions, debris removal will be performed at all of the 68 mine sites. This will involve trash pickup and removal of old equipment, which will be disposed at the Elsa landfill. All WRSA sites will be cleaned up to improve the aesthetics of each site as a minimum reclamation. Site access to all sites in the district will be required to allow heavy equipment access to the sites to fulfill the reclamation tasks.

A screening of the sites has been performed to determine which will be considered for additional reclamation of WRSAs and pits. The criteria for WSRA reclamation is:

- Unstable slopes showing signs of erosion or having the potential for movement
- Significant gullying on steeper slopes
- Waste rock that is a potential chemical source to surface water
- Adit discharge that may be migrating into or across waste rock

The criterion for pit reclamation is:

- Safety hazard (pit wall heights greater than 5 meters)
- Potential sites of meteoric recharge to flowing adits (that is, not free-draining and with a known or suspected connection to a flowing adit)

Sites meeting one or more of the above criteria are identified by an “X” in Table 1.

Table 2 summarizes the sites selected for reclamation and shows the activities being considered. An “X” indicates a required reclamation activity and “O” pertains to an optional activity that will be evaluated based on future environmental and engineering studies. A level 5 cost estimate has been performed for all labeled items in Table 2.

Debris Removal

Old equipment, trash, and miscellaneous mining debris will be removed from all 68 mine sites listed in Table 1. The debris will be loaded into trucks and disposed at the Elsa landfill.

Description of Reclamation Activities for WRSAs

Regrading

For indicated WRSAs in Table 2, regrading will be performed on angle of repose slopes to achieve a stable permanent slope of 2.5:1. In certain circumstances, resloping may include benching and slopes steeper than 2.5:1, but with equivalent stability as a 2.5:1 slope. Using a dozer, this will be performed by pushing waste rock from higher portions of the slope and filling on top of the lower portion of the slope (cut-and-fill). The final surface will be smoothed and contoured to fit as much as possible with the adjacent existing topography. While most of the earth moving will be in a downhill direction, lateral movement will occur on some slopes to avoid waste rock encroachment into natural stream channels (Silver King 100 adit, No Cash 100 pit, and No Cash 500 adit).

Stream Protection

Rip-rap will be placed adjacent to stream channels where the toe of any regraded waste rock slope is close to the active channel. The rip rap will be obtained from a bedrock quarry located north of the Valley Tailings Facility or other suitable facility. Stream protection will not include diversions or significant relocation of existing channels. Stream protection is recommended for WRSAs at the No Cash 100 pit, Keno 700 adit, No Cash 500 adit, and Silver King 100 adit.

Diversions

The purpose of diversions is to reduce surface water and/or adit water flow onto waste rock to reduce erosion and limit chemical leaching of waste rock that could result in degraded water quality. Diversions are required to prevent erosion and gullying.

At the Ruby adit site, a surface water diversion channel will be constructed on the uphill (south) side of WRSA to intercept overland flow and divert this flow around the WRSA. This measure is intended to reduce the potential for gullying on sideslopes that are adjacent to an existing road.

At the Elsa +50, Galkeno 900, Keno 700, No Cash 500, Onek 400, Sadie Ladue 600, and Silver King 100 sites, there are adit discharges that have the potential to contact waste rock. At each of these sites the water treatment design and waste rock closure will be coordinated to ensure that adit discharges will not result in erosion or chemical leaching of the waste rock materials. At a minimum, a channel will be constructed to divert the adit discharge away from the WRSA.

Optional Soil Covers

Optional soil covers are being considered for certain WRSAs containing waste rock that has the potential to be a chemical source to surface water and groundwater. Two cover designs are proposed:

> Vegetation Cover is 0.5 m thick and consists of growth medium and seeding. The primary purpose of a vegetation cover is to reduce erosion and provide a nominal reduction in meteoric infiltration.
>
> Infiltration Cover is 1.0 m thick and consists of a lower soil layer that has been amended to reduce permeability and an overlying layer of seeded growth medium. The purpose of an infiltration cover is to greatly reduce meteoric infiltration into the WRSA and thereby minimize chemical loading from the WRSA to the environment.

The WRSAs being considered for soil covers are Hector 400 adit, Husky shaft, Husky SW shaft, Onek 400 adit, and Townsite adit. The decision to install soil covers on some or all of these WRSAs, and the type of cover utilized, will be based on future additional geochemical evaluations of the waste rock materials. Note that the optional regrades at Husky shaft, Husky SW shaft, and Onek 400 adit will only be performed if a decision is made to place covers on these WRSAs.

Description of Reclamation Activities for Open Pits

Safety Berms

To mitigate the fall hazard for people in vehicles, ATVs, and snow machines, double safety berms will installed along the perimeters of all pit walls that are higher than 5 m. The first berm will generally be located about 5-15 m from the top edge of the pit wall, constructed to a height of 3 m above grade, and have 1:1 side slopes. The second berm will be located adjacent to the primary berm (away from the pit wall) and have the same geometry.

Diversions

Diversion channels will be constructed upslope of most of the mine pits to reduce overland flow that makes its way into a pit and could become groundwater recharge to flowing adits. Reducing recharge at the Calumet pit, Hector pit, and Galkeno 300 area pits is particularly important because discharge from the nearby Galkeno 300 adit produces nearly 90 percent of the total known zinc loading within the District. In most cases, the diversions will be constructed parallel to portions of the safety berms, with the intent of routing surface water around the pit and discharging it downslope of the pit. Where there are several pits close together (e.g., Galkeno 300 pits area), a single diversion channel will be constructed to route surface water away from all the pits.

Pit Backfill with Soil Cover

Two pits, Onek and Silver King, are not free draining and are located close to flowing adits (Onek 400 and Silver King 100, respectively). It is possible that ponded water in these pits (particularly during freshet) provides significant groundwater recharge that reports as discharge from the associated adits. A required reclamation activity for these pits is to place backfill and a soil cover to provide a free draining condition so that ponding is eliminated. In both pits, backfill will be placed in the bottom of the pit to create a smooth floor with a 2 to 5 percent grade and surface water discharge at one end of the pit. For both the Onek and Silver King pits, a 1-m vegetation cover will be placed to promote vegetation growth, reduce infiltration, and reduce groundwater recharge. The operational objective of the pit backfills is to decrease discharge at the Silver King 100 adit and Onek 400 adit to reduce the cost of long-term water treatment at these sites.

Cost Evaluation

A level 5 cost analysis, considered accurate to -50% / +100%, has been performed for all reclamation activities identified in Table 2. A summary of the assumptions used to formulate the cost estimates is provided in Table 3.

Debris removal is estimated based on a unit cost per site that includes a crew, haul truck, excavator, and front loader. A crew of four was also assumed to be required for assistance in debris removal. It is assumed that the average time per site is 2.2 days, so that 150 total days (1 work season) is required to clean up all 68 mine sites.

Material quantities for regrading were estimated by constructing one or more topographic cross-sections across each of the reclaimed WRSAs. Site plans and cross-sections for the WRSAs are shown Figures 2 to 26. In each section, the area of material to be moved downslope was measured using Autocad. Each area was then multiplied by the perimeter distance associated with the section to compute the volume of material to be moved. If more than one section was generated for the WRSA, the total volume was equal to the sum of the volumes associated with each section. A production rate was calculated for each site utilizing a D9 bulldozer, referencing the CAT handbook, and 2010/2011 BC Bluebook, to estimate the cost of moving the material. The average unit cost for regrading the slopes at all selected sites was $1.35/cubic meter.

Stream protection costs were evaluated by estimating the volume of rip-rap required to prevent waste rock encroachment into existing stream channels. A production rate was calculated for each site utilizing a 325 excavator, and a 740 haul truck, referencing the CAT handbook, and 2010/2011 BC Bluebook, to estimate the cost of loading hauling (assumed 5 km borrow site) and placing the material. A unit cost for blasting and screening the rip rap was included. The average unit cost for blasting, screening, hauling, and placing the rip rap was $33.17/cubic meter. The unit cost for material and placement of filter fabric was $5/square meter.

The cost of a diversion was estimated by developing a preliminary alignment of the diversion channel and estimating its length using Autocad. Preliminary alignments of diversions are shown on the site figures. Estimating costs for diversions were similar to stream protection costs as described above, except for the addition of a diversion berm. A production rate was calculated for each site utilizing a D6 bulldozer, 740 Haul Truck, and 980 Loader, and 325 excavator, referencing the CAT handbook, and 2010/2011 BC Bluebook, to estimate the cost of loading hauling (assumed 0.2 km distance to an appropriate borrow site) and placing the berms. The average unit cost for loading, hauling, and placing the channel/berm was $3.29/cubic meter.

Soil cover cost was estimated by determining the area to be covered (either WRSA or pit backfill) using Autocad. A production rate was calculated for each site utilizing a D6 bulldozer, 980 loader, and a 740 haul truck, referencing the CAT handbook, and 2010/2011 BC Bluebook, to estimate the cost of loading hauling (assumed 5 km borrow site) and placing the material. A unit cost for material and applications of seed was included. The average unit cost for the 0.5 m vegetation cover, including loading, hauling, placing the cover, and seeding was $9.71/square meter.

The method for estimating costs for the 1.0 m infiltration cover was similar to the vegetation cover, except for the added thickness and cost amending the soil to a lower permeability. The average unit cost for the infiltration cover including loading, hauling, adding amendments, placing the cover, and seeding was $26.30/square meter.

Safety berm costs were estimated by drawing the berm alignments in Autocad and measuring the lengths. Each length was then multiplied by a material quantity per length. A production rate was calculated for each site utilizing a D6 bulldozer, 740 haul truck, and 980 loader, referencing the CAT handbook, and 2010/2011 BC Bluebook. The average unit cost for loading, hauling (assuming a 0.2 km distance to the borrow source), and placing the safety berms was $3.29/cubic meter. In most cases, berms will be constructed from nearby waste rock.

Backfill volumes for the Onek and Silver King pits were estimated by generating the backfill surface in Autocad and using a utility in the program to compute the volume between the top of backfill and the current pit bottom. A production rate was calculated for each site utilizing a D9 bulldozer, 740 haul truck, and 980 loader referencing the CAT handbook, and 2010/2011 BC Bluebook, to estimate both the cost of loading, hauling, pushing in fill from the rim, and placing the fill. The average unit cost for backfill at the two sites was $5.40/cubic meter. The backfill for both pits will be obtained from WRSAs located near the pits; hence an assumed average distance of 0.2 km for backfill was used in the cost calculations.

After backfilling each pit, a 1 m soil cover will be placed on top of the backfill materials. A production rate for the infiltration cover was calculated for each site utilizing a D6 bulldozer, 740 haul truck, and 980 loader referencing the CAT handbook, and 2010/2011 BC Bluebook, to estimate the cost of loading, and hauling (assumed 5 km borrow site), placing the cover, and seeding. Note that the backfill cover will not contain soil amendments to reduce permeability. The average unit cost of the cover for the pit backfill areas was $14.80/cubic meter.

Cost estimates for required activities (identified by "X" in Table 2), are provided in Table 4. Note that in accordance with a level 5 estimate, this total cost is considered accurate to -50% / +100% of actual cost.

In Table 5, separate cost estimates are provided for optional soil covers that may or may not be constructed at the designated WRSAs. For WRSAs at the Hector 400 and Townsite adits, regrading is a required activity and the soil cover is optional, so the Table 5 costs for these sites only applies to installation of the soil cover. At Husky shaft, Husky SW shaft, and Onek 400 adit, both regrading and soil cover are optional, so the associated costs in Table 4 apply to both activities.

Table 1 Keno District Sites

Site Type	Site Name (b)	Waste Rock Tonnage (a)	Selected for WRSA Reclamation	Selected for Pit Safety Berm and/or Optional Backfill	Rationale
Pit	Bermingham pit and WRSA	1,500,000	X	X	WRSA: large, requires regrade, tension cracks. Possible pit recharge to Galkeno 900 adit
	Black Cap pit and WRSA	390,000	X		Large WRSA, visible (above tree line)
	Calumet Pit pit and WRSA	1,025,000	X	X	WRSA: large, requires regrade. Possible pit recharge to Galkeno 300 asit
	Cub & Bunny pit and WRSA	1,350			No obvious issues on Aerial
	Eagle pit and WRSA				No obvious issues on Aerial
	Galkeno 300 pits and WRSAs	450,000	X	X	WRSA: large, requires regrade. Possible pit recharge to Galkeno 300 adit
	Hector Pit pit and WRSA	110,000	X	X	WRSA: large, requires regrade
	Keno No. 9 System pit and WRSA	small piles			No obvious issues on Aerial
	Lake pit and WRSA	2,550			No obvious issues on Aerial
	Miller pit and WRSA	63,000		X	May require berm
	No Cash 100 pit and WRSA	6,500	X	X	WRSA: requires regrade. Possible pit recharge to No Cash 500 adit
	Onek pit and WRSA	600,000	X	X	WRSA: large, visible, requires regrade. Possible recharge to Onek 400 adit.
	Porcupine pit and WRSA (near Keno 700)	3,400			No obvious issues on Aerial
	Sadie Ladue (Wernacke) pit and WRSA	24,500	X		WRSA: requires regrade. Possible pit recharge to groundwater
	Shamrock pit and WRSA	9,000		X	Requires berm
	Silver King pit and WRSA	120,000	X	X	WRSA: large, requires regrade
Adit or Shaft	Apex adit and WRSA	trenching			No obvious issues on Aerial
	Bellekeno 100 (48 Vein) adit and WRSA	2,450			No obvious issues on Aerial
	Bellekeno 100 (50 Vein) adit and WRSA	500			No obvious issues on Aerial
	Bellekeno 200 adit and WRSA	13,000			No obvious issues on Aerial
	Bermingham adit and WRSA	7,000			No significant issues in 2007 Baseline Environmental Report
	Betty adit and WRSA	none			No obvious issues on Aerial
	Blue Bird adit and WRSA	minimal			No obvious issues on Aerial
	Christal (Dorothy) adit and WRSA	minimal			No obvious issues on Aerial
	Comstock 150 adit and WRSA	3,100			Listed as addits in 2007 Baseline Environmental Report
	Comstock 275 adit and WRSA	3,100			Listed as addits in 2007 Baseline Environmental Report
	Coral & Wigwam adit and WRSA	75,000			No obvious issues on Aerial
	Croesus No. 1 adit and WRSA	minimal			No obvious issues on Aerial
	Divide adit and WRSA	trenching			No obvious issues on Aerial
	Dixie adit and WRSA	19,800	X		Requires regrade, gullies
	Dragon (UN) adit and WRSA	3,200			No obvious issues based on 2007 B.E.R.
	Duncan Creek adit and WRSA	none			No obvious issues on Aerial
	Elsa +50 adit and WRSA	1,550	X		Confirmed collapsed 2007 Baseline Env. Rpt. Possible recharge at collapse feature
	Elsa 200 adit and WRSA	6,000			Confirmed gated and secure intrigue risk 2007 B.E.R.
	Elsa 400 adit and WRSA	44,100			Confirmed gated and secure 2007 B.E.R.
	Fox adit and WRSA	trenching			No obvious issues on Aerial
	Galkeno 300 adit and WRSA	150,000	X		Gullies on WRSA
	Galkeno 900 adit and WRSA	20,800	X		Settling pond constructed on waste rock, unstable with permafrost degradation
	Gerlitski adit and WRSA	10,281			No obvious issues on Aerial
	Gold Hill No. 2 adit and WRSA	100			No obvious issues on Aerial
	Hector 400 adit and WRSA	198,000	X		Large, requires regrade, visible, potential chemical source
	Highlander adit and WRSA	15,000			No obvious issues on Aerial
	Husky shaft and WRSA	4,600	X		Waste rock is a potential chemical source
	Husky SW shaft and WRSA	17,000	X		Waste rock is a potential chemical source
	Keno 200 adit and WRSA	14,600			Small site; very little waste rock
	Keno 700 adit and WRSA	27,500	X		Requires regrade. Adit discharge may flow into waste rock
	Kijo adit and WRSA	minimal			No obvious issues on Aerial
	Klondike Keno adit and WRSA	2,000			No obvious issues on Aerial
	Lake View adit and WRSA	trenching			No obvious issues on Aerial
	Lucky Queen 500 adit and WRSA	61,900	X		Requires regrade, visible (above tree line)
	Lucky Queen shaft and WRSA	5,000			With Lucky Queen 500
	Mackeno adit and WRSA				No obvious issues on Aerial
	Monument & Ladue Fraction adit and WRSA	500			No obvious risks based on info in 2007 B.E.R.
	Nabob adit and WRSA	trenching			No obvious issues on Aerial
	Nabob No. 2 adit and WRSA	480			No obvious issues on Aerial
	No Cash 500 adit and WRSA	138,100	X		Large, requires regrade. Adit discharge may flow flow into waste rock
	Onek 400 adit and WRSA	7,500	X		Adit discharge flows onto waste rock
	Rico adit and WRSA	minimal			No obvious issues on Aerial
	Ruby adit and WRSA	28,900	X		Requires regrade. May require to diversion to keep surface water aaway from waste rock.
	Sadie Ladue shaft and WRSA				2007 B.E.R. shafts collapsed and backfilled
	Sadie Ladue 600 adit and WRSA	9,500	X		No obvious issues on Aerial. Possible pit recharge to groundwater
	Shamrock King adit and WRSA	16,200			No obvious issues on Aerial
	Shepherd adit and WRSA	minimal			No obvious issues on Aerial
	Silver Basin adit and WRSA	trenching			No alarms in 2007 B.E.R.
	Silver King 100 adit and WRSA	43,000	X		Requires regrade. Adit discharge may flow into waste rock
	Stone adit and WRSa	84,540			No obvious issues on Aerial
	Apex adit and WRSA	minimal			No obvious issues on Aerial
	Townsite adit and WRSA	14,300	X		WRSA: potential chemical source

(a) Tonnage- short tons (Source: Primary 1996 SCR, secondary PWGSC 2000 and estimates from SRK inspections)
(b) Bellekeno 625 and Flame & Moth are operating sites that are not being considered for near-term reclamation

[grey]	Not applicable
[yellow]	Retained for cost analysis

Table 2 Reclamation Activities

Site	Reference Figure	Waste Rock Storage Area (WRSA)					Pit Related		
		Tonnage (a)	Regrading to 2.5:1 Slopes	Stream Protection (rip-rap)	Diversions	Soil Cover	Safety Berms	Diversions	Pit Backfill with Cover
Bermingham pit and WRSA	2	1,500,000	X				X	X	
Black Cap pit and WRSA	3	390,000	X				X		
Calumet pit and WRSA	4	1,025,000	X				X	X	
Galkeno 300 area pits and WRSAs	5	450,000	X				X	X	
Hector pit and WRSA	6	110,000	X				X	X	
Miller pit and WRSA	7	63,000					X		
No Cash100 pit	8	6,500	X	X			X	X	
Onek pit and WRSA	9	600,000	X				X	X	X
Sadie Ladue (Wernacke) pit and WRSA	10	24,500	X				X	X	
Shamrock pit and WRSA	11	9,000					X		
Silver King pit and WRSA	12	120,000	X				X	X	X
Dixie adit and WRSA	13	19,800	X						
Elsa +50 adit and WRSA	14	1,550			X				
Galkeno 300 adit and WRSA	5	150,000	X						
Galkeno 900 adit and WRSA	15	20,800	X		X				
Hector 400 adit and WRSA	16	198,000	X			O			
Husky shaft and WRSA	17	4,600	O (c)			O			
Husky SW shaft and WRSA	18	17,000	O (c)			O			
Keno 700 adit and WRSA	19	27,500	X	X	X				
Lucky Queen 500 adit and WRSA	20	61,900	X						
No Cash 500 adit and WRSA	21	138,100	X	X (b)	X				
Onek 400 adit and WRSA	22	7,500	O (c)		X	O			
Ruby adit and WRSA	23	28,900	X		X				
Sadie Ladue 600 adit and WRSA	24	9,500			X				
Silver King 100 adit and WRSA	25	43,000	X	X	X				
Townsite adit and WRSA	26	14,300	X			O			

Notes

X Required
O Optional

(a) Tonnage- short tons (Source: Primary 1996 SCR, secondary PWGSC 2000 and estimates from SRK inspections)
(b) Will include placement of a clay liner
(c) Regrading will be performed only if a soil cover is placed

Table 3 Costing Assumptions

Construction Assumptions

Infiltration cover thickness (soil + synthetic liner)	1	m
Vegetation cover thickness (soil only)	0.5	m
Clay liner thickness (all clay)	1	m
Maximum slope for regraded waste rock	2.5 : 1	
Conversion from slope footprint area to actual slope area	1.2	
Diversion berm height	1.5	m
Diversion berm side slopes	1 : 1	
Diversion berm top width	1	m
Safety berm height	3	m
Safety berm side slopes	1 : 1	
Safety berm top width	1	m
1 Way Distance to Borrow Sites	5	km
Rip rap specific weight	2.10	tonnes/m3
Compost specific weight	0.3	tonnes/m3
Compost thickness	0.05	m
Debris cleanup	2.2	days/site

Unit Costs

Crush & screen	$ 4.45	per	tonne
Organics cost and delivery	$ 81.00	per	m3
Blasting	$ 0.40	per	tonne
Filter fabric (installed)	$ 5.00	per	m2
Seed, fertilizer, spreading	$ 0.55	per	m2
Rehab roads to sites	$ 7,000.00	per	site
Clay amendment cost and delivery	$ 160.00	per	tonne
Debris cleanup	$ 12,405.00	per	site
General labor (a)	$ 61.10	per	hr

Percentage of Direct Cost

Project Management & Field Supervision	7.0	%
Profit & Overhead	10.0	%
Insurance & Bonding	1.4	%
Field Engineering, QA & Surveying	7.0	%
Mob & Demob	15.0	%
Living Allowances	8.0	%
Taxes	7.0	%
Contingency	0.0	%

Equipment (b)

740 Truck 26 m^3/hr	$ 232.82	per	hr
740 Truck m^3/hr	$ 232.82	per	hr
980 Loader 240 m^3/hr	$ 247.02	per	hr
D9 Dozer 800 m^3/hr	$ 323.73	per	hr
D9 Dozer 1200 m^3/hr	$ 323.73	per	hr
D6 Dozer 320 m^3/hr	$ 177.22	per	hr
365 Excavator 400 m^3/hr	$ 403.48	per	hr
966F Loader 336 m^3/hr	$ 157.55	per	hr
325 Excavator 50 m^3/hr	$ 189.87	per	hr
325 Excavator 76 m^3/hr	$ 189.87	per	hr
325 Excavator 276 m^3/hr	$ 189.87	per	hr
Case 580 Backhoe 40 m^3/hr	$ 83.43	per	hr
D8 Dozer 120 m^3/hr	$ 248.00	per	hr
D7 Dozer 100 m^3/hr	$ 213.15	per	hr
Tractor & Disk 400 m^3/hr	$ 253.00	per	hr

(a) Rates for general (non-operator) labor on site are from the 2010 Yukon "Schedule of rates for federal construction contracts" with a loading factor of 112% added. The federal rate is $28.82/hr, which becomes $61.10 with the loading.

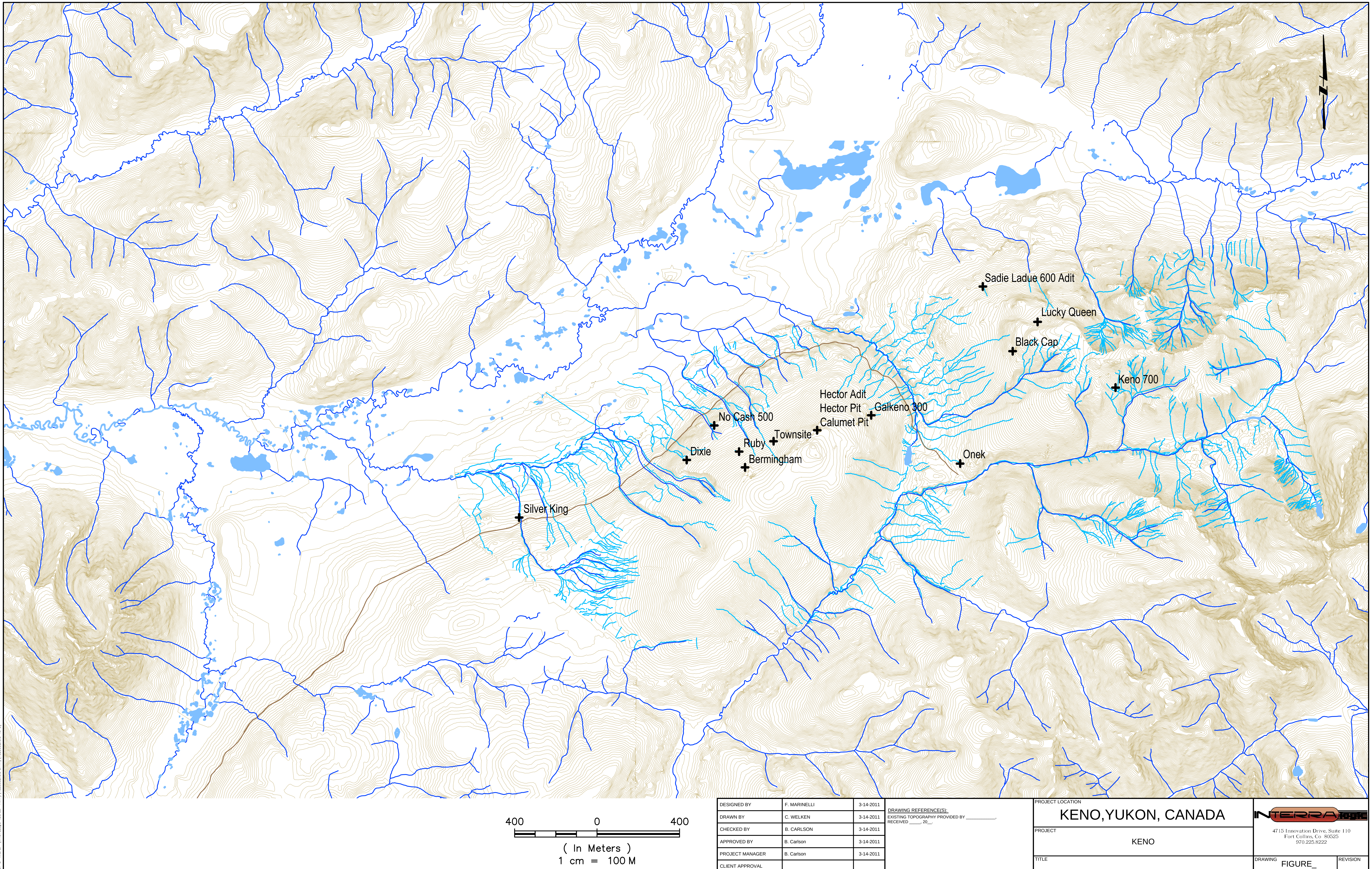
(b) "All found" equipment rates from the 2010/2011 BC Blue Book are used, increased by 15% for Yukon Rates. Operator costs are included in these rates

Table 4 Level 5 Cost Estimate for Required Reclamation Activities

Direct Required Costs											
Waste Rock Pile Name	**Waste Rock Moving Cost**	**Safety Berm Cost**	**Diversion Berm/Channel Cost**	**Pit Fill Growth Media/Seed Area Cost**	**Rip Rap Cost**	**Filter Fabric Cost**	**Clay Liner Cost**	**WRSA Seed Application Cost**	**Site Access Rehab**	**Site Debris Removal**	**Required Total Costs**
Bermingham Pit and (WRSA)	$ 64,762	$ 60,760	$ 6,422		$ 4,743	$ 4,590	$ -	$ 26,409	$ 7,000	$ 12,405	$ 188,000
Black Cap Pit and (WRSA)	$ 32,681	$ 28,899	$ 4,466		$ -	$ -	$ -	$ 18,344	$ 7,000	$ 12,405	$ 104,000
Calument Pit and (WRSA)	$ 17,040	$ 41,030	$ 5,521		$ 4,212	$ 4,090	$ -	$ 8,303	$ 7,000	$ 12,405	$ 100,000
Galkeno 300/Sime Pit (Sections A-D) and (WRSA)	$ 77,767	$ 81,238	$ 4,676		$ 10,679	$ 10,330	$ -	$ 34,209	$ 7,000	$ 12,405	$ 239,000
Hector Pit and (WRSA)	$ 133,955	$ 64,088	$ 7,057		$ 5,240	$ 5,085	$ -	$ 46,751	$ 7,000	$ 12,405	$ 282,000
Miller Pit and (WRSA)	$ -	$ 22,543	$ -		$ -	$ -	$ -	$ -	$ 7,000	$ 12,405	$ 42,000
No Cash 100 Pit and (WRSA)	$ 4,539	$ 15,220	$ 1,012		$ 10,414	$ 9,090	$ -	$ 4,311	$ 7,000	$ 12,405	$ 64,000
Onek Pit and (WRSA)	$ 35,170	$ 78,960	$ 2,159	$ 211,623	$ 1,559	$ 1,515	$ -	$ 32,663	$ 7,000	$ 12,405	$ 384,000
Sadie LaDue (Wernecke) Pit and (WRSA)	$ 1,495	$ 51,285	$ 11,634		$ 10,878	$ 10,245	$ -	$ 22,810	$ 7,000	$ 12,405	$ 128,000
Shamrock Pit and (WRSA)	$ -	$ 43,033	$ -		$ -	$ -	$ -	$ -	$ 7,000	$ 12,405	$ 63,000
Silver King Pit and (WRSA)	$ 9,096	$ 22,464	$ 3,516	$ 118,688	$ 1,592	$ 1,540	$ -	$ 10,395	$ 7,000	$ 12,405	$ 187,000
Dixie Adit and (WRSA)	$ 855	$ -	$ -		$ -	$ -	$ -	$ 1,894	$ 7,000	$ 12,405	$ 23,000
Elsa +50 Adit and (WRSA)	$ -	$ -	$ 1,234		$ 49,980	$ 7,510	$ -	$ -	$ 7,000	$ 12,405	$ 79,000
Galkeno 300 Adit (Section E) and (WRSA)	$ 11,038	$ -	$ -		$ -	$ -	$ -	$ 5,393	$ 7,000	$ 12,405	$ 36,000
Galkeno 900 Adit and (WRSA)	$ -	$ -	$ 888		$ 663	$ 850	$ -	$ 6,366	$ 7,000	$ 12,405	$ 29,000
Hector 400 Adit and (WRSA)	$ 39,544	$ -	$ -		$ -	$ -	$ -	$ 27,533	$ 7,000	$ 12,405	$ 87,000
Husky Shaft and (WRSA)	$ -	$ -	$ -		$ -	$ -	$ -	$ 11,050	$ 7,000	$ 12,405	$ 31,000
Husky SW Shaft and (WRSA)	$ -	$ -	$ -		$ -	$ -	$ -	$ 14,044	$ 7,000	$ 12,405	$ 34,000
Keno 700 Adit and (WRSA)	$ 20,886	$ -	$ 4,565		$ 96,510	$ 25,865	$ -	$ 2,013	$ 7,000	$ 12,405	$ 170,000
Lucky Queen 500 Adit and (WRSA)	$ 12,364	$ -	$ 3,282		$ -	$ -	$ -	$ 6,654	$ 7,000	$ 12,405	$ 42,000
No Cash 500 Adit and (WRSA)	$ 9,727	$ -	$ 1,456		$ 5,141	$ 4,630	$ 7,596	$ 6,181	$ 7,000	$ 12,405	$ 55,000
Onek 400 Adit and (WRSA)	$ -	$ -	$ 1,110		$ 2,421	$ 3,175	$ -	$ 6,470	$ 7,000	$ 12,405	$ 33,000
Ruby Adit and (WRSA)	$ 8,910	$ -	$ 1,431		$ 2,355	$ 2,270	$ -	$ 2,929	$ 7,000	$ 12,405	$ 38,000
Sadie LaDue 600 Pit and (WRSA)	$ -	$ -	$ 1,147		$ 895	$ 1,175	$ -	$ -	$ 7,000	$ 12,405	$ 23,000
Silver King 100 Adit and (WRSA)	$ 593	$ -	$ 185		$ 66,993	$ 13,195	$ -	$ 2,150	$ 7,000	$ 12,405	$ 103,000
Townsite Adit and (WRSA)	$ 8,272	$ -	$ -		$ -	$ -	$ -	$ 4,678	$ 7,000	$ 12,405	$ 33,000
									Sub Total of Direct Costs		**$ 2,597,000**

Table 5 Level 5 Cost Estimate for Optional Reclamation Activities

Direct Optional Costs			
Waste Rock Pile Name	Waste Rock Moving Cost	WRSA Vegegational Cover	WRSA Infiltration Cover inclucing Clay Amendment
Bermingham Pit and (WRSA)	$ -	$ -	
Black Cap Pit and (WRSA)	$ -	$ -	
Calument Pit and (WRSA)	$ -	$ -	
Galkeno 300/Sime Pit (Sections A-D) and (WRSA)	$ -	$ -	
Hector Pit and (WRSA)	$ -	$ -	
Miller Pit and (WRSA)	$ -	$ -	
No Cash 100 Pit and (WRSA)	$ -	$ -	
Onek Pit and (WRSA)	$ -	$ -	
Sadie LaDue (Wernecke) Pit and (WRSA)	$ -	$ -	
Shamrock Pit and (WRSA)	$ -	$ -	
Silver King Pit and (WRSA)	$ -	$ -	
Dixie Adit and (WRSA)	$ -	$ -	
Elsa +50 Adit and (WRSA)	$ -	$ -	
Galkeno 300 Adit (Section E) and (WRSA)	$ -	$ -	
Galkeno 900 Adit and (WRSA)	$ -	$ -	
Hector 400 Adit and (WRSA)	$ -	$ 458,553	$ 1,289,195
Husky Shaft and (WRSA)	$ 13,562	$ 184,039	$ 517,415
Husky SW Shaft and (WRSA)	$ 17,236	$ 233,899	$ 657,593
Keno 700 Adit and (WRSA)	$ -	$ -	
Lucky Queen 500 Adit and (WRSA)	$ -	$ -	
No Cash 500 Adit and (WRSA)	$ -	$ -	
Onek 400 Adit and (WRSA)	$ 7,940	$ 107,755	$ 302,946
Ruby Adit and (WRSA)	$ -	$ -	
Sadie LaDue 600 Pit and (WRSA)	$ -	$ -	
Silver King 100 Adit and (WRSA)	$ -	$ -	
Townsite Adit and (WRSA)	$ -	$ 134,740	$ 219,028



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________,
RECEIVED _____, 20__.

DATUM: NAD83

SCALE: 1 cm = 100 m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
OVERALL PLAN

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DRAWING FIGURE_

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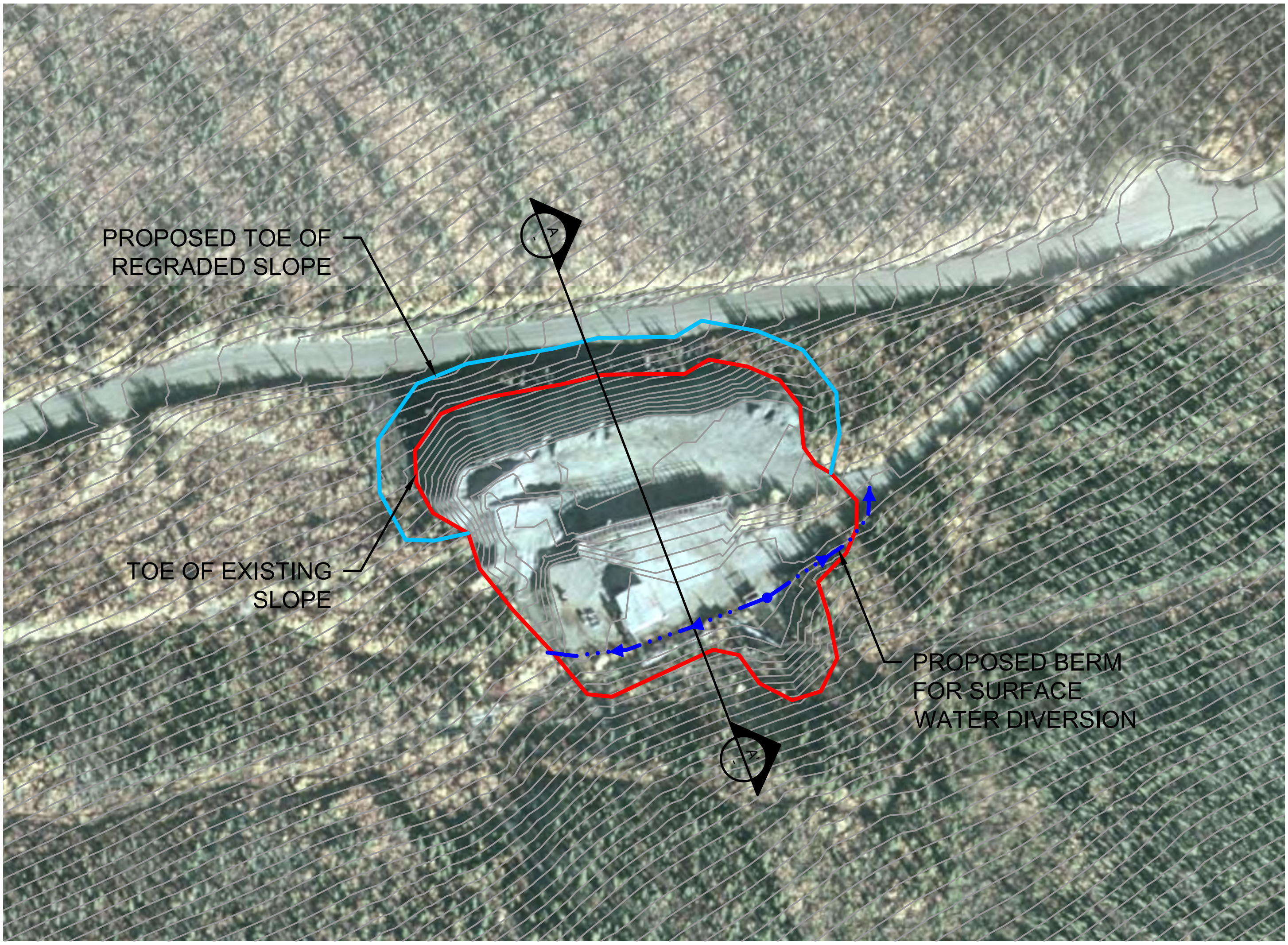
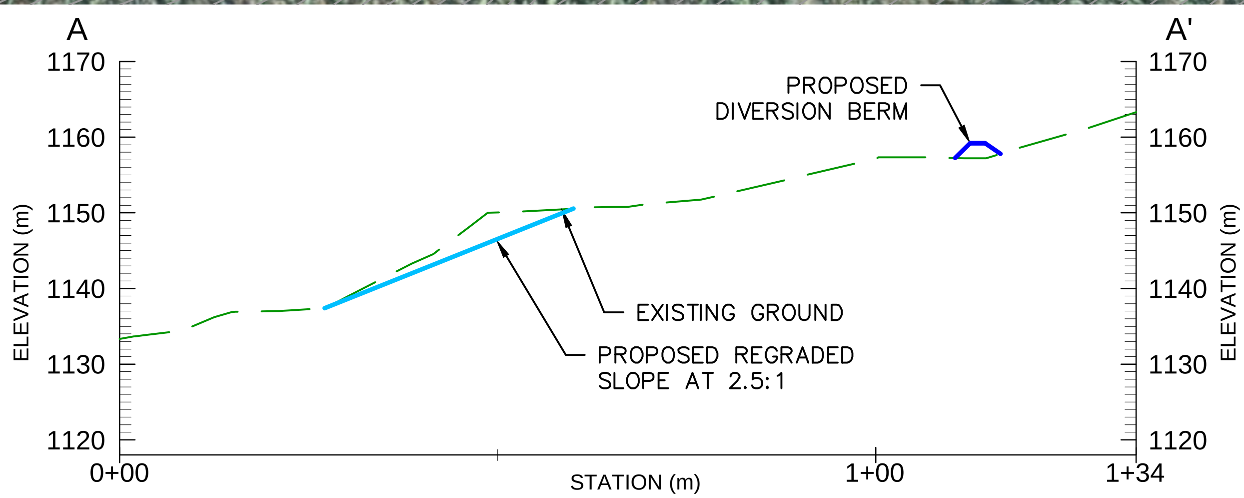
FILE NAME 102000_Overall Map





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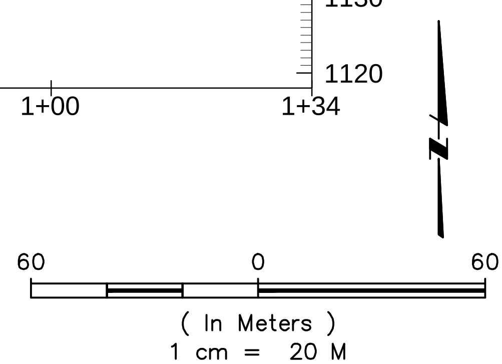

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

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CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

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PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
RUBY
PLAN AND SECTION A

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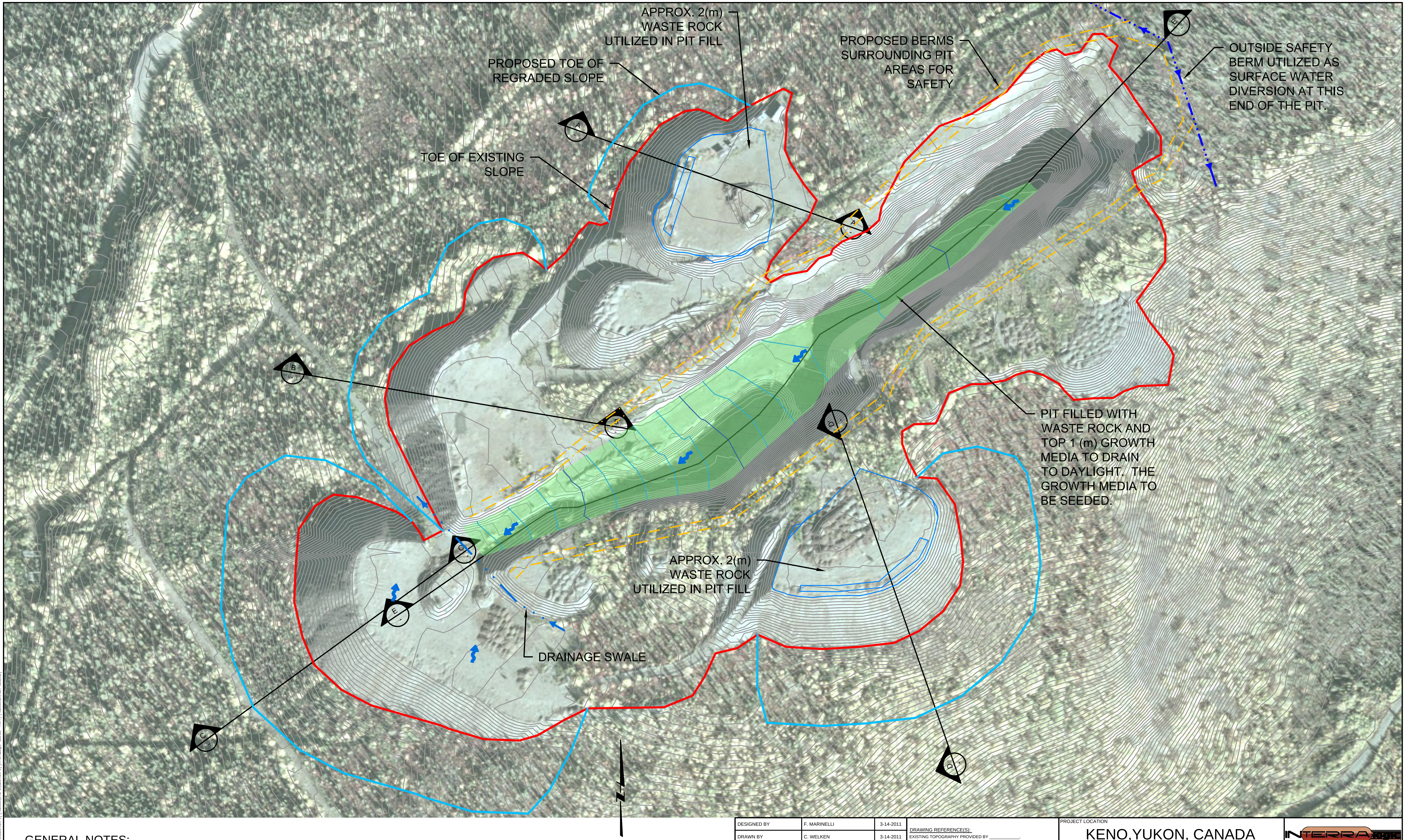

GENERAL NOTES:

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2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

60 0 60

(In Meters)
1 cm = 20 M

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 20 m

PROJECT LOCATION
KENO,YUKON, CANADA

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ONEK
PLAN

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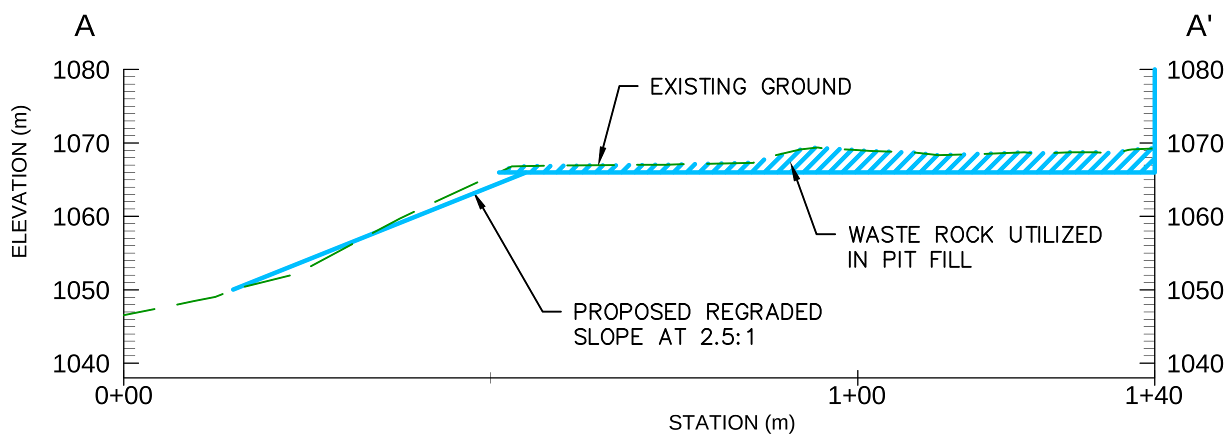
DRAWING FIGURE_ REVISION

FILE NAME 102000_Onek



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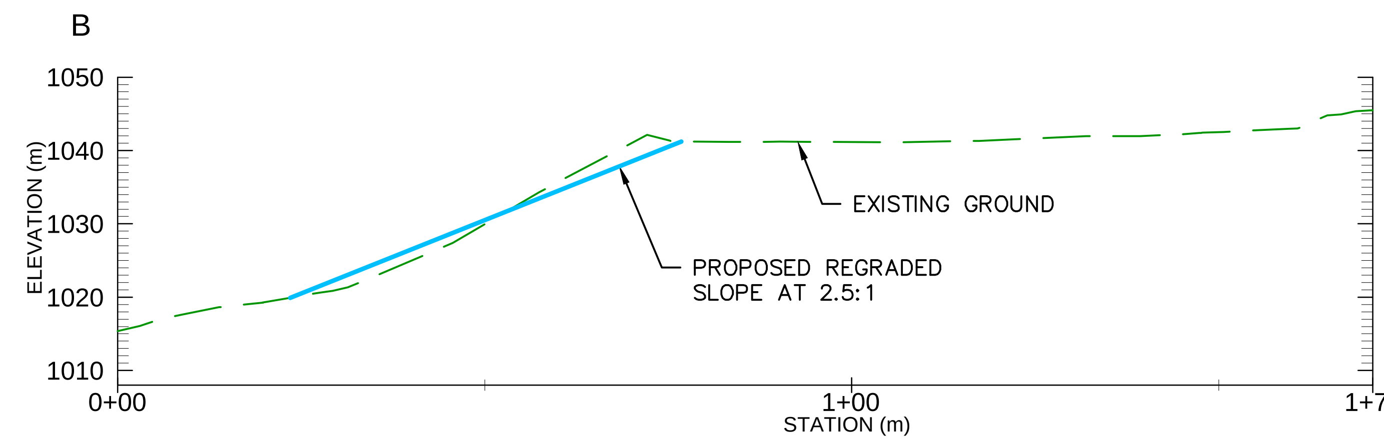

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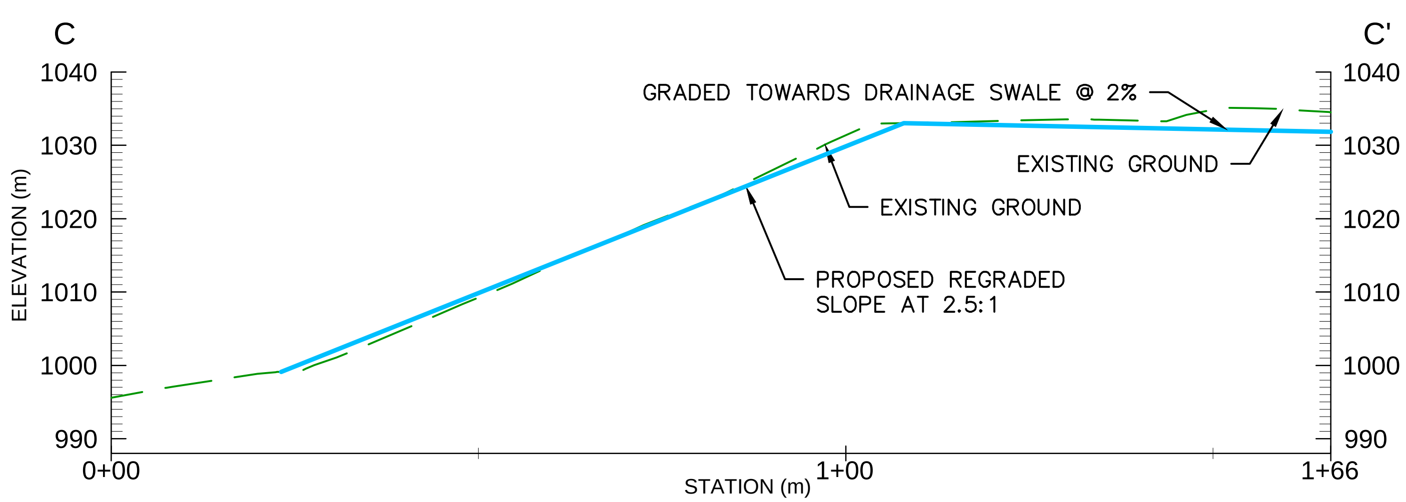

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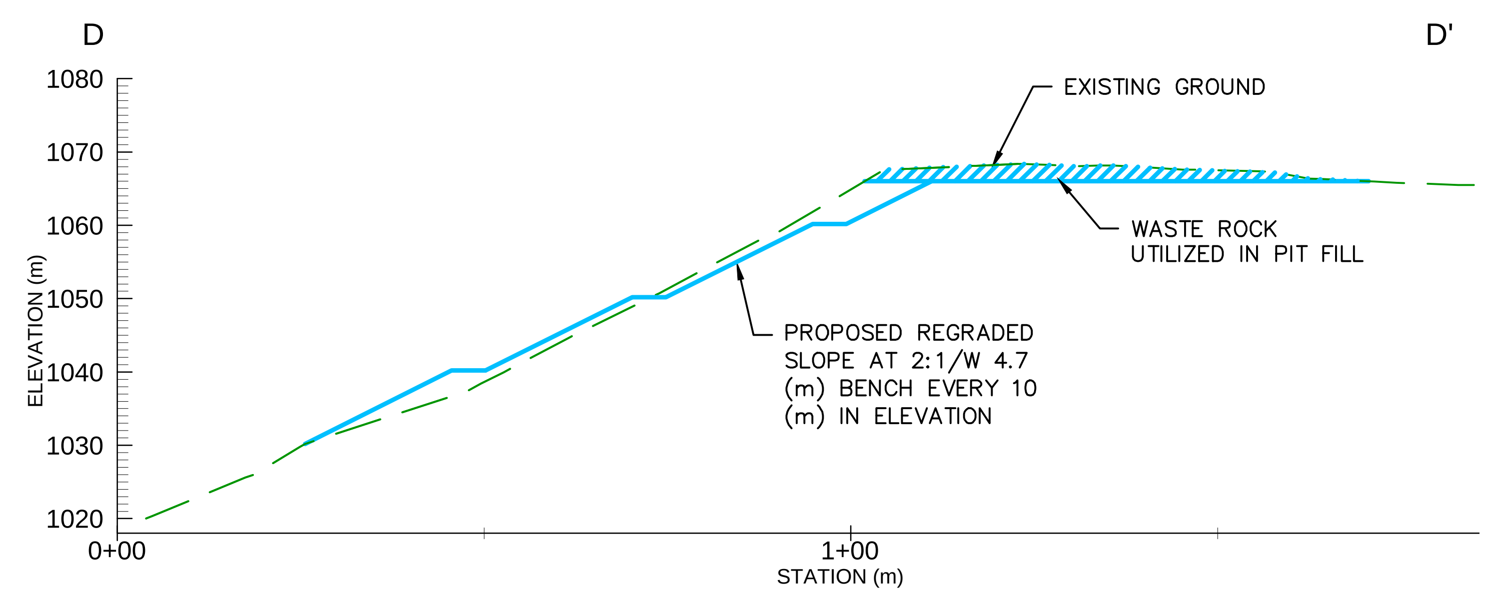

SECTION D-D'

DESIGNED BY	C.GREEN	3-14-2011
DRAWN BY	C. GREEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________,
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DATUM: NAD83
SCALE:

PROJECT LOCATION
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PROJECT
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ONEK
SECTIONS A-D

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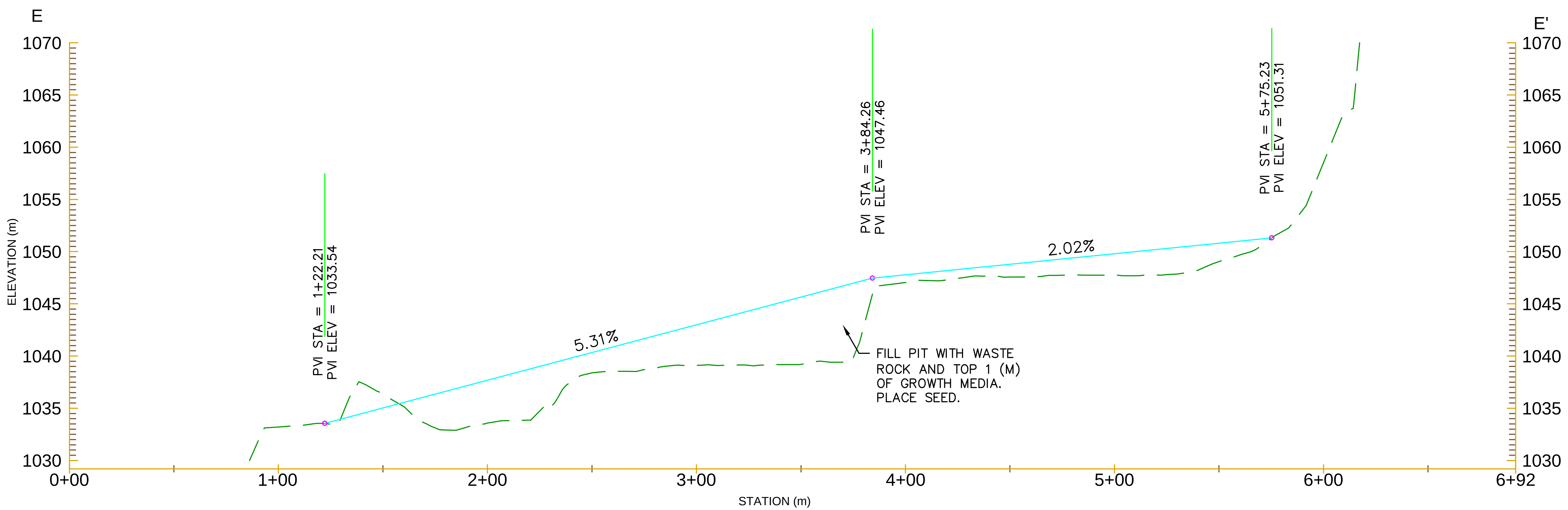
REVISION
FILE NAME 102000_Onek



SECTION E-E'

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DRAWN BY	C. GREEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
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DATUM: NAD83 SCALE:

PROJECT LOCATION
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PROJECT
KENO

TITLE
ONEK
SECTION E

INTERRA

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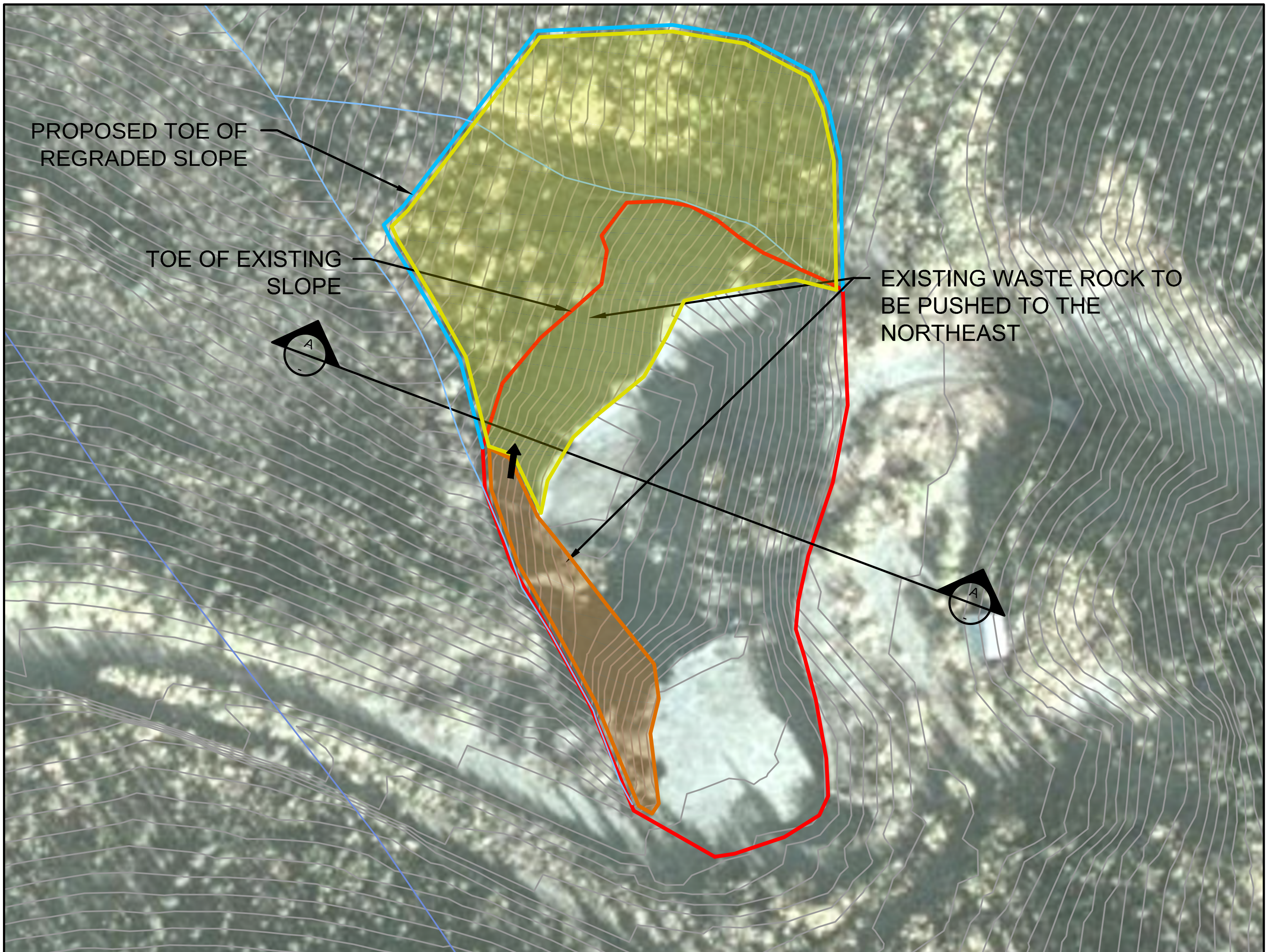
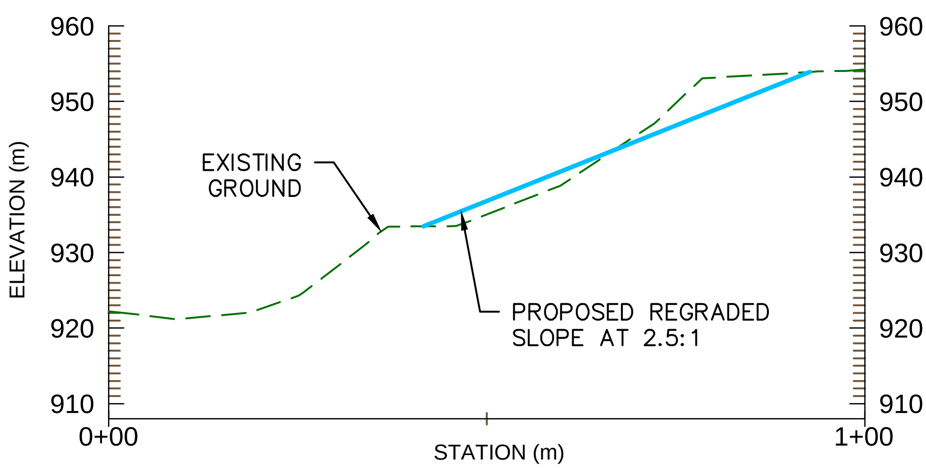
REVISION
FILE NAME 102000_Onek

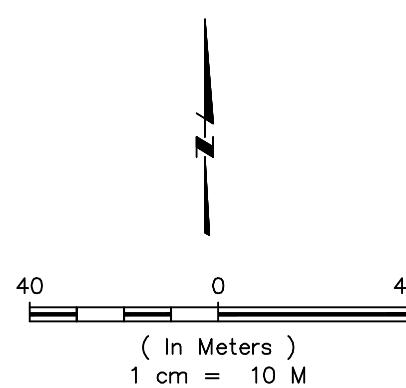




SECTION A-A'

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.



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DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
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DATUM: NAD83 SCALE: 1 cm = 10 m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
NO CASH 500
PLAN & SECTION A

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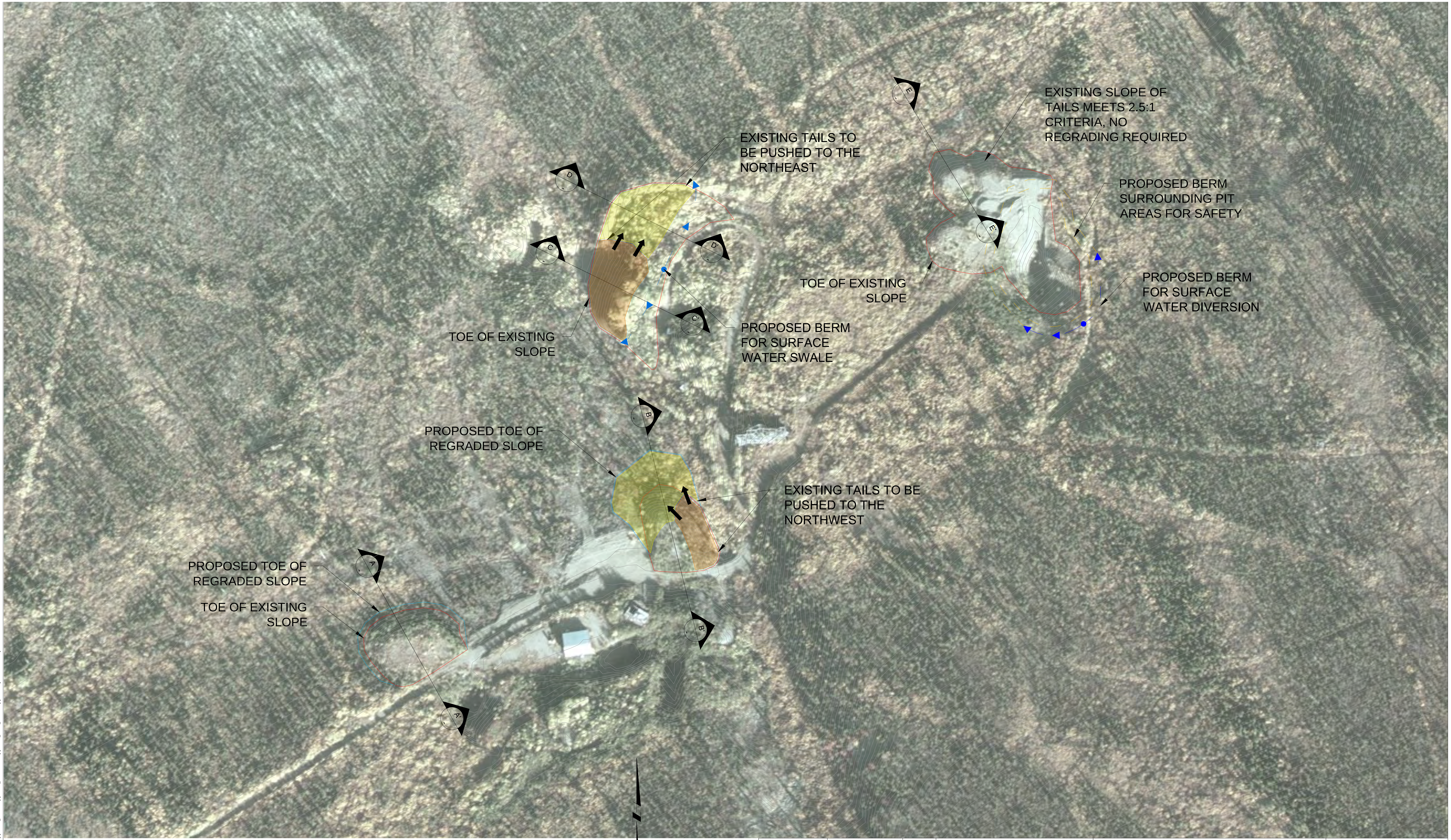

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

60 0 60

(In Meters)
1 cm = 20 M

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CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

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EXISTING TOPOGRAPHY PROVIDED BY ___________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 20 m

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NO CASH 100
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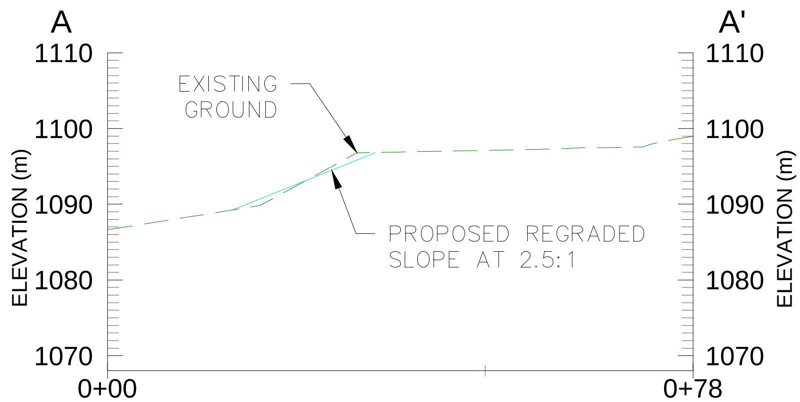
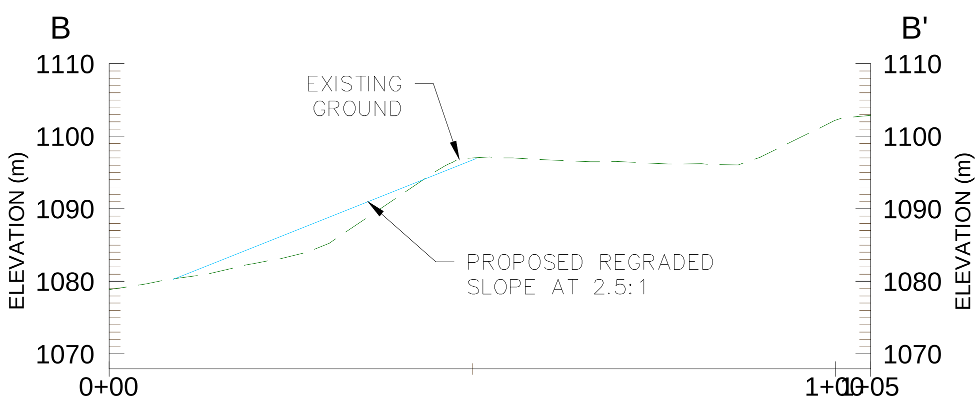
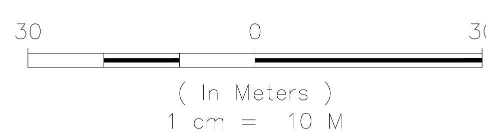
FILE NAME 102000_No Cash 100



SECTION A-A'



SECTION B-B'

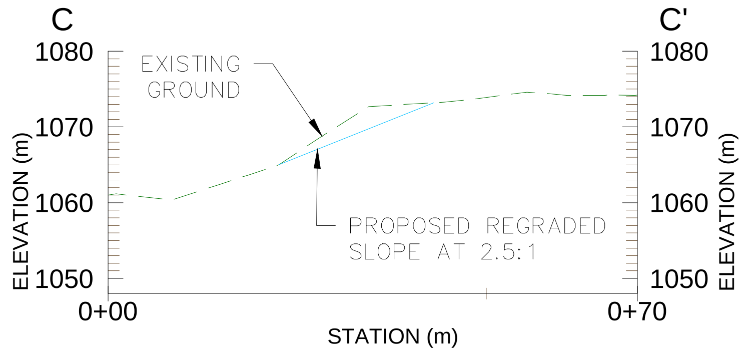


DESIGNED BY	F. MARINELLI	3-14-2011	DRAWING REFERENCE(S): EXISTING TOPOGRAPHY PROVIDED BY ____________. RECEIVED _____, 20__.	PROJECT LOCATION KENO,YUKON, CANADA
DRAWN BY	C. WELKEN	3-14-2011		
CHECKED BY	B. CARLSON	3-14-2011		PROJECT KENO
APPROVED BY	B. Carlson	3-14-2011		
PROJECT MANAGER	B. Carlson	3-14-2011		TITLE NO CASH 100 PROFILES A & B
CLIENT APPROVAL				
CLIENT REFERENCE NO.			DATUM: NAD83 SCALE: 1 cm = 10 m	

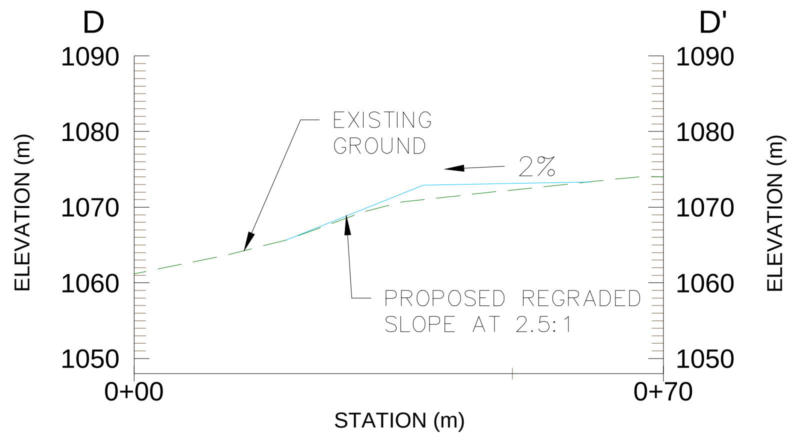
INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING: FIGURE_
REVISION:
FILE NAME: 102000_No Cash 100

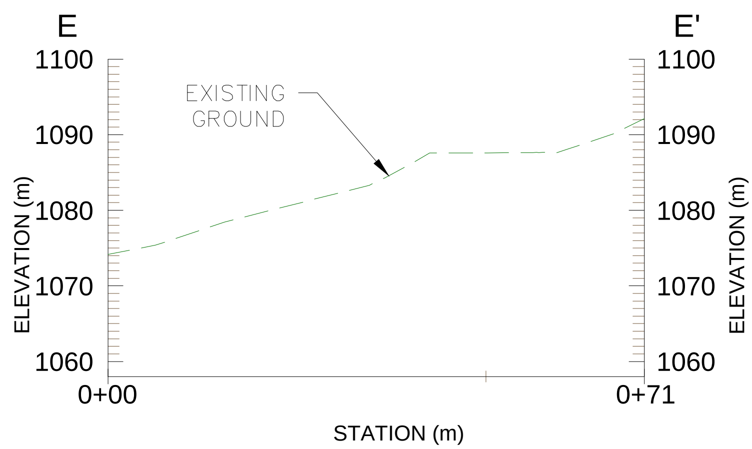
DRAWING FILENAME: C:\Users\jashlin\appdata\local\temp\AcPublish_488\102000_No Cash 100.dwg LAYOUT NAME: NO CASH 100_PROFILE DATE: Mar 25, 2011 - 10:10pm CAD OPERATOR: ACAD
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xGIS DATA] [102000_EXHIBIT LEGEND] [102000_xTOPO_SECTION 5] [InTerraLogic-xborder-11x17]



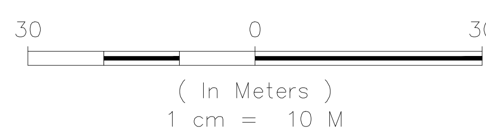
SECTION C-C'



SECTION D-D'



SECTION E-E'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 10 m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
NO CASH 100
PROFILES C, D & E

INTERRAlogic
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Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_No Cash 100

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

N

60 0 60

(In Meters)
1 cm = 20 M

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 20 m

PROJECT LOCATION
KENO,YUKON, CANADA

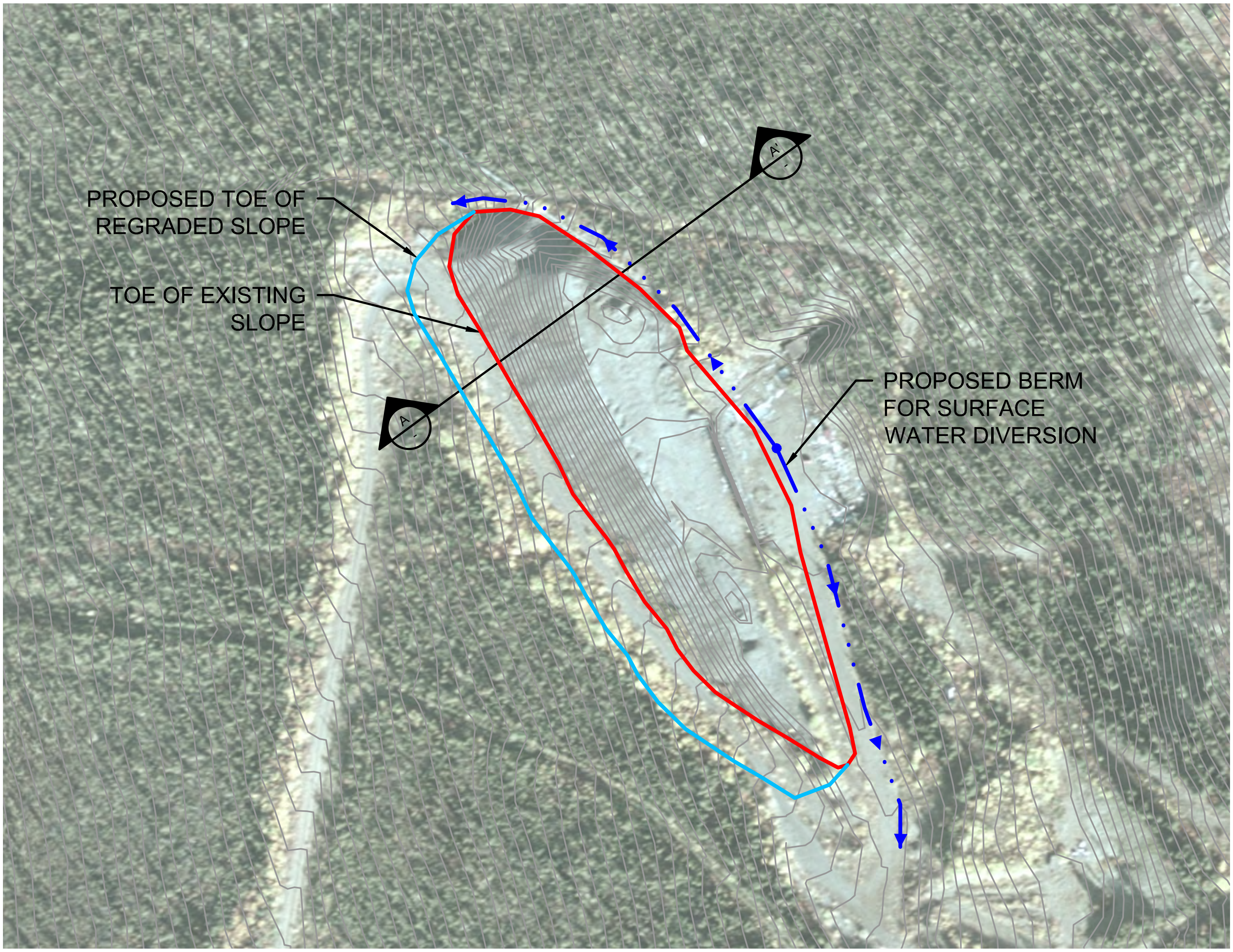
PROJECT
KENO

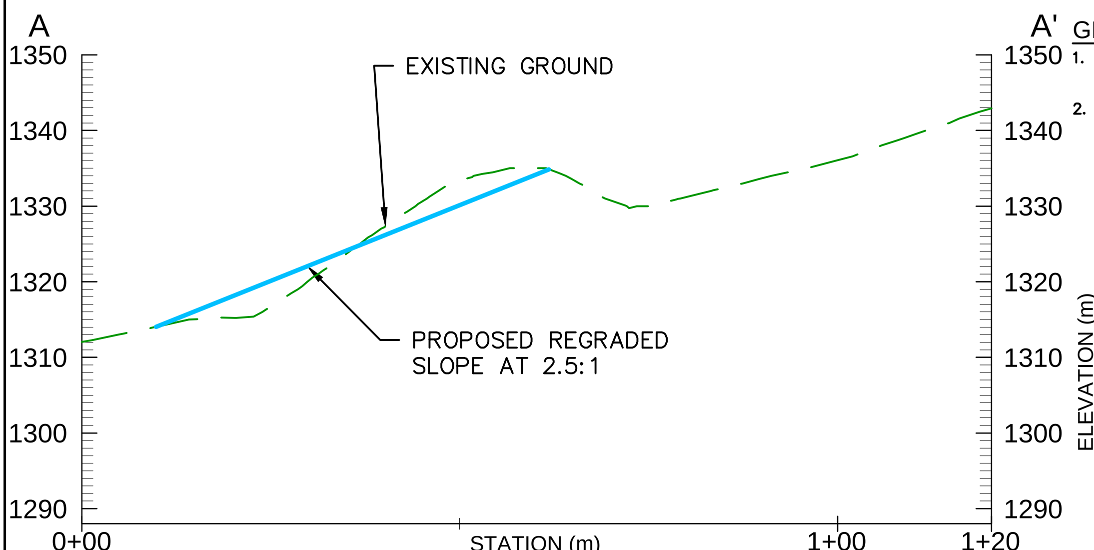
TITLE
MILLER PIT
PLAN

INTERRALOGIC
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Miller

DRAWING FILENAME: I:\Projects\102000 – Keno-Alexco\Keno Cad\Grad\102000_Miller.dwg LAYOUT NAME: Miller Pit DATE: Mar 25, 2011 – 6:51pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [102000_EXHIBIT LEGEND]

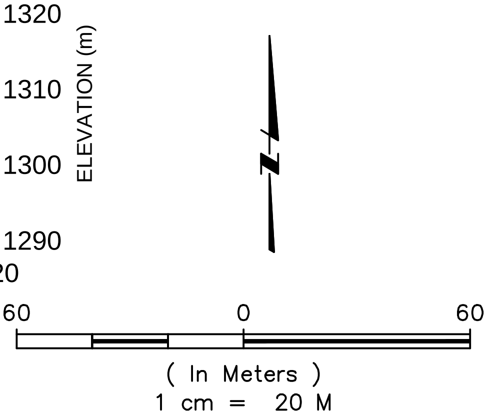




SECTION A-A'

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 20m

PROJECT LOCATION
KENO,YUKON, CANADA

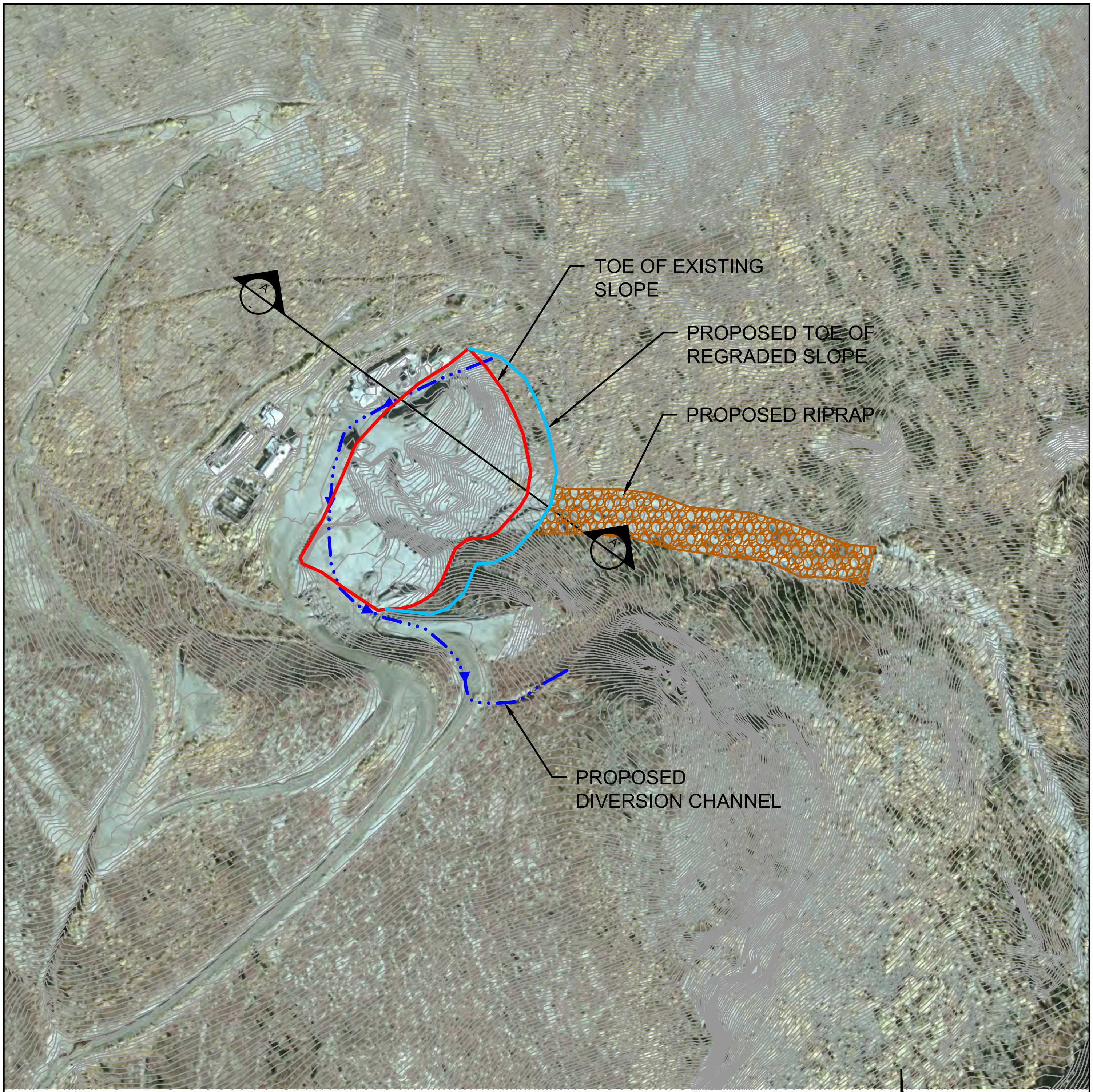
PROJECT
KENO

TITLE
LUCKY QUEEN
PLAN & SECTION A

INTERRAlogic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Lucky Queen

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Lucky Queen.dwg LAYOUT NAME: LUCKY QUEEN PLAN SECTION A DATE: Mar 25, 2011 - 8:20pm CAD OPERATOR: ACAD
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [102000_EXHIBIT LEGEND]



N

100 0 100

(In Meters)
1 cm = 33 M

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 33 m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
KENO 700
PLAN

INTERRA

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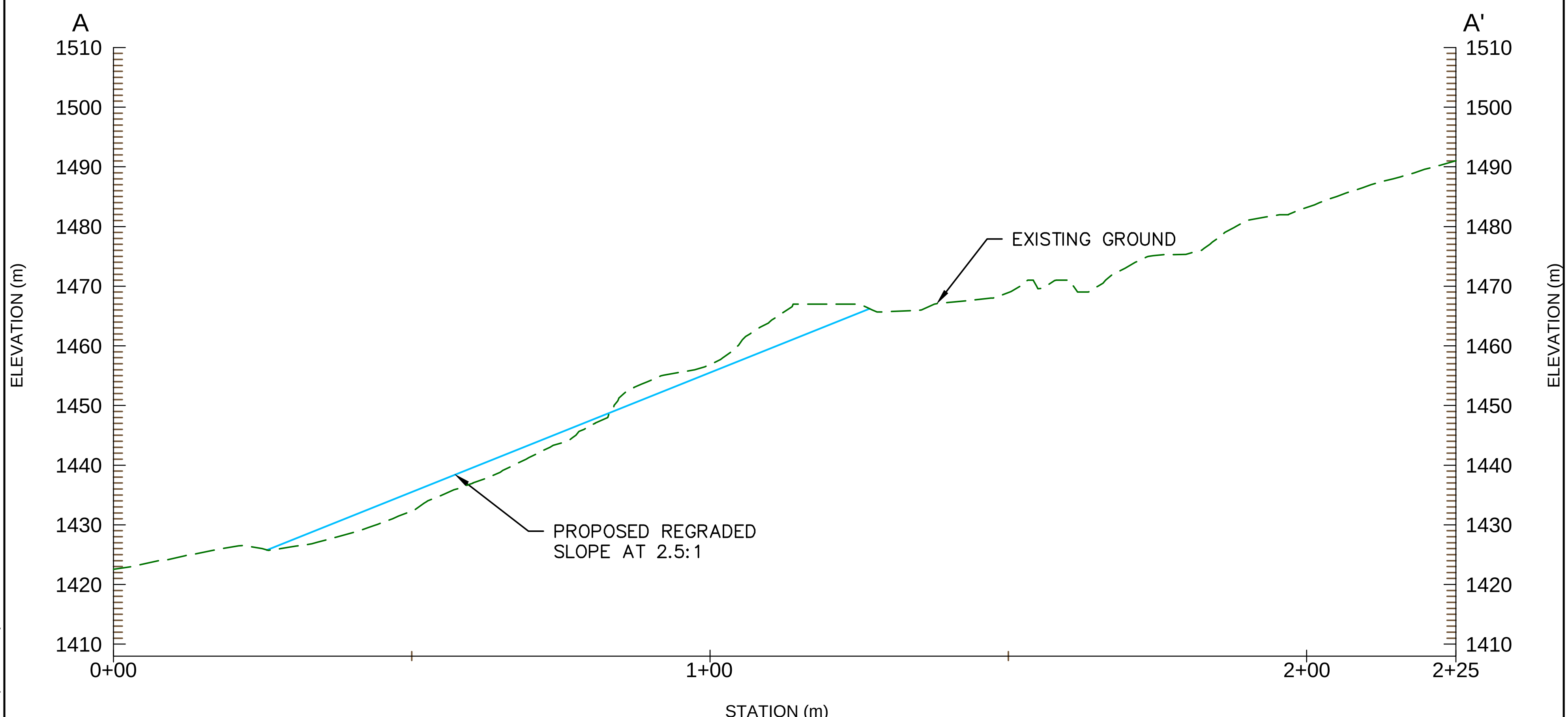
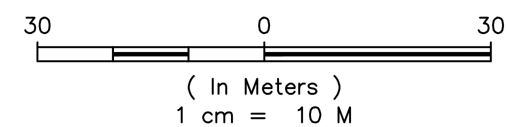
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Keno 700 Dump



SECTION A-A'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ___________,
RECEIVED _____, 20__.

DATUM: NAD83 | SCALE: 1 cm = 10m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
KENO 700
SECTION A

INTERRALOGIC
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
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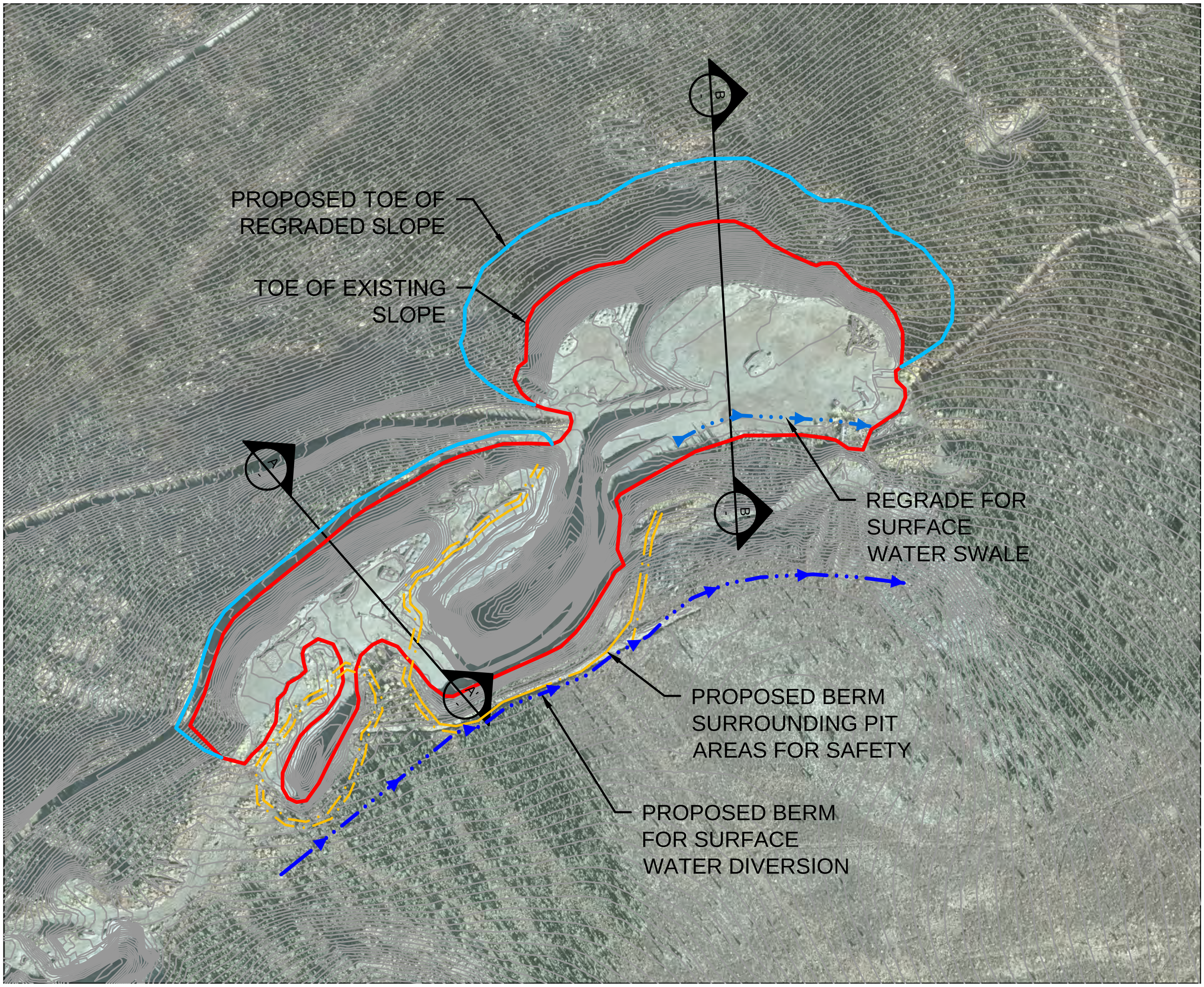
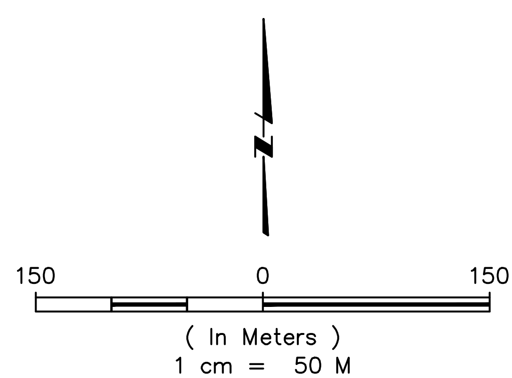
DRAWING	REVISION
FIGURE_	

FILE NAME
102000_Keno 700 Dump





GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83
SCALE: 1 cm = 50 m

PROJECT LOCATION
KENO,YUKON, CANADA

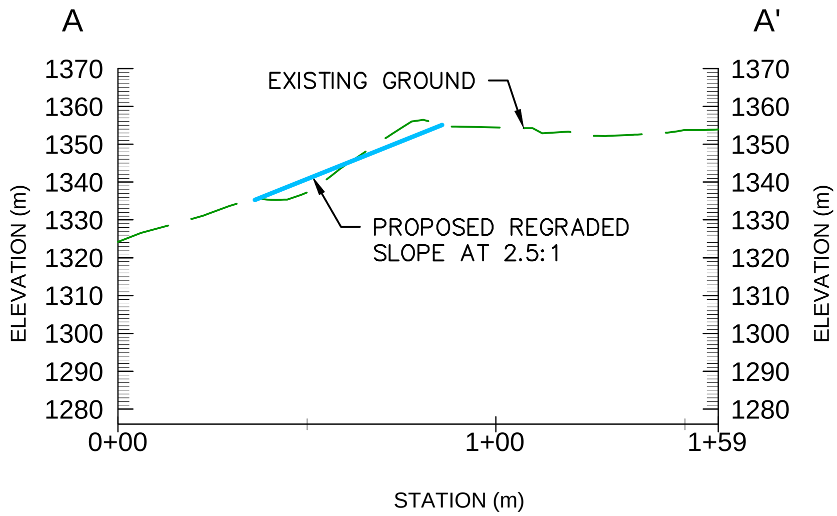
PROJECT
KENO

TITLE
HECTOR PIT
PLAN

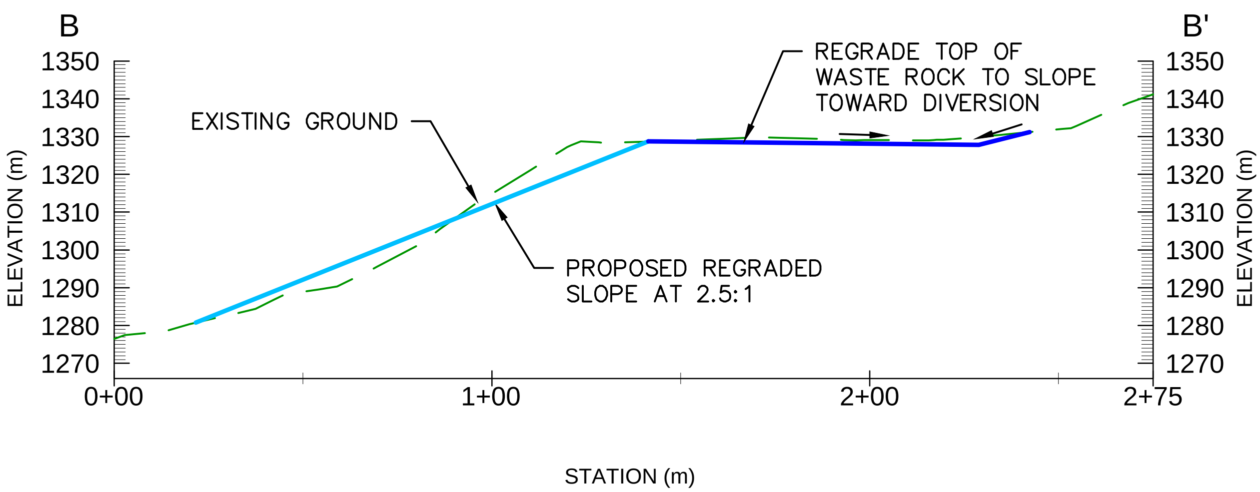
INTERRAlogic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING: FIGURE_
REVISION:
FILE NAME: 102000_Hector Pit

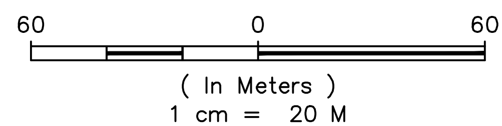
DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Hector Pit.dwg LAYOUT NAME: Hector Pit Plan and Section DATE: Mar 25, 2011 - 6:31pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [102000_EXHIBIT LEGEND]



SECTION A-A'



SECTION B-B'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 | SCALE: 1 cm = 20 m

PROJECT LOCATION
KENO,YUKON, CANADA

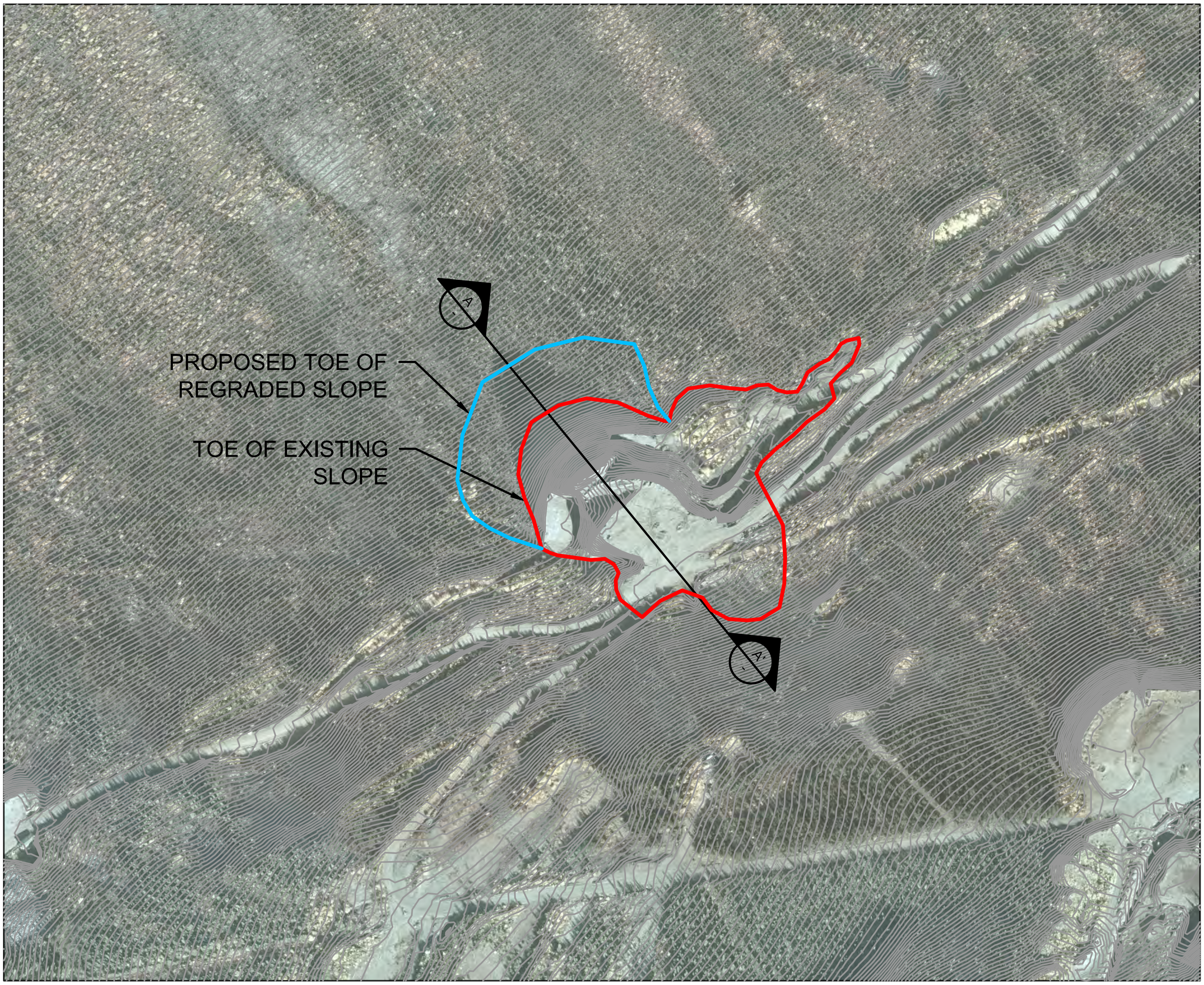
PROJECT
KENO

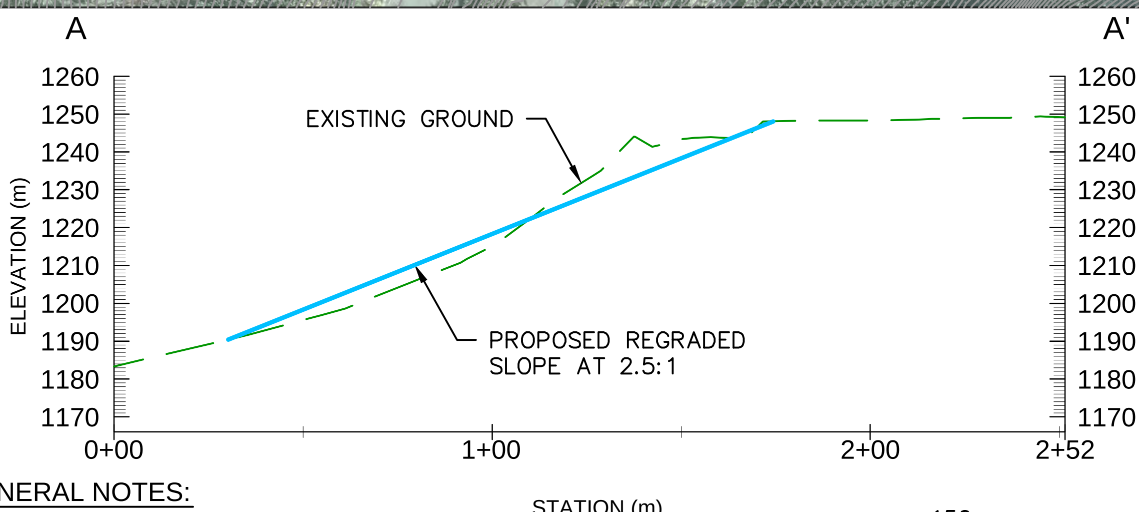
TITLE
HECTOR PIT
SECTIONS A & B

INTERRAlogic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

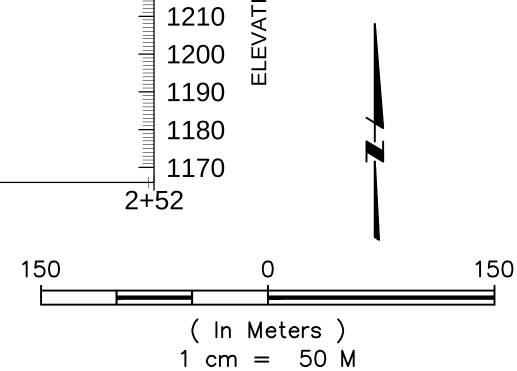
DRAWING FIGURE_ | REVISION

FILE NAME 102000_Hector Pit





SECTION A-A'



GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 | SCALE: 1 cm = 50 m

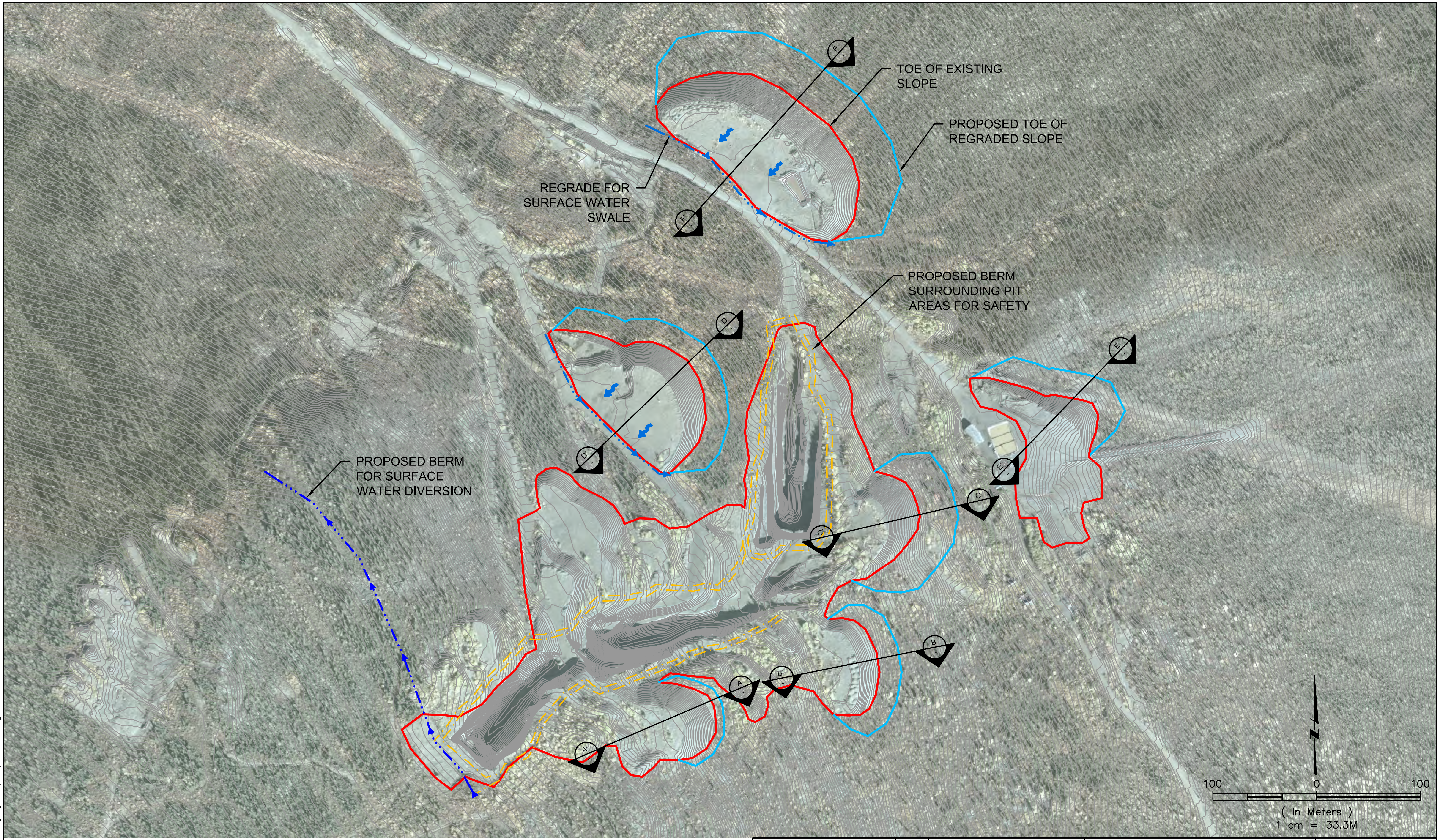
PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
HECTOR ADIT
PLAN & SECTION A

INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Hector Adit



GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 33 m

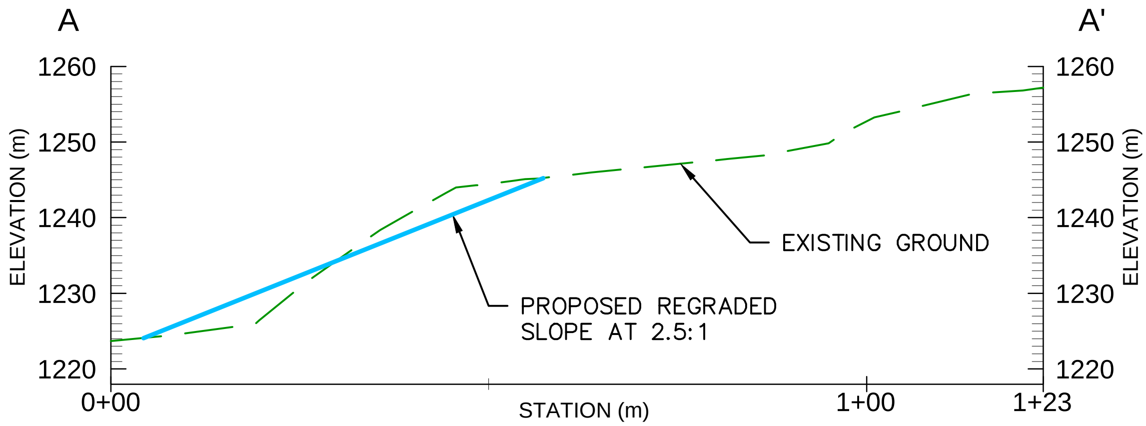
PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

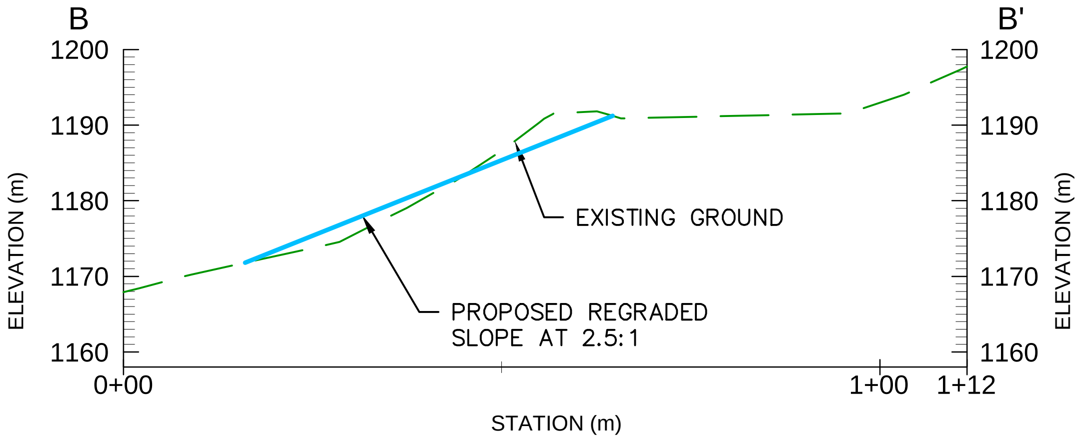
TITLE
GALKENO 300 AND SIME PLAN

INTERRA
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

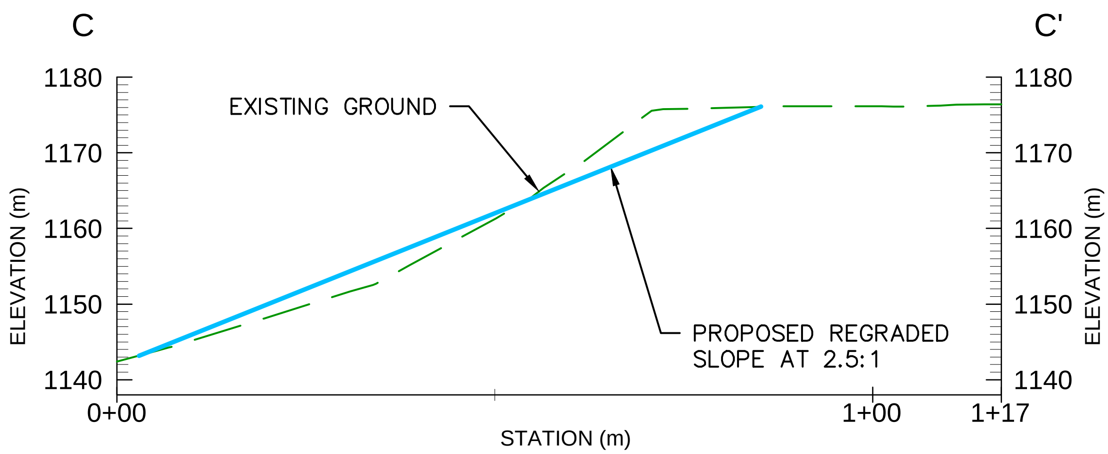
DRAWING FIGURE_ REVISION
FILE NAME 102000_Galkeno 300



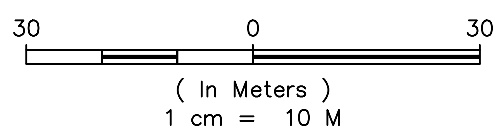
SECTION A-A'



SECTION B-B'



SECTION C-C'

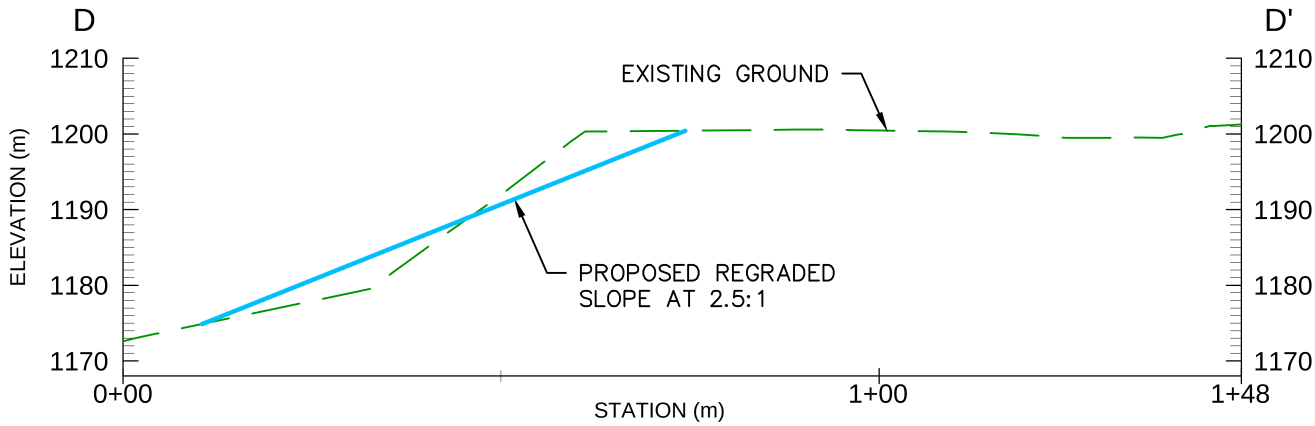


DESIGNED BY	F. MARINELLI	3-14-2011	DRAWING REFERENCE(S): EXISTING TOPOGRAPHY PROVIDED BY ___________, RECEIVED _____, 20__.	PROJECT LOCATION: KENO,YUKON, CANADA
DRAWN BY	C. WELKEN	3-14-2011		
CHECKED BY	B. CARLSON	3-14-2011		PROJECT: KENO
APPROVED BY	B. Carlson	3-14-2011		
PROJECT MANAGER	B. Carlson	3-14-2011		
CLIENT APPROVAL				TITLE: GALKENO 300 AND SIME SECTIONS A, B & C
CLIENT REFERENCE NO.			DATUM: NAD83 / SCALE: 1 cm = 10 m	

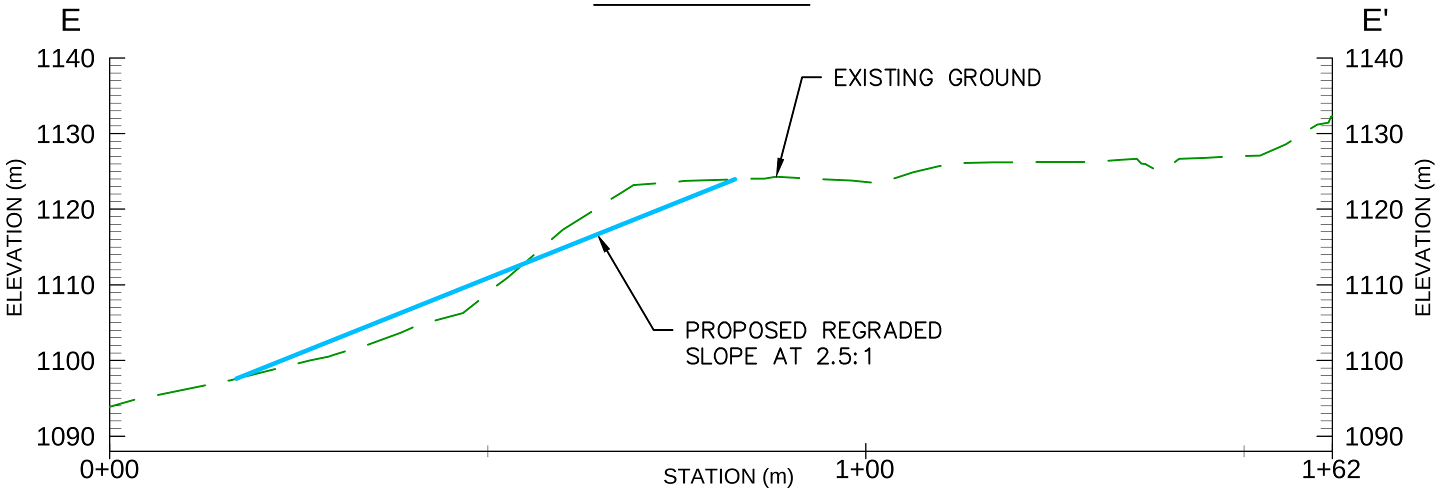
INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING: FIGURE_
REVISION:
FILE NAME: 102000_Galkeno 300

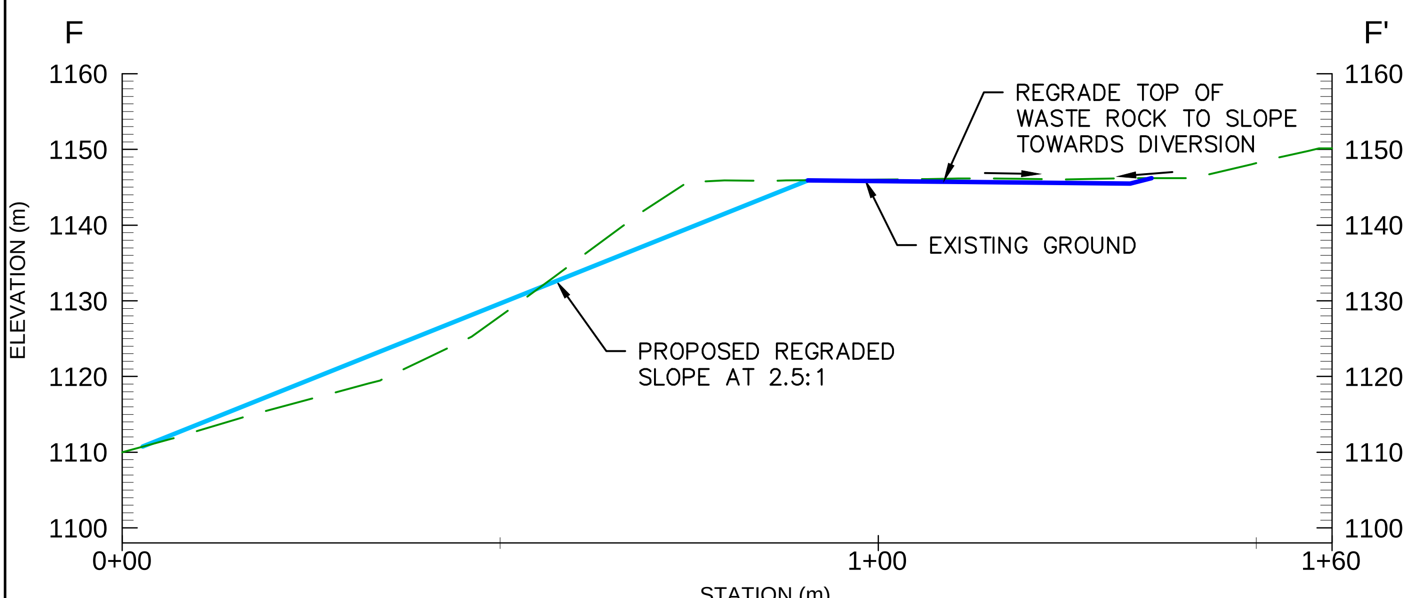
DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Galkeno 300.dwg LAYOUT NAME: Galkeno Section A -C DATE: Mar 25, 2011 - 8:30pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [InTerraLogic-xborder-11x17] [102000_EXHIBIT LEGEND]



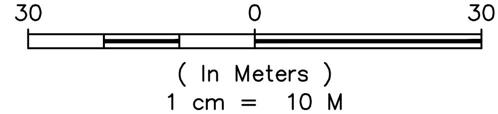
SECTION D-D'



SECTION E-E'



SECTION F-F'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 10 m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
GALKENO 300 AND SIME SECTIONS D, E & F

INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_ REVISION
FILE NAME 102000_Galkeno 300

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Galkeno 300.dwg LAYOUT NAME: Galkeno Section D-F DATE: Mar 25, 2011 - 8:30pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [InTerraLogic-xborder-11x17] [102000_EXHIBIT LEGEND]

GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 10 m

PROJECT LOCATION
KENO,YUKON, CANADA

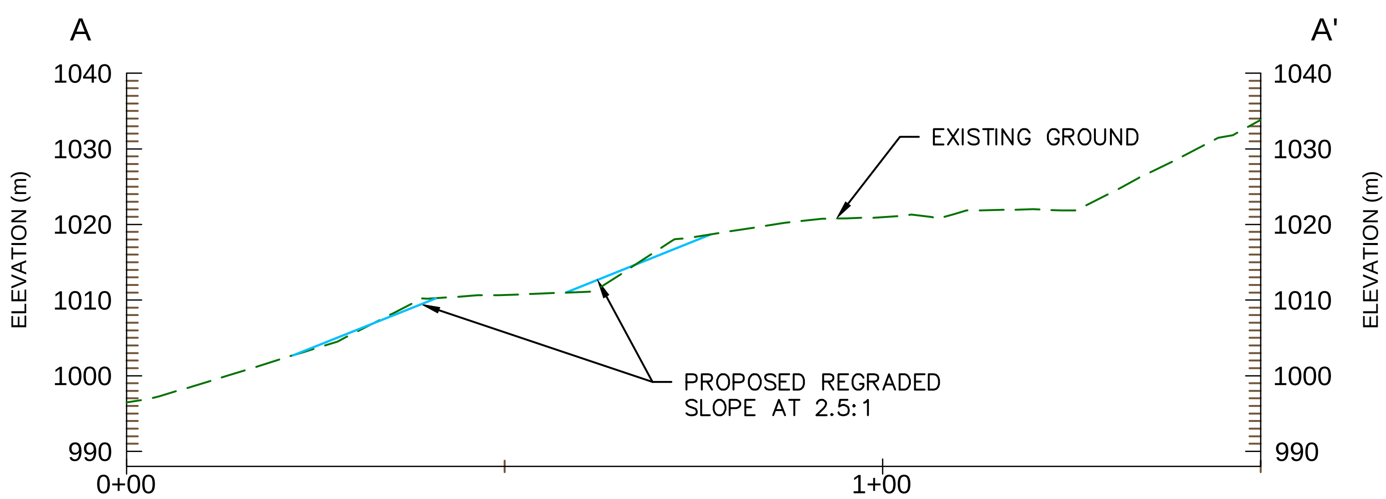
PROJECT
KENO

TITLE
DIXIE WASTE ROCK
PLAN

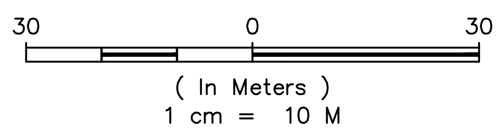
INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Dixie

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Dixie.dwg LAYOUT NAME: DIXIE_PLAN DATE: Mar 25, 2011 - 6:33pm CAD OPERATOR: ACAD
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_EXHIBIT LEGEND]



SECTION A-A'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 10 m

PROJECT LOCATION
KENO,YUKON, CANADA

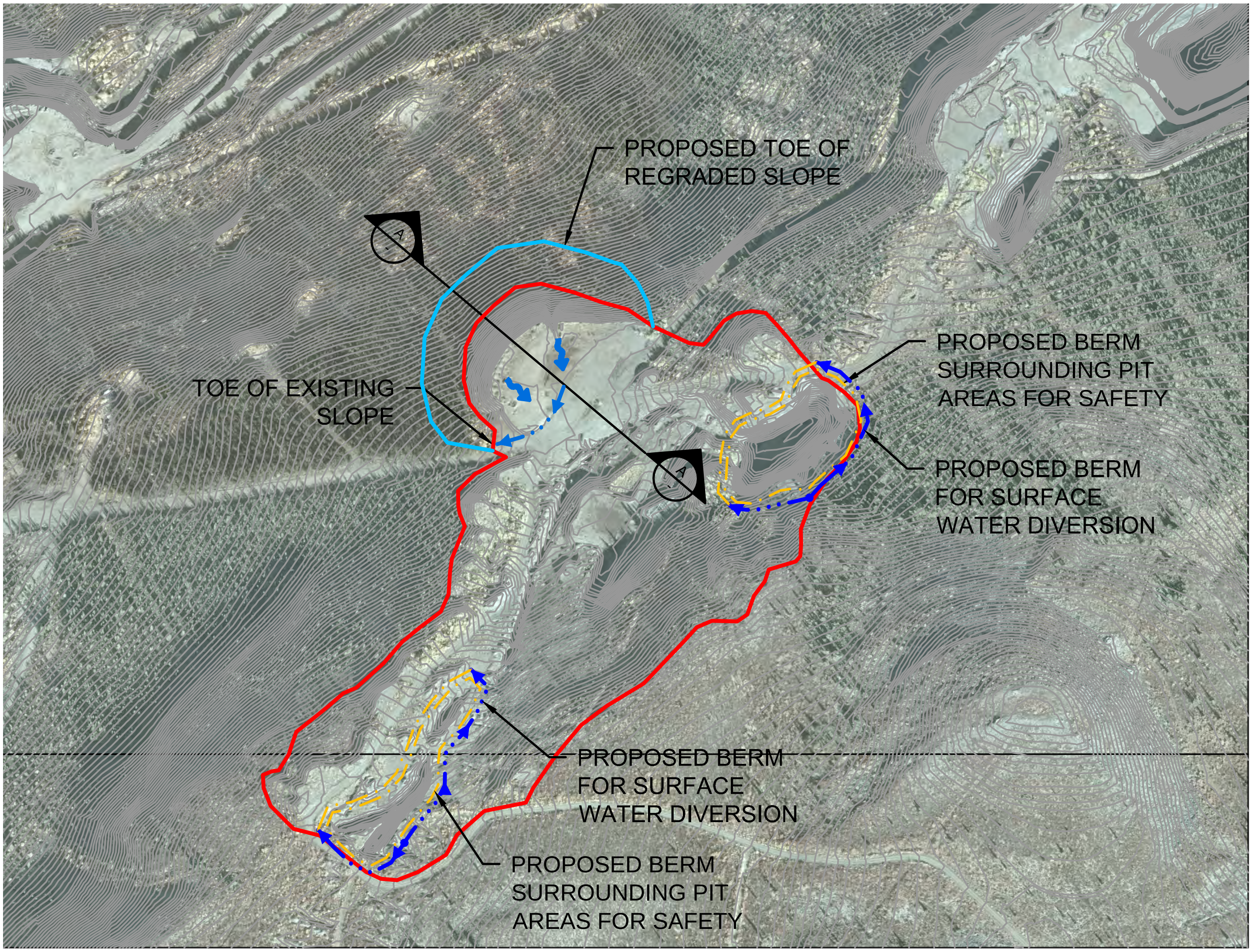
PROJECT
KENO

TITLE
DIXIE WASTE ROCK
SECTION A

INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

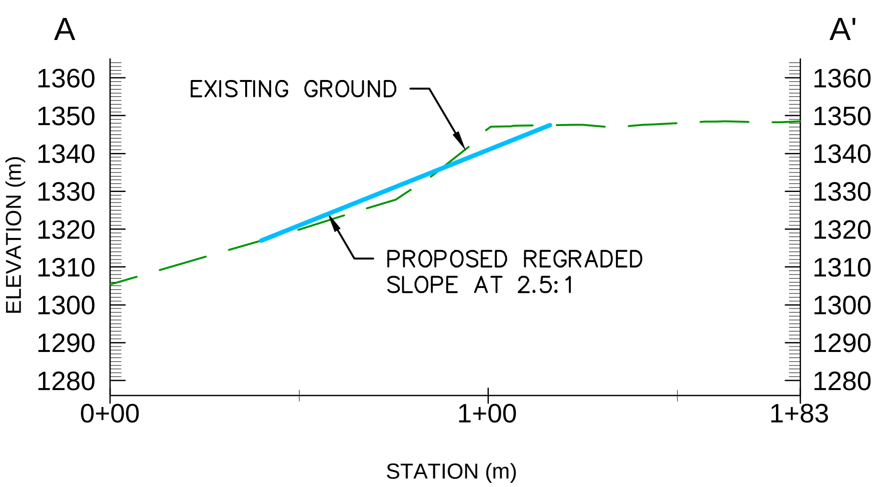
DRAWING: FIGURE_
REVISION:
FILE NAME: 102000_Dixie

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Dixie.dwg LAYOUT NAME: DIXIE_SECTION A DATE: Mar 25, 2011 - 6:46pm CAD OPERATOR: ACAD
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_EXHIBIT LEGEND]

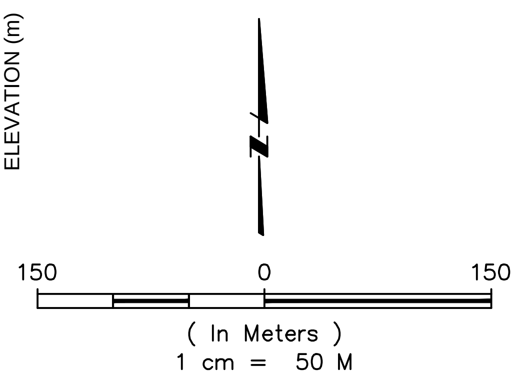


GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.



SECTION A-A'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83
SCALE: 1 cm = 50 m

PROJECT LOCATION
KENO,YUKON, CANADA

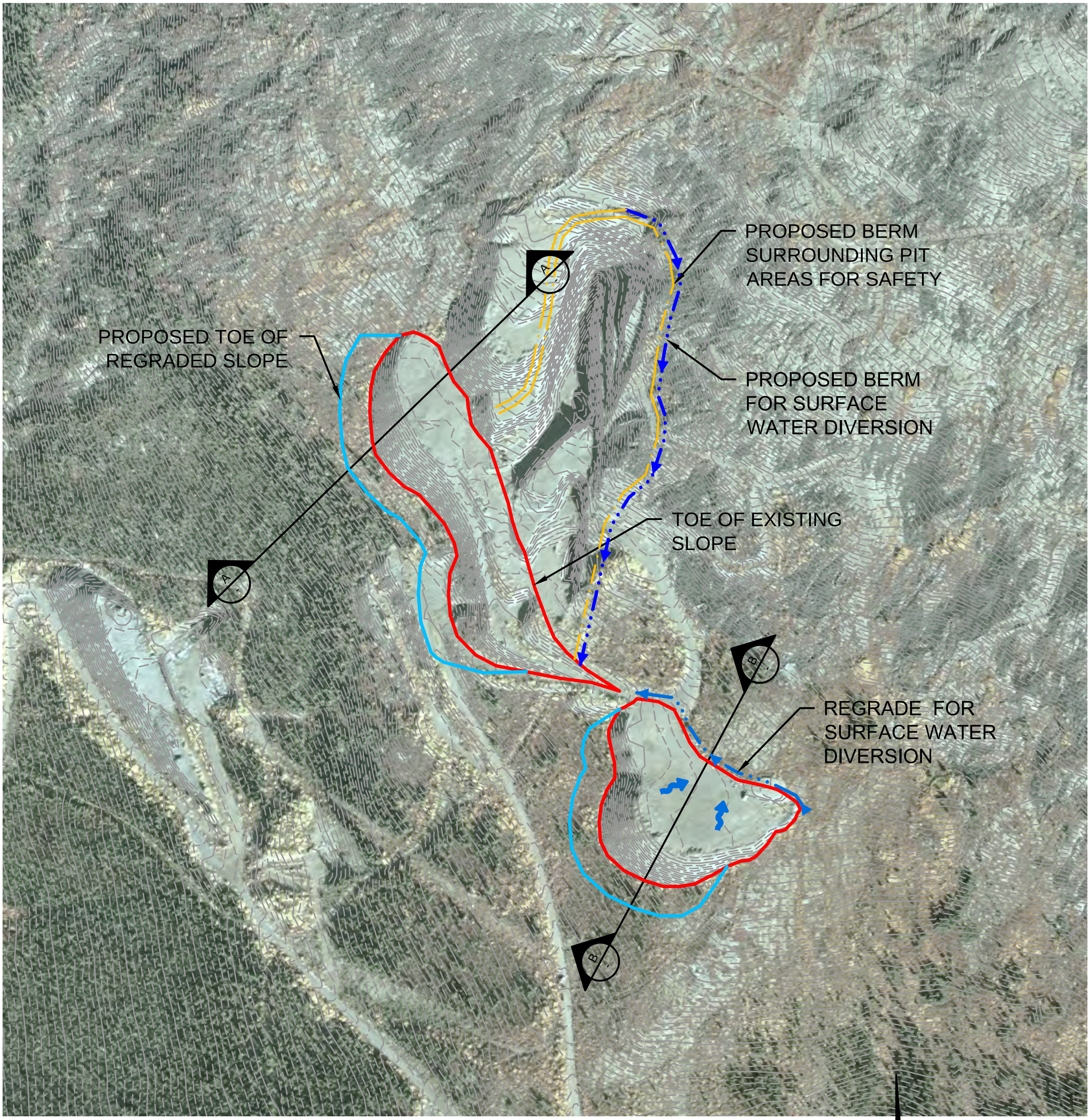
PROJECT
KENO

TITLE
CALUMET PIT
PLAN & SECTION A

INTERRALOGIC
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Calumet Pit

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Calumet Pit.dwg LAYOUT NAME: Calumet Pit Plan and Section DATE: Mar 25, 2011 - 6:06pm CAD OPERATOR: cwelken
LIST OF XREFS: [InterraLogic-xborder-8x11] [102000_xTOPO] [102000_SECTION 5] [102000_EXHIBIT LEGEND]



GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

N

120 0 120

(In Meters)
1 cm = 40 M

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 40m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

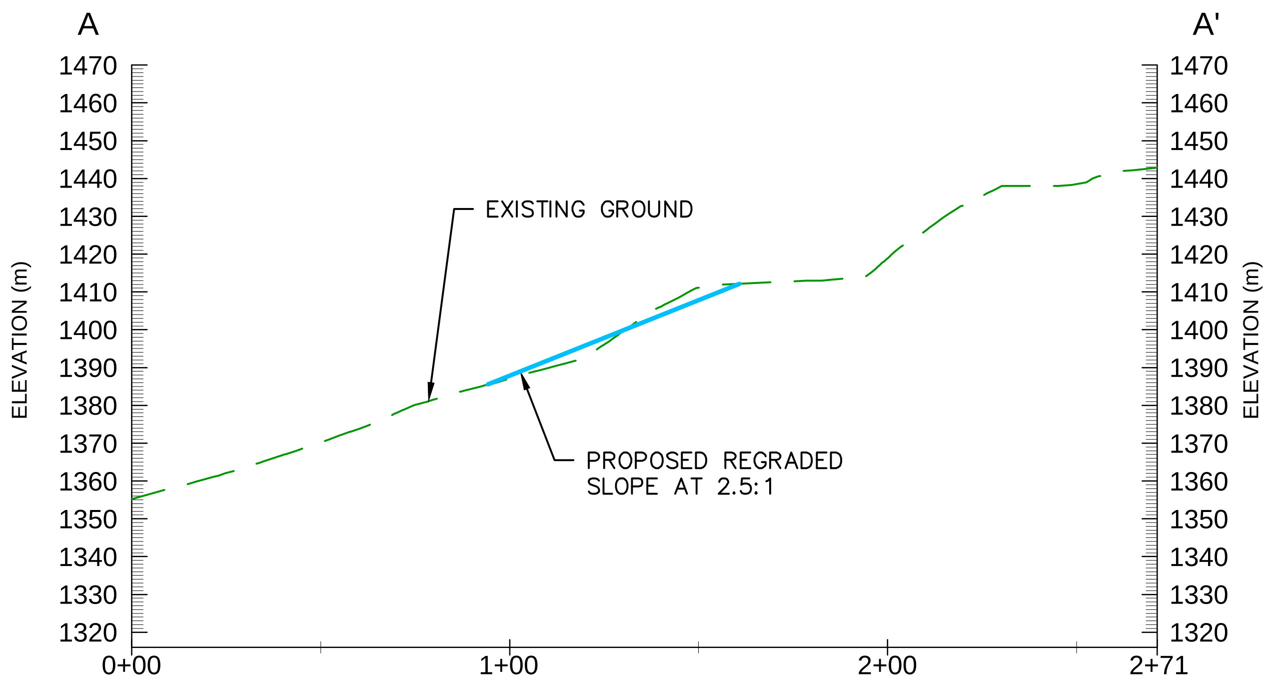
TITLE
BLACK CAP PLAN

INTERRA LOGIC
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

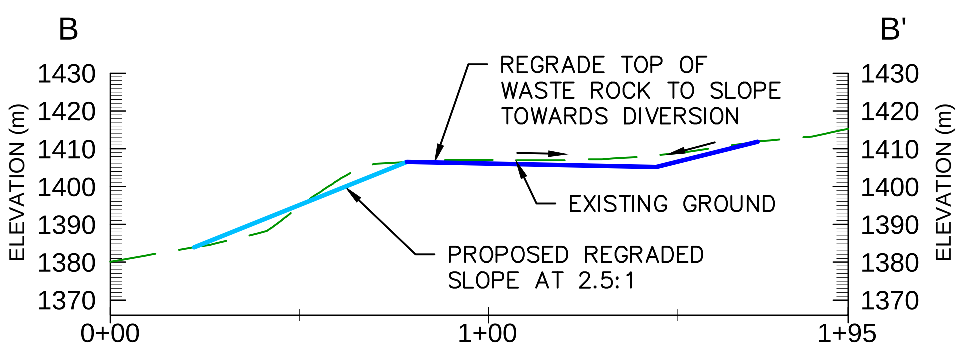
DRAWING FIGURE_ REVISION

FILE NAME 102000_Black Cap

DRAWING FILENAME: C:\Users\cwelken\appdata\local\temp\AcPublish_4460\102000_Black Cap.dwg LAYOUT NAME: BLACK CAP PLAN DATE: Mar 25, 2011 - 5:47pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [102000_EXHIBIT LEGEND]



SECTION A-A'



SECTION B-B'

60 0 60
(In Meters)
1 cm = 20 M

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 20m

PROJECT LOCATION
KENO,YUKON, CANADA

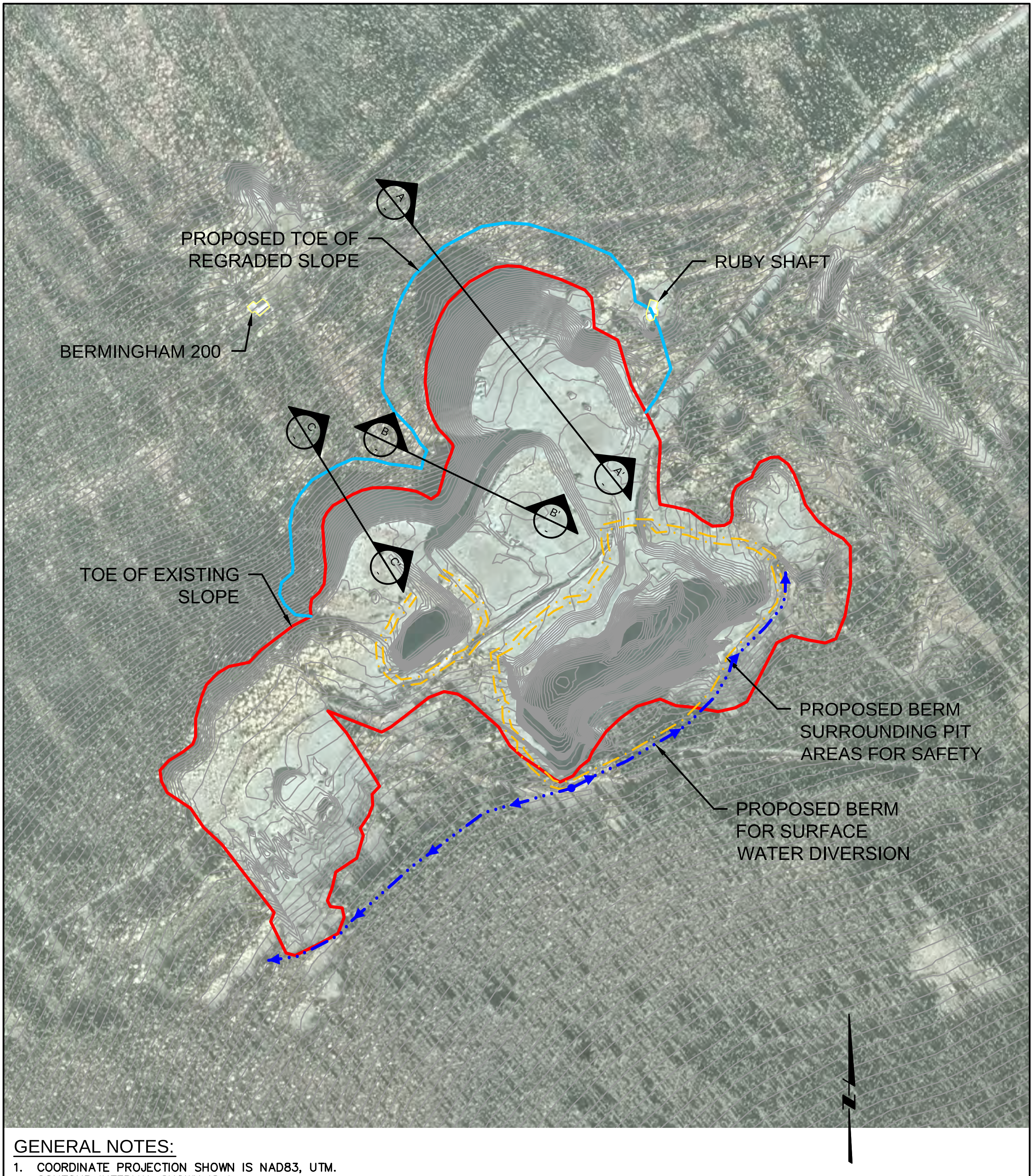
PROJECT
KENO

TITLE
BLACK CAP
SECTIONS A & B

4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING FIGURE_
REVISION
FILE NAME 102000_Black Cap

DRAWING FILENAME: C:\Users\cwelken\appdata\local\temp\AcPublish_4460\102000_Black Cap.dwg LAYOUT NAME: BLACK CAP SECTION A B DATE: Mar 25, 2011 - 5:48pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [102000_xTOPO_SECTION 5] [102000_EXHIBIT LEGEND]



GENERAL NOTES:

1. COORDINATE PROJECTION SHOWN IS NAD83, UTM. CONTOUR INTERVAL SHOWN IS 1 m.
2. PROPOSED TOE OF SLOPE SHOWN WAS FOUND USING A PROJECTED 2.5:1 SLOPE AS SHOWN IN SECTIONS.

120 0 120

(In Meters)
1 cm = 40 M

DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83 SCALE: 1 cm = 40m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

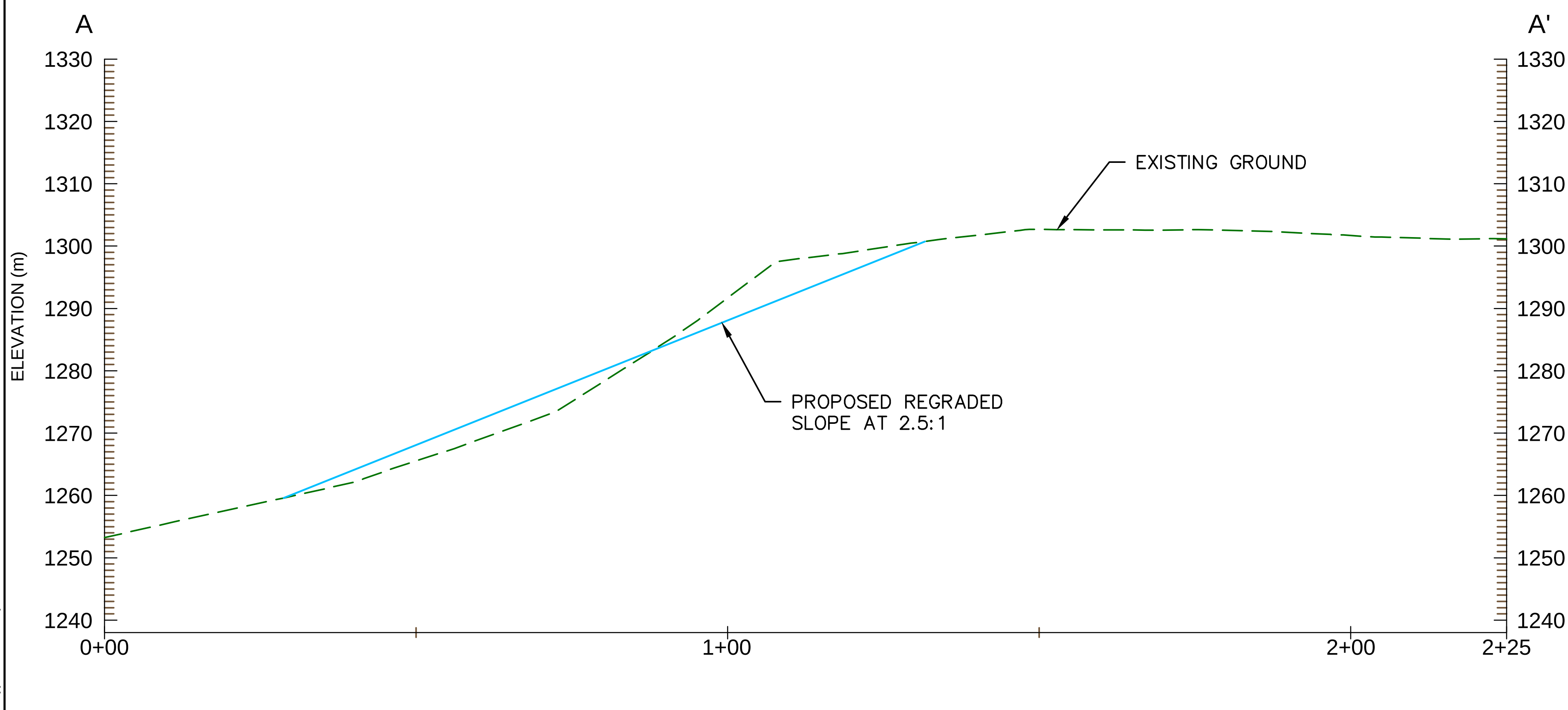
TITLE
BERMINGHAM PLAN

INTERRA

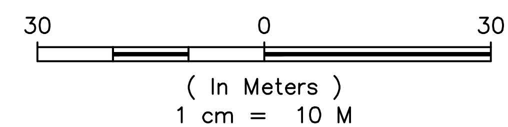
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING: FIGURE_
REVISION
FILE NAME: 102000_Bermingham

DRAWING FILENAME: I:\Projects\102000 – Keno-Alexco\Keno Cad\Grad\102000_Bermingham.dwg LAYOUT NAME: BERMINGHAM_PLAN DATE: Mar 25, 2011 – 5:54pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [InTerraLogic-xborder-8x11_rot] [102000_xTOPO_SECTION 9] [102000_EXHIBIT LEGEND]



SECTION A-A'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________, RECEIVED _____, 20__.

DATUM: NAD83

SCALE: 1 cm = 10m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
BERMINGHAM
SECTION A

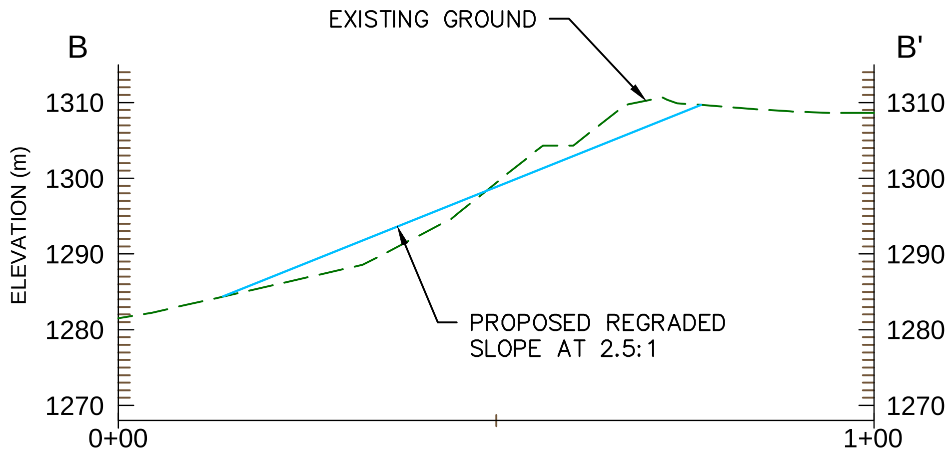
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING
FIGURE_

REVISION

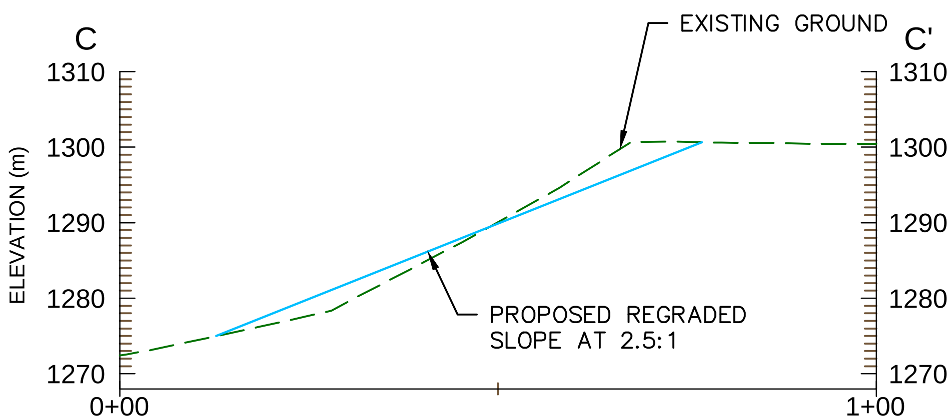
FILE NAME
102000_Bermingham

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Bermingham.dwg LAYOUT NAME: BERMINGHAM_SECTION A DATE: Mar 25, 2011 - 5:54pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [InTerraLogic-xborder-8x11_rot] [102000_xTOPO_SECTION 9] [102000_EXHIBIT LEGEND]



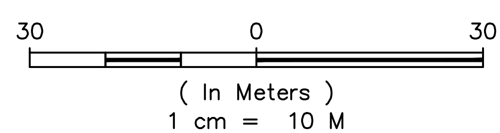
STATION (m)

SECTION B-B'



STATION (m)

SECTION C-C'



DESIGNED BY	F. MARINELLI	3-14-2011
DRAWN BY	C. WELKEN	3-14-2011
CHECKED BY	B. CARLSON	3-14-2011
APPROVED BY	B. Carlson	3-14-2011
PROJECT MANAGER	B. Carlson	3-14-2011
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

DRAWING REFERENCE(S):
EXISTING TOPOGRAPHY PROVIDED BY ____________.
RECEIVED _____, 20__.

DATUM: NAD83 | SCALE: 1 cm = 10m

PROJECT LOCATION
KENO,YUKON, CANADA

PROJECT
KENO

TITLE
BERMINGHAM
SECTIONS B & C

INTERRA logic
4715 Innovation Drive, Suite 110
Fort Collins, Co 80525
970.225.8222

DRAWING: FIGURE_ | REVISION:
FILE NAME: 102000_Bermingham

DRAWING FILENAME: I:\Projects\102000 - Keno-Alexco\Keno Cad\Grad\102000_Bermingham.dwg LAYOUT NAME: BERMINGHAM_SECTION B_C DATE: Mar 25, 2011 - 5:54pm CAD OPERATOR: cwelken
LIST OF XREFS: [InTerraLogic-xborder-8x11] [InTerraLogic-xborder-8x11_rot] [102000_xTOPO_SECTION 9] [102000_EXHIBIT LEGEND]

Dixie Capping

	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
	Load Haul and Place Borrow Material	400 Excavator	per hr	62	$ 200	$ 12,400	
		Kenworth T-800 Tridem (2 trucks)	per hr	31	$ 175	$ 5,410	
		D7-R	per hr	32	$ 235	$ 7,442	
	Cover Compaction	Drum Packer	per hr	4	$ 130	$ 520	
		Tractor Trailer (low bed)	per hr	3	$ 130	$ 390	
	Mob/Demob	Cat 325-L Excavator	per km	50	$ 6	$ 300	
		Kenworth T-800 Tridem	per km	50	$ 3.75	$ 188	
		D7-R	per km	50	$ 6	$ 300	
	Sub-Total						**$ 26,162**
						Unit Cost ($/m3):	**$ 6.23**

DIXIE				
Average haul speed full/empty	10	km/hr	20	km/hr
Haul time:	4.50	mins	from Km 3 Calumet Rd Borrow Source	
Loading time:	5.5	mins		
Dump time and maneuvering:	1	mins		
Return time:	2			
Cycle Time:	13	mins		
Gravel Truck Load:	15	m3		
Haulage (m3/hr/truck):	68	m3/hr		
Hourly haulage (m3)	136	based on 2 trucks		
Volume of Cover Required:	4,000			
Volume to be Hauled:	4,200	assuming 5% swell		
Truck Hours:	31	hrs	excavator hours determined by truck hrs x # trucks	
D7 productivity for spreading waste rock is estimated		360	m3/hr based on push distance of less than 35 m and an 80% efficiency	

D7 waiting at site so to be run intermittently due to higher production rate than the haulage
Assume additional time over optimum productivity for dozer (+20 hours)

Compaction (Optional)		
Three passes over 4000 sq m with overlap (1.2x)	14,400	sqm
Average speed	3.7	kph
Drum packer width	1.7	m
Cycle time (80% eff)	4,884	sqm/hr
Quantity (25% contingency on hours for packing)	4	

Adit	Surface Area (m2)	Cover Thickness (m)	Cover Material Volume (m3)	Distance from Source (km)
Dixie	4,000	1.0	4,000	0.75

Ruby Capping

	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
	Load Haul and Place Borrow Material	400 Excavator	per hr	168	$ 200	$ 33,600	
		Kenworth T-800 Tridem	per hr	84	$ 175	$ 14,674	
		D7-R	per hr	33	$ 235	$ 7,853	
	Cover Compaction	Drum Packer	per hr	4	$ 130	$ 520	
		Tractor Trailer (low bed)	per hr	3	$ 130	$ 390	
	Sub-Total						**$ 57,037**
						Unit Cost ($/m3):	**$ 11.81**

RUBY				
Average haul speed full/empty	10	km/hr	20	km/hr
Haul time:	16.50	mins	from Km 3 Calumet Rd Borrow Source	
Loading time:	5.5	mins		
Dump time and maneuvering:	1	mins		
Return Time	8	mins		
Cycle Time:	31	mins		
Gravel Truck Load:	15	m3		
Haulage (m3/hr/truck):	29	m3/hr		
Hourly haulage (m3)	58	based on 2 trucks		
Volume of Cover Required:	4,600			
Volume to be Hauled:	4,830	assuming 5% swell		
Truck Hours:	84	hrs	excavator hours determined by truck hrs x # trucks	
D7 productivity for spreading waste rock is estimated		360	m3/hr based on push distance of less than 35 m and an 80% efficiency	
D7 waiting at site so to be run intermittently due to higher production rate than the haulage				
Assume additional time over optimum productivity for dozer (+20 hours)				
Compaction (Optional)				
Three passes over 4000 sq m with overlap (1.2x)		16,560	sqm	
Average speed		3.7	kph	
Drum packer width		1.7	m	
Cycle time (80% eff)		4,884	sqm/hr	
Quantity (25% contingency on hours for packing)		4		

Adit	Surface Area (m2)	Cover Thickness (m)	Cover Material Volume (m3)	Distance from Source (km)
Ruby	4,600	1.0	4,600	2.75

Townsite Capping

	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
	Load Haul and Place Borrow Material	400 Excavator	per hr	613	$ 200	$ 122,600	
		Kenworth T-800 Tridem	per hr	204	$ 175	$ 35,777	
		Kenworth T-800 Tridem	per hr	61	$ 235	$ 14,296	
	Cover Compaction	Drum Packer	per hr	13	$ 130	$ 1,677	
		Tractor Trailer (low bed)	per hr	3	$ 130	$ 390	
	Sub-Total						**$ 174,740**
						Unit Cost ($/m3):	**$ 11.89**

TOWNSITE

Average haul speed full/empty	10	km/hr	20	km/hr
Haul time:	20.70	mins	from Km 3 Calumet Rd Borrow Source	
Loading time:	5.5	mins		
Dump time and maneuvering:	1	mins		
Return Time:	10	mins		
Cycle Time:	38	mins		
Gravel Truck Load:	15	m3		
Haulage (m3/hr/truck):	24	m3/hr		
Hourly haulage (m3)	72	based on 3 trucks		
Volume of Cover Required:	14,000			
Volume to be Hauled:	14,700	assuming 5% swell		
Truck Hours:	204	hrs	excavator hours determined by truck hrs x # trucks	
D7 productivity for spreading waste rock is estimated		360	m3/hr based on push distance of less than 35 m and an 80% efficiency	

D7 waiting at site so to be run intermittently due to higher production rate than the haulage
Assume additional time over optimum productivity for dozer (+20 hours)

Compaction (Optional)		
Three passes over 4000 sq m with overlap (1.2x)	50,400	sqm
Average speed	3.7	kph
Drum packer width	1.7	m
Cycle time (80% eff)	4,884	sqm/hr
Quantity (25% contingency on hours for packing)	13	

Adit	Surface Area (m2)	Cover Thickness (m)	Cover Material Volume (m3)	Distance from Source (km)
Townsite	14,000	1.0	14,000	3.45

Husky							
	Work Item Description	**Equipment/Labour**	**Units**	**Quantity**	**Unit Cost**	**Cost**	**Total Cost**
	Load Haul and Place Borrow Material	400 Excavator	per hr	269	$ 200	$ 53,800	
		Kenworth T-800 Tridem	per hr	90	$ 175	$ 15,687	
		D7-R	per hr	35	$ 235	$ 8,127	
	Cover Compaction	Drum Packer	per hr	4	$ 130	$ 520	
		Tractor Trailer (low bed)	per hr	3	$ 130	$ 390	
	Mob/Demob	Cat 325-L Excavator	per km	50	$ 6	$ 300	
		Kenworth T-800 Tridem	per km	50	$ 3.75	$ 188	
		D7-R	per km	50	$ 6	$ 300	
	Sub-Total						**$ 79,311**
						Unit Cost ($/m3):	**$ 15.11**

HUSKY				
Average haul speed full/empty	20	km/hr	20	km/hr
Haul time:	19.80	mins	from Husky SW Borrow Source	
Loading time:	5.5	mins		
Dump time and maneuvering:	1	mins		
Return Time:	20	mins		
Cycle Time:	46	mins		
Gravel Truck Load:	15	m3		
Haulage (m3/hr/truck):	20	m3/hr		
Hourly haulage (m3)	59	based on 3 trucks		
Volume of Cover Required:	5,000			
Volume to be Hauled:	5,250	assuming 5% swell		
Truck Hours:	90	hrs	excavator hours determined by truck hrs x # trucks	
D7 productivity for spreading waste rock is estimated			360	m3/hr based on push distance of less than 35 m and an 80% efficiency

D7 waiting at site so to be run intermittently due to higher production rate than the haulage
Assume additional time over optimum productivity for dozer (+20 hours)

Compaction (Optional)		
Three passes over 4000 sq m with overlap (1.2x)	36,000	sqm
Average speed	3.7	kph
Drum packer width	1.7	m
Cycle time (80% eff)	4,884	sqm/hr
Quantity (25% contingency on hours for packing)	9	

Adit	Surface Area (m2)	Cover Thickness (m)	Cover Material Volume (m3)	Distance from Source (km)
Husky	10,000	0.5	5,000	7

Elsa Cover (25,000 cbm)

	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
	Load Haul and Place Borrow Material	400 Excavator	per hr	753	$ 200	$ 150,500	
		Kenworth T800 Tridem	per hr	376	$ 175	$ 65,844	
		D7-R	per hr	88	$ 235	$ 20,563	
	Mob/Demob	400 Excavator	per km	50	$ 6	$ 300	
		Kenworth T800 Tridem	per km	50	$ 4	$ 188	
		D7-R	per km	50	$ 6	$ 300	
	Sub-Total						**$ 236,906**

Total Borrow Material:	25000	cbm	One way distanc	2.5	km
Average haul speed full/empty	15	km/hr	30	km/hr	
Haul time:	10.00	mins	from Husky SW borrow source		
Loading time:	5.5	mins			
Dump time and maneuvering:	1	mins			
Return Time:	5	mins			
Cycle Time:	22	mins			
Gravel Truck Load:	15	m3			
Haulage (m3/hr/truck):	42	m3/hr			
Hourly haulage (m3)	84	based on 2 trucks			
Volume of Cover Required:	30,000	assuming 20% additional volume			
Volume to be Hauled:	31,500	assuming 5% swell			
Equipment Hours:	376	hrs	excavator hours determined by truck hrs x # trucks		
D7 productivity for spreading waste rock is estimated	360		distance of less than 35 m and an 80% efficiency		

D7 waiting at site so to be run intermittently due to higher production rate than the haulage
Assume additional time over optimum productivity for dozer (+20 hours)

Elsa Clean-up and Misc.

	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
	Removal of garbage dump	400 Excavator	per hr	40	$ 200	$ 8,000	
		Kenworth T800 Tridem	per hr	40	$ 175	$ 7,000	
	Site recontouring and crib wall removal	400 Excavator	per hr	100	$ 200	$ 20,000	
		D7-R	per hr	60	$ 235	$ 14,100	
		CAT 938 H - Loader	per hr	60	$ 180	$ 10,800	
	Steel and Other Non-Heritage value clean-up	Kenworth T800 Tridem	per hr	82	$ 175	$ 14,350	
		400 Excavator	per hr	32	$ 200	$ 6,400	
	Landfill of Garbage Dump and Other Materials	400 Excavator	per hr	40	$ 200	$ 8,000	
		D7-R	per hr	16	$ 235	$ 3,760	
	Mob/Demob	400 Excavator	per km	50	6	$ 300	
		Kenworth T800 Tridem	per km	50	3.75	$ 190	
		D7-R	per km	50	6	$ 300	
		CAT 938 H - Loader	per km	50	4	$ 200	
	Sub-Total						**$ 93,400**

Silver King 100							
	Work Item Description	**Equipment/Labour**	**Units**	**Quantity**	**Unit Cost**	**Cost**	**Total Cost**
1	De-commission Treament Shack	Trade Labour	per hr	8	$ 59.53	$ 476.24	
	and remove piping	Labourer	per hr	8	$ 36.91	$ 295.28	
		Cat 325-L Excavator	per hr	4	$ 180.00	$ 720.00	
		Hiab Flatdeck	per hr	4	$ 125.00	$ 500.00	
		Kenworth T-800 Tridem	per hr	2	$ 175.00	$ 350.00	
						Sub-total:	**$ 2,342**
2	De-sludge treatment pond and haul to	Vacuum Truck	per hr	8	$ 100.00	$ 800.00	
	VTF site	Labourer	per hr	8	$ 36.91	$ 295.28	
						Sub-total:	**$ 1,095**
3	Remove Liner, lock blocks other	Cat 325-L Excavator	per hr	16	$ 180.00	$ 2,880.00	
	infrastructure and recontour pond area	Kenworth T-800 Tridem	per hr	8	$ 175.00	$ 1,400.00	
		Hiab Flatedeck	per hr	8	$ 125.00	$ 1,000.00	
		D7-R	per hr	8	$ 235.00	$ 1,880.00	
		Labourers	per hr	36	$ 36.91	$ 1,328.76	
						Sub-total:	**$ 8,489**
4	Revegetate treatment area		per ha	0.5	$ 2,260	$ 2,260.50	
						Sub-total:	**$ 2,261**
5	Mob/Demob	Cat 325-L Excavator	per km	50	$ 6.00	$ 300.00	
		Kenworth T-800 Tridem	per km	50	$ 3.75	$ 187.50	
		Tractor Trailer (low bed)	per km	50	$ 6.00	$ 300.00	
		D7-R	per km	50	$ 6.00	$ 300.00	
						Sub-total:	**$ 1,088**
						Total:	**$ 15,274**

Galkeno 900							
	Work Item Description	**Equipment/Labour**	**Units**	**Quantity**	**Unit Cost**	**Cost**	**Total Cost**
1	De-commission Treament Shack and piping	Trade Labour	per hr	8	$ 59.53	$ 476.24	
		Labourer	per hr	12	$ 36.91	$ 442.92	
		Cat 325-L Excavator	per hr	8	$ 180.00	$ 1,440.00	
		Hiab Flatdeck	per hr	4	$ 125.00	$ 500.00	
		Kenworth T-800 Tridem	per hr	4	$ 175.00	$ 700.00	
						Sub-total:	**$ 3,559**
2	De-sludge treatment pond and haul to VTF site	Vacuum Truck	per hr	8	$ 100.00	$ 800.00	
		Labourer	per hr	8	$ 36.91	$ 295.28	
						Sub-total:	**$ 1,095**
3	Remove Liner, lock blocks other infrastructure and recontour pond and bioreactor area	Cat 325-L Excavator	per hr	24	$ 180.00	$ 4,320.00	
		Kenworth T-800 Tridem	per hr	12	$ 175.00	$ 2,100.00	
		Hiab Flatedeck	per hr	12	$ 125.00	$ 1,500.00	
		D7-R	per hr	16	$ 235.00	$ 3,760.00	
		Labourers	per hr	36	$ 36.91	$ 1,328.76	
						Sub-total:	**$ 13,009**
4	Revegetate area		per ha	1.5	$ 2,260	$ 2,261.50	
						Sub-total:	**$ 2,262**
5	Mob/Demob	Cat 325-L Excavator	per km	60	$ 6.00	$ 360.00	
		Kenworth T-800 Tridem	per km	60	$ 3.75	$ 225.00	
		Tractor Trailer (low bed)	per km	60	$ 6.00	$ 360.00	
		D7-R	per km	60	$ 6.00	$ 360.00	
						Sub-total:	**$ 1,305**
						Total:	**$ 21,230**

Galkeno 300

	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
1	De-commission Treament Facility and piping	Trade Labour	per hr	80	$ 59.53	$ 4,762.40	
		Labourer	per hr	160	$ 36.91	$ 5,905.60	
		Cat 325-L Excavator	per hr	12	$ 180.00	$ 2,160.00	
		Hiab Flatdeck	per hr	40	$ 125.00	$ 5,000.00	
		Tractor Trailer	per hour	8	$ 100.00	$ 800.00	
		Kenworth T-800 Tridem	per hr	12	$ 175.00	$ 2,100.00	
		Miscellaneous Equipment	lump sum	1	$ 1,500.00	$ 1,500.00	
						Sub-total:	**$ 20,728**
2	De-sludge treatment pond	Vacuum Truck	per hr	16	$ 100.00	$ 1,600.00	
		Labourer	per hr	16	$ 36.91	$ 590.56	
						Sub-total:	**$ 2,191**
3	Remove Liners, lock blocks other infrastructure and recontour area	Cat 325-L Excavator	per hr	40	$ 180.00	$ 7,200.00	
		Kenworth T-800 Tridem	per hr	16	$ 175.00	$ 2,800.00	
		Hiab Flatedeck	per hr	24	$ 125.00	$ 3,000.00	
		D7-R	per hr	40	$ 235.00	$ 9,400.00	
		Labourers	per hr	48	$ 36.91	$ 1,771.68	
						Sub-total:	**$ 24,172**
4	Revegetate area		per ha	1.5	$ 2,260	$ 2,261.50	
						Sub-total:	**$ 2,262**
5	Mob/Demob	Cat 325-L Excavator	per km	70	$ 6.00	$ 420.00	
		Kenworth T-800 Tridem	per km	70	$ 3.75	$ 262.50	
		Tractor Trailer (low bed)	per km	70	$ 6.00	$ 420.00	
		D7-R	per km	70	$ 6.00	$ 420.00	
						Sub-total:	**$ 1,523**
						Total:	**$ 50,874**

KENO 700							
	Work Item Description	Equipment/Labour	Units	Quantity	Unit Cost	Cost	Total Cost
	Re-contouring of Waste Rock Dump	D7-R	per hr	30	$ 235	$ 7,050	
	Drainage Control	Cat 325-L Excavator	per hr	16	$ 200	$ 3,200	
	Rip Rap for drainage channel	-	per m3	150	$ 20	$ 3,000	
	Mob/Demob	Cat 325-L Excavator	per km	50	$ 6	$ 300	
		D7-R	per km	50	$ 6	$ 300	
	Sub-Total						**$ 13,250**

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TECHNICAL MEMO

ISSUED FOR REVIEW

TO:	Scott Davidson, P.Geo, - Access Consulting Group	**DATE:**	March 30, 2011
C:	Jim Harrington - Alexco Lara Reggin, Richard Trimble	**MEMO NO.:**	
FROM:	Jason Pellett, P.Eng. GIT	**EBA FILE:**	V15101043

SUBJECT: Keno Hill Shaft Closures
Conceptual Design and Level 5 Cost Estimate

1.0 INTRODUCTION

This memo presents conceptual designs and preliminary construction cost estimates for permanent closure of a number of vertical shafts at abandoned mine workings across the former United Keno Hill silver mining district near Keno City, YT. We understand that Access Consulting (Access) requires this information as part of overall site closure planning and budgeting.

1.1 Project Understanding

Based on information provided by Access, we understand that the primary objectives of permanent shaft closure at Keno Hill are to prevent public access to the workings and to minimize the flow of air and water into/out of the shafts. A number of sites have also been flagged as "complex sites" where shaft closure is one of several measures to be undertaken as part of site closure and environmental remediation.

1.2 Information Reviewed

The following information was reviewed as part of this study:

- Keno Hill Closure Options Draft (Excel Spreadsheet, dated 03-02-2011) provided by Access;
- MINFILE property summaries for Silver King, Husky, Elsa, Dixie, Coral & Wigwam, Bermingham, Ruby, Hector Calumet, Tin Can, Rico, Onek, Sadie Ladue, Croesus No.1, Lucky Queen, Shamrock, Keno No. 9, Silver Basin, Apex, and Christal.

2.0 SHAFT INVENTORY

From the information provided by Access, a total of 32 shafts have been identified at Keno Hill which require permanent closure; however, existing information for some of the mine sites is limited and it is possible that additional shafts will also require sealing. A summary of these shafts is provided in the attached table.

3.0 SHAFT CLOSURE OPTIONS

The following subsections discuss the recommended options for shaft closure at Keno Hill. Hand sketches of each of the options are attached for reference.

3.1 Concept A – Dry Seal

A dry seal would comprise backfilling the shaft with suitable granular fill material capped with an impermeable seal of bentonite pellets or lean concrete placed just below the bedrock collar of the shaft. The impermeable seal would be covered with additional backfill and the surface re-vegetated. To provide positive drainage of surface run-off and to account for future settlement of the backfill, the completed seal should be mounded above surrounding grades.

In general, dry seals would be suitable for the smaller and less accessible shaft locations, shafts which are partially collapsed / backfilled, and those with no observable water flow or potential for hydraulic heads developing. Of the 32 shaft locations identified, 23 appear to be suitable candidates for a dry seal.

3.2 Concept B – Concrete Cap

This concept would involve sealing the shaft with a cap of reinforced concrete poured across the bedrock collar of the shaft. In general, concrete caps are suitable for the larger and more accessible shaft locations, shafts which are in good condition, and those with observable water inflow/outflow or hydraulic connection to underground workings. Of the 32 shaft locations identified, 9 appear to be suitable candidates for a concrete cap.

The cap would be seated on a narrow ledge of bedrock around the shaft collar and would likely need to be secured with fully grouted dowels. For an assumed maximum soil cover of 1 m and for no hydraulic head, the thickness of the concrete cap would be approximately 0.3 m. Depending on the size and depth of the shaft, it may be more cost-effective to backfill the shaft with suitable granular fill up to slab grade (refer to Concept A, above) to provide a working surface rather than construct formwork to span across the open void. As with Concept A, the cap would be covered with backfill mounded above surrounding grades, and re-vegetated.

3.2.1 Inverted Pyramid Cap

As an alternative to a rectangular-shaped concrete cap as described above, consideration could also be given to sealing the shaft with an inverted pyramid concrete cap. For this option, the concrete would be poured onto a pre-fabricated steel form placed into the shaft (collared in bedrock). This alternative may be more cost effective for sites where constructing formwork and rebar is not practical, or for sites where significant thicknesses of overburden and weathered rock are present. However, this alternative would not be as suitable for sites with water inflows/outflows and hydraulic connection to underground workings.

3.3 Construction Cost Estimate

The attached table presents a summary of estimated construction costs ($CAD) for shaft closure at the various sites across Keno Hill. These costs are preliminary and are considered accurate to "Level 5" criteria (+100% to -50%).

For a dry seal (Concept A), estimated construction costs range from $7,500 to $15,000; for a concrete cap (Concept B), estimated construction costs range from $25,000 to $100,000. The range in estimated costs reflects variations in shaft dimensions, site conditions, access, and other such constraints.

These cost estimates have been based on the following assumptions:

- With the exception of Husky SW, none of the shafts requiring concrete caps (Concept B) have observable water discharge;
- Concrete (standard 25 MPa or 30 MPa mix) can be sourced from a batch plant at Bellekeno Mine. If concrete is not available from the minesite, consideration could be given to employing on-site batching from 1 yd^3 bulk bags of dry ready-mix, although this would be more expensive;
- The majority of the construction equipment required for shaft closure (excavator, rock truck, dump truck, etc.) is already on site or can be procured locally;
- Locally available overburden, clean waste rock, and/or concrete rubble can be used for backfill material where required;
- For the dry seal (Concept A) locations, the sites can be accessed with a tracked excavator. It is assumed that some clearing and grading may be required to improve access but without the need for significant blasting, benching, road building or slope stabilization works;
- For concrete cap (Concept B) locations, the thickness of the concrete cap and rebar detail are based on an assumed maximum soil cover of 1 m. It is also assumed that the shaft locations would be accessible by truck such that concrete pumping over long distances would not be required.

4.0 FUTURE WORK

As discussed with Access, further review and assessment by EBA should be undertaken to verify the preferred shaft closure options, finalize shaft closure designs, and refine the construction cost estimates. This work should include a site reconnaissance to assess shaft conditions, water inflows/outflows, soil and bedrock exposures, required depth of stripping, shaft dimensions, potential borrow sources, site access constraints, etc.

A work plan and budget estimate for this work will be provided to Access under separate cover.

5.0 CLOSURE

We trust that this memo meets your present requirements. If you have any questions or comments please contact us at your convenience.

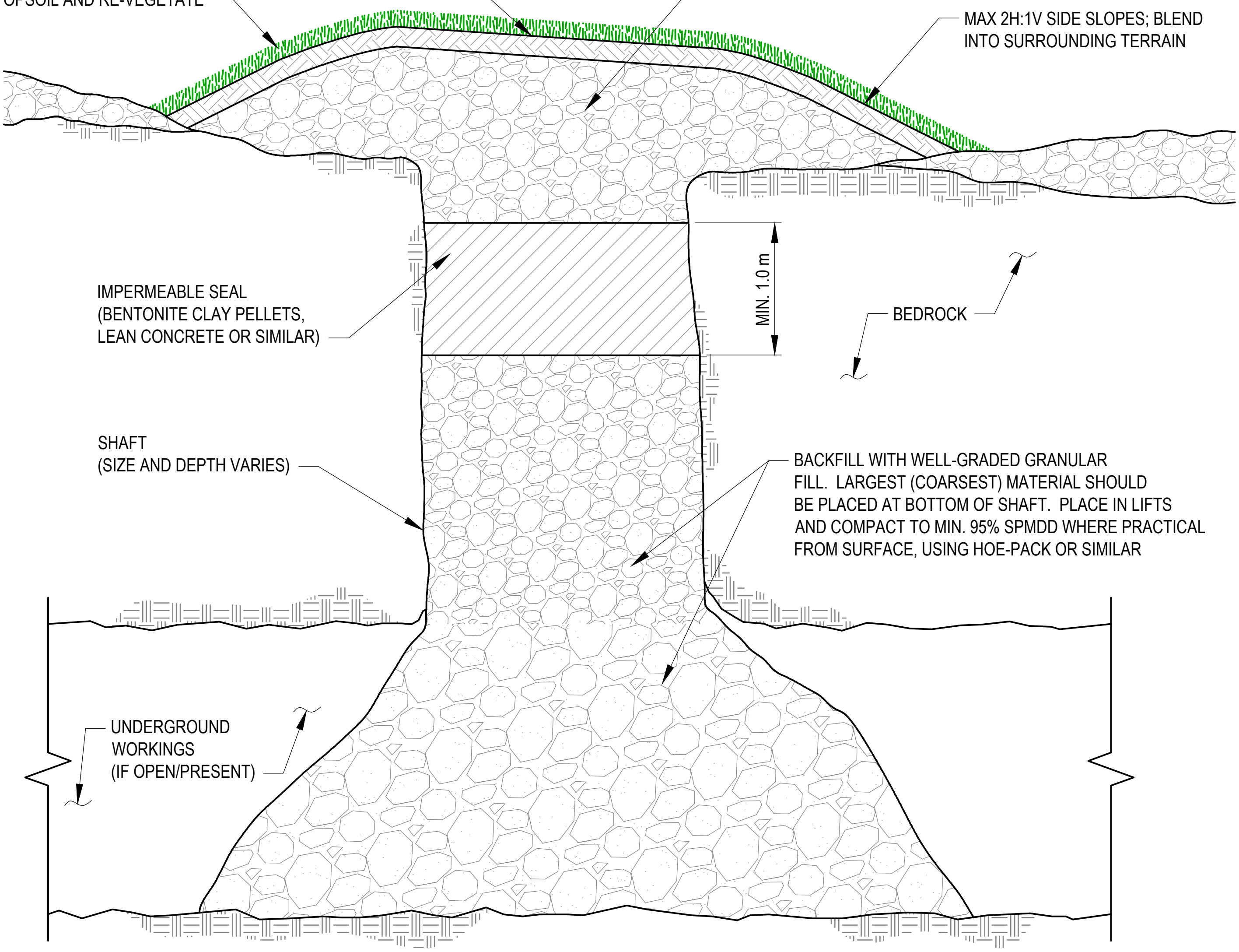
ATTACHMENTS

Shaft Name	PWGSC Ref Site	Description	Dimensions, m (L x W x H)	Support/Condition	Site Physiography	Site Access	Closure Issue Categories			Proposed Option for Closure	Closure Rationale
							Human & Wildlife Health and Safety	Water Management	Physical Stability		
Silver King Vent Raise	Silver King	*A ventilation raise is covered by a wooden shed. Shed is 100 m SE of the open pit; door is kept locked; steel mesh covers raise entrance.*	*2 x 2 x ??*	*Unknown; Appears to be stable*	*NW facing slope; well forested; glacial till overburden; host rock is quartzite and schist*	*Road access; Straddles Hwy 11 at Galena Creek, 4 km SW of Elsa*	intrigue risk; close proximity to tourist area			*remove building; cap raise*	*covering the raise will eliminate intrigue risk and access to workings*
Silver King Shaft #1 (Open Pit Shaft)	Silver King	*Timbers and pipes exposed in the bottom of the open pit identify former shaft, filled with waste rock. This is likely the number 3 shaft, which was the main production shaft for this part of the mine*	*1.5 x 1.5 x ??*	*Milled timber supports/Appears to be stable*	*Northwest corner of the open pit. NW facing slope; well forested; glacial till overburden; host rock is quartzite and schist*	*Shaft can be accessed by vehicle; straddles Hwy 11 at Galena Creek; 4 km SW of Elsa.*			cement cap is dilapidated and poorly placed	*redo cap*	*eliminates access to workings*
Silver King Shaft #2	Silver King	*An old raise lined with log timbers that had been sunk in overburden has been left standing at the edge of the open pit*	*1.5 x 1.5 x ??*	*Round log timbers (about 10 to 20 cm diameter) line the shaft horizontally; the shaft has had overburden removed from around it so that it stands as a tower, leaning; the wood timbers are leaning but moderately stable; the raise is filled with overburden*	*South-central side of the open pit*	*Road access; Straddles Hwy 11 at Galena Creek, 4 km SW of Elsa*	intrigue risk; close proximity to tourist area		`	*cover with pit closure*	*covering the raise will eliminate intrigue risk and access to workings.*
Silver King Raise #1	Silver King	*A small raise was located above Galena Creek canyon on the west side; the site is overgrown with dense vegetation; a pipe extends to surface; the raise is collapsed*	*1m x 1m; collapsed at ~1 m depth*	*Some rotten wood supports are present; raise is collapsed*	*In dense bush about 30 m west of Galena Creek (at the top of the canyon), about 30 m south of the old bridge site.*	*Road access to the site; likely foot access to the shaft due to dense bush*					
Husky Raise	Husky #2	*not investigated; shaft house locked at last visit, and during SRK 2006 and PWGSC 2000 visits*									
Husky Shaft	Husky #2	*not investigated; shaft house locked at last visit, and during SRK 2006 and PWGSC 2000 visits*									
Husky SW Shaft	Husky SW	*Main workings, located at the north of the hoist house; workings are flooded to surface and hydraulically connected with the Husky workings*	*Shaft house is 15m x 8m x 25m*	*Head frame structure is supported; the structure appears to be stable*	*Mining structures on a waste rock plateau; coarse grained soils; significant depth of overburden and till; quartzite host rock with interbedded graphitic/micaceous schists*	*Road access (likely 2WD based on photos)*	- Potential ecological risk to flora/fauna in all areas down gradient of adits discharging to the environment through plant uptake of metals - Potential for public access to workings	produces water; <0.5L/sec; discharge is piped through the dump to a discharge point beyond the dump		*See "Complex Sites" sheet*	
Ruby Shaft	Bermingham & Ruby						accessible to public	does not produce water	shaft is open; ground subsidence occurring near shaft	*fill and cap*	*eliminates public safety and access issues*
McLeod shaft	Galkeno Mine						accessible to public	no water	subsidence around shaft, open holes (2007 SRK Baseline Study)	*fill holes and cap*	*prevents access and further subsidence*
Lone Star Shaft	Onek	*The shaft is mostly filled with open pit rock; some timbers and pipes are visible from the pit; the mine is scheduled for future underground production*	*Unknown dimensions; originally ~100m deep*	*Timers are present, however they have been extensively filled in and do not appear to be supporting the structure; shaft appears stable however material inside shaft may be settling*	*Site is on the south slope of Keno Hill; main open pit is on a relatively flat plateau; certain areas of the site have been overgrown; quartzite with carbonaceous phyllite and greenstone lenses host rock*	*2WD access; immediately north of Keno City*	filled and covered		shaft has been filled; no subsidence	*shaft has been filled; do nothing*	*Shaft is not a public safety hazard and therefore no activity is necessary.*
Fisher Shaft	Onek						filled and covered		shaft has been filled; no subsidence	*shaft has been filled; do nothing*	*Shaft is not a public safety hazard and therefore no activity is necessary.*
Shafts SW of Gravel Level Adit	Elsa Mine						shaft house collapsed over an open shaft, presents an intrigue risk; only one shaft located		ground subsidence immediately adjacent to the shaft house on all sides	*fill shaft and subsidence with local borrow. Cap shaft if required*	*eliminates safety and stability issues*
Dixie Shaft	Dixie	*Site is considered a hazardous area; shaft appears to be filled with water and soil ~3 m below ground level*	*1.2m x 2m x ?*	*Collapsed wood framed shafthouse, lagging has partially collapsed, site is considered hazardous. The eastern and western raises have been backfilled and surface installations removed.*	*NW facing slope dipping ~20°; quartzite host rock*	*4WD access to the shaft*	needs inspection		needs inspection	*cap shaft*	*eliminates access and safety issues*
Brefalt Shaft	No Cash Mine						accessible to public			*cap shaft*	*shaft is open inside the building*
Shaft N of tramway and S of Brefalt shaft dump	No Cash Mine								collapsed; minor depression remains; not a risk	*do nothing*	*no action required*
Jock Shaft	Hector-Caulmet	*Located in the 4-11 pit area; limited accessibility*	*1.5m x 1.5m x ?*	*Wooden support; shaft appears to be completely collapsed*	*The area has a moderately steep slope covered by thick moss, bushes and evergreen trees; quartzite host rock with some graphitic schist and greenstone*	*Accessible by gravel roads (requires 4WD vehicle)*			shaft completely collapsed (PWGSC 2000)	*fill and cap as required*	*eliminates public safety and access issues*
Coral and Wigwam Shaft #1	Coral and Wigwam	*Western shaft; open and accessible*	*1.6m x 1 m x ~8m with what appears to be a drift taking off in the SE direction*	*The shaft is cribbed with round timber that appears sound; the shaft is open and unguarded (safety hazard); the dump from shaft has been bulldozed away during the stripping operation.*	*NW facing slope; soils have been stripped and pushed down slope; stripped material consists of glacial till and quartzite and schist colluvium; backhoe trenches visible in the exposed bedrock; moss floor covering indicative of **permafrost**; host rock of interbedded schists and massive quartzite with veins*	*4WD or more required for a rough cat trail; area appears heavily vegetated in photos and hiking may be required*	open to surface; drift visible from surface	no water	subsidence near shaft	*fill*	*eliminates access and safety issues*
Coral and Wigwam Shaft #2	Coral and Wigwam	*Eastern shaft; collapsed and unguarded (safety hazard)*	*Subsidence zone is ~5m diameter x 3m deep; waste rock dump dimensions are 15m x 3m x 6m*	*The shaft is collapsed with timber and an old ladder in the hole; it is unguarded*	*NW facing slope; soils have been stripped and pushed down slope; stripped material consists of glacial till and quartzite and schist colluvium; backhoe trenches visible in the exposed bedrock; moss floor covering indicative of **permafrost**; host rock of interbedded schists and massive quartzite with veins*	*4WD or more required for a rough cat trail; area appears heavily vegetated in photos and hiking may be required*	collapsed; contains wooden ladder and wood and debris - may present a minor intrigue risk	no water	minor subsidence near shaft; actively ravelling walls of waste rock @ angle of repose	*fill and cap as required*	*eliminates access and safety issues*
Betty shafts	Betty							standing water at bottom of both shafts	potential regressive thawing of permafrost	*fill*	*eliminates access and safety issues*

Tin Can Shaft #1	Tin Can	*Shaft is in a boggy area with water level just below ground surface; shaft is almost entirely filled with water; remains of an old ladder project from the hole*	*2m x 2m x ?*	*No evident support; organic material has slumped into hole; quite unstable due to water filling hole*	*Relatively level area of open muskeg forest; schist and phyllite with greenstone lenses bedrock; (thick vegetation covers the surface therefore geology is from literature); no surface drainage noted*	*Shaft can be accessed on foot; no access road into the site; nearest access road is Hwy 2 located approximately 250 m downhill to the east of Shaft #1*	open to surface; ground sluicing covered by dense alders	no water noted	minor subsidence; ground sluicing to east and southeast	*fill and cap as required*	*eliminates access and safety issues*
Tin Can Shaft #2	Tin Can	*Collapsing timbered shaft; dense vegetation; waste pile rock consists of rusty greenstone with ~1% pyrite*	*2m x 1.5m x ~2.5m*	*Rotted timber support; partially collapsed and filled with debris*	*Relatively level area of open muskeg forest; schist and phyllite with greenstone lenses bedrock; (thick vegetation covers the surface therefore geology is from literature); no surface drainage noted*	*Shaft can be accessed on foot; no access road into the site; nearest access road is Hwy 2 located approximately 250 m downhill to the east of Shaft #1*	open to surface; timber supports intact	no water noted	`	*fill and cap as required*	*eliminates access and safety issues*
Rico Shaft	Rico	*A small gully beside the adit leads uphill to this shaft; log cribbing and windless are above the entrance to the shaft; a metal lid covers half of the shaft opening*	*1.5m x 1.5m x 6m (may be deeper)*	*Well supported by logs; condition is fair; logs are beginning to rot but remain stable*	*Site is on a moderately steep east facing slope; possibly underlain by* ***permafrost*** *; thick vegetation and the ground is covered with a blanket of moss and decaying leaves; no surface water encountered; quartzite host rock (adit was located but so overgrown no rock out cropping)*	*Site has 4WD access on an old dirt road; portal and adit very overgrown therefore difficult to locate; shaft is 30m upslope of the adit portal.*	shaft is difficult to access from the road but marked and open			*fill and cap as required*	*eliminates access and safety issues*
Sadie Ladue Shaft (No. 1 Shaft)	Sadie Ladue - Wernecke	*Shaft head framework has been completely removed; partially open to 5m depth with partial backfilling; opening sealed with wood planks*	*Shaft collar dimensions of 1.2m x 1.4m x ~5m; partially filled with rock*	*No square set timber supports in the collar of the shaft; two timbers protrude out of the collar and the opening is decked over with reasonably sound planking; loose rock could be a safety risk and is partially covering the opening*	*Soils consist of decomposed weathered bedrock and glacial till;* ***discontinuous permafrost*** *(possibly up to 80m depth); some seeps and ponded surface water; carbonaceous phyllite underlying meta-volcanic quartz-sericite-chlorite schists host rock (elevated metal values in the host rock)*	*Accessible by 2WD*			shaft is filled at bottom of pit		
Lucky Queen Shaft #1	Lucky Queen	*Shaft #1 was rehabilitated in the 1970s and is still open. A wooden building has been built to cover the inclined shaft*	*4m x 3m x 5m*	*Large wooden timber structure support; sound and safe conditions; manway and ladders are open and easily accessed*	*Located on a gentle slope; vegetated with grass and trees; sparse soil cover of residual soils over bedrock and till;* ***permafrost*** *is likely present (up to 120 m deep); host rocks include quartzite, sedimentary and felsic meta-volcanic rocks*	*Access via a rough 2WD truck road*	easily accessible	does not produce water		*concrete cap*	
Lucky Queen Shaft #2	Lucky Queen	*Located between trench 2 and trench 3, 40m southwest of shaft #1*	*Not able to determine*	*Wooden log timbers; shaft was caved by recent surface trenching work*	*Located on a gentle slope; vegetated with grass and trees; sparse soil cover of residual soils over bedrock and till;* ***permafrost*** *is likely present (up to 120 m deep); host rocks include quartzite, sedimentary and felsic meta-volcanic rocks*	*Access via a rough 2WD truck road*	collapsed and inaccessible; open for roughly a metre	shaft is producing water		*rock cap and fill*	
Shamrock J18 Raise	Keno No. 9	*The J18 Vein was discovered and mined from the Keno Mine underground workings; a raise to surface was established to provide access for supplies/miners/equipment*	*Unknown Dimensions*	*The ground around the raise and the building covering it are collapsing; an area of ~7 to 10 m has collapsed; unstable*	*Located above treeline; area underlain by* ***permafrost*** *up to 120 m deep; soils are poorly developed and absent over the area; quartzite host rock*	*Road access to the shaft; the raise area has been fenced off*	shaft is open			*fill and cap as required*	*eliminates access issues*
Shamrock Shaft	Shamrock						shaft is located at bottom of open pit and is filled with waste rock; no access	no water has been noted	shaft is filled	*do nothing; remediation with pit closure*	*will be covered with pit borrow*
Prospect Shaft	Shamrock (Original)	*Small waste dump (+/- 5 tonnes); construction pre-1939*	*1.5m x 1.5m x ?; approximately 3 m depth to ice*	*Log timers, fair condition; appears to be stable*	*Site consists of a series of test pits, shafts and adits; drainage goes down a steep talus slope through a single ravine; located in an alpine ecosystem above the treeline with little vegetation; host rock is massive quartzite with graphitic schist and phyllite.*	*Access by 2WD or 4WD on a gravel road; shaft is surrounded by a steep, blocky talus slope which limits access*					
Porcupine Shaft	?									*rock cap and fill*	
Unknown Shaft near 5-2 Adit	?							shaft contains shallow water		*fill shaft and cap if required*	
No. 9 Vein Shaft	Keno No. 9									*no access, do nothing*	
Coesus No. 1 Shafts	Croesus No. 1	*Shaft #1 was likely located in the base of Trench #1 and appears to have been filled by trenching; shaft #2 has collapsed and is now less than 1 m deep*	*Unknown*	*Unknown; shaft is likely filled*	*Located on a moderately steep slope (~26°); thickly vegetated; 1.5m of colluvial materials on the surface below 1230m; above 1230m glacial gravels cover bedrock; minor earth flows evident;* ***permafrost*** *is likely present; no surface water; host rock consists of schist and phyllite in contact with a large greenstone lens*	*2WD access to a location 160 m from the site; from photos it appears hiking may be required to the shafts*			reported to be filled; not located in August 2009 site visit	*do nothing*	
Lower Lake Shaft	?						high intrigue risk; accessible to public		hanging wall of shaft collapsed; may deteriorate to produce an open hole	*remove timber and debris; fill and cap as required*	
Upper Lake Shaft	?						open to surface	water observed in shaft	minor subsidence	*remove timber and debris; fill and cap as required*	
Silver Basin Hand Shafts (Shaft #1)	Silver Basin	*The shaft has collapsed ~1 m below the surface; shaft cannot be accessed*	*1m x 1m x 3m*	*Log cribbing supports*	*Above treeline; likely underlain by continuous* ***permafrost*** *; quartzite host rock*	*4WD access*				*fill*	
Apex Shaft	Apex	*Located in the bottom of trench 3 approximately 58 m from the waste rock dump at the south end of the trench; another shaft was reported at the site but only this one was located*	*2m x 1.5m x ~5m*	*Poor condition; caved in 5 m below surface*	*Located on a flattened ridge; above treeline; major rock type is thin to medium bedded quartz*	*Road access; 4WD likely require to reach shaft location*	open for 2m		timber shaft supports are rotten	*fill and cap if required*	
Christal Shaft #1	Christal	*At the base of a steep north facing slope about 75 m north of the camp site*	*1.5m x 1.5m x ?*	*Timbered shaft support; shaft is collapsed; water accumulated to within 1 m of surface*	*Site is on the western slope of Keno Hill; site slopes from the uphill trenches down to Shafts 1,2 and 3 with a change in elevation of ~200 m; terrain consists of dense forests and fields of moss covered boulders; schist, phyllite and quartzite are the major rock types*	*Access to the site by foot on a trail ~2.5 km out of Keno City with a campsite located at the end of the trail; shaft can be accessed by foot from the campsite*				*fill and cap as required*	
Christal Shaft #2	Christal	*Shaft is under a collapsed shed at the base of a steep facing slope ~75 m north of the camp site*	*Unknown*	*Timbered shaft support; shaft is likely collapsed; water accumulated to within 1 m of surface*	*Site is on the western slope of Keno Hill; site slopes from the uphill trenches down to Shafts 1,2 and 3 with a change in elevation of ~200 m; terrain consists of dense forests and fields of moss covered boulders; schist, phyllite and quartzite are the major rock types*	*Access to the site by foot on a trail ~2.5 km out of Keno City with a campsite located at the end of the trail; shaft can be accessed by foot from the campsite*				*fill and cap as required*	
Christal Shaft #3	Christal	*Not located during PWGSC site investigation, SRK site investigation or ACG 2009 site investigation*									

Shaft Name	PWGSC Ref Site	Recommended Shaft Closure Concept	Estimated Construction Cost ($CAD)**		
			Cost	Cost +100%	Cost -50%
Silver King Vent Raise	Silver King	Concept B (Concrete Cap)	$ 35,000.00	$ 70,000.00	$ 17,500.00
Silver King Shaft #1 (Open Pit Shaft)	Silver King	Concept B (Concrete Cap)	$ 25,000.00	$ 50,000.00	$ 12,500.00
Silver King Shaft #2	Silver King	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Silver King Raise #1	Silver King	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Husky Raise	Husky #2	Concept B (Concrete Cap)	$ 35,000.00	$ 70,000.00	$ 17,500.00
Husky Shaft	Husky #2	Concept B (Concrete Cap)	$ 80,000.00	$ 160,000.00	$ 40,000.00
Husky SW Shaft	Husky SW	Concept B (Concrete Cap)	$ 100,000.00	$ 200,000.00	$ 50,000.00
Ruby Shaft	Bermingham & Ruby	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
McLeod shaft	Galkeno Mine	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Lone Star Shaft	Onek	Do Nothing	$ -	$ -	$ -
Fisher Shaft	Onek	Do Nothing	$ -	$ -	$ -
Shafts SW of Gravel Level Adit	Elsa Mine	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Dixie Shaft	Dixie	Concept B (Concrete Cap)	$ 25,000.00	$ 50,000.00	$ 12,500.00
Brefalt Shaft	No Cash Mine	Concept B (Concrete Cap)	$ 40,000.00	$ 80,000.00	$ 20,000.00
Shaft N of tramway and S of Brefalt shaft dump	No Cash Mine	Do Nothing	$ -	$ -	$ -
Jock Shaft	Hector-Caulmet	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Coral and Wigwam Shaft #1	Coral and Wigwam	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Coral and Wigwam Shaft #2	Coral and Wigwam	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Betty shafts	Betty	Concept A (Dry Seal)	$ 20,000.00	$ 40,000.00	$ 10,000.00
Tin Can Shaft #1	Tin Can	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Tin Can Shaft #2	Tin Can	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Rico Shaft	Rico	Concept A (Dry Seal)	$ 12,500.00	$ 25,000.00	$ 6,250.00
Sadie Ladue Shaft (No. 1 Shaft)	Sadie Ladue - Wernecke	Concept B (Concrete Cap)	$ 25,000.00	$ 50,000.00	$ 12,500.00
Lucky Queen Shaft #1	Lucky Queen	Concept B (Concrete Cap)	$ 60,000.00	$ 120,000.00	$ 30,000.00
Lucky Queen Shaft #2	Lucky Queen	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Shamrock J18 Raise	Keno No. 9	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Shamrock Shaft	Shamrock	Do Nothing	$ -	$ -	$ -
Prospect Shaft	Shamrock (Original)	Concept A (Dry Seal)	$ 15,000.00	$ 30,000.00	$ 7,500.00
Porcupine Shaft	?	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Unknown Shaft near 5-2 Adit	?	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
No. 9 Vein Shaft	Keno No. 9	Do Nothing	$ -	$ -	$ -
Coesus No. 1 Shafts	Croesus No. 1	Do Nothing	$ -	$ -	$ -
Lower Lake Shaft	?	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Upper Lake Shaft	?	Concept A (Dry Seal)	$ 10,000.00	$ 20,000.00	$ 5,000.00
Silver Basin Hand Shafts (Shaft #1)	Silver Basin	Concept A (Dry Seal)	$ 7,500.00	$ 15,000.00	$ 3,750.00
Apex Shaft	Apex	Concept A (Dry Seal)	$ 12,500.00	$ 25,000.00	$ 6,250.00
Christal Shaft #1	Christal	Concept A (Dry Seal)	$ 12,500.00	$ 25,000.00	$ 6,250.00
Christal Shaft #2	Christal	Concept A (Dry Seal)	$ 12,500.00	$ 25,000.00	$ 6,250.00
		TOTALS	**$ 707,500.00**	**$ 1,415,000.00**	**$ 353,750.00**

** Level 5 Construction Cost Estimate for shaft closure at noted locations. No allowance has been made for related costs, including (but not limited to) Design, Permitting, Environmental Remediation, Consultation, Compensation, Site Supervision, Contract Administration, or other.



NOTES:

1. Quantities will vary with shaft depth, connection to underground workings, and other conditions.
2. Remove and dispose of timber, trash, brush, topsoil and other debris in and around shaft area, prior to backfilling. Strip down to bedrock surface at collar where practical.
3. Dewater shaft and workings (if practical) prior to backfilling.
4. Existing steel pipe, concrete rubble (if present) should be removed or incorporated into backfill as directed by engineer.

CONCEPT DRAWING
NOT FOR CONSTRUCTION

STATUS
ISSUED FOR REVIEW

SCALE 1:50

500 0 500 1000 2000mm

CLIENT

ACCESS CONSULTING GROUP

eba A TETRA TECH COMPANY

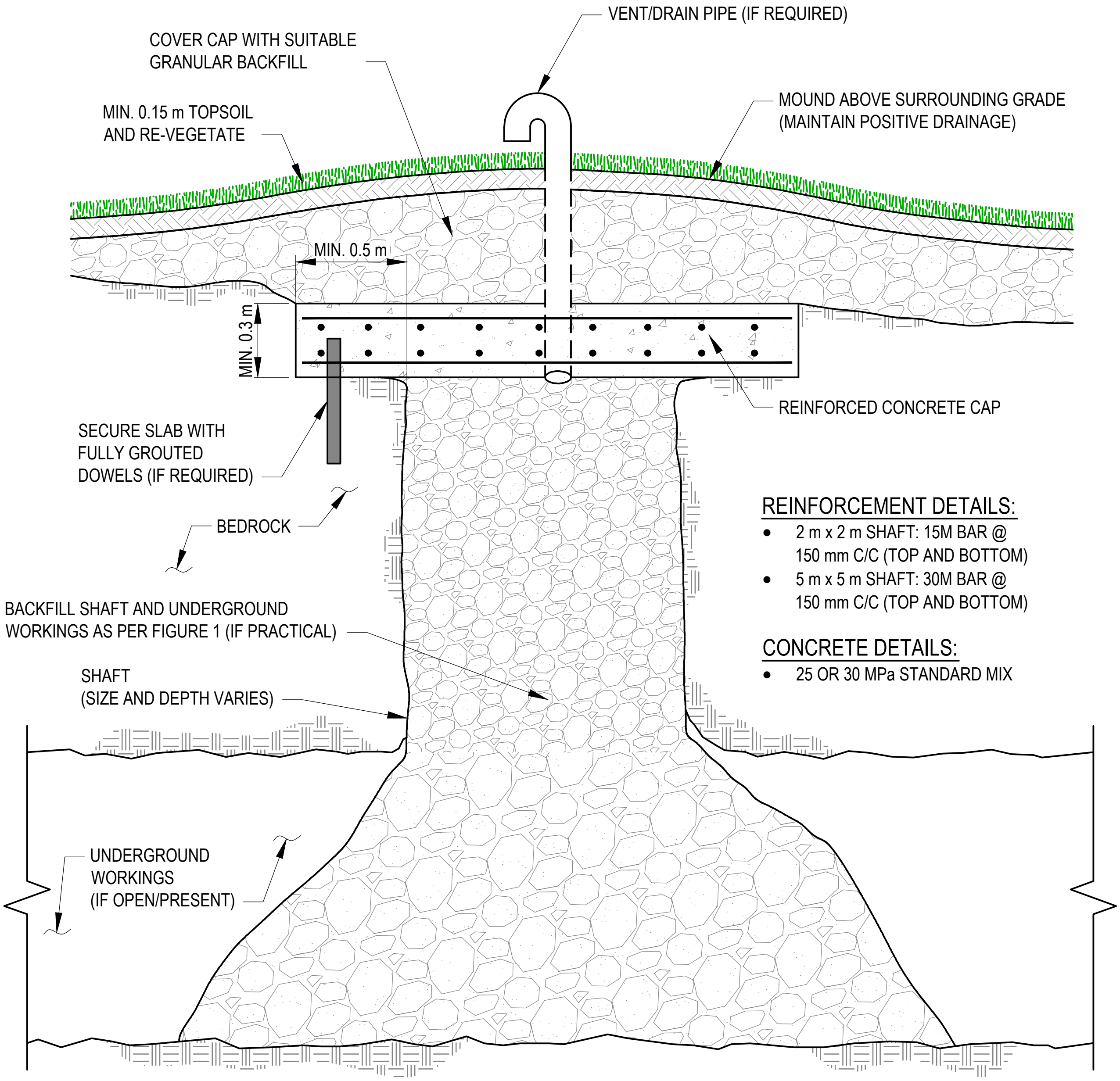
KENO HILL SHAFT CLOSURES
KENO HILL, YT

CONCEPT A
DRY SEAL

PROJECT NO.	DWN	CKD	REV
V15101043	SF	JP	0

OFFICE	DATE
VANC	April 4, 2011

Figure 1



REINFORCEMENT DETAILS:

- 2 m x 2 m SHAFT: 15M BAR @ 150 mm C/C (TOP AND BOTTOM)
- 5 m x 5 m SHAFT: 30M BAR @ 150 mm C/C (TOP AND BOTTOM)

CONCRETE DETAILS:

- 25 OR 30 MPa STANDARD MIX

NOTES:

1. Quantities will vary with shaft size and required depth of stripping.
2. Remove and dispose of timber, trash, existing buildings, brush, topsoil, and other debris in and around shaft area. Excavate to expose competent, sound rock at collar.
3. Cap dimensions and reinforcement detail assume max 1 m burial at surface, and no uplift hydrostatic or ice loads on base of cap. (To be verified during design).

CONCEPT DRAWING
NOT FOR CONSTRUCTION

STATUS
ISSUED FOR REVIEW

SCALE 1:50

500 0 500 1000 2000mm

CLIENT

ACCESS CONSULTING GROUP

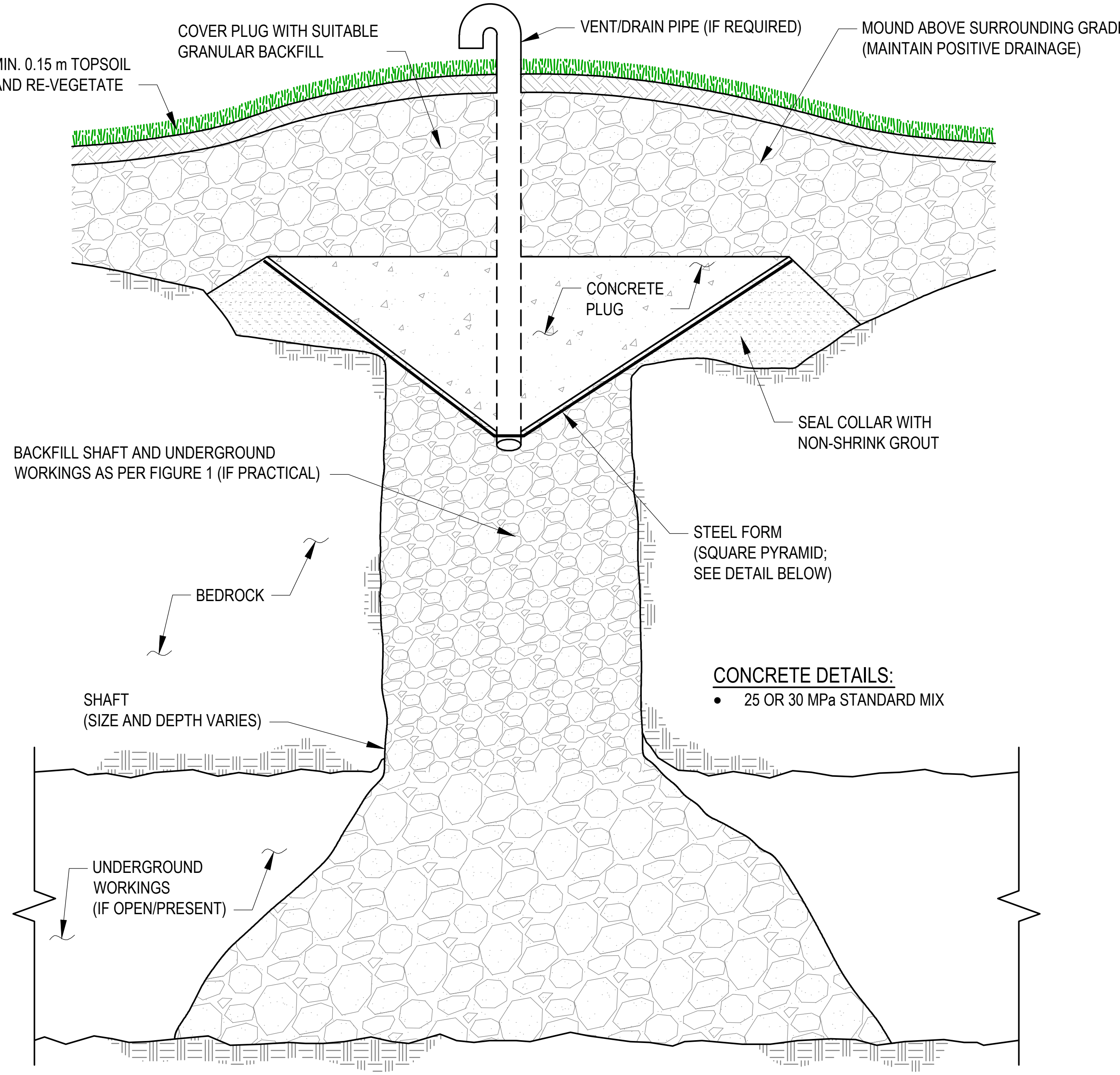
eba A TETRA TECH COMPANY

KENO HILL SHAFT CLOSURES
KENO HILL, YT

CONCEPT B
CONCRETE CAP

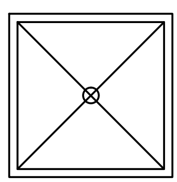
PROJECT NO.	DWN	CKD	REV
V15101043	SF	JP	0
OFFICE	DATE		
VANC	April 4, 2011		

Figure 2



CONCRETE DETAILS:

- 25 OR 30 MPa STANDARD MIX



PLAN VIEW
STEEL PYRAMID FORM

SCALE 1:200

2 0 2 4 8m

NOTES:

1. Quantities will vary with shaft size, depth of stripping and other conditions.
2. Remove and dispose of timber, trash, existing buildings, brush, topsoil and other debris in and around shaft area. Excavate to expose competent sound bedrock at collar.

CONCEPT DRAWING
NOT FOR CONSTRUCTION

STATUS
ISSUED FOR REVIEW

SCALE 1:50

500 0 500 1000 2000mm

CLIENT

ACCESS CONSULTING GROUP

eba A TETRA TECH COMPANY

KENO HILL SHAFT CLOSURES
KENO HILL, YT

CONCEPT B
INVERTED PYRAMID CONCRETE CAP

PROJECT NO.	DWN	CKD	REV
V15101043	SF	JP	0

OFFICE	DATE
VANC	April 4, 2011

Figure 3

Q:\Vancouver\Drafting\Engineering\V151\V15101043\V15101043_FIG 1-3_R0.dwg [FIGURE 3] April 04, 2011 - 3:33:20 pm (BY: FOURNIER, SAMUEL)

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's Client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's Client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. EBA's instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.